Changes in Math Prerequisites and Student Performance in Business Statistics:

Do Math Prerequisites Really Matter?

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Abstract

We use a binary probit model to assess the impact of several changes in math prerequisites on student performance in an undergraduate business statistics course. While the initial prerequisites did not necessarily provide students with the necessary math skills, our study, the first to examine the effect of math prerequisite changes, shows that these changes were deleterious to student performance. Our results helped convince the College of Business to change the math prerequisite again beginning with the 2008/2009 academic year. Thus, this study is also the first to actually help strengthen math prerequisites and improve student performance in business statistics.

Changes in Math Prerequisites and the Performance of Business Statistics Students: Do Math Prerequisites Really Matter?[1]

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> "… students are generally screened by the use of prerequisite course requirements … before enrollment into a course or program is granted. An additional concern is whether the screening process correctly identifies students with inadequate math skills and prevents their enrollment in courses they are poorly prepared for."[3]

When asked "What does business want from higher education?", Arthur Rothkopf, Senior Vice-President and Counselor to the President of the U.S. Chamber of Commerce, answered that "business wants graduates who can read, write, and speak intelligently; solve problems; work collaboratively; understand math and science; and possess a good work ethic and professional attitude. The problem is a failure of the education community at all levels to produce these kinds of future employees."[4] To encourage business schools to produce graduates who are able to solve problems and understand math, the Association to Advance Collegiate Schools of Business (AACSB) requires AACSB-accredited business schools to provide their graduates with "analytic skills." Although AACSB does not mandate any specific method to achieve this result, virtually all accredited business schools require their students to take one or more courses

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[3] Ely and Hittle (1990), p. 59
[4] Mattoon (2007), p. 3.

in both mathematics and business statistics. Most introductory business statistics courses also have math prerequisites.

How effective are these prerequisite math courses in preparing students to understand and use statistical concepts and analyses? There is no way to answer this question because these prerequisites typically remain unchanged for years. We do know, however, that, despite these math prerequisites, "… for many students, Business Statistics is the most hated, most unpopular course in the business program."[5] Whether this view is due to statistics anxiety, how the class is taught or inadequate math preparation remains an open and highly contentious issue.[6]

Once in a great while, however, substantial changes in the math prerequisite do occur which provide a unique opportunity to examine their impact on student performance in business statistics. In this paper, we examine the consequences of such changes at a large Midwestern university.

Changes in Math Prerequisites

Prior to being admitted to the College of Business, undergraduate pre-business students are required to attain junior standing with a minimum overall GPA of 2.0 and to complete nine core courses with a minimum GPA of 2.25. Two of these core courses, a designated mathematics course and ECON 221: Business Statistics, are intended to provide the analytic skills for our undergraduate business majors.[7] The mathematics

[5] Nonis and Hudson (1999), p. 233.

[6] There is an immense and growing literature on the problems that U.S. college students have in learning statistics. For discussion of inadequate math skills prior to entering college, see Kronholz (2004) and Tomsho (2006). For statistics anxiety, see Onwuegbuzie and Wilson (2003). For a small sample of the vast literature on improving business statistics instruction, see Becker (1998), Becker and Greene (2001), Hakeem (2001), Hillmer (1996), McAlevey et al. (2001) and Ng et al. (2005).

[7] The other required business core courses include two accounting principles courses, two economics principles courses, two English courses and a business information systems course.

course required for admission to the business school is also the math prerequisite for ECON 221.

MATHS 132: Brief Calculus for Business was the required math course for decades. However, because it had its own math prerequisite course, MATHS 131: Finite Mathematics for Business, pre-business students were actually required to complete the six-unit MATHS 131/132 sequence before they could enroll in ECON 221. Alternatively, students were allowed to substitute either of the more rigorous MATHS 161: Applied Calculus I (3 units) or MATHS 165: Calculus I (4 units) courses for the MATHS 131/132 sequence. Detailed descriptions of these and other courses discussed in this paper are shown in Table A in the Appendix.

