Redefining Student Success:
Assessing Different Multinomial Regression Techniques for the Study of Student Retention and Graduation Across Institutions of Higher Education[1]

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[1] This paper incorporates several minor changes from last year's paper: including, but not limited to: corrections of grammatical and typographical errors, improved citations of relevant literature, as well as several formatting changes designed to improve readability.

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Abstract: Current definitions of retention and graduation rates distort the picture of student success by limiting it to completion of a degree at the institution of entry. By incorporating data from the National Student Clearinghouse (NSC), a clearer picture emerges. The NSC data captures retention and graduation at both entry and transfer institutions. To accommodate this polychotomous definition of success, more sophisticated methods of modeling limited dependent variables are needed. Though multinomial logit is the most approachable method, the strict assumptions it imposes may be inappropriate. We therefore compare multinomial regression techniques to assess their utility in modeling multi-institutional student success.

Keywords: categorical dependent variable; student success; student persistence; multinomial logit; multinomial probit; independence of irrelevant alternatives; National Student Clearinghouse.

Introduction: Considerable theoretic and empirical effort has been given to understanding the process of student retention and graduation in higher education. Accountability pressures from the federal government have further raised the importance to all institutions of identifying and removing barriers to student progress and success (U.S. Department of Education, 2006). However, these efforts have been based primarily on a narrow definition of student success. The standardized definitions of student success that followed the student right-to-know (SRK) act of 1990 were by necessity narrowly defined due to the complications of tracking transfer students (Burd, 2004). Currently, four-year institutions fulfill SRK reporting requirements by completing the Integrated Postsecondary Education Data System (IPEDS) Graduation Rate Survey (GRS). Graduation rates are based on following a cohort of new full-time entering freshmen until they complete a bachelor's degree within 150% of normal time to program completion (typically six-years) at the same institution. By ignoring the transfer outcome, the current IPEDS methodology based on institution-specific graduation rates distorts the true picture of student success in higher education by underestimating the actual rate of student success (Adelman, 1999). Data available from the National Student Clearinghouse (NSC), a national database of enrollment and degrees awarded, offers the opportunity to broaden the definition of student success and to better understand the antecedents of student success in higher education by using a more inclusive definition of success. The emerging use of multi-institutional retention and graduation rates as part of the Voluntary System of Accountability (VSA) lends additional imperative to our understanding of student success in this larger context. Identifying factors leading to success across the different paths students take through higher education requires statistical techniques suited for multi-category variables. We modeled a three category outcome of student success; 1) baccalaureate degree from the home institution, 2) baccalaureate degree from other institution

and 3) associate degree/certificate award from other institution. The selection of the appropriate "tools" to model this expanded behavioral choice set is critical to our understanding of this broader definition of success, since the variety of outcomes indicates that different policies may be necessary to meet the diverse needs of these students and that more refined intervention strategies are required (Porter, 2003).

Our paper is presented in five sections. The first section provides a brief overview of retention theory and the rationale for the selection of the independent variables used in the models. The second section provides an overview of logit and probit models. The third section describes the sample and estimated models of degree attainment utilizing a series of binary logit models (BL), multinomial logit (MNL) and multinomial probit (MNP) models, respectively. The fourth section discusses and compares the resulting models. The last section discusses the implications of the findings and directions for future research.

Theoretical Framework: Our selection of factors to include in the model is based loosely on Tinto's theory of student persistence, although the selection of independent variables is based not only on theory, but also by pragmatic criteria. The selected variables needed to have high coverage of the cohorts in question, and be fairly easy to obtain from the central records of the study institution. It is widely understood that student's background/demographics and incoming academic ability (i.e., pre college measures) are important predictors of a student's ability to persist to graduation (Perkhounkova, Noble & McLaughlin, 2006; Ishitani & Snider, 2006; Ishitani, 2003; Tinto, 1975). Previous retention research on students at the University of Minnesota-Twin Cities found that not only were background and pre-college characteristics important, but also that "academic fit", as measured by admission to a student's first-choice

college and first-term academic progress, were significant predictors of academic success (Radcliffe, Huesman, Kellogg, & Jones-White, 2009; Radcliffe, Huesman & Kellogg, 2006; DeLong, Radcliffe, & Gorny, 2007). Social integration has been theorized by Tinto (1975, 1993) to be a key contributor to student persistence, and "social fit" indicators as measured by living learning communities have shown to play a key role in our understanding of the success of students (Matthews, 1996; Tinto, 1998). The community aspects of living in a residence hall, especially during the first year, may promote social interaction which is a necessary step towards social integration (Braxton & Hirschy, 2004) and student success (Astin, 1973). Living on-campus may also be related to a student's socioeconomic/academic background; Levin & Clowes (1982) found that students who live on campus generally have higher socioeconomic status and are better prepared academically then those who do not. Ishitani (2006) found that on average, low-income students are more likely to dropout early and less likely to graduate than students from higher income families.

These previous studies illustrate the complexity of the underlying process that influences a student's choice to persist in higher education. These studies utilized multivariate statistical procedures that accounted for a number of factors related to student persistence/graduation but yet the outcomes were reduced to a simple binary alternative (with the exception of Ishitani's study which utilized NELS:88 data). Most traditional studies of student retention/persistence treat dropout/stopouts from higher education and transfers who continue their education identically by combining them into one category in their statistical analyses. A pair of researchers have expanded these definitions to examine whether freshmen return, quit, or go elsewhere for their sophomore year. Porter (2002, 2003) and Herzog (2005), making use of the NSC student tracker service, differentiate between stopouts/dropouts, transfer-outs, and returning

students. They found the significant independent variables in their persistence models varied considerably depending on whether or not a student was a stopout or transferred. Based on these results, Porter argued that "…researchers must take into account the different choices faced by students when studying student persistence" (2002, 3). It seems reasonable to conclude that there are differences between these groups and our models should take into account these differences.

