The Impact of Change of Major on Time to Bachelor's Degree Completion with Special Emphasis on STEM Disciplines: A Multilevel Discrete-Time Hazard Modeling Approach[1]

Final Report

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ABSTRACT

This national level study addresses the impact of changing major on yearly risk of graduation, emphasizing changes to STEM and non-STEM majors. Results of multilevel discrete-time hazard models applied to longitudinal data from the 2004/2009 Beginning Postsecondary Students Longitudinal Study (BPS:04/09) revealed significant differences in the risk of graduation between students who switched to STEM or non-STEM majors and those who persisted. Furthermore, the association between switching majors and graduation risk depended to an extent on the student's gender, entering declared major status, the timing of the switch, and various other student-level and institutional-level characteristics. In general, switching early to a non-STEM major has the least impact on graduation risk and typical time to graduation, and switching early to a STEM major has an immediate negative impact on graduation risk that is smaller for female students than male students; however, the negative impact for both males and females diminishes in the years after the switch. The results of the study can be used by administrators and academic advisors to provide general guidance to students interested in changing majors, particularly from STEM to non-STEM or non-STEM to STEM majors.

INTRODUCTION

Many students entering college do not persist in their first declared major through graduation. According to data used for the current study, 46% of all first-time, full-time students entering four-year institutions in 2003 switched majors at least once by 2009.[2] Furthermore, this figure varied between 10% and 75% at the institutions included in this study.[3] Surprisingly, little research has focused on the impact of changing majors on college outcomes such as graduation. Various single institution studies that report graduation rates by change of major patterns have been conducted (for example, see Foraker (2012), Micceri (2001), and Sklar (2013)), but extensive analyses at the national level have not been performed.

Alternate pathways to a bachelor's degree may be needed for students who dislike their current major or who cannot successfully complete the requirements of their current major, and changing majors is a common option. Yet students seeking to change majors may be concerned about potential delays in graduation and expenses that could be incurred if additional time is needed to complete the degree requirements in the new major. In addition, administrators and academic advisors may be under the impression that high change of major rates could decrease timely graduation rates, increase time to graduation and decrease retention rates, thereby discouraging some students from leaving their current major. It has been suggested that decreasing the number of students who change major may improve university graduation rates (Allen and Robbins, 2008), but no substantial evidence has been provided to support this claim. University officials currently have limited empirical results available regarding graduation outcomes for students who change majors. This information would not only be valuable to students seeking to change majors, but also to those officials responsible for developing and implementing campus change of major policies.

Current literature also points to a relatively high rate of students who are switching from STEM fields to non-STEM fields (Chen, 2013; PCAST, 2012) as well as lower STEM degree completion rates among females and minority students compared to males and non-minorities (Chen, 2013). Due to evidence of high attrition to non-STEM majors from STEM majors, the current study emphasizes changes to STEM and non-STEM majors, while also controlling for whether students entered college declared in a STEM or non-STEM major, or entered undeclared.

Given that institutional change of major rates can be quite high, it is important to examine whether and how changing major affects time to graduation, so that, ultimately, students will be better informed about the potential

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[2] Figure calculated from the BPS:04/09 data based on full-time first-time students entering four-year institutions who planned to pursue a bachelor's degree.

[3] Based on BPS:04/09 data. Non-weighted proportion of students who changed majors at least once at schools with a sample size of at least 20 students.

risks involved with changing majors. Not only is it important to understand the reasons why students select particular majors or why they switch majors, it is also equally important to understand the implications of switching majors on graduation outcomes. Prior studies focusing on changing majors, although informative, have not utilized methodology to capitalize on existing student- and institutional-level background variables, as well as the longitudinal nature of enrollment data. This is believed to be the first national-level study investigating the relationship between changing majors and graduation outcomes, specifically time to graduation. The current study attempts to provide a comprehensive national-level analysis of the impact of changing to a STEM or non-STEM major on time to graduation and yearly graduation risk, and compares the graduation experiences among students who persist, change to STEM majors, and change to non-STEM majors.

LITERATURE REVIEW

Change of Major and Major Persistence

As Foraker (2012) noted, rigorous quantitative studies on major changing activity are rare. Many studies have examined factors associated with student retention, persistence and degree completion, while others have investigated factors associated with persisting in one's major, but few studies have integrated major persistence into analysis of college outcomes.

Single institution studies have investigated the impact of changing major to a limited extent, but results have conflicted. Micceri (2001) reported that students at one university who had changed their major at least once had a higher overall graduation rate than those students who had not changed majors. Only raw percentages were provided and background predictors were not incorporated into the analysis. Foraker (2012) found that changing major after the second year was associated with lower graduation rates and longer time-to-graduation; however, the methods used were also descriptive rather than model-based and ignored background student characteristics. Among one of the few single-institution studies that included change of major as a predictor of graduation, Kreysa (2007) found that for students requiring remedial courses, changing majors increased the likelihood of graduation, but for non-remedial students, changing majors decreased the likelihood of graduating. Although enlightening, the study did not focus solely on the impact of changing major, and was limited in the sense that the classification of the new and previous declared major (e.g. STEM versus non-STEM) was not investigated.

A more thorough examination of the effects of changing major at a single institution is discussed in an unpublished report by Sklar (2013). By applying discrete-time survival analysis (event history) techniques to 6-year enrollment data on first-time freshmen at a large public mostly undergraduate university, Sklar (2013) found that after controlling for several background student variables, the effect of changing major on the risk of graduating significantly depended on the categorization of the first declared major, quarterly GPA, and year that the switch occurred, but did not significantly depend on ethnicity or gender of the student (after controlling for the remaining predictors). Furthermore, switching to a STEM major tended to decrease the risk of graduating at the end of four years (compared to students who persisted in their major); however, switching to a non-STEM major in the second year tended to increase the risk of graduating at the end of four years. In addition, students who switched to a STEM major during any year of enrollment tended to take longer to graduate, while students who switched to a non-STEM major tended to take slightly less time to graduate than students who persisted in their major. Although illuminating, the results of the single-institution investigation were only applicable to other colleges and universities with student-level and institution-level characteristics similar to those of the study institution. There were also additional methodological concerns that needed to be addressed with that analysis.[4]

Other researchers have focused on factors associated with the selection of a college major or persistence in college major (Allen and Robbins, 2008; 2010; Pike, 2006; Porter and Umbach, 2006) using components from Holland's theory of careers (Feldman, Smart, and Ethington, 1999; Holland, 1997). The general finding has been that students whose interests are congruent with their academic environments and who have a higher first-year GPA

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[4] Report available upon request. Several helpful comments and suggestions were made on an earlier submitted version of the paper, and have been incorporated into the current study.

are more likely to persist in their majors (Allen and Robbins, 2008; 2010). Furthermore, students with higher interest-major congruence are more satisfied with their academic major and are more likely to graduate in a timely manner because they did not change majors (Allen and Robbins, 2010).

Persistence and Degree Completion

There is an extensive body of work examining student and institutional factors related to postsecondary outcomes. Studies examining student-level factors have found that high school GPA, socioeconomic status, gender, and SAT and ACT scores are associated with persistence outcomes (Astin, 1993; Tinto, 1993; Cabrera, Nora, and Castaneda, 1993). Ishitani (2006) found that first-generation students have higher dropout risk than their counterparts. There is evidence that attending full-time (versus part-time) is positively associated with the probability of graduating (Kim, 2007). Recent studies have found measures of academic and social integration to be associated with both dropout and persistence outcomes. Academic integration was significantly positively associated with the probability of graduation (Kim, 2007), and negatively associated with dropout risk (Chen and DesJardins, 2010; Chen, 2012). Both were negatively associated with the chance of withdrawing (Rhee, 2008). Social integration was negatively associated with dropout risk (Chen, 2012). Declaring a major has been found to be positively associated with persisting at the student's first institution (Titus, 2006); however, the classification of the declared major (STEM vs non-STEM) was not considered in that study. Recent studies on the effects of financial aid on persistence and retention have found that type of aid and amount of aid are significant predictors. Pell grant amount, subsidized and unsubsidized loan amounts have been found to be negatively associated with dropout risk (Chen, 2012; Chen and DesJardins, 2008; 2010), and Kim (2007) found that grant amount was positively associated with the probability of graduating when excluding institutional-level predictors from the analysis.

Other studies have found various institutional structural characteristics to be associated with persistence and dropout. Enrollment size of the institution has been found to be positively associated with college persistence (Titus, 2004; 2006a), although other studies have found it not to be significantly associated with degree completion (Osegura and Rhee, 2009; Kim, 2007). The proportion of minority students on campus was found to be positively associated with dropout (Rhee, 2008). It has been shown that students attending private institutions have lower dropout risk than those attending public institutions (Ishitani, 2006) and higher chance of graduating (Kim, 2007), and students attending more selective institutions are predicted to have a higher chance of graduation (Osegura and Rhee, 2009; Kim, 2007) and lower chance of dropout (Ishitani, 2006) than students attending public institutions.

Persistence in STEM Fields

The recent research emphasis in STEM degree completion is especially pertinent to change of major studies given the high attrition rates of students entering as STEM majors leaving to non-STEM majors (Chen 2009; Chen 2013). In an analysis of Beginning Postsecondary Students 2004-2009 (BPS:04/09) data by Chen (2013), 28% of bachelor's degree students entered a STEM field at some point between 2003 and 2009; however, 48% of beginning bachelor's students who entered as a STEM major had left the STEM field by 2009 (Chen, 2013). The same analysis also revealed that females switched from STEM to non-STEM majors at a higher rate than male students; however, males left STEM majors by dropping out of college at a higher rate than females (Chen, 2013).

Research studies have also focused on student and institutional characteristics associated with STEM degree completion or persisting in a STEM major. STEM attrition occurs more frequently among students with weaker academic backgrounds (Shaw and Barbuti, 2010; Kokkelenberg and Sinha, 2010). Motivation and confidence in one's ability to complete a STEM degree are also associated with STEM major attrition (Burtner, 2005; Huang, Taddese, and Walter, 2000). Financial aid may also play an important role. STEM degrees typically take longer to complete, and more financial support may be necessary to complete a degree STEM field (Fenske, Porter, and Dubrock, 2000). Maltese and Tai (2011) found that the number of science courses completed in high school was significantly associated with STEM degree completion rates; however, race, gender, and socio-economic status were not.

Other research has found evidence that women, underrepresented minorities, first generation students, and students from low-income backgrounds tend to leave STEM fields at higher rates and are less likely to graduate with STEM degrees than their counterparts (Crisp, Nora, and Taggart, 2009; National Science Board, 2007; Shaw and Barbuti, 2010). In other studies, females who did graduate in a STEM field were more likely to have switched into it after initially declaring interest in non-STEM fields (Ma, 2011; Xie and Shauman, 2003). Using data from two separate studies, the National Longitudinal Survey of Freshmen (NLSF), and the National Educational Longitudinal Survey (NELS:88), Griffith (2010) examined student level factors associated with switching to a STEM major by the second or fourth year. Data from the NLSF study revealed that male minority students were less likely to switch to a STEM major than male non-minority students, and female non-minority students were less likely to switch than male non-minorities. The NELS data also revealed that females were less likely to switch into a STEM major than males. This finding was also consistent with a single institution study conducted by Crisp, Nora, and Taggart (2009). They investigated student characteristics associated with declaring a STEM major, changing from non-STEM to STEM majors, and attaining a STEM degree at a single Hispanic Serving Institution, and found that women were less likely than men to declare a STEM major, change to a STEM major, and graduate with a degree in a STEM field.

Eagan, Hurtado, and Chang (2010) examined institutional factors associated with completing a degree in a STEM field. Results revealed that the institutions that offered more undergraduate research opportunities had higher STEM degree completion rates than comparable institutions that offered fewer opportunities. Chang, Sharkness, Newman, and Hurtado (2010) found that among underrepresented minority students, the selectivity of the institution was negatively related to persistence in a STEM major, while the proportion of students majoring in STEM fields was positively associated with STEM major persistence.

Although there have been extensive research contributions to the areas of college persistence, including persistence in STEM fields, and major persistence, there are no national level studies integrating major persistence measures into the college persistence framework. Given potentially high institutional change of major rates and their potential implications for delayed graduation and decreased graduation rates, there is a golden opportunity to explore the impact of this important college experience on graduation outcomes. The current study seeks to combine elements from current research on change of major behavior, college persistence and retention, and STEM major persistence. Using a large longitudinal national dataset and multilevel modeling techniques, this study addresses the impact of changing major on time-to-graduation, emphasizing changes to STEM and non-STEM majors while controlling for a variety of student- and institutional-level background variables. Results of the study will be useful for university administrators responsible for developing and maintaining change of major policies, as well as academic advisors who need to appropriately guide students who are considering major changes.

CONCEPTUAL FRAMEWORK AND RESEARCH QUESTIONS

The conceptual framework of the proposed research study draws upon student-centered and institutional-centered theories of student persistence, and integrates change of major behavior into the student-centered theories of persistence. Tinto's theory of student departure (1975; 1993) emphasizes academic and social integration as important predictors of student retention. A good match between institutional environment and student commitment results in better integration into the social and academic domains of college life, increasing the likelihood of persisting through college until degree completion. Furthermore, academic integration and commitment to remain at the institution is associated closely with satisfaction with academic environment (Tinto, 1975; 1993). It is arguably justified and noted by Allen and Robbins (2008; 2010) that major persistence or changing major are important indicators of satisfaction (or dissatisfaction) with academic environment, and that students who are in majors that interest them may be more likely to feel integrated into their campus and, therefore, more likely to persist.