During the 2003/2004 academic year, the business college's Undergraduate Curriculum Committee discussed potential changes in the required math course. Initially, they considered making MATHS 131 the only prerequisite math course. However, the final decision was to require a new four-unit course, MATHS 135: Mathematics for Business. Accordingly, the mathematics department eliminated MATHS 131, added MATHS 135 to the university's 2004-2006 Undergraduate Catalog, and started offering it in Fall 2004. Similarly, the College of Business changed the math requirement for its business core to MATHS 135 and made it the prerequisite for business statistics.

Unfortunately, a large number of pre-business students had taken MATHS 131 but were now unable to complete the MATHS 131/132 sequence. MATHS 132 was never offered by the mathematics department after the Spring 2004 semester.[8] Moreover, MATHS 135 included many topics covered previously in MATHS 131. To resolve this

[8] There were 347 students enrolled in MATHS 131 in Spring 2004. Unfortunately, the MATHS department, inadvertently, no doubt, exacerbated this transition problem by offering MATHS 131 (to 44 students), but not MATHS 132, during the 2004 summer sessions.

transition problem, the business college allowed these students to enroll in ECON 221 in the Fall 2004 and Spring 2005 semesters. Naturally, they responded to this sharp decline in the math "cost" of ECON 221 by enrolling in record numbers.[9]

Finally, in response to some casual evidence that the math prerequisite change had reduced student performance in the business statistics course, the College of Business added an additional requirement to the university's 2006-2008 catalog: A minimum grade of C is required in MATHS 135—the only course-specific grade requirement for the nine core business courses.[10]

The Effect of Different Math Prerequisites: An Overview

Table 1 lists the proportion of all grades of C- or better (A to C-) and D+ or worse (DFW) earned by students enrolled in the business statistics course for the first time from Fall 2001 through Summer 2006. They are displayed by the specific prerequisite math course taken. These proportions illustrate three important points about math prerequisites and student performance in the business statistics course.

First, students find business statistics to be a very difficult subject to learn. The DFW rates range from 14.3% to 38% with an overall weighted average rate of 30.12%.[11] Second, students who take more challenging math courses do better in business statistics. The DFW rates fall monotonically as the rigor of the prerequisite math course rises—

[9] In the previous four years, ECON 221 enrollment had averaged 200 students in the Fall semester and 270 students in the Spring semester. Enrollment in Fall 2004 soared to 340 students and to 355 students in Spring 2005. It then declined to 216 and 293 students in the following Fall 2005 and Spring 2006 semesters, respectively

[10] Our study does not incorporate the impact of the MATHS 135 minimum grade requirement on student performance in business statistics because our data sample ends in Summer 2006. However, a counterfactual analysis that imposes this requirement on MATHS 135 students in our sample does not change our general results or conclusions.

[11] Other studies have noted similarly high DFW rates for statistics students. See, for example, Hakeem (2001) and Ng et al. (2005).

from 38% (MATHS 131) through 34.4% (MATHS 135), 30.6% (MATHS 131/132), 18.7% (MATHS 161) to 14.3% (MATHS 165).

Third, the changes in the math prerequisite from Fall 2004 through Summer 2006 lowered student performance in business statistics. The DFW rates are higher for students who took MATHS 131 or 135 than for those who had previously taken the MATHS 131/132 sequence.[12] Of course, these differences are, at best, suggestive of the impact of different math prerequisites on student performance because they ignore the effect of other potentially important explanatory factors on student performance. In the following section we incorporate several of these potentially confounding variables in our analysis.

The Model

Our study focuses on the impact of different math prerequisites on the probability of a student receiving a grade of C- or better or, in contrast, D+ or worse when he/she enrolls in a business statistics course for the first time.[13] Analysis of this issue is important because it affects the rate of statistics recidivism (re-enrollment in business statistics classes) and, thus, the number of semesters that it takes students to graduate. If students find it more difficult to enter the business school and, perhaps, to graduate in a

[12] One-tailed hypothesis test results for the difference in the proportion of DWF grades for students who took MATHS 131/132 and those who took MATHS 131 reject the null hypothesis (both rates are equal) at the .01significance level (p-value is 0.0035). A similar test for the difference between the DFW rates for those who took MATHS 131/132 vs. MATHS 135 rejects the null hypothesis (both rates are equal) at the .10 level (p-value equals 0.099).