This study provides a statistically rigorous approach to analyzing multi-institutional degree attainment. To the extent students vary in one or more of these areas, can we identify the factors that are associated with those who earn a degree at the home institutions, those who transfer and earn a degree elsewhere versus those who do not?

Sample: This study utilized central student records and the student tracker service from NSC to examine degree attainment of three new freshmen-cohorts from the University of Minnesota-Twin Cities campus. The University of Minnesota at the Twin Cities is a Carnegie classified Research University with Very High Research Activity (RU/VH). The data sample consisted of 15,496 students who entered as first-time full-time degree-seeking freshmen during the 1999 thru 2001 fall semesters. The cohort was initially divided into two groups; those who were successful (61.5%, graduated within six-years) at the originating institution and those who were not. A total of 5,968 students were not successful by this criteria (38.5%), these records were sent to the NSC Student Tracker service to determine enrollment/degree attainment at other institutions of higher education. A six-year window was mimicked for these students, by tracking enrollment from the original fall semester of matriculation (August 15, starting year) to August 1, six years later and degree attainment thru October 15, six years later. Taken together the data collected

captured graduation at both entry and transfer institutions as well as enrollment at other institutions at any point in time, and included students for whom no NSC match was found (see Table 1).

[Table 1 about here]

The student tracker service is composed of both Enrollment and Degree verification services. Currently the majority of institutions of higher education participate in the enrollment verification (n=3,152) which represents 91% of the nation's college enrollment, and a smaller percentage in the degree verification (n=1,461), representing 68% of all U.S. college degrees (NSC presentation, 4/22/2008).

The independent variables are divided into six categories that follow our theoretical model; Academic performance, academic background, demographics, geography, social integration, and financial background. Table 2 provides a more detailed listing of the variables incorporated into the models and their associated coding schemes and table 3 provides the descriptive statistics of the full data set utilized for this study.

[Tables 2 & 3 about here]

Methodology/analysis: Relative to dropping out of college, we modeled three scenarios of student degree attainment within six-years from matriculation as new entering fall freshmen; 1) baccalaureate degree from home institution; 2) baccalaureate degree from another institution and 3) associate degree/certificate award from another institution. Traditionally, when modeling student success, our assumption of the dichotomous nature of the dependent variable lends itself well to limited dependent variable techniques such as binary logit or probit models.

Unfortunately, the expansion of outcomes precludes us from this traditional route. Though it is possible to run separate logit models for each of the different choice comparisons, the potential number of necessary comparisons makes such an approach conceptually and computationally confusing (Long, 1997). In order to accommodate our redefined interpretation of student success, a more complicated statistical procedure may be necessary to identify reliable parameter estimates for the antecedents of success.

To overcome this problem, most researchers trying to estimate models with multi-categorical outcomes, have utilized the multinomial logit model (Porter, 2002; Herzog, 2005; Stratton, O'Toole, & Wetzel, 2008). Long (1997) has suggested that the multinomial logit can be conceptualized by the simultaneous estimation of different binary logit models "for all possible comparisons among the outcome categories" (p. 149). By simultaneously estimating all the logits, the MNL both "…enforces the logical relationship between the parameters and uses data more efficiently" (Long 1997 p. 151). Although this is a very desirable aspect of multinomial logit models, one limitation of MNL estimation procedures is a strict assumption about the alternatives available in the choice set. This assumption, referred to as the independence of irrelevant alternatives (or IIA) assumption, states that the odds of an outcome "are determined without reference to the other outcomes that might be available" (Long, 1997, p. 182). If the odds of each of our definitions of student success are not independent, alternative methodological approaches become necessary as violations of the IIA assumption lead to "incorrect probability estimates" (Washington, Karlaftis, & Mannering, 2003, p. 274). To best estimate the factors contributing to student success in its multiple forms, we compared the multinomial logit with the multinomial probit, to assess whether the added complexity of the MNP improves our estimation of student success.

To examine both the substantive factors which lead to student success, accounting for the possibility that students continue their education at another institution, and the methodological considerations inherent in working with that expanded definition of success, we estimate four models of student graduation.

1) A binary logit model using the standard definition of student success (graduation from the school of original admission within six years or not)
2) A set of binary logit models where the two outcomes are graduation with a particular category of credential (associates-level, bachelors-level from another institution, or a bachelors-level degree from the entry institution) or not graduating from any institution within six years of entry
3) A multinomial logit model where the outcomes are graduating with an associates-level degree, graduating with a bachelors-level degree from another institution, graduating with a bachelors-level degree from the entry institution, or not graduating from any institution within six years of entry
4) A multinomial probit model with the same outcomes as the multinomial logit model.

Results: The traditional binary logit model produces results consistent with previous research at the University of Minnesota (see e.g. Radcliffe, Huesman, and Kellogg, 2006) and in other studies. Academic preparation and performance measures are key factors, as are measures of academic fit, geography, social integration, and financial need. While these results comport well with both logic and experience, they are blind to an important point – many of those students who are marked as unsuccessful actually did complete a degree within the standard graduation

tracking window. They simply did so at another institution. From the standpoint of meeting society's need for an educated citizenry, this is indeed success, and if the student found an institution that better suited their academic and social needs, it can easily be labeled an individual success as well. These results, therefore, while far from useless, are unnecessarily limited and may conceal important findings both for the institution and for citizens, legislatures, state governing boards, and others with a broader interest in higher education. Since our interest is in this broader definition of student success, we will not discuss the traditional model results in depth. The detailed results are available in table 4.

[Table 4 about here]

Perhaps the simplest approach to address the gap in moving to an expanded concept of student success is simply to run several logit models, with the data partitioned to examine graduates at both similar and dissimilar institutions. In each case, the reference group is those students who failed to complete their degree at any institution for which we can obtain data within the six-year graduation window. The results for these models also appear in table 4. Again, these models are consistent with the expectations formed from both earlier studies at this institution and from the wider literature on student persistence. However, this approach needlessly throws out the information gained from the full data set, reducing the model's predictive power, and makes direct comparisons between different outcomes more difficult. We, therefore, set aside a detailed discussion of the model's predictions to focus on those produced by a more robust methodology.