Berger and Milem's (2000) framework, drawing on organizational behavior theory (Bolman and Deal, 1991), integrates structural and demographic institutional characteristics into models of student persistence. Several recent conceptual models have emphasized the integration of institutional characteristics with student level factors when examining persistence (for example, see Chen (2012), Oseguera and Rhee (2009), and Titus (2004)); however, these studies are more focused on the role of institutional-level variables on student outcomes. The framework for this study incorporates institutional-level control factors, but focuses specifically on student behavior, i.e. change of major, and attempts to integrate college major persistence patterns into theories of college persistence. The underlying hypothesis of the current study is that change of major behavior is associated with the risk of graduation, but the association will depend to an extent on student demographic and academic characteristics, as well as institutional-level variables. Multilevel discrete-time hazard models are implemented to address three primary research questions:

1) Adjusting for student-level and institutional-level variables, does the risk of completing a bachelor's degree depend on change of major behavior, i.e. does the risk significantly vary between students who persist in their first declared major, switch to a STEM major, or switch to a non-STEM major?

2) Adjusting for student-level and institutional-level variables, does the association between changing major and risk of degree completion depend on student-level and institution-level characteristics including type of first declared major (STEM versus non-STEM), gender, ethnicity, and public/private status of the institution?

3) What is the expected additional amount added to graduation time for students who switch major, and how does this amount differ between students who switch to STEM and those who switch to non-STEM majors?

METHODOLOGY

Due to the study's focus on the longitudinal process of persistence and degree completion, survival analysis (also called event history analysis) techniques are used. Survival analysis techniques incorporate "censoring," a feature common to time-to-event data (such as time until graduation) that occurs when observation on the subject ends before the event of interest occurs. Censoring is especially relevant to college enrollment data because students may drop out during their college career or may graduate after the data collection period ends. Students who graduated by the end of the 2009 academic year (an academic year runs from July 1 to June 30) will have complete event times, i.e. the time until graduation will be known exactly. Those students who were still enrolled in the first institution at the end of 2009, or dropped out before graduating by 2009 will have censored event times, i.e. their times to graduate are known only up to the year of last enrollment. Students who transferred or stopped out are also censored at the year they leave their first institution. The dependent variable is time until graduation from first institution and is measured by the number of academic years that a student took to complete a bachelor's degree. Due to BPS:04/09 data limitations, as well as methodological considerations to be discussed, it was necessary to focus on first-institution graduation. Furthermore, because time-to-graduation is measured in years, and there are only six years of enrollment data, it is more appropriate to use *discrete-time* survival analysis methods (Singer and Willett, 2003).

Due to the nested structure of the BPS data (students within institution), multilevel discrete-time hazard models will be used. Multilevel models will account for the possibility that students within a particular institution may behave more similarly than students attending other institutions. Multilevel discrete-time survival methods have not been used extensively in the persistence literature; however, some recent examples include works by Wao (2010), who used multilevel discrete-time hazard models to investigate the time until doctorate degree completion, and by Chen (2012) who examined institutional characteristics associated with dropout. In addition, the proposed methods have been explored in sociology (Barber, Murphy, Axinn, and Maples, 2000) and demography (Browning, Leventhal, and Brooks-Gunn, 2004). To make results generalizable to the population of all first-time, bachelor's degree seeking students who were enrolled full-time in four-year institutions in 2003, sampling weights (appropriately scaled) at both the student and institutional levels from an accompanying BPS:04/09 weight file were also incorporated in the multilevel analysis.

Data and Sample

This study primarily used data from the 2004/2009 Beginning Postsecondary Students Longitudinal Study (BPS:04/09). Additional information was also taken from the 2004 National Postsecondary Student Aid Study (NPSAS:2004) and from the Integrated Postsecondary Education Data System (IPEDS) from 2003. The BPS:04/09 was administered by the National Center for Education Statistics (NCES) and consisted of a nationally representative sample of students beginning postsecondary education in 2003. The target population for the

BPS:04/09 cohort consisted of all students who began their postsecondary education in the 2003-2004 academic year at any postsecondary institution in the United States or Puerto Rico that was eligible for inclusion in the 2004 National Postsecondary Student Aid Study (NPSAS:04). Students selected for the first wave of the BPS:04/09 in 2003-04 were surveyed again in 2006 (first follow-up study), and in 2009 (second follow-up study). The BPS:04/09 restricted data is the most recent national level longitudinal data available on the attributes and outcomes of post-secondary students and includes information on student demographic characteristics, school experiences, persistence, and degree attainment. Under the presumption that students who entered college intended to obtain at least a bachelor's degree, the final sample for analysis is limited to first-time, bachelor's degree seeking students who enrolled at four-year institutions full-time in the fall 2003. After listwise deletion of students with missing data on one or more variable, there were approximately 6800 students enrolled at approximately 620 institutions used in the analyses.

Control Variables

Several control variables, some of which were time-varying, were selected for inclusion in the analysis based on previous research studies confirming their association with retention or graduation. The student-level control variables included gender, race, first generation status, income, SAT math and verbal scores, cumulative high school GPA (a categorical measure), first-year entering type of major, yearly (time-varying) college attendance intensity, academic and social integration indices, first-year college GPA, yearly (time-varying) combined Stafford (subsidized and unsubsidized) and Perkins loan amounts, and yearly (time-varying) Pell grant amount. The first-year institutional-level background variables include control, selectivity, enrollment size, and percentage of minority students on campus. The BPS variables used in the analysis are provided in the Appendix.

First generation students are those with neither parent completing any college credits. First year academic integration is a derived measure of the overall academic integration the student experienced at the first institution attended during the 2003-2004 academic year based on the number of times the student participated in study groups, had social contact with faculty, met with an academic advisor, and discussed academic matters with faculty outside of class. First year social integration is a derived measure of the overall social integration the student experienced at the first institution attended during the 2003-2004 academic year based on how often the student attended fine arts activities, participated in intramural or varsity sports, and participated in school clubs. First-year entering major type has three levels: entered college as a STEM major, entered college as a non-STEM major, and entered college undeclared. A major was designated as STEM if it belonged to the following categories: Agriculture/natural resources, biological and biomedical sciences, computer/information science, engineering, mathematics and statistics, physical sciences, science technologies/technicians, or engineering technologies/related fields. Majors falling within any other category were designated as non-STEM. The BPS variable MAJ04A indicated the student's major field during the 2003-04 academic year or if the student was undeclared. The major fields were further classified as STEM or non-STEM according to specifications given in recent NCES reports (for example, see Chen and Ho (2012), and Chen and Weko (2009)).

Descriptive statistics for the background student- and institutional-level predictors, appropriately weighted to account for the complex sampling design, are provided in Table 1. The BPS:04/09 panel weight, WTB000, was used when calculating the descriptive statistics, and the standard errors of the estimates were computed using the bootstrap replicate weights provided in the BPS:04/09 data file. See the methodology report (Wine, Janson, and Wheeless, 2011) for a discussion of variance estimation using the replicate weights.

Table 1: Descriptive Statistics for Study Variables

Variable	Weighted Proportions or Means*	Standard Error
STUDENT-LEVEL VARIABLES		
Race/Ethnicity		
White	0.73	0.014
African American	0.09	0.012
Hispanic	0.08	0.005
Asian	0.05	0.004

Table 1 (continued): Descriptive Statistics for Study Variables

Other	0.05	0.005
Gender		
Male	0.44	0.010
Female	0.56	0.010
Income		
Low	0.18	0.007
Medium	0.48	0.008
High	0.34	0.008
First Generation		
Yes	0.18	0.007
No	0.82	0.007
Cumulative HSGPA		
D- to C-	0.01	0.003
C to B-	0.15	0.010
B to A	0.84	0.009
First-Year Major Type		
STEM	0.17	0.006
Non-STEM	0.56	0.010
Undeclared	0.27	0.010
Cumulative Persistence or Attainment at First Institution by 2009		
Bachelor's Degree	0.60	0.011
Associate's Degree	0.01	0.002
Certificate	0.002	0.001
Still Enrolled (No Degree)	0.04	0.004
Left without Return (No Degree)	0.11	0.007
Transferred (No Degree)	0.24	0.008
Academic Integration Index	90.04	0.957
Social Integration Index	67.88	1.355
First-Year College GPA	2.92	0.016
First-Year Attendance Intensity (Full-Time)	0.94	0.005
First-Year Financial Aid		
Pell Grant ($)	717.81	19.299
PLUS Loan ($)	1377.72	70.527
Stafford + Perkins Loans ($)	1673.38	36.498
SAT Math	536.96	2.930
SAT Verbal	535.77	2.559
FIRST-YEAR INSTITUTION VARIABLES		
First Institution Selectivity		
Very Selective	0.30	0.020
Moderately Selective	0.60	0.022
Minimally Selective	0.10	0.016
First Institution Control		
Public	0.66	0.016
Private	0.34	0.016
Enrollment Size	13,683	613
Percent Minority	23.68	1.156

Undergraduate Change of Major Behavior

Before discussing the change of major predictors that were included in the analysis, it is worthwhile to discuss national-level change of major figures, as well as characteristics of students who did and did not change majors. Table 2 displays the breakdown of change of major activity by number of switches. These figures are based on the values of the BPS variables MAJ06CHG and MAJ09CHG[5]. These two variables contain the responses to survey questions asking students to indicate whether they had changed major exactly once, more than once, or not at all during each of the follow-up periods. Although the majority of switchers changed majors only once, a sizable portion (25%) changed majors 2 or more times.

Table 2: Approximate number of major changes.

Change of Major Activity	Weighted Proportions	Standard Error
Did not change majors	0.54	0.010
Changed majors exactly once	0.21	0.010
Changed majors at least two times	0.18	0.010
Changed majors at least three times	0.04	0.004
Changed majors at least four times	0.03	0.003

Table 3 displays major persistence behavior by select student and institutional characteristics. Males were almost twice as likely to switch to a STEM major than females (16% to 9%), while a slightly higher proportion of females persisted than males (53% to 49%). About the same percentage of males switched to a non-STEM field as females (41% to 42%).

The rate at which different ethnic groups switched to non-STEM majors varied between 34% (Asians) and 45% (African Americans). The proportion of Asians that switched to a STEM major was 18%, the highest among all ethnic groups (11% in each of the other groups). The proportion in each group that persisted was somewhat similar across groups, ranging from 49% (African Americans) to 54% (Asians).

The major persistence patterns among students from different SES backgrounds were very similar. Forty-one percent of students in each SES group had switched to a non-STEM major, and between 11-12% of students in each group had switched to a STEM major. Fifty-one percent of students from middle and high SES backgrounds persisted in their first declared major. A slightly higher percentage (54%) of students from low SES backgrounds persisted in their majors.

There was considerable variation in the proportion of students from different entering declared major types who switched to STEM and non-STEM majors. Among students who entered college declared as STEM majors in 2003, 48% switched to a non-STEM major at some time during enrollment, 28% switched to another STEM major, and 33% persisted in their declared STEM major. Among students who entered college declared as non-STEM majors in 2003, 45% switched to a non-STEM major at some time during enrollment, only 10% switched to a STEM major, and 49% persisted in their declared non-STEM major. Finally, of those students who entered college undeclared in 2003, 28% switched to a non-STEM major at some time during enrollment, only 5% switched to STEM major, and 68% never changed majors[6].

Figures reported by Chen (2013) and Chen and Ho (2012) indicated that 28% of STEM entrants between 2003 and 2009 had left their STEM disciplines by switching to a non-STEM major by 2009. The figure reported

[5] There appears to be slight disagreement between the values of MAJ06CHG and MAJ09CHG, and information provided by the major code variables MAJ04A, MAJ06A, and MAJ09A used to determine the STEM status of the most recently declared major. For example, the major codes given in MAJ04A and MAJ06A for a student may indicate STEM and non-STEM majors, respectively; however, no change of major is indicated in MAJ06CHG. For purposes of consistency, MAJ06CHG and MAJ09CHG were used to determine if a change of major occurred and if a change occurred, the major code variables MAJ04A, MAJ06A, and MAJ09A were used to determine whether the change was to a STEM or non-STEM major.

[6] Students entering college undeclared may have either eventually declared a major, dropped out of their first institution without ever declaring a major, or never declared a major by the end of the study.

here is much higher because the analysis conducted in this study included students who changed fields between 2004 and 2006 as well as between 2006 and 2009.

In general, students who graduated from their first institution were more likely to have switched majors than students who did not graduate. Students who eventually graduated had slightly higher switching rates than students who did not graduate. Forty-two percent of students who graduated college had switched to a non-STEM major, while 39% of students who did not graduate had switched to a non-STEM major. Twelve percent of students who graduated had switched to a STEM major, while only 9% of non-graduates switched to a STEM major. The proportion of non-graduates who had persisted in their majors was higher than that of graduates (55% compared to 49%).

There is also some variability in the switching behaviors between students who attended public and private institutions with a higher proportion of students at private institutions persisting in their majors. Of those students attending public institutions, 44% changed to a non-STEM major, 13% changed to a STEM major, and 48% persisted in their declared major. Among students at private institutions, only 35% switched to a non-STEM major, 10% changed to a STEM major, and 58% remained in their majors.

Table 3: Proportion of individuals with indicated characteristics that switched to Non-STEM and STEM majors[7]. Standard errors in parentheses.