[13] No previous study has examined the effect of changes in math prerequisites on student performance in business courses. However, a number of studies have examined the impact of specific mathematics skills or courses on student performance in various business courses. For statistics, see Johnson and Kuennen (2006) and Rochelle and Dotterweich (2007); for economics, see Brasfield et al. (1992), Butler et al. (1998), Cohn et al. (1998), Ely and Hittle (1990), Gallo and Johnson (2007), Hoag and Benedict (2007), and Von Allmen (1996); for finance, see Didia and Hasnat (1999).

timely fashion, some will decide to select less restrictive majors.[14]

The model we use incorporates general student characteristics often used in studies of student performance as well as the specific math prerequisite courses for business statistics and entry into the business school. The independent variables consist of the student's SAT math score (SATM); dummy variables for intercollegiate athletic participation (Athlete) and gender (Gender); the grades received in the first accounting (AC201), first economics (E201) and prerequisite math (MATH) courses taken prior to first-time enrollment in the business statistics course; the grade point average (GPA) in the semester immediately prior to first-time enrollment in the business statistics course; dummy variables for the prerequisite math course taken (M131, M135, M161 and M165); their associated interaction terms (M131Int, M135Int, M161Int, and M165Int), which equal the math dummy variable multiplied by its respective math grade; and, finally, a dummy variable (Summer) indicating if the business statistics course was taken during the summer.

Naturally, we do not include a dummy variable for the MATHS 131/132 sequence. It represents the base math prerequisite against which the marginal impacts of the other math prerequisite courses are measured.

The dependent variable (E221) in this study is a binary variable that equals 1 if the student received a grade of C- or better in ECON 221 the first time he/she enrolled in the course and 0 otherwise. A detailed list of the definitions and mnemonic symbols for these variables appears in Table B in the Appendix.

[14] Nonis and Hudson (1999) are concerned with potential impacts within the business school. They argue that, if students find business statistics difficult to learn and use, "… [t]his … could encourage potential students interested in a marketing career to change their majors to other business disciplines with less emphasis on business statistics and research." (p. 233).

Specifically, our model is

$$E221 = \beta_0 + \beta_1 \text{Athlete} + \beta_2 \text{Gender} + \beta_3 \text{SATM} + \beta_4 \text{AC201} + \beta_5 \text{E201} + \beta_6 \text{MATH} + \beta_7 \text{GPA} + \beta_8 \text{M131} + \beta_9 \text{M131Int} + \beta_{10} \text{M135} + \beta_{11} \text{M135Int} + \beta_{12} \text{M161} + \beta_{13} \text{M161Int} + \beta_{14} \text{M165} + \beta_{15} \text{M165Int} + \beta_{16} \text{Summer} + \varepsilon.$$

We anticipate that the estimated coefficients for SATM, AC201, E201, MATH, GPA, M161, M165 and Summer will be positive. Previous studies have found that higher SAT math scores, college math grades and GPAs generally have positive influences on student performance in business statistics and other courses. Similarly, students who do well in accounting and economics courses should also do well in business statistics; these courses are considered to be analytic in content and nature.[15] In addition, previous studies have shown that summer school course grades are generally higher than those for courses taken during the usual fall/spring semesters.[16] Since the coefficients for M161 and M165 measure the marginal impact on student performance in business statistics relative to those students who took the MATHS 131/132 sequence, our previous discussion suggests that these coefficients will be positive. In contrast, we expect that the estimated coefficients for M131 and M135 will be negative because these math courses involve fewer class hours and, thus, less "time on task" compared to the MATHS 131/132 course sequence.