A statistical methodology that makes use of the full data set in forming more precise estimates, and allows for direct comparisons between any pair of outcomes is the multinomial logit model. The multinomial logit model produces three simultaneously-estimated equations comparing the

probability of each alternative outcome to the one selected as the base. In the model estimated, the base outcome was not graduating from any higher education institution. This includes both those students who are still enrolled at the end of the observation window and those who have completely discontinued their education. It is impossible to know whether or not those students who are still enrolled will ever complete their degrees, although a follow-up study after more time has passed would improve the likelihood that all students have reached their final level of educational attainment. The results of this model appear in table 5.

[Table 5 about here]

Associate Degrees: The outcomes for students who are "reverse transfers," leaving the four-year study institution to obtain a two-year, associates-level degree, are more difficult to predict than for the other categories. These represent a smaller subgroup, so it may be possible that still more observations could improve the precision of the model, but it may also be that their decisions are more idiosyncratic. Perhaps most interestingly, unlike bachelor-level degree attainment, first-term academic performance as measured by first-term GPA, ratio of credits completed successfully to those attempted, and number of course withdrawals are not statistically significant predictors of associates-level degree attainment. However, measures of academic preparation and academic fit are statistically significant. All other things equal, students with higher ACT/SAT scores are less likely to complete an associates-level degree than to fail to graduate. Students who enrolled in the University of Minnesota's developmental education college, known as General College, were also less likely to attain an associates-level degree than to not graduate, all other factors equal. Those students who were admitted to their first choice college at the University of Minnesota were also less likely to earn an associates degree than not

to graduate. Advanced credits transferred at enrollment were not statistically significant predictors of associates-level degree attainment.

Some demographic factors were also statistically significant predictors of associates-level degree attainment. All other things equal, female students were more likely to complete an associates-level degree, while Asian students (although only at a permissive .10 level of significance) and underrepresented minority students were less likely to complete an associates-level degree than not to graduate. Compared to other similar students, those from states within the tuition reciprocity area are less likely to attain an associates-level degree than not to graduate. For associates-level degree attainment, none of the social integration or financial need indicators were statistically significant predictors, with the exception of a modest (.10 level) finding that students who were eligible for Pell grants were less likely to complete an associates-level degree relative to not graduating.

Baccalaureate Other: Academic factors play a prominent role in the success of students in obtaining a bachelors-level degree from an institution other than the University of Minnesota. In their first term of enrollment at the University of Minnesota, students who have higher grade point averages, successfully complete more of their courses, or withdraw from fewer courses are more likely to eventually complete a bachelors-level degree from another institution than not to graduate. As with associates-level degree attainment, higher ACT or SAT scores and enrollment in General College lead to a statistically significant decrease in the likelihood of attaining a bachelors-level degree than not graduating. Finally, being admitted to the student's first-choice college at the University of Minnesota reduces the likelihood of completing a bachelors-level degree at another institution compared to not graduating.

A variety of demographic factors were also statistically significant predictors of bachelors-level degree attainment from another institution. As with associates-level degree attainment, female students were more likely to graduate, while Asian students and underrepresented minority students were less likely to graduate with a bachelors-level degree from another institution than not to graduate at all. The pattern for geographic factors, however, reverses what was seen for associates-level degrees. Students from tuition reciprocity states and those from states beyond the reciprocity area were more likely to complete a bachelors-level degree from another institution than not to graduate.

Students who lived on campus their first term were significantly more likely to graduate with a bachelors-level degree from another institution than not to graduate, suggesting the influence of social integration may extend beyond the entry institution. Financial need, however, worked to reduce the likelihood of degree attainment. Being eligible for a Pell grant again showed a negative and statistically significant impact on the probability of completing a bachelors-level degree from another institution compared to not graduating.

Baccalaureate University of Minnesota: First-term academic performance factors were also significant predictors of the probability of attaining a bachelors-level degree from the University of Minnesota. Students whose first term grade point average was higher, who completed more of the credits they attempted, or withdrew from fewer courses were more likely to graduate from the University of Minnesota relative to not graduating. Lower levels of academic preparation as measured by enrollment in General College were associated with lower estimated probabilities of graduation from the University of Minnesota, all other factors equal. Unlike the results for associates-level degrees and bachelors-level degrees from other institutions, the number of

credits a student brought with them at admission was a statistically significant predictor of the probability of graduating from the University of Minnesota compared to not graduating, with additional credits transferred increasing the likelihood of graduation. However, ACT and SAT scores were not statistically significant predictors of the likelihood of graduating from the University of Minnesota, controlling for other factors.

The findings for academic fit also stand in contrast to the results for associates-level degrees and bachelors-level degrees from institutions other than the University of Minnesota. Students who were admitted to their first choice college at the University of Minnesota were more likely to graduate without transferring. Combined with the findings that admission to the first-choice college was negatively associated with the attainment of an associates-level degree or a bachelors-level degree from another institution, this suggests strongly that students who are admitted to their first-choice college are more likely to stay at the University of Minnesota and either succeed or fail, while students who were not admitted to their first-choice college were more likely to consider alternative institutions to complete their education.

Consistent with the estimates for the other outcomes, female students were more likely than others to complete their degrees at the initial institution compared to the probability of not graduating. Likewise, students who were members of underrepresented minorities were less likely than otherwise similar students to complete a bachelors-level degree at the University of Minnesota compared to not completing a degree.

Geographic factors also appear to play a role in the successful completion of a degree without moving to another institution. Students from states within the tuition reciprocity region were less likely than their otherwise similar in-state peers to complete their degree at the University of

Minnesota. Combined with the finding that these same students were more likely than similar in-state students to complete a bachelors-level degree at another institution compared to not graduating, this reinforces the notion that students from nearby states who find the University of Minnesota is not a good fit for them academically, socially, or financially are likely to turn to other institutions to complete their bachelors-level degree rather than discontinuing completely.

