How Much Math Do Students Need to Succeed in Business and Economics Statistics? An Ordered Probit Analysis

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Abstract

Because statistical analysis requires both familiarity with and the ability to use mathematics, students typically are required to take one or more prerequisite math courses prior to enrolling in the business statistics course. Despite these math prerequisites, however, students find it extremely difficult to learn business statistics.

In this study, we use an ordered probit model to examine the effect of alternative prerequisite math course sequences on the grade performance of 1,684 business and economics statistics students at a large Midwestern university. In addition, we show how the imposition of a minimum grade requirement of C- for the math prerequisite course would impact student success in the business statistics course. Although several studies have examined the impact of different math skills on student success in business and economics statistics courses, our study is the first to provide a detailed analysis of the impact of different prerequisite math course sequences on student performance in business statistics. Our study shows that, other things the same, taking more math credit hours, taking math courses that emphasize calculus, and imposing a minimum grade of C- on the prerequisite math course have significantly positive impacts on student grade performance in the business and economics statistics course.

How Much Math Do Students Need to Succeed in Business and Economics Statistics? An Ordered Probit Analysis[1]

Virtually all accredited business schools require their students to take one or more courses in both mathematics and business statistics. In addition, most introductory business statistics courses also require one or more math courses to provide the necessary mathematical foundation for statistics. Despite these prerequisite math courses, many students do poorly in their business and economics statistics (hereafter, business statistics) course. It has even been alleged that "… Business Statistics is the most hated, most unpopular course in the business program."[2] Potential reasons for such poor student performance include, among others, statistics anxiety, inadequate statistics instruction, inadequate math preparation before matriculation and/or inadequate math prerequisites prior to taking the statistics course.[3]

In this study, we focus on the importance of math prerequisites for student performance in the business statistics course. Specifically, we use an ordered probit model to examine the relationship between alternative prerequisite math course sequences and student grades in their first business statistics course. We then show how

[1] We would like to thank Janice Replogle, formerly the Director of Undergraduate Programs, College of Business, for her interest and support for this study and Dr. Tung Liu, Chair of the Economics Department, for patiently guiding us through the intricacies of probit analysis. We also want to thank Michael T. Costello (University Computing Services) for providing us with the student data and the College of Business 2005 Summer Faculty Research Program for financial support at an early stage of this study. Finally, we would like to thank Lee Hansen and other session participants at the Eastern and Midwest Economic Associations 2008 Annual Meetings for their insightful comments.

[2] Norris and Hudson (1999), p. 233.

[3] For discussion of statistics anxiety, see Onwuegbuzie and Wilson (2003). For a small sample of the vast literature on how to improve statistics instruction, see Becker (1987, 1998), Becker and Greene (2001), Carlson (1999), Gandhi et al. (1991), Hakeem (2001), Hillmer (1996), McAlevey et al. (2001), and Parr and Smith (1998). For discussion of inadequate math preparation prior to entering college, see, Kronholz (2004) and Tomsho (2006). Finally, for a discussion of inadequate math prerequisites, see Green et al. (2007).

the imposition of a minimum grade requirement of C- for the prerequisite math course would be expected to raise student performance in business statistics.

Several studies have previously examined the impacts of mathematics *skills* and topics on student performance in business statistics.[4] To our knowledge, however, this is the first study to examine the effect of alternative prerequisite math course sequences on student performance.[5] It is also the first study to demonstrate the effect on student success in business statistics of the imposition of a minimum grade requirement for the prerequisite math course.

"Different Strokes for Different Folks": Alternative Prerequisite Math Course Sequences for Business Statistics

Undergraduate pre-business students at our university are required to complete a designated math course and ECON 221: Business Statistics before they can enroll in the College of Business and take specialized upper division business courses.[6] The mathematics course required for admission to the College is also the prerequisite math course for the business statistics course.