	Switched to a Non-STEM major	Switched to a STEM major	Did not Switch
Total	0.41 (0.008)	0.12 (0.004)	0.51 (0.008)
Gender			
Male	0.41 (0.014)	0.16 (0.007)	0.49 (0.013)
Female	0.42 (0.011)	0.09 (0.005)	0.53 (0.011)
Ethnicity			
White	0.42 (0.009)	0.11 (0.005)	0.51 (0.009)
African American	0.45 (0.029)	0.11 (0.018)	0.49 (0.030)
Hispanics	0.40 (0.031)	0.11 (0.017)	0.53 (0.029)
Asians	0.34 (0.031)	0.18 (0.024)	0.54 (0.029)
Income Background			
Low	0.41 (0.023)	0.11 (0.012)	0.54 (0.023)
Middle	0.41 (0.012)	0.12 (0.007)	0.51 (0.012)
High	0.41 (0.013)	0.12 (0.008)	0.51 (0.014)
Type of Major in 2003			
STEM	0.48 (0.020)	0.28 (0.016)	0.33 (0.018)
Non-STEM	0.45 (0.012)	0.10 (0.006)	0.49 (0.011)
Undeclared	0.28 (0.014)	0.05 (0.006)	0.68 (0.016)
STEM Entrant	0.43 (0.016)	0.14 (0.006)	0.29 (0.014)
Non-STEM Entrant	0.47 (0.009)	0.09 (0.005)	0.49 (0.009)
First Institution Selectivity			
Very Selective	0.37 (0.014)	0.14 (0.010)	0.53 (0.014)
Moderately Selective	0.45 (0.011)	0.11 (0.006)	0.49 (0.011)
Minimally Selective	0.38 (0.034)	0.12 (0.017)	0.55 (0.034)

[7] Note that column totals sum to more than 1 due to students who switched to both STEM and non-STEM majors.

Table 3 (continued): Proportion of individuals with indicated characteristics that switched to Non-STEM and STEM majors[8]. Standard errors in parentheses.

First Institution Control			
Public	0.44 (0.010)	0.13 (0.006)	0.48 (0.010)
Private	0.35 (0.011)	0.10 (0.008)	0.58 (0.012)
Graduated			
Yes	0.42 (0.009)	0.12 (0.005)	0.49 (0.010)
No	0.39 (0.015)	0.09 (0.026)	0.55 (0.016)

Person-Period Data Set

Before the hazard models were developed, the original "person-level" data set (where each row of data corresponded to a single student) was converted to the "person-period" format (Singer and Willett, 2003) where each student had multiple rows of data equal to the number of years that the student was enrolled. The values of each time-invariant predictor variable such as gender and SAT score are identical in each year enrolled in the person-period data set, while values for each time-varying predictor such as Pell Grant amount and academic intensity could potentially change from year to year. Change of major indicator variables (to be discussed in the next section) were created to indicate whether a change to a STEM or non-STEM major occurred and whether the change happened during the first or second follow-up period.

Change of Major Indicators

To investigate the role of change of major behavior on graduation risk, it was necessary to construct predictor variables to indicate whether and when a change of major to either a STEM or non-STEM major occurred. Two major limitations of the BPS data imposed certain restrictions on the values that the change of major predictor variables could take, as well as the extent to which the impact of changing major could be examined. First, the exact year that a change of major occurred is not available; it is only known whether students changed their major at least once between July 2004 and June 2006 (the first follow-up period), and at least once between July 2006 and June 2009 (the second follow-up period) as indicated by BPS variables MAJCHG06 and MAJCHG09. The second limitation of the BPS data is that yearly STEM status (STEM or non-STEM) of a major is not known; the STEM status of a major can only be determined in 2003 (base year of survey), 2006 (end of first follow-up period) and 2009 (end of second follow-up period). For the small percentage of students who changed their majors more than once within the first follow-up (6.8%) and second follow-up (8.4%) periods, it is not possible to determine the STEM statuses of the majors corresponding to multiple switches within a follow-up period; only the STEM status of the major corresponding to the last switch within a follow-up period can be known. Furthermore, the year of each switch cannot be determined for the students who changed majors more than once within a follow-up period. Therefore, information regarding multiple changes of major within a follow-up period could not be incorporated into the analysis. A student was simply designated as a switcher if the student formally changed majors at least once within a follow-up period. Hence, due to limitations of the available change of major information, each change of major predictor indicates whether the student performed one of the following switching operations:

- The first change of major to a STEM discipline occurred during the first follow-up period.
- The first change of major to a non-STEM discipline occurred during the first follow-up period.
- The first change of major to a STEM discipline occurred during the second follow-up period.
- The first change of major to a non-STEM discipline occurred during the second follow-up period.

Information from MAJCHG06 and MAJCHG09 was used to determine whether the first change of major (at least one change of major) occurred in the first or second follow-up period, and the BPS variables MAJ06A and MAJ09A indicated student's most recently declared major field, e.g. physical sciences, education, and engineering,

[8] Note that column totals sum to more than 1 due to students who switched to both STEM and non-STEM majors.

in the first and second follow-up periods, respectively. These major fields were classified as STEM or non-STEM using the coding scheme of Chen and Ho (2012). It was then determined whether a change to a STEM or non-STEM major was made based on the major information provided in the follow-up surveys. For example, if a student changed majors in the first follow-up period, and that student's most recently declared major in 2006 was classified as STEM, it was known that the student had formally changed to a STEM major sometime between 2004 and 2006.

Based on the information provided by the variables discussed above, derived time-varying indicator variables *CSTEMEarly*, *CNSTEMEarly*, *CSTEMLate*, and *CNSTEMLate*, were created to identify whether and in which year (to the extent possible) students changed to a STEM or non-STEM major. For coding purposes, if the student switched majors for the first time in the first follow-up period, then it was assumed to have occurred in year 2, and if the student changed majors for the first time during the second follow-up period, then the switch was assumed to have happened in year 4. This coding decision was based on the definitions of MAJCHG06 and MAJCHG09. MAJCHG06 applies to students who were enrolled after the 2003-2004 year, i.e. they were enrolled during year 2, while MAJCHG09 applies to students who were enrolled in year 4. Hence, if the student's first change of major occurs in the first follow-up period and is to a STEM major, then *CSTEMEarly* takes the value 0 in year 1 and a value 1 in year 2 and each year thereafter that the student is enrolled. Otherwise, *CSTEMEarly* takes the value 0 in all years of enrollment. If the student's first change of major occurs in the second follow-up period and is to a STEM major, then *CSTEMLate* takes the value 0 in years one through three and the value 1 in year 4 and each year thereafter that the student is enrolled. Otherwise, *CSTEMLate* takes the value 0 in all years of enrollment. Similar definitions apply to *CNSTEMEarly* and *CNSTEMLate*, adjusted for changing early or late to non-STEM majors. By including the four change of major indicators in appropriate hazard models, the effects of changing to a STEM or non-STEM major early (during the first follow-up period) or late (during the second follow-up period) on risk of graduation could be estimated. Although precise assessments of changing major in a specific year of enrollment cannot be obtained, the effects of changing major within crucial time periods in college can still be estimated relatively precisely.

For sake of brevity, the following terms may be used to describe students who changed to a STEM major, changed to a non-STEM major, or never switched from their first declared major. The term *persister* refers to a student who never changed major (whether or not a major was ever eventually declared) during the duration of first institutional enrollment. More specifically, a *STEM persister* or *non-STEM persister* refers to a student who entered college declared in a STEM or non-STEM major and never switched majors. An *early STEM switcher* or *early non-STEM switcher* is a student who changed to a STEM or non-STEM major during the first follow-up period (assumed to be in year 2 of enrollment). A *late STEM switcher* or *late non-STEM switcher* is a student who changed to a STEM or non-STEM major during the second follow-up period (assumed to be in year 4 of enrollment).

Although the focus of the current research was on first change of major, it was important to control for multiple switches due to the proportion of students who indicated at least two switches (see Table 2). Limited information on number of changes and year of change resulted in a dichotomous "multiple switches" predictor that takes the value 0 in years preceding the follow-up period in which two or more major changes were indicated, and the value 1 in the period (year 2 or year 4) when two or more switches occurred. With the set of change of major predictors, the impact of changing to a STEM or a non-STEM major early or late in college on graduation risk can be investigated while also taking into account whether the student switched majors more than once.

Statistical Model

The research questions were investigated using multilevel discrete-time hazard models, beginning with the so-called "baseline" model that did not include interactions between the change of major indicators and background predictors. To address Research Question 1, a multilevel model without interactions was fit to the person-period data. This model, based on the previously established theoretical frameworks, was used to confirm whether a significant relationship between changing major and graduation risk existed after controlling for demographic, academic, and institutional characteristics. Because the risk of graduation is essentially 0 in the first year (no one in the sample graduated after one year) and close to 0 in year two, an alternative to the dummy variable specification of the main effect of time was selected for the hazard models (Singer and Willett, 2003). The lifetable estimates of hazard (not shown) revealed low hazard prior to the third year, a sharp increase in the fourth year, and then slight increase in the fifth and sixth years. Hence, a cubic polynomial main effect of time was proposed for the multilevel model. The time-to-graduation variable, *CenTime*, was centered at year 6 so that the model intercept had a meaningful interpretation as the log-odds of graduating in the sixth year. The student-level model is given by:

$$\ln\left(\frac{h_{ijt}}{1-h_{ijt}}\right) = \beta_{0j} + \beta_{1j} CenTime_{ij} + \beta_{2j} CenTime_{ij}^2 + \beta_{3j} CenTime_{ij}^3 + \beta_{4j} CSTEMEarly_{ijt} + \beta_{5j} CNSTEMEarly_{ijt} + \beta_{6j} CSTEMLate_{ijt} + \beta_{7j} CNSTEMLate_{ijt} + \sum_k \beta_{kj} (Student\ \ Characteristics)_{ij} , \quad (1)$$

where h_{ijt} represents the hazard of graduating for person *i* at institution *j* during year *t*, or more precisely it is the probability that student *i* graduates from institution *j* during year *t* given that the student had not graduated in any previous year. The left side of equation (1), $\ln\left(\frac{h_{ijt}}{1-h_{ijt}}\right)$, represents the conditional log-odds of graduating at time *t*, and *CSTEMEarly*, *CNSTEMEarly*, *CSTEMLate*, and *CNSTEMLate* are the change of major indicators discussed above. (*Student Characteristics)* is a vector of student-level predictors, including some that are time-varying such as financial aid quantities and attendance intensity. The intercept, β_{0j}, in equation (1) is allowed to vary by institution and depends on first-year institutional-level predictors described above: *Enrollment*, *Percent Minority*, *Private*, and *Selectivity*. The institution-level model is expressed as:

$$\beta_{0j} = \gamma_{00} + \gamma_{01} Enrollment_j + \gamma_{02} PercentMinority_j + \gamma_{04} Private_j + \gamma_{05} Selectivity_j + u_{0j} , \quad (2)$$

where u_{0j} is the random effect assumed to follow a normal distribution with mean 0 and variance τ_{00}.

Some background qualitative variables used in the model were collapsed to reduce the number of categories, and, hence, the number of parameters that would later require estimation for the fitted models. Income level (according to dependency status) in 2003 was collapsed from four to three groups: low, middle, and high. “Low middle” and “high middle” groups were combined to form a “middle” category. Race was reduced to include only white and non-white categories due to the limited percentages of students from minority groups in the final sample. Attendance intensity classified student’s yearly enrollment pattern as part-time, full-time, or a mixture of part-time and full-time. It was recoded into two categories with the “part-time” and “mixture of full and part-time” categories were combined into a “less than full-time” group. Cumulative high school GPA is a categorical variable that originally was divided into 7 intervals. Because the median cumulative high school GPA among students in the final analysis sample was approximately 3.4, the 7 intervals were collapsed into two: 3.4 or lower and above 3.4. Among the two categorical institutional-level variables, control indicated whether the first institution attended was public or private, and selectivity indicated whether or not the institution was highly selective.

Student-level and institutional-level quantitative predictors with non-meaningful 0 values were centered at their respective grand means, while those with meaningful 0 values were left uncentered. Hence, SAT math and verbal scores, academic and social integration indices, first year college GPA, enrollment size, and percentage of minority students on campus were grand-mean centered. Grand-mean centering was used because it was of interest to examine how much of the observed differences in first-institution graduation risk could be attributed to differences in students, not differences in the features of the institutions themselves (Rumberger and Thomas, 2000). Grand-mean centering controls for differences between institutions in student characteristics and experiences, and allows one to examine how differences in the outcomes are due to characteristics of the students. In addition, except for the declared status of entering major, the reference group for each qualitative predictor was set to the modal category, i.e. the category that occurs most frequently. The centering values for the quantitative variables and the reference groups for the qualitative variables are presented in Table 4, and can be regarded as the “baseline” characteristics for students in the sample. Hence, the intercept, β_{0j}, can be interpreted as the adjusted (conditional) log-odds of graduating in year 6 for a student in the baseline group, i.e. for a student with the baseline characteristics attending a typical four-year institution. Appropriate centering also allows for meaningful interpretation of the remaining coefficients in the model.

Table 4: Student and school characteristics for individuals in the baseline group

Predictors	Baseline Characteristics
Student-Level	
Major Persistence	No Change
Gender	Male
Ethnicity	White
Income	Middle
First Generation	No
HSGPA	Above 3.4
SAT Math	537
SAT Verbal	536
First Year Academic Integration	90.04
First Year Social Integration	67.88
First Year GPA	2.92
First Year Major Type	Undeclared
Stafford and Perkins Loans	$0
Pell Grant	$0
Plus Loan	$0
Academic Intensity	Full Time
First-Year Institutional-Level	
Selectivity	Minimally or Moderately Selective
Control	Public
Enrollment Size	13,683
Percent Minority	23.68

Research question (2) sought to investigate how the association between changing major and risk of graduation depended on select first-year student-and institutional-level predictors. Interaction terms were created between each first-year background predictor and two derived change of major variables indicating whether the student's first change was to a STEM or a non-STEM major. The indicator variable *CSTEM* takes the value 0 in the years prior to the change to a STEM major, and 1 in the year of the switch (year 2 if the switch occurred in the first follow-up period or year 4 if the switch occurred in the second follow-up period), and each subsequent year that the student was enrolled. If no change to a STEM major was made, then *CSTEM* takes the value 0 in all years of enrollment. The variable *CNSTEM* is defined similarly for first change to a non-STEM major. Note that there are no separate indicators for early (first follow-up period) or late switches (second follow-up period), thereby reducing the number of parameters that would potentially need to be estimated in a model that would include all interactions.