Social integration also appears to improve the likelihood of graduating from the University of Minnesota rather than not completing a degree. Students who live on campus their first term, and therefore are more likely to be enmeshed in the campus culture, are statistically significantly more likely to complete their degree at the University of Minnesota than otherwise similar students who lived off-campus. Financial need, however, shows a persistent pattern of lowering the likelihood of completing a degree. Controlling for other factors, students who were eligible for Pell grants were less likely to complete a degree without moving to another institution compared to students with greater financial resources.

MNL Assumptions: As noted above, the appropriateness of the multinomial logit methodology, and therefore the reliability of the results we have just described, rely on an assumption known as the independence of irrelevant alternatives, or IIA. This concept is that the decision between any pair of alternatives is not impacted by the existence of other options. For example, if one is deciding between chocolate and vanilla ice cream, it may well not matter whether or not cherry ice cream is available. In making decisions about the direction of one's academic career, however, this assumption does not ring true. The existence of associates-level degrees, for example, seems quite likely to impact the decision of whether to continue at ones original institution, move to a different institution offering the same level of degrees, or to discontinue

higher education altogether. A student who is struggling academically at the bachelors level, or who needs to enter the workforce more quickly for family or financial reasons, may well find an associates-level degree an attractive option, and the existence of that option could clearly impact the selection among other alternatives. However, the logical concerns about this assumption do not necessarily mean that it is not tenable in practice (Dow and Endersby, 2004). Two avenues that can be pursued to assess the empirical significance of the IIA assumption are formal statistical tests of IIA and substantive comparisons of models that relax this assumption with those that do not.

Two options that are available in Stata for testing the IIA assumption are Hausman tests and Small-Hsaio tests (StataCorp, 2007). For each test, one of the alternatives is omitted to test the sensitivity of the results to a change in the number of alternatives, and this is repeated for each alternative. For this data set, the results are consistent, with both tests failing to find statistically significant impacts. While not unequivocal, these results suggest that the IIA assumption is likely appropriate for this data.

Multinomial probit models are conceptually very similar to multinomial logit, but allow for the correlations between the errors for the comparison between alternatives to be estimated, rather than assuming independence. The estimates for this model appear in table 6. Because the model estimates additional parameters, it is more computationally complex, vulnerable to convergence difficulties, and demanding in terms of available observations. In return, it can provide more precise and reliable estimates. The critical question is whether that trade-off is worthwhile. At its most basic level, that question depends on whether potential violations of the independence of irrelevant alternatives assumption impact the model estimates. To ascertain whether that is an

issue for this data set, one can compare the results from the multinomial logit and multinomial probit models. In this case, there are no substantive differences in the conclusions between the two models, and very slight differences in the estimated coefficients. There is not, therefore, a compelling reason for this study to use the more complex and demanding methodology.

[Table 6 about here]

One of the strengths of the multinomial logit approach is that is produces estimates that are relatively more easily interpreted than those of the multinomial probit model. The exponential of each coefficient in the model indicates the change in the odds ratio of that pairwise comparison of outcomes that results from a one-unit change in the associated independent variable. These exponentiated coefficient values are referred to as factor change scores as they indicate the factor by which the odds ratio shifts. In addition, it is fairly straightforward to calculate predicted probabilities for each outcome for any set of observations. This allows the practical impact of changes in the independent variables to be illustrated.

Selected Interpretations: Four variables in the models above tell interesting stories that can be represented through the factor change scores and predicted probabilities. These are whether the student was admitted to their first-choice college upon admission to the University of Minnesota, whether the student lived on campus their first term, whether the student was from a reciprocity state, and whether the student was eligible for a Pell grant in their first term of enrollment.

The influence of a student being admitted to their first choice college can be seen in figure 1. As mentioned above, students who were admitted to their first-choice college were more likely to graduate from the University of Minnesota relative to not earning a degree. These students were, however, less likely to graduate from another institution relative to their likelihood of not

graduating. This can be seen from the graph of factor change scores, as the value for University of Minnesota graduates (labeled "UM" in figure 1) is greater than one (the base outcome, labeled "ND" for no degree) and distinct. The box around the symbols for associates-level degrees ("AA") and bachelors-level degrees from another institution ("BA") indicate that these outcomes cannot be statistically significantly distinguished from each other. However, the base outcome and graduating from the University of Minnesota lie outside the box, indicating those differences are statistically significant. Substantively, then, the influence of being admitted to one's first-choice college is similar for other institutions, and the opposite of that for graduating from the University of Minnesota. This suggests students who are unable to find their desired academic fit at the University of Minnesota may turn to other institutions, or leave higher education altogether. The predicted probabilities in figure 1 illustrate the size of this impact, as a student who is otherwise at the mean on all other variables increases their odds of graduating from the University of Minnesota from 54.9% if not admitted to their first-choice college to 61.7% if they are. Likewise, the odds of our otherwise-average student graduating from another institution, at either the associates level or the bachelors level, increases if the student is not admitted to their first choice college at the University of Minnesota. A final perspective of these phenomena can be seen in the percentage of those in each category who had been admitted to their first choice college. While nearly 80% of those who graduated from the University of Minnesota were admitted to their first choice college, just fewer than 70% of those who earned a bachelors-level degree at another institution were admitted to their first choice college, and for those who earned an associates-level degree, that number drops under 60%. Clearly, academic fit matters for student success at the University of Minnesota.

[Figure 1 about here]

Using the same set of tools, the impact of living on campus during the first term of enrollment is examined in Figure 2. The factor change scores for ND and AA are indistinguishable, while those for the BA and UM categories are higher and statistically distinct from the other outcomes. Living on campus has a strong positive impact on the relative odds of graduating from the University of Minnesota compared to all other outcomes. Interestingly, living on campus the first term also increases the odds of graduating from another institution with a bachelors-level degree compared to the other outcomes except staying at the University of Minnesota. It would appear that whether through the impact of social integration into the university community or as a proxy for greater resources, living on campus during the first term increases the odds of the attainment of a bachelors-level degree, regardless of at which institution it is earned. Looking at the predicted probabilities, it would appear that while statistically significant, the impact for bachelors-level degrees at other institutions are small By contrast, living on campus increases the probability of our theoretical average student graduating from the University of Minnesota by over twelve percentage points. The distribution of living arrangements for students in each category is striking, with roughly 80% of eventual University of Minnesota and other bachelors-level graduates living on campus, while the percentages for associates-level graduates and non-graduates hover in the low 60s.