We have no prior expectations for the signs of the estimated coefficients for Athlete or Gender. These variables have occasionally been found to have significant

[15] Lee (1960, p. 17) commented that " … business school faculties needed a few courses, required of all business students, which could be pointed to as "rigorous," In most schools, accounting, economics, and statistics served these purposes …". Other studies that have used accounting and/or economic principles grades as independent variables for student performance include Borde et al. (1998), Brasfield et al. (1992), Butler et al. (1998), Didia and Hasnat (1999), Ely and Hittle (1990) and Von Allmen (1996).
[16] See, for example, Austin and Gustafson (2006) and Terry and Galchus (2003).

influences—although with different signs across studies.[17] We also have no a priori expectations for the signs of the estimated coefficients for the math interaction terms (M131Int, etc.).The expected signs of the estimated coefficients for the math dummy variables indicate their marginal effect on the expected probability of success (grade of C- or better) in business statistics by taking these courses, instead of the MATHS 131/132 sequence, regardless of the grade received. The estimated coefficient for MATH indicates the impact on the expected probability of success for a unit change in the grade received in MATHS 132. The estimated coefficient for each math interaction term shows the difference in the impact on the expected probability of success for a unit change in the grade received in that math course relative to that for MATHS 132. For example, if the estimated coefficient for a specific math course interaction term is positive, a student who earns a B rather than a C grade in that course will have a larger increase in his/her expected probability of receiving a C- or better grade in ECON 221 than a similar student who has taken MATHS 132. The opposite is true if the coefficient for a specific math interaction term is negative. We have no reason to expect, a priori, that the signs of these estimated interaction coefficients will necessarily be positive or negative.

The Results

Since the dependent variable, E221, is a discrete variable that takes on the values 1 or 0, we use binary probit analysis to estimate the model described in the previous

[17] For different conclusions about the role of gender in student performance, see Austin and Gustafson (2006), Bollinger et al. (2006), Borde et al. (1998), Brasfield et al. (1992), Butler et al. (1998), Caviglia-Harris (2006), Cohn et al. (1998), Dutton and Dutton (2005), Gallo and Johnson (2007), Hoag and Benedict (2007), and Krieg and Uyar (2001). For studies that incorporate student extra-curricular activities, including intercollegiate athletics, on student performance, see Brasfield et al. (1992), Cohn et al. (1998), Krieg and Uyar (2001), and Mangold et al. (2003).

section.[18] The university student records office provided us with an extensive data set that included the relevant personal and academic information for all students (2,491 in total) who received a grade in business statistics from Fall 2001 through Summer 2006. We utilized data for 2,317 students who had taken their math prerequisite course at this university. In our initial model estimation, we included only students who had taken ACC 201: Principles of Accounting I and ECON 201: Elementary Microeconomics at this university and who also had submitted SAT scores for admission.[19] These constraints reduced our initial sample to 1,647 students.

The results of the binary probit model estimations for the probability of student success in business statistics are shown in Table 2. They include estimates for the full model and for two variations, Models 1 and 2, which sequentially exclude variables that are not statistically significant at the .10 significance level. The p-values in parentheses are two-tailed p-values that must be halved to determine the statistical significance for the estimated coefficients that require one-tailed significance tests. The differences in sample sizes shown at the top of each column in Table 2 indicate that, by eliminating statistically non-significant variables, we were able to increase the sample size when we re-estimated the model. At the bottom of each model (column), we also show the number of students who earned a C- or better (E221 = 1) and a D+ or worse (E221 = 0). Finally, each column includes measures commonly used to evaluate binary probit models—the McFadden R-squared, the Schwarz Criterion (SIC) and the log likelihood function.

The estimation results for the full model are shown in the 2nd column. They are generally consistent with our a priori expectations. The estimated coefficients for AC201,

[18] The use of binary probit analysis to examine the determinants of student performance was first developed over 25 years ago by Spector and Mazzeo (1980).
[19] Students may submit either SAT or ACT scores as part of the university admission process.

E201, MATH, GPA and Summer are positive and statistically significant.