Over the past 20 years, pre-business students have satisfied the prerequisite math requirement in a variety of ways. Through the Spring 2004 semester, the vast majority of pre-business students completed the nine credit-hour math sequence: MATHS 108: Intermediate Algebra (3 hours), MATHS 131: Finite Mathematics for Business (3 hours)

[4] See, for example, Johnson and Kuennen (2006), Larson (2003) and Rochelle and Dotterweich (2007).
[5] Green et al. (2007) examined the impact of prerequisite math course changes on the DFW rate using a binary probit analysis. They did not examine the letter grade performance of students in the business statistics course.
[6] They are also required to complete two accounting and two economics principles courses, two English courses and a computer skills course.

and MATHS 132: Brief Calculus for Business (3 hours). Other students chose to take the more mathematically rigorous nine credit-hour sequence: MATHS 108 (or MATHS 111: Pre-Calculus Algebra (3 hours)), MATHS 112: Pre-Calculus Trigonometry (3 hours) and MATHS 161: Applied Calculus I (3 hours). Still others took the thirteen credit-hour sequence: MATHS 108, MATHS 111, MATHS 112 and MATHS 165: Calculus I (4 hours).[7]

During the 2003/04 academic year, the Business College's Undergraduate Curriculum Committee decided to replace the MATHS 108/131/132 sequence with a seven-unit math sequence: MATHS 108 and a new four credit-hour course, MATHS 135: Mathematics for Business. This change, which became effective in the Fall 2004 semester, created a transition problem for students who had taken MATHS 131 but had not completed MATHS 132 by the end of the Spring 2004 semester.[8] These students were permitted to enroll in ECON 221 in the Fall 2004 and Spring 2005 semesters, even though they had only completed a six-unit math sequence: MATHS 108/131.[9]

The differences in the math topics covered in the various preliminary math courses (MATHS 108, 111 and 112) and the alternative prerequisite math courses (MATHS 131, 132, 135, 161 and 165) for the business statistics course are depicted in Table 1. As Table 1 shows, the two preliminary algebra classes (MATHS 108 and 111) differ in terms of the topics covered. Because MATHS 108 is a prerequisite for MATHS

[7] Students were allowed to enroll in MATHS 131, MATHS 161 or MATHS 165 without taking all the math prerequisites for these courses if they had sufficient background in algebra and trigonometry as evidenced by their high school record, SAT/ACT score, and/or score on the mathematics placement test, or permission from the chair of the mathematics department.
[8] MATHS 132 was not offered after the Spring 2004 semester.
[9] Again, students could avoid taking MATHS 108 by getting an appropriate score on the mathematics placement test.

111, their common topics are covered in greater detail in MATHS 111, which also includes numerous additional topics as well.

Table 1. Alternative Prerequisite Math Courses and Topics

A. Preliminary Math Courses

Topic	MATHS		
	108 (3)	111 (3)	112 (3)
Factoring	X		
Quadratic equations	X	X	
Inequalities	X	X	
Relations and functions	X		
Rational exponents	X		
Systems of linear systems	X	X	
Exponential and logarithmic functions	X	X	
Determinants		X	
Mathematical induction		X	
Binomial theorem		X	
Permutations, Combinations and Progressions		X	
Trigonometric functions, identities and equations			X
Graphs of trigonometric and inverse trigonometric functions			X
Solution of right and general triangles			X
Polar coordinates			X
Complex numbers			X

B. Alternative Prerequisite Math Courses for the Business Statistics Course

Topic	MATHS				
	131 (3)	132 (3)	135 (4)	161 (3)	165 (4)
Mathematics of finance	X		X		
Probability	X		X		
Matrix algebra	X				
Linear programming	X				
Differential calculus		X	X	X	X
Integral calculus		X		X	X

Table 1 also shows that the alternative prerequisite math courses (MATHS 131, 132, 135, 161 and 165) for the business statistics course differ considerably in terms of

their math coverage. Specifically, MATHS 131 did not cover calculus at all, while MATHS 132 provided an introduction to both differential and integral calculus.[10] Its replacement, MATHS 135, included only an introduction to differential calculus when the decision was made to pool selected topics from the 6-credit hour MATHS 131/132 sequence into a single 4-credit hour course.