[Figure 2 about here]

The impact of attending the University of Minnesota from a reciprocity state is striking in that the factor change scores of each outcome are statistically distinguishable from the others, as illustrated in Figure 3. A clear hierarchy of relative probabilities therefore emerges. Relative to the other outcomes, students from reciprocity states are more likely to graduate with a bachelors-

level degree from another institution than their otherwise similar peers. By contrast, they are least likely to earn an associates-level degree, and less likely to earn a degree from the University of Minnesota. This echoes findings from earlier studies at the University of Minnesota, which suggest that it struggles to achieve similar levels of success with students from reciprocity states to those of in-state students. As the predicted probabilities indicate, it is still more likely that a student from a reciprocity state will graduate from the University of Minnesota than that they will graduate elsewhere or discontinue, but the decline in that probability is noticeable, and the odds that an otherwise average student will graduate with a bachelors-level degree from another institution doubles when that student is from a reciprocity state rather than hailing from within Minnesota.

[Figure 3 about here]

The last highlighted result is for students who are Pell eligible is presented in Figure 4. Even though financial aid is available to these students, it is clear that all other things equal, they are not as successful as their wealthier peers. The picture that emerges from the factor change scores is that there is little difference in the relative likelihood of any particular successful outcome, but that all of them are less probable for a student who is Pell eligible than an otherwise similar student who is not. For a student who is otherwise average on all other observed factors, being Pell eligible raises the probability of not graduating by nearly ten percentage points. Pell eligible students are likewise more common among associates-level degree recipients and non graduates than among bachelors-level degree recipients.

[Figure 4 about here]

Discussion/Implications: By assessing the appropriateness of different multinomial regression techniques, the findings of this study provide guidance to institutions for dealing with the methodological complexities of multi-institutional definitions of student success. This helps ensure that policy innovations related to student retention and graduation are based on sound empirical data and replicable analyses. In addition, the substantive findings of this study can inform institutional practices aimed at either increasing student success at the entry institution or in higher education more generally.

The National Student Clearinghouse's data collection provides an important opportunity for higher education institutions to expand their definition of student success to include enrollment and degree attainment at other institutions. With the advent of the Voluntary System of Accountability (VSA) the public reporting of student success across institutions through the NSC data should give us a much better appreciation of the success of public higher education in the United States. The more complex question of "where" and "why" can also now be examined with the data available through the NSC student tracker service.

Using this data and appropriate methodologies for multi-category, unordered variables also provides institutions the opportunity to separate competitive disadvantages from more universal hurdles to student success. In this study, for example, we find that when students are not admitted to their first choice college there is a potential competitive disadvantage, as some appear to choose to move to another institution to complete their education, presumably one that will afford them a place in their field of interest. By contrast, we find that Pell eligibility among our incoming freshmen impacts success at both our own and alternative institutions at similar levels, so it represents a broad barrier to student success. The University of Minnesota has taken

steps to address both of these issues, increasing the role of students' college preferences in admissions decisions and instituting the Founders Free Tuition Program to provide full tuition coverage for incoming students with significant financial need.

The multi-categorical, unordered nature of multi-institutional graduation outcomes necessitates the use of alternative methodologies to the standard logit model. Options such as multinomial logit and multinomial probit are well suited to this analytic challenge. A further advantage of this approach is that it reduces known measurement error in our observations of student success, capturing information on students who successfully obtain a degree at another institution. These students would otherwise be grouped with non-graduates, but as we have shown, they differ systematically from other students who leave their institution of first enrollment. This reduction in measurement error improves the confidence we can have in our parameter estimates.

In dealing with these models, it is important to be aware of their inherent assumptions and to assess whether they are appropriate given the data and research question. A critical distinguishing feature of multinomial logit and multinomial probit models is the former's reliance on the assumption of the independence of irrelevant alternatives (IIA). As we have shown, it is possible to test the validity of this assumption. Further, even if it is violated, it may not necessarily matter on a practical level. Investigation of these issues is critical in establishing the reliability of model estimates. It is also worth noting that, while it is more computationally demanding, the multinomial probit model is by no means beyond the reach of readily available statistical software and computer hardware. It will, however, take more time to process, and care should be taken to ensure the model does not run into convergence problems.

As more data becomes available, it may be possible to further distinguish the set of student outcomes. For example, we might distinguish students who enroll at a similar institution, in our case a major research university, from those who go on to pursue a bachelors-level degree in a markedly different environment, such as a small liberal arts college. In addition, we may be able to determine the factors that lead to student success over a longer period versus those who complete their degree on schedule.

Other methodological approaches are also worth exploring. Options such as nested logit, conditional logit, or structural equation modeling provide the opportunity to examine characteristics of both the student and the institutions in their choice set. There are, however, limiting issues in terms of aggregating the results to meaningful groups of institutions. Additional work can also be done on model verification. Monte Carlo simulations offer a means to test the appropriateness of the model specification and its sensitivity to changes in the underlying data.

The path to success for many students is not the simple, direct route represented by the traditional institutional graduation rate. To understand the complexities of those journeys and devise effective and efficient approaches to improving student success, an expanded definition of graduation and an alternative set of methodological tools are needed. The approach we have outlined provides a means to address these questions and establish confidence in the resulting conclusions.