Table 5 displays the interaction terms that were created to examine the impact of the predictor on the association between changing major and graduation risk. Each set of interaction terms (second column of Table 5) was added to the baseline model given in equation (1) without any other interaction terms present and tested for significance using a change in deviance test. Those that were individually significant were added to the baseline model to create a final "interaction model." The results of the interaction model were also used to address the third research question. Due to the potentially large number of parameters that would require estimation in the model, additional two-way and higher order interactions were not considered. The interaction model replaces equation (1) and will take the form:

$$\ln\left(\frac{h_{ijt}}{1-h_{ijt}}\right) = \beta_{0j} + \beta_{1j}CenTime_{ij} + \beta_{2j}CenTime_{ij}^2 + \beta_{3j}CenTime_{ij}^3$$
$$+ \beta_{4j}CSTEMEarly_{ijt} + \beta_{5j}CNSTEMEarly_{ijt} + \beta_{6j}CSTEMLate_{ijt} + \beta_{7j}CNSTEMLate_{ijt}$$
$$+ \sum_k \beta_{kj}(Student\ \ Characteristics)_{ij} \qquad (3)$$
$$+ \sum_k \beta_{kj}(Student\ \ Characteristics)_{ij} \times CSTEM_{ijt}$$
$$+ \sum_k \beta_{kj}(Student\ \ Characteristics)_{ij} \times CNSTEM_{ijt}$$

The institution-level model remains identical to equation (2).

Table 5: Interaction terms created to determine how the association between changing majors depended on select first-year student and institutional characteristics

First-Year Predictors	Interaction Terms Created
Gender	CSTEM × Female
	CNSTEM × Female
Race	CSTEM × White
	CNSTEM × White
First Year GPA	CSTEM × FYGPA
	CNSTEM × FYGPA
Academic Integration	CSTEM × Academic Integration
	CNSTEM × Academic Integration
Social Integration	CSTEM × Social Integration
	CNSTEM × Social Integration
Entering Major Type	CSTEM × Declared STEM
	CNSTEM × Declared STEM
	CSTEM × Declared NSTEM
	CNSTEM × Declared NSTEM
Control	CSTEM × Private
	CNSTEM × Private
Selectivity	CSTEM × Highly Selective
	CNSTEM × Highly Selective

The third research question regarding the additional time necessary to graduate is addressed by comparing predicted median graduation times for students with baseline characteristics who persisted in their majors, changed to STEM majors, and changed to non-STEM majors. The median graduation time for a subgroup of students is the time at which half those individuals have graduated and half have not. When examining subgroups of students, e.g. persisters and switchers, with only a limited number of time points (six years for the current study), the median graduation time calculated in the manner described above may not properly characterize the differences in the graduation experiences among the groups. Hence, interpolation between two time points has been recommended as an alternative method to estimate median survival times (Singer and Willett, 2003).

Median times to graduate for students who persist in their first declared majors (or who remain undeclared through enrollment), switch to a STEM major, and switch to a non-STEM major will be predicted based on the fitted hazard probabilities of the interaction model given in equation (3). Let $\hat{h}_t$ represent the estimated hazard probability of graduating at time *t* (for sake of brevity, the *i* and *j* subscripts have been dropped), and

$$\hat{S}_j = \prod_{t=1}^{j} \left(1 - \hat{h}_t\right) \tag{4}$$

be the estimated probability of not having graduated (surviving) beyond time *j*. Then the estimated median time to graduate is given by:

$$\text{Estimated Median} = m + \left[\frac{\hat{S}_m - .5}{\hat{S}_m - \hat{S}_{m+1}} \right], \tag{5}$$

where m is the first time when the estimated survival function $\hat{S}_t$ is above .5 (see Singer and Willett (2003)). The predicted hazard probabilities $\hat{h}_t$ are computed from the results of the interaction model, fixing the student- and institutional-level predictors at their respective reference values (see Table 4), setting the financial aid variables to their respective median values, and setting the random effect u_{0j} to 0.

LIMITATIONS

There are at least four important limitations of the study that warrant discussion. As discussed earlier, the year that the change of major occurred cannot be precisely determined. Change of major behavior can only be assessed at the time of the follow-up stages of the BPS, limiting the precision of assessing the impact of the date of the switch. Hence the yearly effect of changing major cannot be investigated. Only the "period" (early or late) effect of switching major on graduation risk can be estimated. It is also possible that because a student could change majors more than once during in a follow-up period, changes to both STEM and non-STEM majors could have occurred within a single follow-up period. This behavior cannot be captured in the analyses of this study. Because the type of major was only indicated at the end of each follow-up period, i.e. in 2006 and 2009, it was only possible to determine the type of major of the latest switch within the follow-up period. Nevertheless, the current study still addresses the impact of changing *at least once* to a STEM or non-STEM major.

Second, the results of this study only apply to first-institution graduation, and are not applicable to overall graduation from any bachelor's degree granting institution. This restriction was necessary due to the institutional-level information available in the BPS:04/09, as well as preserving the nested structure of students within the same institution over time. Although yearly transfer status and graduation status are available for all students, institutional-level characteristics are only available for the first institution attended. If longitudinal information on students who transfer to another four-year institution such as enrollment, financial aid amounts, academic intensity, and graduation outcome is included in the analysis, then the effects of first institution characteristics on graduation risk will be confounded with the effects of transfer institution characteristics on graduation risk. In addition, following students in their origin institution over time maintains a consistent nested structure of student *i* attending institution *j* in each year of the study. In this manner it is possible to isolate and estimate the contribution of the characteristics of an institution and the student's experiences (academic and social) at the same institution to the risk of graduating at the origin institution.

Thirdly, as is the case for most studies on retention and persistence, the current investigation does not adjust for self-selection on several student-level variables, including change of major activity. Therefore, it is not possible to determine whether changing major actually causes an increase or decrease the risk of graduating, only whether a significant association between changing major and graduation risk can be established.

Finally, the results of the study are not applicable to transfer students who graduated or students who left their first institution but later returned, i.e. stopouts, and graduated. Continuously enrolled students were followed at their first institution until they graduated or left the institution before graduating. Students who transferred to another university and stopouts were treated as censored cases. These students may have eventually graduated, but their first-institution experience effectively ends the first year there is a break in their enrollment.

RESULTS

The multilevel models were fit to the person-period data using the GLLAMM program (Rabe-Hesketh, Skrondal, and Pickles, 2002) for the Stata (Version 13) software package. The GLLAMM routine can estimate the parameters of generalized multilevel models, while also incorporating sampling weights at each level of the model to compensate for unequal probability of selection[9]. As suggested by Raudenbush and Bryk (2002), an unconditional model was first fit to the data to explore the variation in (six-year) graduation rates by institution ignoring any student-level or institutional-level predictors. Using the results of the unconditional model, the probability of graduating (degree completion) varied considerably between institutions from a low of 20.0% to a high of 93.8%. The intraclass correlation coefficient was .182 indicating that roughly 18.2% of the variation in graduation rates is attributed to difference in colleges and universities. The estimated variance of the random effect was .73 with standard error .11. Due to the considerable variation in the graduation rates, a generalized multilevel modeling approach is warranted.

The association between the model predictors and graduation risk also potentially depended on the time to graduation, thereby violating the proportional odds assumption (Singer and Willett, 2003). Hence, after the baseline model was fit, time-varying predictor effects were investigated by testing interactions between each predictor and a time variable. To investigate time-varying effects of changing major, interactions between each change of major indicator and a time variable measuring the (approximate) number of years after the switch (YAS) were created. The years after switch variable was centered at year 1 so that the coefficient corresponding to each change of major indicator would represent the effect of changing major (early or late to a STEM or non-STEM major) in the year after the switch. If no centering were implemented, then the coefficient would represent the change of major effect on graduation risk in the year that the switch occurred. Given that students are less likely to graduate in the year that they changed major, assessing the effect on graduation risk in the year that the switch occurred was deemed not as meaningful as assessing the effect in the year following the switch. To assess the time varying effects of the background predictors, interaction terms were constructed between the first-year background predictors and time to graduation. Because four years is the time that institutions expect their students to graduate, time to graduation was centered at four years to provide more meaningful interpretations of the individual coefficients corresponding to the background predictors.

The baseline model was fit to the person-period data to address the first research question. Adjustments to the model were implemented to reflect the presence of some time-varying effects. Next, interactions between change of major indicators and first-year predictors were tested to examine how the association between changing majors and graduation risk depends on select student and institutional factors. Finally, the results of the interaction model were used to compute predicted median graduation times to address differences in typical graduation times between persisters, STEM switchers, and non-STEM switchers.

Baseline Model

After fitting the baseline model to the person-period data, it was determined that the effects of entering major type and changing early or late to a STEM major on graduation odds significantly varied over time. Hence, interactions between the STEM major change indicators and years after switch, as well as interactions between first-year entering major type and time were found to be individually significant (at the .05 level) and included in the baseline model. The first three columns of Table 6, respectively, display parameter estimates, robust standard errors, and predicted odds ratios corresponding to significant (or marginally significant) predictors (or predicted ratios of odds ratios corresponding to significant interaction terms). The estimate of the random effect variance is .307 with a standard deviation estimated to be .082. Results of the estimated baseline model reveal that yearly

[9] Sampling weights at both the student and institutional levels were created by multiplying together appropriate weight components located in the supplementary BPS:04/09 Component Weight File.

graduation risk significantly depends on several student- and institutional-level control variables, and that after adjusting for the background predictors in the model, there is a significant association between changing major and graduation risk, or more specifically, the conditional log-odds of graduating. For sake of brevity, the following interpretations of the predicted odds ratios adjust for the remaining predictors in the model, as well as the institutional random effect. In addition, the "odds of graduating" should be interpreted as the odds of graduating in a given year conditional on being enrolled (not graduating) the previous year.

Females have higher (conditional) chance of graduating from college than males: a female student's odds of graduating are predicted to be 55% higher than those of a male student ($p < .001$). Non-white students have lower chance of graduating from college than white students: The odds of graduating for a non-white student are predicted to be 17% lower than the graduation odds for a white student ($p < .05$). Students from high income backgrounds have a higher chance of graduating from college than students from middle income backgrounds: The odds of graduating for a student from a high income background are predicted to be 53% higher than the graduation odds for a student from a middle income background ($p < .001$). Students with a lower cumulative high school GPA were also less likely to graduate from college: the graduation odds for a student with a high school GPA below the median (approximately 3.4) were about 23% less ($p < .001$) than the odds for a student with a GPA above the median. Math SAT score was positively associated with graduation risk: each hundred point increase beyond the average score is associated with a 21% increase in the odds of graduating ($p < .001$). First-year college GPA is also an important indicator of future college success. Each half-point increase in GPA above the average is associated with a 35.5% increase in the odds of graduating ($p < .001$).

First-year entering major type did not have any significant impact on graduation risk in year 4, i.e. the odds of graduating for students who entered undeclared, declared in a STEM field, or declared in a non-STEM field did not significantly differ after four years; however, beginning in the fifth year the odds of graduating for students who entered declared in either a STEM or non-STEM major became significantly less than the odds for those who began college undeclared, and the gap in odds continued growing in subsequent years. Adjusting for the control variables, the odds ratio comparing a student who entered as a STEM major to a student who began undeclared is predicted to decrease by 25% each additional year beyond the fourth ($p < .05$), while the odds ratio comparing a student who entered as a non-STEM major to a student who began undeclared is also predicted to decrease by 25% ($p < .01$). The results imply that students entering college undeclared may have some advantage later in their post-secondary career over students entering with a declared major.

Attending college full-time throughout enrollment is also strongly associated with increased probability of graduating. The graduation odds of a student attending less than full-time throughout their college career are predicted to be 76% ($p < .001$) less those that of a student who attends full-time.

Based on previous research studies, it was expected that the financial aid amounts would be positively associated with graduation risk. It was somewhat surprising to find that the financial aid variables, combined Stafford and Perkins loan amount, as well as Pell grant amount, were negatively associated with the risk of graduating. Each increase of $1000 is associated with a predicted 4% decrease in the odds of graduating ($p < .01$), while each $1000 increase in amount of Pell grant received was associated with a 8% decrease in the odds of graduating ($p < .05$).

Finally, the structural institutional characteristics were all significantly related to yearly graduation risk. Students attending larger institutions were predicted to have a slightly lower risk of graduating: each additional 1000 students enrolled was associated with a 1% decrease in the odds of graduating ($p < .01$). The proportion of enrolled undergraduate minority students was also found to be slightly negatively associated with graduation risk: Each additional percent increase was associated with about a 1% decrease in graduation odds. Students attending private institutions and highly selective institutions have higher graduation risk than students at public institutions. The odds of graduating for a student from a private institution are predicted to 66% higher than those of a student from a public institution ($p < .001$). Highly selective institutions are also associated with higher graduation risk. The odds of graduating for a student from a highly selective institution are predicted to be 71% higher than the graduation odds for a student from a non-highly selective institution ($p < .001$).

After accounting for student and institutional variables, results indicate that with the exception of switching early to a non-STEM major, changing majors is initially associated with a lower chance of graduation. Changing early or late to a STEM major is initially negatively associated with the (conditional) chance of graduating in the year after the switch. After controlling for background predictors, the odds of graduating from college in the year following the change of major for an early STEM switcher are predicted to be 53% lower than those of a student who persists ($p < .05$), while the odds of graduating in the year following a late change to a STEM major are predicted to be 35% lower than those of a student who persists ($p < .05$).