Finally, MATHS 161 and 165 differ from MATHS 132 and 135 in two significant ways. First, their prerequisite courses include MATHS 108/111 and/or 112, instead of only MATHS 108. Because MATHS 111 and MATHS 112 are required for math and science majors, the math content in MATHS 161 and 165 is more rigorous than that in MATHS 131/132 or MATHS 135. Second, the MATHS 165 course sequence involves 13 credit-hours instead of the 7 or 9 credit-hours in the MATHS 135 or 132 sequences, respectively.[11]

Student Performance in Business Statistics: An Overview

Table 2 shows the grade distribution (percent and cumulative percent for grades A through F) for virtually all first-time business statistics students from Fall 2001 through Summer 2006. [12] About 11 percent of the students failed their first business statistics class and more than 25 percent earned grades of D or F. Had we included students who

[10] MATHS 131 was only allowed as a prerequisite math class for business statistics in the 2004/05 academic year. However, comparison of MATHS 131 with other math prerequisite courses is particularly relevant because it was initially considered to be the course that would replace the MATHS 131/132 sequence.

[11] There is a third important difference between the math courses generally taken by the pre-business students (MATHS 131/132 and 135) and the math and science students (MATHS 161 and 165). The former classes are generally taught by contract faculty, while the latter courses are typically taught by tenure-track faculty.

[12] It excludes 174 transfer/transient students who enrolled in ECON 221 but who had taken their math prerequisite courses elsewhere and 157 students who received a grade of W in ECON 221 because they withdrew before the end of the semester. The source of these data is described later in the model estimation section of this paper.

enrolled and then withdrew from the course before the semester ended, more than 30 percent of our students earned a D, F or W grade in their first business statistics course. Other studies have noted similarly low levels of performance for statistics students.[13]

Table 2. Grade Distribution for Students Enrolled in Business Statistics

Fall 2001 – Summer 2006

Grade	Percent of Total Grades	Cumulative Percent (F to A)
A- To A	21.10	100
B- to B+	28.64	78.91
C- to C+	25.16	50.28
D- to D+	13.88	25.12
F	11.24	11.24
Number of Students	2162	

As we noted earlier, among several factors that might account for the poor student performance in their first business statistics course was inadequate prerequisite math courses. Several recent changes in math prerequisites at our university provided us with a unique opportunity to examine the extent to which different math prerequisite course sequences can influence student performance in the business statistics course.

The Model

Our study focuses on the effect of different prerequisite math course sequences on the probability of a student receiving a specific grade from A to F when he/she enrolls in a business statistics course for the first time. Our model is

$$STAT = \beta_0 + \beta_1 D131 + \beta_2 D135 + \beta_3 D161 + \beta_4 D165 + \beta_5 MATH + \beta_6 GPA + \beta_7 ACC + \beta_8 ECON + \beta_9 Summer + \varepsilon.$$

[13] See for example, Green et al. (2007), Hakeem (2001), Keeler and Steinhorst (1994), and Lewis et al. (2005).

The dependent variable (STAT) is an index of the grade (A = 11, A- = 10, ... , F=0) that students received in business statistics the first time they enrolled in and completed the course. The first set of independent variables consists of four 0, 1 dummy variables (D131, D135, D161 and D165) for the last course in the prerequisite math sequence taken instead of the MATHS 132 sequence and MATH (the numerical grade (A = 4, A- = 3.7, ..., F = 0) that students received in the last course of their prerequisite math sequence. We do not use a dummy variable for MATHS 132 because the MATHS 108/131/132 sequence is the base against which the impacts of the other prerequisite math sequences are measured.

The second set of independent variables consists of selected student characteristics often used in studies of student performance. These include the students' cumulative grade point average (GPA) immediately prior to first-time enrollment in the business statistics course, the numerical grades (A = 4, A- = 3.7, ..., F = 0) received in the principles of accounting (ACC) and microeconomics (ECON) courses taken prior to enrollment in the business statistics course, and a 0, 1 dummy variable (Summer) indicating whether the business statistics course was taken during the summer instead of the fall or spring semesters. The Table in the Appendix provides a detailed description of the definitions of these variables.

The estimated coefficients for D161, D165 and MATH are expected to be positive. The coefficients for D161 and D165 measure the impact on student performance in business statistics for those who took the more rigorous math sequences relative to the impact for those who took the MATHS 108/131/132 sequence. The estimated coefficient

for MATH measures the impact of the grade (the extent of math knowledge) earned in the prerequisite math class and, thus, would be expected to be positive.