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Table 1. Degree/certificate attainment rates Six-Years after entry term for fall 1999 to fall 2001 Freshmen Cohorts

		Fall 1999		Fall 2000		Fall 2001		Total	
	Outcome	N	%	N	%	N	%	N	%
Earned degree	Earned UM degree	3,155	60.7%	3,003	60.6%	3,370	63.1%	9,528	61.5%
	Earned BA other institution	384	7.4%	393	7.9%	381	7.1%	1,158	7.5%
	Earned AA/cert	119	2.3%	122	2.5%	115	2.2%	356	2.3%
	Total: earned degree	3,658	70.4%	3,518	71.0%	3,866	72.3%	11,042	71.3%
No degree	Earned UM degree >6 yrs	155	3.0%	97	2.0%			252	1.6%
	Enrolled UM at 6 yr pt	82	1.6%	132	2.7%	190	3.6%	404	2.6%
	Enrolled other institution	625	12.0%	604	12.2%	605	11.3%	1,834	11.8%
	Unknown outcome	675	13.0%	606	12.2%	683	12.8%	1,964	12.7%
	Total: no degree	1,537	29.6%	1,439	29.0%	1,478	27.7%	4,454	28.7%
	Total	5,195	100.0%	4,957	100.0%	5,344	100.0%	15,496	100.0%

Table 2. Variable Labels and Descriptions

Category	Variable Name	Description
Response variables: Binary logit	Old definition (OD): Success	Coded 1 if earned baccalaureate (BA) from University of Minnesota (UM), 0 otherwise.
	Associates degree (AA): Other	Coded 1 if earned associates or certificate (AA), 0 if no degree, system missing if earned BA anywhere
	Bachelors degree (BA): Other	Coded 1 if earned BA from other institution , 0 if no degree, system missing if earned BA from the UM
	Bachelors degree (BA): UM	Coded 1 if earned UM BA, 0 if no degree, system missing if earned BA/AA elsewhere
Response variable: MNL & MNP	New definition (ND): Success	Coded 1 if earned AA, 2=earned BA other institution, 3=earned BA from the UM, 0 otherwise
Academic Performance	First-term GPA	First-term Grade Point Average (GPA)
	W Count	Number of Ws (course withdrawals) first semester
	Completion Ratio	First-term credits earned to attempted (sans withdrawls)
Academic Background	ACT/SAT Score	ACT composite score/SAT converted
	General College	Coded 1 if admitted to General College, 0 otherwise
	Not admitted to 1st choice college (1^{st} Choice)	Coded 1 if Admitted to first-choice college, 0 otherwise
	Advanced Credit	Number of credits brought by student at matriculation (e.g. AP, CLEP, PSEO, etc.)
Demographics	Gender	Coded 1 if Female, 0 otherwise
	Asian	Coded 1 if Asian, 0 otherwise
	Underrepresented Minority (Minority)	Coded 1 if American Indian/Black/Hispanic, 0 otherwise
	Cohort Year 2000 (2000)	Coded 1 if entry term fall 2000, 0 otherwise
	Cohort Year 2001 (2001)	Coded 1 if entry term fall 2001, 0 otherwise
Geography	Reciprocity	Coded 1 if from tuition reciprocity state, 0 otherwise
	Non-reciprocity	Coded 1 if from non-tuition reciprocity state, 0 otherwise
Social	On-campus Housing	Coded 1 if living in residence hall first-term, 0 otherwise
	Living & Learning Communities (LL Communities)	Coded 1 if in living & learning community "house", 0 otherwise
Financial Need	Applied for Financial Aid (Applied FA)	Coded 1 if Submitted Free Application for Federal Student Aid (FAFSA), 0 otherwise
	Pell Grant Eligible (Pell)	Coded 1 if eligible for Pell grant, 0 otherwise

Table 3. Descriptive Statistics of the Analysis Sample (N=15,496)

Variable	Obs	Mean	Std. Dev.	Min	Max
OD: Success	15496	0.61	0.49	0	1
AA: Other	4810	0.07	0.26	0	1
BA: Other	5612	0.21	0.40	0	1
BA: UM	13982	0.68	0.47	0	1
ND: Success	15496	2.02	1.34	0	3
First-term GPA	15201	2.99	0.85	0	4
Completion Ratio	15226	0.94	0.18	0	1
W Count	15496	0.17	0.55	0	7
ACT/SAT	14739	24.51	4.15	9	36
General College	15496	0.18	0.38	0	1
1st Choice	15496	0.73	0.44	0	1
Advanced Credit	15496	4.70	9.95	0	101
Female	15496	0.52	0.50	0	1
Asian	15496	0.10	0.30	0	1
Minority	15496	0.07	0.25	0	1
2000	15496	0.32	0.47	0	1
2001	15496	0.34	0.48	0	1
Reciprocity	15496	0.27	0.44	0	1
Non-reciprocity	15496	0.03	0.18	0	1
On-campus housing	15496	0.73	0.44	0	1
LL Communities	15496	0.11	0.31	0	1
Applied FA	15496	0.70	0.46	0	1
Pell	15496	0.18	0.38	0	1