Although the graduation risk of STEM switchers is smaller than that of persisters in the year following the change of major, the effect of switching early or late to a STEM major was found to (marginally) significantly depend on time ($p < .1$ for early or late switchers).[10] Because the time since the STEM switch is centered at one year, the coefficients corresponding to the interactions with the change of major indicators represent the multiplicative changes to the odds ratios (comparing a switcher to a persister) associated with each year beyond the year after the change of major occurred. Hence, the gap in the log-odds of graduating between STEM switchers and persisters begins to narrow in the second year after the switch. Specifically, adjusting for the remaining predictors, the odds ratio (comparing an *early* STEM switcher to a persister) is predicted to increase 38% ($p < .1$) each year beginning the second year after the switch; while the odds ratio (comparing a *late* STEM switcher to a persister) is predicted to increase 56% ($p < .1$) each year beginning the second year after the switch. The implications of the time-varying effect of changing to a STEM major will be further explored when discussing the results of the interaction model.

An early switch to a non-STEM major is not significantly associated with the probability of graduation in any year following the switch. It is possible that switching early to majors in non-STEM disciplines requires fewer sequence courses in subjects such as calculus, physics, and chemistry. Switching late to a non-STEM major has a negative impact on the chance of graduation that does not depend on time. Adjusting for the remaining predictors in the model, a late change to a non-STEM major is associated with a 35% ($p < .01$) decrease in the odds of graduating in any year following the switch.

Finally, although the estimated coefficient for the multiple switch predictor indicates decreased graduation risk for those students who changed majors more than once, the result is not significant ($p = .18$) in the baseline model. Hence, after adjusting for the remaining student and institutional variables, changing majors more than once does not have a significant impact on graduation risk.

Interaction Model

The first research question addressed the impact of changing major on graduation risk for students in the baseline group, but did not investigate how the association depends on the level of other predictors. The second research question examines how the relationship between changing major and graduation risk depended on the level of some select first-year predictors. Interactions between the two change of major indicators, *CSTEM* and *CNSTEM*, and select predictors were individually tested for significance in the baseline model, and those that were significant were kept.[11] Results of the interaction model indicate that after adjusting for student- and institutional-level variables, the association between changing to a STEM major and graduation risk was found to significantly (or marginally significantly) vary by gender, first-year GPA, academic integration, entering major type, and institutional control. A change-in-deviance test indicated that the inclusion of these interaction terms to the baseline model (1) was significant (test-stat = 90.0, df = 12, p-value < .001). The estimate of the random effect variance is .306 with a standard deviation estimated to be .082. Parameter estimates, robust standard errors, and predicted odds ratios (or predicted ratios of odds ratios corresponding to significant interaction terms) corresponding to significant (or marginally significant) predictors are displayed, respectively, in columns four through six of Table 6.

[10] Each interaction term was individually significant at the .05 level; however when all interactions were included, the STEM switch by time interaction terms became marginally significant.

[11] Each interaction term included in the model was individually significant at the .05 level; however when all interactions were included some became marginally significant.

All of the control variables that were significant in the baseline model remained significant in the interaction model, and the direction of their association with graduation risk remained the same as well; however, the interpretations of the coefficients corresponding to predictors now depend on whether they interact with change of major indicators CSTEM and CNSTEM. The estimated coefficient for a predictor not interacting with change of major indicators can be interpreted as the predicted multiplicative change in the (conditional) odds of graduating associated with a unit increase in the predictor, adjusting for the remaining variables in the model. The association between these predictors and the odds of graduating remains the same regardless of whether the student changes major or persists in a declared major. Coefficients corresponding to predictors that interacted with change of major indicators reflect the multiplicative change in the odds of graduating associated with a unit increase in the predictor specifically for students who *persisted*, adjusting for the remaining variables in the model. Once again, the following interpretations of the predicted odds ratios adjust for the remaining predictors in the model, as well as the institutional random effect.

Control Variables

Among persisters, the odds of graduating for a female student (with baseline characteristics) are predicted to be 67.0% higher than the odds for a male student ($p < .001$) (with baseline characteristics), while the odds of a non-white student graduating is 18% smaller than the odds of a white student graduating ($p < .05$). A student from a high income background is predicted to have odds of graduating that are 52% higher than those of a student from a middle income background ($p < .001$). High school GPA, math SAT score, first year GPA, and enrollment intensity were significant academic predictors of risk. A student entering with a lower high school GPA is predicted to have odds of graduating 23% lower than those of a student with a high school GPA greater than 3.4 (roughly the median high school GPA) ($p < .001$). Each 100 point increase in math SAT score was associated with a 21% increase in the odds of graduating ($p < .001$). Among persisters, first year college GPA was positively related to the odds of graduating: a point increase above the mean GPA was associated with a 71% increase in the odds of graduating ($p < .001$). Full-time enrollment was significantly and positively associated with graduation risk. The odds of graduating for a student who attended school part-time or a mixture of part and full-time are predicted to be 76% lower than those for a student who attended full time ($p < .001$).

For persisters, declaring a STEM or non-STEM major did not have a significant association with graduation risk in year 4; however, the association between entering major type and graduation risk significantly depends on time. Hence, the odds ratio comparing a student who declared a STEM major to a student who entered undeclared is predicted to decrease by 25% each year after the fourth ($p < .05$), and the odds ratio comparing a student who declared a non-STEM major to a student who entered undeclared is also predicted to decrease by 25% each year after the fourth ($p < .01$). This result implies that after 4 years in college, STEM and non-STEM persisters actually perform worse (in terms of graduation risk) than persisters who began college undeclared.

Combined Stafford and Perkins loan amounts and Pell grant amounts are financial aid variables significantly negatively associated with graduation risk. Each additional $1000 in combined Stafford and Perkins loan amounts received was associated with a 4% decrease in the odds of graduating ($p < .01$). This result is consistent with studies showing that either loans were negatively associated with college persistence (Hochstein and Butler, 1983) or that students who financed their education with loans took longer to graduate (Knight and Arnold, 2000). Each additional $1000 in Pell Grants received was associated with a predicted decrease of 8% in the odds of graduation ($p < .01$). A potential explanation for the negative association is that greater financial need entails more work commitment, which in turn can make it more difficult for students to graduate in a timely manner.

Finally, enrollment size, percent minority students, control, and selectivity are institutional factors significantly associated with graduation risk. Larger institutions are associated with lower risk of graduating: each additional 1000 students enrolled was associated with a 1% decrease in the odds of graduating ($p < .05$). The proportion of enrolled undergraduate minority students was also found to be slightly negatively associated with graduation risk: Each additional percent increase was associated with about a 1% decrease in graduation odds ($p < .05$). Students attending private institutions and highly selective institutions have higher graduation risk than students at public institutions. Among persisters, the odds of graduating for a student from a private institution are predicted to be 48% higher than those of a student from a public institution ($p < .01$). Highly selective institutions are also associated with higher graduation risk. The odds of graduating for a student from a highly selective institution are predicted to be 70% higher than the graduation odds for a student from a non-highly selective institution ($p < .001$).

Impact of Changing Majors

After adjusting for the control variables, the association between switching (early or late) to a STEM major and graduation risk, as well as the relationship between switching late to a non-STEM major and graduation risk remained significantly negative; however, the degree of the associations varied by level of some student- and institutional-level predictors, as well as the time after the switch.

The negative impact of changing to a STEM major is less severe for females than males, i.e. the gap in the graduation odds between a STEM switcher and a persister is smaller for female students than for male students. Specifically, the odds ratio (comparing the odds of graduating between a STEM switcher and a persister) is predicted to be 58% higher for female students compared to male students (fixing all other predictors) ($p < .05$). Changing to a non-STEM major has a larger negative impact for females than males, with the gap in the graduation odds between a non-STEM switcher and a persister predicted to be smaller for male students than for female students. The odds ratio (comparing the odds of graduating between a non-STEM switcher and a persister) is predicted to be 23% lower for female students compared to male students ($p < .1$).

Among students who switched to a STEM major, first-year college GPA had a larger effect on the odds of graduating than it did for students who persisted. The odds ratio (comparing the odds of graduating between a STEM switcher and a persister) is predicted to increase by 21% for each half point increase above the average first year GPA ($p < .1$).

The association between changing major and graduation risk depended significantly on first year academic integration index. Among students who switched to a STEM major, first-year academic integration has a negative impact on the odds of graduating. Each 25-point increase above the average first year academic integration index is associated with about a 14% decrease in the odds ratio comparing a student who changed to a STEM major to one who persisted in his/her major ($p < .1$). In contrast, for students who switched to a non-STEM major, first-year academic integration index has a significant positive impact on the odds of graduating. Each 25-point increase above the average first year academic integration index is associated with an 8% increase in the odds ratio comparing a student who changed to a non-STEM major to one who persisted ($p < .05$).

There were significant differences in the effects of switching major on graduation risk by entering major type. The primary difference was found between entering STEM students who switched to STEM majors and undeclared students who switched to STEM majors with the odds ratio comparing STEM switchers and persisters predicted to be smaller for students who entered declared in STEM fields compared to students who entered undeclared. The odds ratio comparing a student who switched to a STEM major to a student who persisted is predicted to be 139% higher for students who entered declared as STEM majors compared to students who entered undeclared ($p < .01$). Hence, there is a clear advantage of switching to another STEM major from a declared STEM major compared to switching to STEM major after entering college undeclared.

The relationship between changing to a STEM major and graduation risk at private institutions was also significantly different than the association at public institutions. Attending a private institution is generally associated with a higher odds ratio comparing STEM switchers to persisters. Among students switching to STEM majors, the odds ratio comparing a student from a private institution to a student from a public institution is predicted to be 64% ($p < .01$) higher than the odds ratio among persisters.

In the original baseline model, the effects of early or late switching to a STEM major on graduation risk significantly depended on the time since the switch occurred, so that as time after the switch progressed, the difference in log-odds graduation between STEM switchers and persisters decreased. These time-dependent effects remained significant in the final interaction model, and in fact became stronger with the inclusion of the other interaction terms. Beginning in the second year following the switch, the odds ratio (comparing a student who switched early to a STEM major to a persister) is predicted to increase by 69% each year ($p < .01$), while the odds ratio comparing a late STEM switcher to a persister is predicted to increase by 83% each year thereafter ($p < .05$). Although the associated risk of graduation significantly decreases in the year after an early or late switch to a STEM major, students are able to readjust fairly quickly and their odds of graduating quickly become on par with those of students who persisted.

Once again, the estimated coefficient for the multiple switch predictor indicated reduced graduation risk for those students who changed majors more than once; however, the result was not significant ($p = .16$), suggesting that changing majors more than once does not have a significant impact on graduation risk, after adjusting for the student- and institutional-level predictors.

Table 6: Estimated coefficients, standard errors, significant odds ratios, and significant ratios of odds ratios corresponding to interaction terms (when applicable)

	Baseline Model			Interaction Model		
Predictor	Coef	Robust S.E.	Estimated Odds Ratio	Coef	Robust S.E.'s	Estimated Odds Ratio
Constant	2.032***	0.239		2.161***	0.250	
CenTime	2.230***	0.342		2.249***	0.344	
$CenTime^2$	1.554***	0.246		1.552***	0.248	
$CenTime^3$	0.512***	0.053		0.512***	0.053	
Student-Level Fixed Effects						
CSTEMEarly	-0.762*	0.295	0.47	-1.983***	0.495	0.14
CNSTEMEarly	0.071	0.151		0.084	0.222	
CSTEMLate	-0.428*	0.202	0.65	-1.221***	0.336	0.30
CNSTEMLate	-0.435**	0.126	0.65	-0.443*	0.193	0.64
Multiple Switches	-0.208	0.156		-0.228	0.162	
No (reference)						
Female	0.436***	0.071	1.55	0.510***	0.096	1.67
Race	-0.183*	0.082	0.83	-0.201*	0.083	0.82
White (reference)						
Income Level						
Low	0.034	0.101		0.035	0.100	
High	0.425***	0.077	1.53	0.417***	0.076	1.52
Middle (reference)						
First Generation	-0.022	0.093		-0.017	0.093	
No (reference)						
HSGPA (Above 3.4)	-0.264***	0.075	0.77	-0.267***	0.076	0.77
Math SAT/100	0.191***	0.045	1.21	0.187***	0.045	1.21
Verbal SAT/100	0.032	0.048		0.024	0.048	
Academic Integration	0.001	0.001		0.00005	0.001	
Social Integration	0.001	0.001		0.001	0.001	
First-Year GPA	0.534***	0.066	1.71	0.537***	0.086	1.71
First-Year Major Type						
STEM	-0.080	0.111		-0.244~	0.136	0.78
Non-STEM	-0.006	0.079		-0.076	0.120	
Undeclared (reference)						
Attendance Intensity	-1.434***	0.156	0.24	-1.438***	0.159	0.24
Full-Time (reference)						
Stafford and Perkins Loan /1000	-0.044**	0.013	0.96	-0.044**	0.013	0.96
Pell Grant/1000	-0.079*	0.031	0.92	-0.084**	0.032	0.92
PLUS Loan/1000	-0.006	0.008		-0.006	0.008	
Institutional-Level Fixed Effects						
Enrollment Size/1000	-0.014**	0.005	0.99	-0.014*	0.005	0.99

Table 6 (continued): Estimated coefficients, standard errors, significant odds ratios, and significant ratios of odds ratios corresponding to interaction terms (when applicable)

Percent Minority	-0.006*	0.003	0.99	-0.006*	0.003	0.99
Private	0.506***	0.126	1.66	0.393**	0.134	1.48
Highly Selective	0.535***	0.108	1.71	0.531***	0.109	1.70
Interaction Effects						Ratio of OR's
CSTEMEarly × (YAS - 1)	0.319~	0.174	1.38	0.523**	0.197	1.69
CSTEMLate × (YAS - 1)	0.443~	0.233	1.56	0.603*	0.255	1.83
STEM × (Time - 4)	-0.291*	0.132	0.75	-0.329*	0.135	0.72
Non-STEM × (Time - 4)	-0.287**	0.105	0.75	-0.306**	0.106	0.74
Change of Major × Gender						
CSTEM × Female				0.455*	0.229	1.58
CNSTEM × Female				-0.257~	0.138	0.77
Change of Major × FYGPA						
CSTEM × FYGPA				0.389~	0.221	1.48
CNSTEM × FYGPA				-0.054	0.109	
Change of Major × Academic Integration						
CSTEM × Acad Int				-0.006~	0.003	0.99
CNSTEM × Acad Int				0.003*	0.002	1.003
Change of Major × Entering Major Type						
CSTEM × STEM				0.872**	0.326	2.39
CNSTEM × STEM				0.239	0.204	
CSTEM × NSTEM				0.519	0.357	
CNSTEM × NSTEM				0.069	0.167	
Change of Major × Control						
CSTEM × Private				0.496~	0.268	1.64
CNSTEM × Private				0.221	0.153	
Random Effects						
Variance τ_{00}	.307			.306		
Standard deviation of τ_{00}	.082			.082		

~p < .10; *p <.05; **p <.01; ***p < .001

Predicted Graduation Hazard Profiles

To supplement the results of the interaction model, yearly graduation hazard probabilities were also computed for male and female students with baseline characteristics based on major persistence patterns and first-year entering major. To reflect more typical financial aid amounts, the value of each financial aid variable (combined Stafford and Perkins loan amounts, Pell grant amount, and Plus loan amount) in the interaction model was set equal to the grand median total amount (appropriately weighted) over the six year enrollment period.[12] Median total combined Stafford and Perkins loan amounts, median total Pell grant amount, and median total Plus loan amount were equal to $6125, $0, and $0, respectively. The remaining background student- and institutional-level variables were set to the reference levels outlined in Table 4. The following section attempts to provide some insight into the yearly graduation hazards (and median graduation times in the next section) for common students attending typical post-secondary institutions.