The signs of the estimated coefficients for the math course dummy variables indicate that their relative impact on the probability of success in business statistics is consistent with our earlier discussion—negative for MATHS 131 and 135 and positive for MATHS 161 and 165 compared to students who took the MATHS 131/132 sequence. Although the MATHS 161 and 165 coefficients are statistically significant at the .05 and .10 significance levels, respectively, the MATHS 131 and 135 coefficients do not appear to be statistically significant. However, this result is caused by multicollinearity between the math dummy variables and their associated interaction variables.[20] Redundant variable tests indicate that the math dummy variables and their interaction terms should not be removed from the models.[21] Thus, the math dummy variables and their interaction terms, in combination, are statistically significant. The estimated coefficient for the gender dummy variable is positive and statistically significant at the .05 level. Female students at this university perform better than their male counterparts when they first take business statistics. This result is unusual; previous studies have generally shown that women either do worse or about the same as male students in analytic courses.[22]

However, neither SATM nor Athlete has statistically significant impacts on the probability that a student will earn a C- or better grade in business statistics. The SATM result is not especially unusual; other studies have found similar results when they

[20] Correlation coefficients between these associated pairs exceed 0.93 in all cases; correlations between them and the other independent variables do not exceed 0.66.
[21] The redundant variable test for removing the M131/M131Int pair from the estimated equation yields an F statistic = 2.654 (Prob. F(2, 1630) = 0.0707). Similar tests for removing the M135/M135Int and M165/M165Int pairs from the estimated equation yields F statistics = 4.556 (Prob. F(2, 1630) = 0.0106) and 6.682 (Prob. F(2,1630) = 0.0013), respectively.
[22] See the studies cited in footnote 17.

included GPA and individual course grades.[23]

After deleting the SATM and Athlete variables, we re-estimated the model using a slightly larger sample of 1,797 students resulting from the addition of 150 students who had taken the ACT instead of the SAT. These results, shown as Model 1 in the 3rd column of Table 2, are very similar to those for the full model. All estimated coefficients for variables with a priori expectations have the predicted signs. Except for E201, all estimated coefficients are either statistically significant on their own or in combination (the math dummy variables and their associated interaction terms).

We then deleted the E201 variable and re-estimated the model once again. By dropping the constraint that students had to have taken ECON 201 prior to enrolling in the business statistics course, we increased our sample to 1885 students. These results, labeled Model 2, appear in the 4th column. Once again, they are very similar to those for the full model and Model 1. The estimated coefficients for variables with a priori expectations have the predicted signs, and all estimated coefficients are either statistically significant on their own or in combination.

We then solved Model 2 for the predicted probabilities of success (a grade of C- or better) and non-success (a grade of D+ or worse) for students taking their first business statistics course. The mean predicted probabilities, shown in the 2nd and 3rd columns of Table 3, indicate how student performance is influenced by the specific prerequisite math course taken after adjusting for the impact of the other significant factors (grades, gender and summer school attendance).

Separate discussion of the student success and non-success categories for each math prerequisite is obviously redundant because they are complementary outcomes

[23] See, for example, Butler et al. (1998).

whose expected probabilities sum to 1. Consequently, we will focus on the predicted probabilities for the DFW grade (non-success) category because it typically receives more attention in discussions of problems associated with specific courses or programs.

The results in Table 3 provide statistical support for our conjecture, motivated by the results in Table 1, that alternative math prerequisite courses have impacts—for good or ill—on student performance in the business statistics course. First, the mean predicted probabilities for a grade of DFW decrease monotonically as the general level of rigor in the prerequisite math course increases: they range from 35.93% (MATHS 131) down to 7.27% (MATHS 165). Second, the predicted probabilities of non-success in ECON 221 are 30% or higher for the MATHS 131/132 sequence, MATHS 131 and the current MATHS 135 math prerequisite; these high rates of non-success indicate that neither the previous nor the current math prerequisite course provides first-time students with the necessary math foundation to do well in business statistics. Moreover, the changes in the math prerequisite course that occurred since Fall 2004 have had negative impacts on student performance. The predicted probabilities for DFW grades are higher for students who took MATHS 131 (35.93%) and MATHS 135 (32.52%) than for those who had taken the previous MATHS 131/132 sequence (29.99%).