Table 4. Binary logit parameter estimates

	OD: Success[1]		AA:Other[2]		BA:Other[3]		BA:UM[4]	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
First-term GPA	0.8259***	0.0321	-0.1020	0.0869	0.4211***	0.0579	0.9414***	0.0366
Completion Ratio	2.0607***	0.1902	0.5106	0.3355	1.8507***	0.3406	2.3379***	0.2053
W Count	-0.6515***	0.0572	0.0930	0.1146	-0.4171***	0.1039	-0.7050***	0.0623
ACT/SAT	0.0060	0.0062	-0.0638***	0.0182	-0.0332**	0.0120	-0.0069	0.0071
General College	-0.9737***	0.0623	-0.6736***	0.1613	-0.9660***	0.1207	-1.2220***	0.0691
1st Choice	0.2867***	0.0473	-0.2793*	0.1288	-0.1289	0.0861	0.2275***	0.0541
Advanced Credit	0.0169***	0.0025	0.0051	0.0075	0.0051	0.0052	0.0174***	0.0029
Female	-0.0502	0.0402	0.6128***	0.1225	0.4168***	0.0770	0.1226**	0.0460
Asian	0.0129	0.0712	-0.2791	0.1893	-0.5600***	0.1523	-0.1370	0.0777
Minority	-0.0875	0.0845	-0.7399**	0.2439	-0.7244***	0.1794	-0.2625**	0.0915
2000	-0.1388**	0.0486	0.1378	0.1430	0.0295	0.0915	-0.1125*	0.0556
2001	-0.0689	0.0482	0.0984	0.1443	-0.0563	0.0921	-0.0665	0.0550
Reciprocity	-0.3743***	0.0467	-0.6524***	0.1728	0.5298***	0.0844	-0.2099***	0.0551
Non-reciprocity	-0.3547*	0.1521	-0.2937	0.4729	0.4193	0.2532	-0.2211	0.1756
On-campus Housing	0.5017***	0.0497	0.1105	0.1328	0.3710***	0.0972	0.5785***	0.0554
LL Communities	0.1831*	0.0709	-0.2020	0.2665	-0.1063	0.1397	0.1110	0.0827
Applied FA	0.0128	0.0427	0.1073	0.1301	-0.0983	0.0802	-0.0172	0.0491
Pell	-0.3445***	0.0533	-0.2753	0.1491	-0.5082***	0.1048	-0.4534***	0.0591
Constant	-4.1713	0.2351	-1.1415	0.5297	-3.4534	0.4298	-4.1129	0.2607

* p<.05, **p<.01,***p<.001

1 Base category no UM degree

2 Base category no degree, BA category removed

3 Base category no degree, AA and BA from U of M removed

4 Base category no degree, AA and BA from other institutions removed

Table 5. Multinomial Logit Parameter Estimates

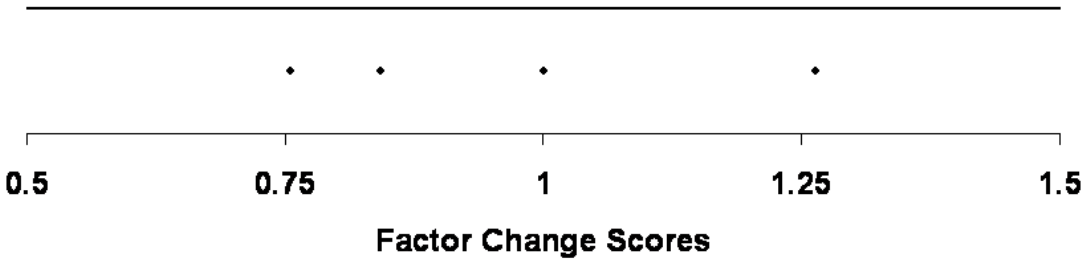
	AA:no degree		BA Other:no degree		UM BA: no degree	
ND: Success	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
First-term GPA	-0.1053	0.0898	0.4811***	0.0582	0.9337***	0.0358
Completion Ratio	0.5507	0.3393	1.7177***	0.3357	2.2870***	0.2012
W Count	0.1005	0.1144	-0.3860***	0.1022	-0.7220***	0.0613
ACT/SAT	-0.0680***	0.0182	-0.0352**	0.0117	-0.0061	0.0070
General College	-0.6863***	0.1587	-1.0206***	0.1183	-1.2135***	0.0678
1st Choice	-0.2801*	0.1284	-0.1709*	0.0845	0.2332***	0.0529
Advanced Credit	0.0060	0.0074	0.0053	0.0049	0.0185***	0.0028
Female	0.6193***	0.1215	0.4146***	0.0747	0.0916*	0.0453
Asian	-0.3279	0.1889	-0.5492***	0.1511	-0.1023	0.0769
Minority	-0.7401***	0.2433	-0.7344***	0.1769	-0.2614***	0.0902
2000	0.1344	0.1421	0.0160	0.0886	-0.1249*	0.0548
2001	0.0875	0.1436	-0.0566	0.0890	-0.0754	0.0543
Reciprocity	-0.6610***	0.1718	0.5546***	0.0825	-0.2313***	0.0543
Non-reciprocity	-0.2841	0.4707	0.5595*	0.2475	-0.2218	0.1724
On-campus Housing	0.0976	0.1328	0.3704***	0.0958	0.5814***	0.0545
LL Communities	-0.1871	0.2650	-0.1747	0.1354	0.1257	0.0820
Applied FA	0.0913	0.1292	-0.1113	0.0775	-0.0107	0.0484
Pell	-0.2716	0.1486	-0.4802***	0.1035	-0.4643***	0.0581
Constant	-1.0453	0.5245	-3.4141	0.4178	-4.0521	0.2551

* p<.05, **p<.01,***p<.001

Table 6. Multinomial Probit Parameter Estimates

	AA: no degree		BA Other:no degree		UM BA: no degree	
ND: Success	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
First-term GPA	0.0551	0.0500	0.3390***	0.0370	0.7303***	0.0277
Completion Ratio	0.5122	0.2033	1.2060***	0.2025	1.7629***	0.1541
W Count	-0.0133	0.0708	-0.2896***	0.0655	-0.5576***	0.0485
ACT/SAT	-0.0368***	0.0101	-0.0230**	0.0074	-0.0036	0.0055
General College	-0.5278***	0.0909	-0.7234***	0.0745	-0.9669***	0.0543
1st Choice	-0.1252	0.0722	-0.0833	0.0551	0.1987***	0.0420
Advanced Credit	0.0045	0.0040	0.0041	0.0030	0.0142***	0.0021
Female	0.3739***	0.0671	0.2621***	0.0479	0.0669	0.0355
Asian	-0.2106	0.1084	-0.3424***	0.0913	-0.0812	0.0615
Minority	-0.4378**	0.1330	-0.4811***	0.1075	-0.2135**	0.0725
2000	0.0628	0.0791	0.0085	0.0574	-0.0949	0.0430
2001	0.0357	0.0795	-0.0412	0.0574	-0.0589	0.0425
Reciprocity	-0.3461***	0.0885	0.3292***	0.0539	-0.2018***	0.0420
Non-reciprocity	-0.2017	0.2563	0.3060	0.1658	-0.2034	0.1330
On-campus Housing	0.1142	0.0753	0.2712***	0.0603	0.4609***	0.0434
LL Communities	-0.0885	0.1373	-0.0874	0.0851	0.1089	0.0623
Applied FA	0.0349	0.0711	-0.0634	0.0504	-0.0057	0.0378
Pell	-0.1956	0.0831	-0.3433***	0.0653	-0.3668***	0.0465
Constant	-1.2777	0.3021	-2.4270	0.2570	-3.1518	0.1961