[12] Median instead of mean amounts were used because total combined Stafford and Perkins loan amounts, total Pell grant amounts, and total Plus loan amounts were heavily skewed to the right. The median is a more appropriate measure of central tendency than the mean for skewed data.

The hazard profiles for baseline persisters, early/late STEM switchers, and early/late non-STEM switchers are displayed in Figure 1 for male students and in Figure 2 for female students who entered postsecondary institutions undeclared, declared as STEM majors, and declared as non-STEM majors.[13] The values of the graduation hazard probabilities are also provided in Tables 7 and 8. The hazard probabilities for students in change of major groups that are significantly lower than the corresponding hazard probabilities for persisters are noted with an asterisk "*".[14] A double asterisk "**" identifies the hazard probability for female students who entered college as a STEM major and early switched to another STEM major that is significantly higher than the corresponding hazard probability for females who began college in a STEM field and persisted. Year 3 and 4 hazard probabilities for late switchers are not shown in the tables.

Figure 1: Predicted Hazard Curves by Major Persistence Pattern for Male Students (with Baseline Characteristics)

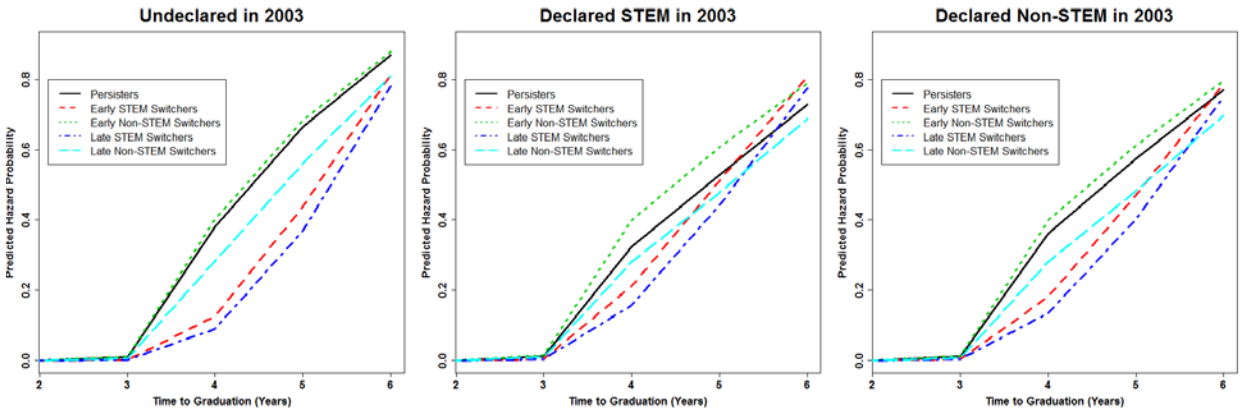
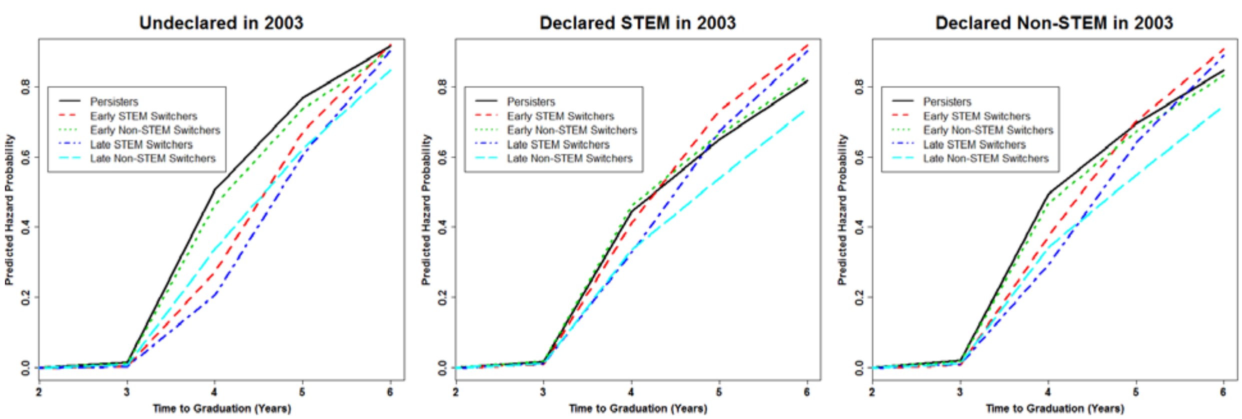


Figure 2: Predicted Hazard Curves by Major Persistence Pattern for Female Students (with Baseline Characteristics)



An important feature of the profiles is that the hazard probabilities corresponding to students who switched to STEM or non-STEM majors reflect the hazard of graduating in those types of major. The graduation hazard probabilities have been calculated with the multiple switches predictor set to its reference value, i.e. the student did

[13] Recall that it is assumed that early switches occur in year 2 and late switches occur in year 4. Therefore, profiles for early STEM or early non-STEM switchers are only meaningful in years 3 through 6, and profiles for late STEM or late non-STEM switchers are meaningful only in years 5 and 6.

[14] Comparisons of hazard probabilities were based on results of constructed 95% confidence intervals for odds ratios comparing the graduation odds for specific change of major groups to the odds for persisters.

not switch majors more than once. Hence, a student who switched to a STEM or non-STEM major and graduated is assumed to have graduated in that major field. Persisters who entered declared in STEM or non-STEM fields are assumed to have graduated in those types of majors as well. Hence, the hazard profiles (for those students who entered declared in a specified major field) can be used to directly compare the hazard of graduating in a STEM or non-STEM major between students who change only once to a STEM major or change only once to a non-STEM major, and those who persist. Unfortunately, due to the specified model, it is unknown whether persisters who entered college undeclared graduated in a STEM or in a non-STEM field. Hence, the hazard profiles for persisters who entered college undeclared (left panels of Figures 1 and 2) might not be directly comparable to the profiles for switchers because the profiles for switchers reflect hazard of graduating in STEM or non-STEM fields.

The predicted graduation hazard probabilities always increase over time with the highest risk occurring in year 6. The profiles in Figure 1 indicate that for male persisters (bold black solid line) and early non-STEM switchers (dotted green line) hazard increases fastest (the profiles are steepest) between years 3 and 4, while the increase in hazard is largest between years 4 and 5 for early STEM switchers (dotted red line). For female students who entered college declared as a STEM major or as a non-STEM major, hazard increases fastest between years 3 and 4 for those who persisted, early switched to a STEM major, and early switched to a non-STEM major (see Figure 2).

Among the change of major patterns, switching early to a non-STEM can be observed to have the least impact on graduation hazard (relative to persisting in one's major) over time. For both male and female students, the predicted profiles for persisters and early non-STEM switchers are typically very similar across all major persistence patterns and entering major type (see Figures 1 and 2), although the predicted yearly hazards for male students who switched early to non-STEM majors from STEM majors are slightly higher than the hazards for males who persist (see middle panel of Figure 1). However, none of the graduation hazards for early non-STEM switchers significantly differed from those of persisters.

Switching late to a non-STEM major has a larger negative effect on yearly graduation risk for females than males. Female late non-STEM switchers have significantly lower graduation hazard probabilities (dark blue dotted line) in years 5 and 6 than female persisters, regardless of whether they entered college undeclared, declared in a STEM major, or declared in a non-STEM major (see Figure 2 and Year 5 and Year 6 columns of Table 8). Male late non-STEM switchers who entered college undeclared or declared in a non-STEM major had significantly lower graduation hazards than male persisters who entered college undeclared or declared in a non-STEM major in years 5 and 6 (see left and right panels of Figure 1 and Year 5 and Year 6 columns of Tables 7(a) and 7(b)). Male late non-STEM switchers who entered college as STEM majors did not have significantly different graduation hazards from male persisters who began in non-STEM fields (see middle panel of Figure 1 and Year 5 and Year 6 columns of Table 7(b)).

The predicted graduation hazard probabilities for early and late STEM switchers tend to be lower than those for persisters (as well as early non-STEM switchers) in years 3 and 4; however, due to the interaction with time, the predicted graduation hazards of STEM switchers approach and for some groups (particularly those students who entered as STEM majors) exceed those of persisters by the fifth or sixth year. In addition, due to the interaction between CSTEM and gender, the gap in the hazard probabilities between STEM switchers and persisters closes more quickly for females than males. Male STEM switchers take one to two more years than female STEM switchers until their graduation hazard becomes indistinguishable (not significantly different at .05 level) from that of persisters. Furthermore, the year six graduation hazard for female students who entered college declared in a STEM major and early switched to another STEM major is actually significantly higher than the graduation hazard for female students who persisted in their STEM majors (see middle panel of Figure 2 and Year 6 column of Table 8(b)).

Table 7: Predicted graduation hazard probabilities for males with baseline characteristics

(a) Undeclared Major Status in 2003				
	Year 3	Year 4	Year 5	Year 6
Persisters	0.009	0.380	0.665	0.869
Early STEM Change	0.001*	0.125*	0.437*	0.815

Table 7 (continued): Predicted graduation hazard probabilities for males with baseline characteristics

Early Non-STEM Change	0.010	0.400	0.683	0.878
Late STEM Change			0.369*	0.782
Late Non-STEM Change			0.560*	0.810*
(b) Declared STEM Major in 2003				
	Year 3	Year 4	Year 5	Year 6
Persisters	0.010	0.324	0.528	0.729
Early STEM Change	0.003*	0.210*	0.512	0.810
Early Non-STEM Change	0.013	0.399	0.607	0.788
Late STEM Change			0.441*	0.776
Late Non-STEM Change			0.477	0.687
(c) Declared Non-STEM Major in 2003				
	Year 3	Year 4	Year 5	Year 6
Persisters	0.011	0.362	0.575	0.769
Early STEM Change	0.003*	0.181*	0.471	0.788
Early Non-STEM Change	0.013	0.398	0.612	0.796
Late STEM Change			0.402*	0.751
Late Non-STEM Change			0.482*	0.697*

Table 8: Predicted graduation hazard probabilities for females with baseline characteristics

(a) Undeclared Major Status in 2003				
	Year 3	Year 4	Year 5	Year 6
Persisters	0.015	0.505	0.768	0.917
Early STEM Change	0.003*	0.272*	0.671	0.920
Early Non-STEM Change	0.013	0.462	0.735	0.903
Late STEM Change			0.606*	0.904
Late Non-STEM Change			0.621*	0.846*
(b) Declared STEM Major in 2003				
	Year 3	Year 4	Year 5	Year 6
Persisters	0.016	0.444	0.650	0.818
Early STEM Change	0.008	0.412	0.733	0.918**
Early Non-STEM Change	0.017	0.461	0.665	0.827
Late STEM Change			0.674	0.901
Late Non-STEM Change			0.540*	0.739*
(c) Declared Non-STEM Major in 2003				
	Year 3	Year 4	Year 5	Year 6
Persisters	0.020	0.494	0.695	0.847
Early STEM Change	0.007*	0.375	0.703	0.906
Early Non-STEM Change	0.018	0.468	0.673	0.833
Late STEM Change			0.641	0.887
Late Non-STEM Change			0.548*	0.746*

Median Graduation Times

The predicted hazard probabilities can be used to examine which students will be at higher risk of graduating in a particular year. A student from a particular major persistence group with consistently higher yearly graduation hazards than those of another comparable student from a different major persistence group will take less time to graduate. To determine how much additional time is required to graduate for students who change major compared to those who persist, the predicted median graduation times by gender and entering major type were calculated using equations (4) and (5).[15] The median graduation times for persisters, early STEM/non-STEM switchers, and late STEM/non-STEM switchers are presented in Table 9 according to gender and entering major type.