The estimated coefficients for D131 and D135 measure the impact on student performance in business statistics for students who took the MATHS 108/131 or MATHS 108/135 sequences relative to those who took the MATHS 108/131/132 sequence. Their estimated coefficients are expected to be negative because these prerequisite sequences are less rigorous and have fewer credit-hours. [14]

The estimated coefficients for GPA, ACC, ECON and Summer are expected to be positive. Previous studies have found that higher grade point averages and better grades in accounting and microeconomics courses have positive influences on student performance.[15] Finally, because studies have shown that grades are higher for classes taken in the summer than in either the fall or spring semesters, the estimated coefficient for Summer is expected to be positive.[16]

In our preliminary research, we examined the impact of several other variables often used in student performance studies—the student's math SAT score, gender and participation in varsity athletics. However, none of these were statistically significant and, therefore, we excluded them from our model.

The Ordered Probit Model Estimation

Because the dependent variable, STAT, is a discrete variable that takes on the values 0 (F) through 11 (A), depending on the actual grade received in the business

[14] For a discussion of the impact of increased class time on math skills, see Toppo (2007).
[15] For example, see Brasfield et al. (1992), Borde et al. (1998), Butler et al. (1998), Didia and Hasnat (1999), Ely and Hittle (1990), Green et al. (2007), Haley et al. (2007) and Von Allmen (1996).
[16] See, for example, Austin and Gustafson (2006), Garces-Ozanne (2005), Green et al. (2007), and Terry and Galchus (2003).

statistics course, we used an ordered probit analysis to estimate the model described in the previous section. 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 had enrolled in business statistics from Fall 2001 through Summer 2006. We used data for 1,684 students who had received a grade of A through F in their business statistics course after having taken their math, accounting, and microeconomics courses at this university.

Table 3 shows our results. All estimated coefficients have the expected signs. The estimated coefficients for D161 and D165 are positive and statistically significant, indicating that students who took either the MATHS 161 or 165 prerequisite sequences had higher probabilities of success in their business statistics course compared to those who took the MATHS 132 sequence.

Table 3. The Impact of Alternative Math Course Sequences and other Variables on Student Performance in their First Business Statistics Course[17]

Variable	Coefficient	Standard Error	P-Value
D131	-0.070	0.073	.3402
D135	-0.074	0.076	.3346
D161	0.192**	0.089	.0311
D165	0.374***	0.147	.0107
Math	0.272***	0.036	.0000
GPA	1.075***	0.093	.0000
ACC	0.196***	0.038	.0000
ECON	0.088**	0.040	.0266
Summer	0.597***	0.084	.0000
Pseudo-R-sq.	0.132		
Obs.	1684		

[17] Superscripts *, **, and *** on the estimated coefficients denote significance at the .10, .05 and .01 levels respectively.

Although the estimated coefficients for D131 and D135 are negative, neither is statistically significant. These results suggest that students who took the MATHS 131 or 135 prerequisite sequences had somewhat lower probability of success in business statistics compared to students who took the MATHS 132 sequence. However, this negative impact on student performance was statistically indiscernible from that for students who had taken the MATHS 132 sequence.

The estimated coefficients for GPA, MATH and ACC are positive and statistically significant at the .01 level, while that for ECON is positive and significant at the .05 level. Thus, students who earn higher grades in their prerequisite math class (the last math class in the prerequisite math sequence), in their university courses in general, and, specifically, in their accounting and microeconomics principles courses are expected to achieve better performance in their business statistics course as well.

Finally, the estimated coefficient on Summer is positive and statistically significant. This result indicates that students who take the business statistics course during summer have higher probabilities of earning higher grades, other things the same, than those who take the statistics course during the fall or spring semesters. While this result is well known, there is currently little research that explains why this seasonal phenomenon exists.

Comparing Student Performance in Business Statistics Across Different Prerequisite Math Sequences

We used our estimated ordered probit model to derive the predicted probabilities

of grades from A to F in the business statistics course conditional on the prerequisite math sequence and the grade earned in the last math course in the sequence. These probabilities are shown in Table 4. We list the math course sequences in order of the number of credit-hours required for the sequence. The prerequisite math sequence is identified by the last math course in the prerequisite math sequence.