The marginal impact on the predicted probability for DFW grades for each alternative math prerequisite relative to the MATHS 131/132 sequence is depicted in the 4th column. Compared to students who took the previous MATHS 131/132 sequence, students who took MATHS 131 and 135 had higher estimated probabilities of 5.94 percentage points (about 20%) and 2.53 percentage points (8.4%) of earning DFW grades, respectively. In contrast, students who took MATHS 161 or 165 had lower

predicted probabilities of 11.54 percentage points (38.5%) and 22.72 percentage points (about 76%), respectively. These latter results suggest that some potential changes in math prerequisites might actually increase student performance in business statistics.

Aftermath

> "Some circumstantial evidence is very strong, as when you find a trout in the milk" – Henry David Thoreau

We undertook this study for two reasons. First, it presented a unique opportunity to assess the impact of a substantial change in the math prerequisite for the business statistics course. Second, we were convinced, albeit by circumstantial evidence, that the change in the prerequisite math course had produced students who were less prepared to succeed in business statistics. Needless to say, we were not surprised when the results of this study strongly confirmed our suspicions. Apparently, the circumstantial evidence in Table 1 is the business statistics equivalent to the trout in Thoreau's milk.

We were surprised, however, by the impact that this study had on our colleagues and the administration in the College of Business. There has been continuing discussion within the College over the past several years about the potential benefits associated with raising the quality of entering business students and reducing their time to graduation. Our analysis, however, indicated that the recent change in the math prerequisite course would produce precisely the opposite results. Partially in response to our findings, the College of Business decided to strengthen the math requirement for the business core and the business statistics course. The new four-unit math prerequisite course includes three more weeks of calculus and requires MATHS 111: Pre-Calculus Algebra instead of MATHS 108: Intermediate Algebra as its prerequisite. It will take effect in Fall 2008.

Summary

Although math prerequisites for business programs and courses have been around for decades, there has been no way to determine if they really matter—i.e., if their screening process is working as desired or, for that matter, could be improved by appropriate changes in these prerequisites. A few years ago, however, the College of Business decided to substantially change the math prerequisite for business statistics and for the business core program. This change provided one of those rare opportunities to examine how math prerequisites and their changes actually affect student performance.

In this study we use a binary probit model to show that the math prerequisite changes had significant negative impacts on student performance in business statistics. Not only do math prerequisites matter, some are actually hazardous to student performance.

One important result of this study is that it provided the impetus for math and business faculty to reconsider their decision on the math prerequisite for the College of Business's core curriculum and for the business statistics course. Surprisingly, given the usual speed of academic debate and curricular change, a new and more rigorous math prerequisite quickly emerged from these discussions. This new math prerequisite course will take effect in Fall 2008. Occasionally, faculty members and college administrators actually learn something interesting and useful from studies of student performance.

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Appendix

Table A. Course Descriptions and Prerequisites

ACC 201: Principles of Accounting I. (3)
An introduction to accounting emphasizing the basic principles underlying the accounting cycle. Includes the preparation of reports to management and external users of financial statements.

Prerequisite: sophomore standing.

ECON 201: Elementary Microeconomics. (3)
A study of why people specialize as producers and exchange what they produce with others. Includes analysis of how market structure affects prices. Discusses the issue of whether self-interested economic behavior promotes or hinders society.

Prerequisite: none.

ECON 221: Business Statistics. (3)
Introduction to various statistical and probabilistic concepts and techniques with application to business problems including random variables and probability distributions, measures of central tendency and dispersion, testing of hypotheses, simple linear regression, and correlation

Current Prerequisite: (Fall 2006 – present): C or better grade in MATHS 135; sophomore standing; demonstrated proficiency in computer skills.

Previous Prerequisite: (Summer 2005 – Summer 2006) MATHS 135; sophomore standing; demonstrated proficiency in computer skills.

Previous Prerequisite: (Fall 2004 and Spring 2005): MATHS 131 or MATHS 135; sophomore standing; demonstrated proficiency in computer skills.

Previous Prerequisite: (Prior to Fall 2004): MATHS 132.

E221 Math Prerequisite Courses: MATHS 131, 132 and 135 and their Prerequisites:

MATHS 108: Intermediate Algebra (3)
Reviews of factoring, quadratic equations and inequalities, relations and functions, rational exponents, systems of linear equations, and exponential and logarithmic functions. Offered credit/no-credit only

Recommended background: Two years of college preparatory mathematics in high school or the equivalent.