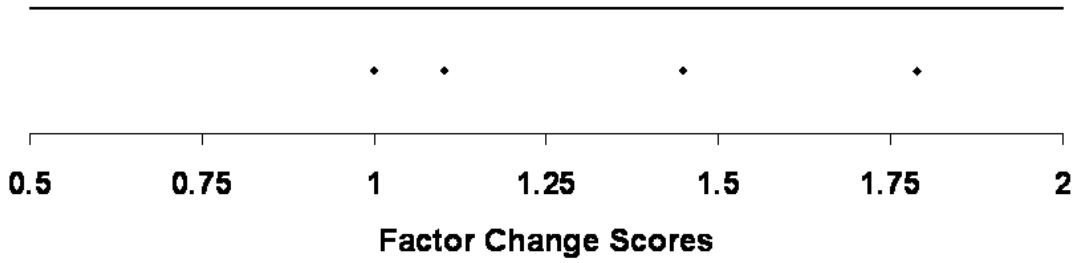
* p<.05, **p<.01,***p<.001



Predicted Probabilities (All other variables at means)			
Outcome	No	Mean	Yes
ND	34.0%	30.7%	29.5%
AA	2.5%	1.9%	1.7%
BA	9.3%	7.5%	6.9%
UM	54.9%	59.9%	61.7%

Percentage Admitted to First Choice College			
Outcome	No	Yes	Students
ND	38.8%	61.2%	3,969
AA	41.5%	58.5%	330
BA	30.9%	69.1%	1,066
UM	20.6%	79.4%	9,100

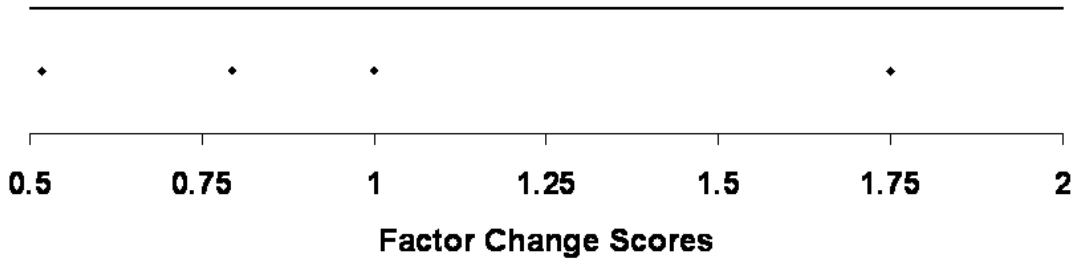
Figure 1. MNL impacts: Admitted to first choice college



Predicted Probabilities (All other variables at means)			
Outcome	No	Mean	Yes
ND	39.7%	30.7%	27.7%
AA	2.3%	1.9%	1.8%
BA	7.4%	7.5%	7.5%
UM	50.6%	59.9%	63.1%

Percentage Living on Campus			
Outcome	No	Yes	Students
ND	37.5%	62.5%	3,969
AA	37.3%	62.7%	330
BA	19.4%	80.6%	1,066
UM	20.1%	79.9%	9,100

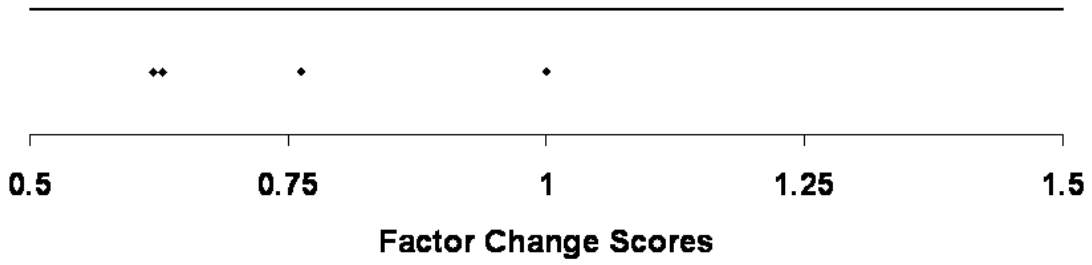
Figure 2. MNL impacts: Living on campus



Predicted Probabilities (All other variables at means)			
Outcome	No	Mean	Yes
ND	29.8%	30.7%	32.8%
AA	2.2%	1.2%	1.2%
BA	6.3%	7.5%	12.1%
UM	61.8%	59.9%	53.9%

Percentage From a Reciprocity State			
Outcome	No	Yes	Students
ND	78.0%	22.0%	3,969
AA	85.4%	14.6%	330
BA	56.1%	43.9%	1,066
UM	71.6%	28.4%	9,100

Figure 3. MNL impacts: Student from reciprocity state



Predicted Probabilities (All other variables at means)			
Outcome	No	Mean	Yes
ND	24.3%	30.7%	33.7%
AA	1.8%	1.9%	1.9%
BA	8.3%	7.5%	7.1%
UM	65.6%	57.2%	61.7%

Percentage Eligible for Pell Grants			
Outcome	No	Yes	Students
ND	73.4%	26.6%	3,969
AA	77.6%	22.4%	330
BA	86.2%	13.8%	1,066
UM	86.3%	13.7%	9,100

Figure 4. MNL impacts: Eligible for Pell grants