The business statistics grades are shown in the first column grouped into grade categories: A- to A, B- to B+, etc. The predicted probabilities for each statistics grade category for simply taking the specific math sequence are listed in the second column (Overall). The third through the sixth columns show the predicted probabilities for the business statistics grades by the math grade earned (again, grouped into grade categories) in the prerequisite math course.

Comparisons of the predicted probabilities for the grade ranges for the business statistics course across the alternative prerequisite math sequences and math grades show the impact of the math coverage (especially, the extent of calculus covered), the number of math credit-hours, and the math knowledge gained (the grade in the math class taken) on student performance. Whether we view the Overall column or the specific math grade columns across the alternative prerequisite math courses, we see that students who take math sequences with more rigorous math coverage, more time devoted to calculus and more credit hours have higher probabilities of earning higher grades and lower probabilities of earning lower grades in business statistics.

For example, as examination of the Overall column shows, the probability of earning an A or A- grade in business statistics doubles from 16.26 percent, for students

who took the MATHS 131 sequence, to 35.02 or 33.87 percent for those who took the MATHS 161 or 165 sequences, respectively.

Table 4 Predicted Probabilities of Statistics Grades Related to Alternative Prerequisite Math Courses and Math Grades

	MATHS 131	Grade in MATHS 131			
Stat Grades	Overall	A- to A	B- to B+	C- to C+	D- to D+
A- to A	16.26 %	44.02 %	17.96 %	7.05 %	1.93 %
B- to B+	29.25	36.88	35.11	25.47	12.58
C- to C+	26.67	14.49	27.73	31.84	26.16
D- to D+	14.97	3.54	11.74	19.79	24.79
F	12.86	1.07	6.46	15.85	34.55
Number	277	45	101	89	42

	MATHS 135	Grade in MATHS 135			
Stat Grades	Overall	A- to A	B- to B+	C- to C+	D- to D+
A- To A	17.77 %	50.06	23.85 %	8.78 %	2.77 %
B- to B+	30.29	33.52	37.67	28.09	15.55
C- to C+	26.42	12.03	25.11	31.17	28.10
D- to D+	14.21	3.18	9.34	17.96	24.06
F	11.31	1.21	5.04	14.01	29.54
Number	241	31	68	119	23

	MATHS 132	Grade in MATHS 132			
Stat Grades	Overall	A- to A	B- to B+	C- to C+	D- to D+
A- To A	20.29 %	48.72 %	23.27 %	8.58 %	2.85 %
B- to B+	29.64	34.68	36.37	27.22	16.48
C- to C+	25.13	12.47	24.95	31.24	29.20
D- to D+	13.76	3.08	12.73	18.49	24.02
F	11.19	1.05	5.31	14.46	27.43
Number	929	194	272	305	158

	MATHS 161	Grade in MATHS 161			
Stat Grades	Overall	A- to A	B- to B+	C- to C+	D- to D+
A- To A	35.02 %	59.85 %	38.04 %	19.91 %	5.05 %
B- to B+	33.01	29.5	38.76	34.28	20.21
C- to C+	18.68	8.36	17.14	26.06	29.25
D- to D+	7.84	1.75	4.56	12.01	22.24
F	5.45	0.53	1.50	7.73	23.50
Number	179	47	62	50	20

	MATHS 165	Grade in MATHS 165			
Stat Grades	Overall	A- to A	B- to B+	C- to C+	D- to D+
A- To A	33.87 %	69.69 %	40.70 %	22.25 %	5.82 %
B- to B+	33.36	24.85	35.45	35.25	26.95
C- to C+	20.12	4.78	16.47	25.27	34.62
D- to D+	8.20	0.67	5.20	11.04	19.81
F	4.45	0.09	2.18	6.23	12.82
Number	58	7	23	23	5

In contrast, the predicted probability of earning an F in the business statistics course declines by two-thirds, from 12.86 percent for students who took the MATHS 131 sequence, to 4.45 percent for those who took the MATHS 165 sequence. These substantial differences in predicted probabilities demonstrate the overall importance that the math content and math credit hours have on student success in business statistics.[18]