MATHS 131: Finite Mathematics for Business. (3)
Topics in mathematics particularly suited to the needs of business majors, including mathematics of finance, probability, matrix algebra, and linear programming. [This course, which does not appear in the 2004-2006 university catalog, was last taught in Summer 2004.]

Prerequisite: MATHS 108 or an appropriate score on the mathematics placement test.

MATHS 132: Brief Calculus for Business. (3)
Brief survey of differential and integral calculus. Emphasizes applications to business. [Although listed in the 2004-2006 university catalog, it was last taught in Spring 2004.]

Current Prerequisite: MATHS 135.

Previous Prerequisite: MATHS 131.

MATHS 135: Mathematics for Business. (4)
Topics in mathematics particularly suited to the needs of business majors, including mathematics of finance, probability, and differential calculus. [It was listed in the 2004/2006 BSU Undergraduate Catalog and first offered in Fall 2004.]

Prerequisite: MATHS 108 or an appropriate score on the mathematics placement test.

Table A. (continued):

Alternative E221 Math Prerequisite Courses: MATHS 161and 165 and their Prerequisites:

MATHS 111: Pre-Calculus Algebra. (3)
Such topics as polynomial functions and equations, exponential and logarithmic functions, determinants, systems of equations and inequalities, mathematical induction, the binomial theorem, permutations and combinations and progressions.

Prerequisite: MATHS 108, or appropriate score on the SAT/ACT or Mathematics Placement test, or permission of the department chairperson.

MATHS 112: Pre-Calculus Trigonometry. (3)
Trigonometric functions, identities, and equations; graphs of the trigonometric and inverse trigonometric functions; solution of right and general triangles; polar coordinates; and complex numbers. Students will be required to use scientific calculators.

Prerequisite: MATHS 108 or 111 or permission of the department chairperson.

MATHS 161: Applied Calculus 1. (3)
Discussion of limits, derivatives, differentials, and appropriate applications. The definite integral, area, fundamental theorem of calculus, indefinite and improper integrals.

Prerequisite: MATHS 112 or permission of the department chairperson. *Not open to* students who have credit in MATHS 165.

MATHS 165: Calculus 1. (4)
Differential calculus of algebraic and transcendental functions and applications, antidifferentiation and the Riemann integral. Includes the use of graphing calculators and computer software.

Prerequisite: MATHS 111, 112; or sufficient background in algebra and trigonometry as evidenced by the student's high school record, SAT/ACT scores, and/or score on the mathematics placement test.

TABLE B: Variables and Definitions Used in Binary Probit Model

Dependent Variable

E221: A dummy variable (C- or better = 1; 0 otherwise (including W)) for the grade that the student received the first time that he/she enrolled in ECON 221.

Independent Variables

SATM: The student's SAT Math score.

Athlete: A dummy variable identifying whether a student competes in intercollegiate athletics (Yes = 1; 0 otherwise).

Gender: A gender dummy variable (Female = 1; 0 otherwise).

AC201: The numeric grade (F = 0, D- = .7, …, A- = 3.7, A = 4) that the student received in the ACC 201 course taken prior to his/her first enrollment in ECON 221.

E201: The numeric grade (F = 0, D- = .7, …, A- = 3.7, A = 4) that the student received in the ECON 201 course taken prior to his/her first enrollment in ECON 221.

MATH: The numeric grade (F = 0, D- = .7, …, A- = 3.7, A = 4) that the student received in the relevant prerequisite math class.

GPA: The student's cumulative GPA in the semester prior to first enrollment in ECON 221.

M131: A dummy variable identifying whether the student took MATHS 131 as the prerequisite math course for ECON 221 (Yes = 1; 0 otherwise).

M135: A dummy variable identifying whether the student took MATHS 135 as the prerequisite math course for ECON 221 (Yes = 1; 0 otherwise).

M161: A dummy variable identifying whether the student took MATHS 161 as the prerequisite math course for ECON 221 (Yes = 1; 0 otherwise).

M165: A dummy variable identifying whether the student took MATHS 165 as the prerequisite math course for ECON 221 (Yes = 1; 0 otherwise).