Table 9: Predicted median times (years) to graduate for male and female students with baseline characteristics

	Undeclared in 2003			Declared STEM in 2003			Declared Non-STEM in 2003	
	Males	Females		Males	Females		Males	Females
Persisters	4.28	3.98		4.48	4.13		4.36	3.99
Early STEM Switchers	4.98	4.46		4.71	4.19		4.82	4.28
Early Non-STEM Switchers	4.23	4.08		4.26	4.09		4.26	4.06
Late STEM Switchers	5.16	4.61		4.92	4.37		5.04	4.45
Late Non-STEM Switchers	4.53	4.39		4.63	4.45		4.62	4.42

The predicted median graduation times varied between about four years (3.98 years for female persisters who entered college undeclared) and slightly over five years (5.16 years for male late STEM switchers who entered undeclared), and males take longer to graduate than females, all else being equal. With the exception of some early non-STEM switchers, students who change majors can typically expect to stay in college at least as long as students who persist in their major, although the amount of additional time depends on gender and entering major type.

Students who early switched to a STEM major had median graduation times that ranged between .06 to .70 years longer than those of students who persisted. The largest gap in median graduation times between early STEM switchers and persisters occurred among males who entered college undeclared. The predicted median time for undeclared males (with baseline characteristics) who early switched to STEM majors is 4.98 years, while the median time for undeclared males who persist in their first declared major is 4.28 years. In contrast to undeclared males, the predicted median graduation time of female students (with baseline characteristics) who entered college declared as STEM majors and early switched to other STEM majors was virtually identical to the median time of female students who persisted in their declared STEM majors (4.19 years and 4.13 years, respectively).

Students who switched early to non-STEM majors generally had slightly shorter or very similar predicted median graduation times to those of persisters. Males who had declared STEM majors and early switched to non-STEM majors had a median graduation time (4.26 years) that was about a quarter of a year less than the median time for males who had declared a STEM major and persisted (4.48 years). Females who entered undeclared and early switched to non-STEM majors had a median graduation time (4.08 years) that was slightly longer than the median time for females who had entered undeclared and persisted (3.98 years).

Among the change of major groups, students who switched late to a STEM major generally take the longest to graduate with median graduation times that are predicted to be between about a quarter of a year to almost a year longer than the median time for persisters. Females who entered as STEM majors and late switched to another STEM major had a predicted median graduation time (4.37 years) about a quarter of a year longer than females who persisted in their declared STEM major (4.13 years). Males who entered undeclared and late switched to a STEM major take about a year longer to graduate than males who entered undeclared and persisted (5.16 years compared to 4.28 years).

Students who switched late to non-STEM majors had slightly greater predicted median graduation times than those of persisters. Males who late switched to a non-STEM major after entering college in a STEM field added less than a quarter of a year to their median graduation time had they persisted in their STEM major (4.63 years compared to 4.48 years, respectively), while the median graduation time for females who entered undeclared

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[15] The predicted hazard probabilities used to compute the median graduation times were based on the results of the interaction model with values of each financial aid variables set to its average across all years and the values of the remaining student- and institutional-level predictors set equal to their reference values in Table 4.

and late switched to a non-STEM major was a little over a third of year longer (.39 years) than the median graduation time for undeclared females who persisted (4.39 years compared to 3.98 years).

DISCUSSION

There is generally a negative impact[16] of changing to a STEM major on graduation risk in the year after the switch, i.e. the graduation odds of a STEM switcher is typically lower than that of a persister with comparable characteristics; however, the magnitude of the decrease in odds varies by gender, first-year college GPA, entering major type, academic integration, and institutional control. Students who switch earlier to a STEM major have a larger decrease in graduation odds (in the year following the change of major) than students who switch late to a STEM major. Furthermore, over time, the negative impact of switching (early or late) to a STEM major effectively disappears, regardless of level of background student- and institutional-level characteristics. Hence, in many cases, the immediate deficit (if any) in graduation risk associated with switching early to a STEM major tends to be made up in one or two years.

In general, the association between switching to a non-STEM major and graduation risk is also negative with a larger negative effect (in magnitude) for female students, but with a decreasing negative association as academic integration increases. The impact on graduation risk is relatively minimal if the non-STEM switch occurs early, but is significant if the switch occurs late. Unlike the impact of switching to a STEM major, the effect of changing to a non-STEM major does not vary over time, i.e. the association between changing to a STEM major and graduation risk is the same regardless of year.

The decrease in graduation risk in the year following the switch for STEM switchers is less severe for females than for males, or equivalently, females who switch to a STEM major are at an advantage compared to males who switch to a STEM major. This finding has some positive implications for female STEM switchers. They have higher yearly graduation hazards and graduate sooner than comparable male STEM switchers. Interestingly, the decrease in graduation risk in the year following the switch for non-STEM switchers is greater for females than for males. Although the negative effect of switching to a non-STEM major is larger for females, female non-STEM switchers still have higher yearly graduation risk than their male counterparts due to the stronger female impact on graduation risk.

A higher first-year college GPA weakens the negative association (i.e. decreases the magnitude of the negative effect) between changing to a STEM major and graduation risk in the year after the switch; however, a higher first-year GPA has no effect on the association between changing to a non-STEM major and graduation risk. It is possible that a higher GPA is required in order to switch to a STEM major, hence, students are already more motivated or higher achieving once they switch, resulting in better graduation rates. Some studies have linked GPA with persistence and success in STEM majors (Crisp, Nora, and Taggart, 2009; Griffith, 2010). High GPA's are typically not needed to switch to non-STEM majors, and so has less of an impact on the relationship between switching to a non-STEM major and graduation risk.

The negative impact of switching to a STEM major is smaller for students who entered college declared in a STEM major than for students who entered undeclared. Students who were originally in a STEM major most likely had taken course sequences (such as calculus, physics, or chemistry) prior to switching that could be applied to the requirements of another STEM major, in turn assisting them to graduate in a more timely manner than STEM switchers from non-STEM majors or students who entered undeclared. It might be questionable to compare the switching impact on graduation risk between students who entered declared in a major and those students who

[16] This is true for students with reference characteristics (see Table 4) who change to a STEM major. Due to the significant interaction terms in the model, some students who change to a STEM major are actually predicted to have higher graduation risk in the year following the switch than similar students who persist, even after adjusting for other variables. For example, a female who entered declared in a STEM major at a private institution and changes to another STEM major is expected to have higher graduation odds (in the year after the switch) than a comparable female who persists, adjusting for the remaining variables.

entered undeclared. According to the description of the BPS:04/09 change of major variables, MAJ06CHG and MAJ09CHG, students who indicated that they changed majors did so from another declared major. Thus, students who entered undeclared and changed majors had to first declare a major, but due to limitations of the data, it is not known whether that declared major was STEM or non-STEM. Furthermore, first declaring a major and then switching to a STEM major could involve more unnecessary coursework compared to a student already declared in a STEM major who switches to another STEM major.

A somewhat surprising result was how academic integration impacts the association between switching to a STEM major and graduation risk differently from the association between switching to a non-STEM major and graduation risk. Higher first-year academic integration strengthens the negative effect (i.e. increases the magnitude of the negative association) of switching to a STEM major on graduation risk, but diminishes the negative effect of switching to a non-STEM major. It is possible that students who participate more academically by attending study groups and meeting more with faculty and academic advisors are less likely to switch to a STEM than a non-STEM major, and there is some evidence supporting this claim (Eagan, Hurtado, and Chang, 2010). Separate exploratory analyses using the BPS:04/09 data (results not shown) also revealed that there is a significant negative association between academic integration and the likelihood of changing majors; however, the relationship is weaker for students changing to STEM majors. Although previous research has confirmed the relationship between academic integration and college persistence and graduation outcomes (for example, see Pascarella and Chapman (1983)), future research might address whether the association between academic integration and college persistence depends on whether a STEM or non-STEM degree is being pursued.

Given the lack of evidence that students attending private institutions have an advantage in STEM degree completion rates over those students attending public institutions (for example, see Eagan, Hurtado, and Chang (2010)), it is somewhat surprising that the decrease in graduation risk for STEM switchers was found to be smaller for students who attend private institutions than for students attending public institutions. Hence, the result suggests that there is a smaller negative impact of switching to a STEM major on graduation risk at private institutions than at public institutions. It is possible that private institutions provide more resources for students pursuing STEM majors such as research opportunities allowing for increased faculty interaction. Undergraduate research opportunities have been linked to greater persistence success in STEM fields (Chang, Sharkness, Newman, and Hurtado, 2010).

Finally, it is important to point out again that the negative effect of switching (early or late) to a STEM major diminishes as more time passes after the switch; however, this was not the case for those who switched (early or late) to a non-STEM major. Changing to a non-STEM major may not require many new courses, unlike switching to a STEM major which would require, in many cases, completion of course sequences in mathematics, chemistry, or physics. Hence, STEM switchers may be subject to a more severe "adjustment" period and need to play catch-up in terms of coursework (particularly students who switched from non-STEM majors) before their risk of graduating is on par again with those who persisted in their major.

Baseline Students

The complex nature of the change of major impact can be further facilitated by restricting the discussion to baseline students[17] whose hazard profiles and median graduation times were examined earlier. In general, for these students, switching early to a non-STEM major is least negatively impactful on graduation risk regardless of gender or entering major type. Yearly graduation risk for early non-STEM switchers is either not significantly different from or even slightly higher than the yearly graduation risk for persisters, resulting in median graduation times that are very similar or slightly less than those of persisters, particularly persisters who began as STEM majors. Thus, it appears that changing to a non-STEM major early in one's college career does not alter the typical expected time to graduate. In addition, changing early to a STEM major generally has a negative impact on graduation risk in the next year or two after the switch with the magnitude of the impact depending on gender and entering major type (see below). Over time, the negative impact diminishes, so that by the fifth year (or earlier), the graduation hazards

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[17] Students with reference characteristics given in Table 4 and financial aid variables set to grand median amounts over the six-year study period.

between a persister and an early STEM switcher are no longer statistically distinguishable. The above results imply that changing majors early may have little to no impact on the risk of graduating later in college (fifth year or earlier), which means that little or no additional time is added to typical graduation time. These results are consistent with findings from Forraker (2012), Miccieri (2001), and Sklar (2013).

Some particularly interesting findings concern the role of gender in switching to a STEM major and completing a degree in a STEM field. Although it is well documented in the current literature that females have higher overall graduation rates than males, it has also been suggested that females are less likely than males to enter STEM fields, change to STEM majors, and graduate with a STEM degree. The current results appear to be more favorable and encouraging for female STEM switchers, as well as female STEM persisters. In particular, one important finding is that females who change (early) to a STEM major after entering college as a non-STEM major or undeclared generally perform about as well as (or no worse than) comparable female STEM persisters. Graduation hazards for females who early switched to STEM majors from non-STEM majors are not significantly different from the graduation hazards for female STEM persisters in years 4, 5, or 6, and the graduation hazards for female early STEM switchers who entered undeclared are also not significantly different from the graduation hazards for female STEM persisters in years 5 or 6 (see Tables 7 and 8). The relatively similar graduation hazards among female STEM persisters and early STEM switchers lead to relatively similar predicted median graduation times for female early STEM switchers and female STEM persisters. In addition, female early STEM switchers do as well or better than (comparable) male early STEM switchers and male STEM persisters, exhibiting consistently higher yearly graduation hazards and shorter predicted median graduation times (see Tables 7 and 8). So although the overall proportion of females who change to STEM majors is small, those who do are as successful as their female STEM persister counterparts, and more successful than comparable male STEM persisters or STEM switchers.

The reasons why female STEM switchers perform as well as their STEM persister counterparts, better than comparable male STEM switchers, and better than comparable male STEM persisters are beyond the scope of this study; however, recent studies have indicated that among women who received STEM degrees, most had switched into those fields during college after originally indicating interest in or declaring non-STEM majors (Ma, 2011; Xie and Shauman, 2003). The current study results are consistent with Ma (2011) who found that women were as persistent as men in obtaining a STEM degree once they declared a STEM major in college. Females who were interested in or very capable of succeeding in STEM fields prior to college but had not declared STEM majors may have decided to make the switch to STEM majors after being exposed to STEM courses or programs during their first year in college. Not only is early STEM awareness (primary and secondary school) crucial, but early STEM exposure in college may also encourage females to switch into the STEM "pipeline."

Although the focus of the study has been the impact of changing majors, several additional findings related to student persistence have also emerged. Consistent with studies examining the probability or risk of graduation, this study found that student-level characteristics positively associated with graduation risk include being female, being white, coming from a high income background, high school GPA, math SAT score, first-year entering major type, first-year college GPA, and attending college full-time. Interestingly, financial aid variables such as combined Stafford and Perkins loan amounts and Pell grant amount are negatively associated with graduation risk, results that appear to be inconsistent with those of other studies examining the association between financial aid variables and persistence (Chen, 2012; Chen and DesJardins, 2008; 2010). In addition, the strong effect of attending college full-time versus part-time (or a mixture) should not be overlooked. Obviously, students who are not taking a full course load each quarter/semester will take longer to graduate, but these students may also be working more hours, commuting longer to school, require more financial assistance or possess other characteristics that are associated with lower persistence and higher dropout.

Due to the positive gender effect, the yearly graduation risk of female persisters is significantly greater than that of male persisters regardless of entering major type (an additional test confirmed that there was no significant interaction between gender and entering major type). Hence, yearly graduation hazards for female STEM persisters (females who entered declared in a STEM major and persisted in that major) are higher than those for male STEM persisters (after adjusting for the remaining predictors including change of major behavior) (see Tables 7 and 8). It is evident in the literature that STEM degree completion rates are lower for females than males (Chen and Weko, 2009), and additional studies have found that the likelihood of STEM degree completion for females is lower than that of males (Crisp, Nora, and Taggart, 2009; Ma, 2011) (adjusting for background predictors). While the results from this current study do not necessarily contradict those of the aforementioned investigations, they are particularly encouraging for females who entered college seeking STEM degrees.