M131Int: An interaction term for MATHS 131 (M131Int = M131 x MATHS).

M135Int: An interaction term for MATHS 135 (M135Int = M135 x MATHS).

M161Int: An interaction term for MATHS 161 (M161Int = M161 x MATHS).

M165Int: An interaction term for MATHS 165 (M165Int = M165 x MATHS).

Summer: A seasonal dummy variable for the term in which ECON 221 was first taken (summer = 1; 0 otherwise).

Table 1. ECON 221 Grade Proportions for Alternative Math Prerequisite Courses: Fall 2001 through Summer 2006

MATHS Prerequisite Course	A to C- (%)	DFW (%)	Number of Students
131/132	69.40	30.60	1202
131	61.98	38.02	384
135	65.63	34.37	323
161	81.27	18.73	331
165	85.72	14.28	77

Notes:
1. This sample includes all students who enrolled in ECON 221 for the first time from Fall 2001 through Summer 2006 and who had also taken their math prerequisite at this university. It does not include 174 transfer/transient students who enrolled in ECON 221 but who had taken their math prerequisite course elsewhere. For comparison, their A to C- and DFW rates were 68.39% and 31.61%, respectively.

2. DFW designates a grade of D+ or lower including a grade of W which indicates that the student withdrew from the course.

Table 2: Binary Probit Estimation Results: Dependent Variable is E221

	Full Model	Model 1	Model 2
Included observations:	n = 1647	n = 1797	n = 1885
Variable	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)
SATM	-0.0000434 (0.9306)		
Athlete	0.206050 (0.2048)		
Gender	0.195975[@] (0.0121)	0.179572[@] (0.0150)	0.176750[@] (0.0133)
AC201	0.156617* (0.0024)	0.156937* (0.0015)	0.149728* (0.0018)
E201	0.075634[#] (0.1832)	0.054485 (0.3138)	
GPA	1.083799* (0.0000)	1.106640* (0.0000)	1.164117* (0.0000)
MATH	0.245131* (0.0001)	0.217423* (0.0002)	0.208658* (0.0002)
M131	-0.032208 (0.9142)	-0.073218 (0.7936)	-0.084885 (0.7502)
M131Int	-0.053265 (0.6582)	-0.032022 (0.7775)	-0.030175 (0.7809)
M135	-0.348342 (0.3248)	-0.380103 (0.2600)	-0.380264 (0.2523)
M135Int	0.055205 (0.7166)	0.060570 (0.6724)	0.081183 (0.5651)
M161	0.713063[@] (0.0523)	0.657341[@] (0.0687)	0.721322[@] (0.0361)
M161Int	-0.282377[@] (0.0425)	-0.246433[#] (0.0723)	-0.26371[@] (0.0430)
M165	1.373635[#] (0.1273)	1.040620 (0.2179)	1.126551[#] (0.1778)
M165Int	-0.169390 (0.6719)	-0.040252 (0.9163)	-0.045412 (0.9049)
Summer	0.893199* (0.0000)	0.855279* (0.0000)	0.812643* (0.0000)
C	-3.812205* (0.0000)	-3.76775* (0.0000)	-3.76784* (0.0000)
McFadden R-squared	0.241780	0.236860	0.233351
SIC	0.985731	0.980744	0.9852999
Log likelihood	-748.7924	-824.9946	-875.8528
Obs with Dep=0	473	520	555
Obs with Dep=1	1174	1277	1330

* significant at the .01 level, one- or two-tailed test as appropriate
[@] significant at the .05 level, one- or two-tailed test as appropriate
[#] significant at the .10 level, one- or two-tailed test as appropriate

Table 3. Predicted Probabilities: ECON 221 Grade Outcomes From Model 2

MATHS Prerequisite Course	A to C- (%)	DFW (%)	MATHS DFW Rate Minus MATHS 131/132 DFW Rate (%)
131/132	70.01	29.99	---
131	64.07	35.93	5.94
135	67.48	32.52	2.53
161	81.55	18.45	-11.54
165	92.73	7.27	-22.72