First-year entering major status is also significantly negatively associated with graduation risk, but only beginning in the fifth year of enrollment. Adjusting for the remaining predictors, after the fourth year, persisters who declared either a STEM or non-STEM major have significantly lower risk of graduating than persisters who entered college undeclared. Hence, through year four, students who entered undeclared do not exhibit significantly different graduation risks from those who are declared, adjusting for the remaining predictors; however, beginning in year 5, the declared students lose ground compared to the students who entered undeclared. This result does not necessarily imply that it is better to enter college undeclared. It is not possible to determine whether the undeclared student eventually declared a STEM or non-STEM major, so it is not possible to determine whether the undeclared persister graduated with a STEM or non-STEM degree. Hence, for undeclared persisters, yearly hazard probabilities could either be measuring graduation risk for students who earn STEM degrees or non-STEM degrees.

Consistent with persistence studies that have examined the influence of institutional characteristics (Osegura and Rhee, 2009; Titus, 2004), current results indicate that persisters attending a private institution or a highly selective institution are predicted to have higher risk of graduation than those attending a public institution or non-highly selective institution. Somewhat inconsistent with findings from other researchers (for example, see Titus, 2004), institutional enrollment size is negatively associated with graduation risk. Persisters at larger institutions are predicted to have lower yearly graduation risk than persisters at comparable institutions with lower enrollments. This study also found that the percent of minority students on campus is negatively associated with graduation risk for persisters.

CONCLUSIONS

This extensive study investigated the impact of changing to a STEM or a non-STEM major on the time to graduation using the BPS:04/09 data. Results of multilevel discrete-time hazard models reveal a complex relationship between changing major and first-institution graduation risk that depends on various student and institutional characteristics. After adjusting for the remaining predictors, the association between changing to a STEM major and graduation risk depends on gender, first-year college GPA, first-year entering major status, first-year academic integration, and institutional control, while the association between changing to a non-STEM major and graduation risk depends on gender and academic integration. In addition, potential negative effects of switching to a STEM major on graduation risk diminish as time after the switch increases.

Although the relationship between changing majors and graduation risk is quite complex, there are some general statements that can be made regarding the study results. All else being equal, switching late (either to a STEM or non-STEM major) negatively affects graduation risk more than switching early. Students who switch late are likely going to need to complete more new coursework later during their college career, thereby reducing their graduation risk soon after the switch more so than if they had switched earlier. Over time, however, the negative effects of switching (early or late) to a STEM major are reduced, and if switching to a STEM major early, it is still possible for these students to graduate in roughly the same amount of time (or in an additional quarter or semester) as students who persisted. Regardless of switching pattern, female students exhibit higher yearly predicted graduation hazard probabilities than male students. Women who switch to STEM majors outperform comparable males who switch to STEM majors in terms of higher graduation hazard and shorter predicted median graduation times. This study also provides evidence that higher first-year college GPA strengthens the relationship between changing to a STEM major and graduation risk. Emphasis should be placed on first year GPA, particularly in STEM courses, for those students interested in switching to a STEM major. Previous research has shown that higher academic performance in STEM courses is associated with lower dropout and higher graduation rates in STEM fields (Griffith, 2010). Regarding the role that institutional characteristics play in the association between changing major and graduation risk, only institutional control had a marginally significant impact. Students attending private institutions who switch to STEM majors are at less of a disadvantage (in terms of reduced graduation risk) than students attending public institutions.

For students with baseline background characteristics, switching early to non-STEM majors or switching between STEM majors has minimal, if any, impact on graduation risk resulting in virtually no change to predicted median graduation times. There is no significant evidence that students entering college in non-STEM majors who switch early to other non-STEM majors exhibit significantly different hazard rates from those students who persist in their non-STEM majors (controlling for remaining predictors). In addition, female students entering college in STEM majors who switch early to STEM majors do not exhibit significantly different yearly graduation risk from females who persist in STEM majors. Male students entering college in STEM majors who switch early to other STEM majors only exhibit significantly lower graduation risk than male STEM persisters in the first two years after the switch. Administrators need not necessarily be concerned that students who switch majors will take significantly longer to complete their degrees than if they had persisted. While this can be true in some instances, especially when switching late to a STEM major from a non-STEM major, it cannot be generally concluded that changing majors adversely affects graduation outcomes.

Finally, undeclared persisters, i.e. students who entered college undeclared and persisted in their eventually declared major, had predicted yearly graduation hazard probabilities that were either no different or higher than those of STEM or non-STEM persisters. Although it is unclear whether the graduation hazard probabilities for these undeclared persisters are in STEM or non-STEM majors, the finding implies that there is no particular advantage to entering college already declared in a major: students who enter undeclared are just as successful (in terms of graduation risk) as those who are declared in a major.

STUDY IMPLICATIONS

The results of this study can be used by administrators, as well as academic advisors, to inform students about the implications of changing majors and raise awareness about potential changes to expected graduation times for students who plan to switch or want to switch majors, particularly if the change is from a non-STEM to a STEM major. The results can also be considered by department and college personnel responsible for developing and maintaining change of major policies.

Advisors can disclose the potential graduation risks to students considering major changes based on the type (STEM or non-STEM) of their current and new major of interest major type (STEM or non-STEM), as well as their first-year GPA and their academic connection with the campus, e.g. how often they study in groups, meet with faculty, etc. Students might consider whether a change of major is in their best interests by the end of the first year in college, and if a major change is warranted, college advisors should focus on facilitating change of major during the first couple years of college. It has been shown in this and other studies that switching early is less (negatively) impactful than changing late (Foraker, 2012; Sklar, 2013), and there is now empirical evidence that switching early between majors of the same type, or from STEM to non-STEM majors minimally impacts the time to graduation.

As a potential method to retain students already in the STEM pipeline but who are seeking to switch, advisors could recommend switching to other STEM majors for students who are performing relatively well in their STEM major coursework. This is based on the findings that the predicted median graduation times of students switching between STEM majors were comparable to STEM persisters (with baseline characteristics), particularly among female students. This type of switch is especially relevant for students who have successfully completed much of the lower level course sequences in, say, mathematics, chemistry, or physics, but who are not interested in pursuing their current majors. If it is in students' best interests, advisors could recommend new STEM major options for those who have completed overlapping coursework in their current STEM major.

The results for students entering college undeclared were also particularly interesting. Undeclared persisters tended to have higher yearly graduation risk and shorter predicted median graduation times than students who entered declared in a major. Entering undeclared may provide students more opportunities to explore different subjects and major options. Several colleges and universities, e.g. Arizona State University, Ithaca College, and The Florida State University, offer "exploratory" programs for first-year students who want more exposure to courses in general areas (e.g. engineering or the behavioral sciences), and that can help them decide on majors that best fit their interests. In addition, as a possible way to increase STEM major participation, particularly among students who enter college undeclared or who have little exposure to STEM fields, more institutions might even consider supporting or adopting exploration programs in STEM disciplines in the first year of college to encourage declaration of STEM majors or to support students interested in switching to STEM majors.

Administrators and institutional researchers might consider using methodology similar to that of this study to focus on investigations of the impact of change of major on graduation outcomes at their college or university. Single institution studies can examine change of major impact with current enrollment data and using similar survival analysis techniques (but not multilevel) and variables suggested by this research. The (non-hierarchical) models could be similar to discrete-time hazard models presented in Sklar (2013). Furthermore, individual institutions can examine whether and how new change of major policies have affected the impact of change of major on graduation rates after existing change of major policies are modified.

Finally, although difficult to assess, the impact of changing major most likely depends to an extent on the change of major policies of each institution, and this study cannot account for differences in policies. Furthermore, it is not entirely clear how policies would affect the impact of changing major on graduation outcomes. Policies that require a particularly high GPA in courses in the new major in order to switch might not only hinder a student's effort to change majors, but could also delay graduation if the student cannot meet the requirements and must remain in the current major. Of course, policies must be restrictive to an extent in order to ensure that students who seek a major change will be able to successfully complete the new degree requirements. Nevertheless, it seems reasonable to assume that policies that expedite the official change will allow students to stay on track to graduate in a timely manner.

FUTURE RESEARCH

While the results of the current investigation shed light on the association between change of major and graduation risk, there are several implications for future change of major research. Firstly, this study did not address switching between different STEM disciplines or non-STEM disciplines. Future studies could examine the impact of changing majors within select STEM fields (e.g. engineering to biological sciences) or select non-STEM fields (e.g. sociology to English). Additional smaller scale studies could also examine the impact of switching between STEM subfields, e.g. different engineering majors such as mechanical and electrical. It is not uncommon for engineering students to switch from one field of engineering, e.g. electrical, to another field such as mechanical.

Female students have typically been underrepresented in STEM disciplines, with the proportions graduating in or switching to STEM majors lower than those for male students. Yet the findings that yearly graduation risk of females who early switched to STEM majors from non-STEM majors were comparable to yearly risk for females who persisted in STEM or non-STEM majors, and significantly higher than yearly risk for male STEM persisters warrant further examination. Perhaps early exposure to more STEM coursework in college or other STEM opportunities are driving catalysts for females who were interested in STEM fields but had not declared a STEM major to ultimately switch to STEM majors. Studies by Ma (2011) and Xie and Shauman (2003) have shown that females who earned STEM degrees had switched to or declared STEM majors after entering college undeclared or in non-STEM fields, suggesting that women may pick up their interest in STEM fields early in college. The reasons behind the positive findings for female STEM switchers have yet to be fully understood.

Finally, the current research focuses on the impact of change of major on the time to graduation. Another approach is to examine the change of major impact on the (unconditional) probability of graduating from college, ignoring the year when graduation occurred, and not incorporating any time-varying predictors or time-varying predictor effects. Hierarchical generalized linear models (HGLM) (Raudenbush and Bryk, 2002) with the binary outcome graduate/not graduate could be applied to the BPS data.[18] This is a common methodological approach of studies investigating student and institutional characteristics associated with persistence and dropout (see, for example, Kim (2007), Osegura and Rhee (2009), and Titus (2004, 2006(a)(b))). Use of these models would avoid

[18] Technically, the multilevel discrete-time hazard model is a hierarchical generalized linear model with a binary outcome; however, the binary outcome is graduate in year *i*, given that graduation did not occur in year *i-1*. To avoid confusion, HGLM's will refer to multilevel logistic regression models with an unconditional binary outcome.

the problem of trying to accurately estimate the yearly effect of switching majors. These models also might make it easier to estimate the effect of multiple major changes on the probability of graduation. At least one study has suggested that multiple major changes are associated with increased graduation rates (Micceri, 2001); however, that was a single institution study and did not control for any background characteristics. Although the current study included a control variable for multiple, it did not indicate the number of switches made (nor the type of new major), and the precise year of each switch was unknown due to the BPS data limitations. With the HGLM's, the exact timing of the major change would not be an issue. The primary drawbacks of the HGLM methodology are that the longitudinal nature of the enrollment data would not be exploited and censoring would be ignored. In addition, yearly performance measures, e.g. yearly graduation probabilities, cannot be computed based on the multilevel model. Nevertheless, the benefits of implementing HGLM's make it worthwhile to explore the methodology and compare the results with those from the current investigation.

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APPENDIX

Variables used in the study and corresponding BPS:04/09, IPEDS, and NPSAS variables used to construct study variables

BPS, IPEDS, and NPSAS Variable Name	BPS, IPEDS, and NPSAS Variable Description	Study Variable or Other Specific Use
PROUTF1- PROUTF6	Cumulative retention and attainment at first institution from 2003-04 to 2008-2009	Time to graduate at first institution
GENDER	Gender	Gender
RACE	Race/ethnicity	Race
INCGRP2	Income group 2003-04	Income level
PAREDUC	Parent's highest level of education	First generation status
HCGPAREP	High school grade point average	Cumulative high school GPA
TESATMDE	Derived SAT math score	SAT math score
TESATVDE	Derived SAT verbal score	SAT verbal score
ACAINX04	Academic integration index 2004	First-year academic integration
SOCINX04	Social integration index 2004	First-year social integration
GPA	Grade point average 2003-04	First-year college GPA
MAJ06CHG	Major changed as of 2006	Changed major at least once in first follow-up period (between July 1st, 2004 and June 30th 2006)
MAJ09CHG	Major changed as of 2009	Changed major at least once in second follow-up period (between July 1st, 2006 and June 30th 2009)
MAJ04A	Major when first enrolled in 2003-04 (comparable to 2006, 2009)	First-year declared major type (STEM/non-STEM) or undeclared status
MAJ06A	Major when last enrolled 2006	Major type (STEM/non-STEM) as of June 30th, 2006
MAJ09A	Major when last enrolled 2009	Major type (STEM/non-STEM) as of June 30th, 2009
ENINPT1- ENINPT6	Attendance intensity pattern from 2003-04 to 2008-09	Yearly attendance intensity: enrolled full-time/not full-time
T4LNAMT1, T4XLN05- T4XLN09	Stafford and Perkins loans amount in 2003-04 through 2008-09	Yearly total Stafford and Perkins loans amount
PELL04-PELL09	Pell grant amount in 2003-04 through 2008-09	Yearly Pell grant amount
ENRLSIZE	Enrollment size 2003-04	Enrollment Size
PCT_MIN	Percent minority enrollment 2003-04	Percent Minority
FCONTROL	First institution control 2003-04	Control (Public/Private)
SELECTV2	First institution selectivity 2003-04	Selectivity (Highly Selective/Not Highly Selective)
SCHIPEDS	IPEDS number	Used to identify institution in multilevel analysis
WTB000	BPS:04/06/09 study respondents (panel) weight	Sampling weight used to calculate descriptive statistics
WTB001- WTB200	BPS:04/09 bootstrap replicate weights for panel respondents	Used to compute estimated variances of descriptive statistics
Wt1-Wt8, B6AWt1- B6AWt4, B9AWt1, B9AWt2, B9BWt1, B9BWt2, B9CWt1, B9CWt2	Weight components from the BPS:04/09 Component Weight	Weights used in the multilevel analysis