Similarly, for each prerequisite math sequence, the probabilities of better (worse) student performance in the business statistics course decline (rise) as the grade earned in the prerequisite math class declines. Once again, these changes in the probability of student success in the business statistics course are substantial. Viewed across the alternative math sequences, the decline in the probabilities of earning an A or A- grade in business statistics ranges from 92 to 96 percent as the grade earned in the prerequisite math course decreases from A to D-. For example, the probability of earning an A in business statistics declines from 44.02 percent to 1.93 percent as the grade earned by a student in MATHS 131falls from A to D-. Similarly, for students who took MATHS 165, the probability of earning an A grade in business statistics declines from 69.69 percent to 5.82 percent as the grade earned in the math class falls from A to D-. In contrast, the probabilities of earning an F in business statistics are anywhere from 24 to 142 times higher as the grade earned in the prerequisite math class declines from A to D-.

Finally, we can examine the joint impact that both the prerequisite math sequence and the grade earned in the math class have on the probabilities of student success in the business statistics course. For example, the probability of earning an A or A- grade in the business statistics course rises about 50%, from 44.02 percent to 69.69 percent, for

[18] The increase in the probabilities of earning A and A- grades is significant at the .01 level, while the decrease in the probabilities of F grades is significant at the .05 level.

students who earned an A grade in MATHS 131 compared to students who earned an A grade in MATHS 165. Similarly, the probability of earning an A or A- grade in the business statistics course rises by about 200%, from 1.93 percent to 5.82 percent, for students who earned a D grade in MATHS 131 compared to students who earned a D grade in MATHS 165. Thus, both students who do well and those who do poorly in their prerequisite math course sequence have much higher probabilities of doing well in their business statistics course if they take the more rigorous math courses with more credit-hours of instruction.

There are three interesting and important conclusions that arise from examination of the probabilities for student performance in business statistics displayed in Table 4. First, more rigorous math coverage, especially more calculus, and more time spent on math in general (more credit hours of math) contribute substantially to higher probabilities of better student performance in business statistics. For example, students who earned a C grade in their MATHS 161 or 165 course had nearly identical probabilities of earning B or C grades in business statistics compared to students who earned a B grade in their MATH 131, 135 or 132 course.

Second, students who have a better grasp of the material covered (higher grades) in their prerequisite math classes, regardless of which sequence they took, have higher probabilities of earning better grades in the business statistics course. Better students will "probably" always do better, other things the same.

Finally, Table 4 shows the extremely high predicted probabilities of poor student performance in business statistics for students who earned a D grade in their math course—regardless of which math sequence they took. The probability that these students

will earn a D or F grade in business statistics ranges from 59.3 percent, for students who took the MATHS 131 sequence, to 32.6 percent, for students who took the MATHS 165 sequence. These probabilities are approximately double the probabilities of a D or F grade in business statistics for students who earned C grades in their prerequisite math courses.

These last results strongly suggest that the imposition of a minimum grade requirement of C- or higher for the prerequisite math class will substantially increase student performance in the business statistics course. In our sample, 248 out of 1, 684 students earned less than a C- grade. Thus, other things unchanged, about 15% of the students in our sample would have had to repeat the prerequisite math course or forego pursuing a business or economics degree. Of course, had the minimum C- grade requirement for the prerequisite math course actually been imposed, the proportion of students that would have been affected would have been lower, perhaps much lower, than this. Imposition of this minimum grade requirement would provide a strong incentive for pre-business students to devote more time and effort to mastering the material covered in their prerequisite math course.

Summary and Aftermath

In this study, we demonstrated that prerequisite math course sequences that contain more credit hours, more rigorous coverage and more emphasis on calculus substantially increase the probabilities that a student will earn better grades and reduce the probabilities of a D or F grade in business statistics. We also show that the imposition

of a minimum grade requirement of C- in the prerequisite math course has similar effects on student performance.

We hope that these results will encourage business schools to re-examine the performance of their students in their business and economics statistics courses and to re-assess the effectiveness of the prerequisite math courses that their students are required to take. At our university, our preliminary research contributed to two important recent changes in the prerequisite math course sequence required for business statistics and admission to the College of Business. First, the College introduced the requirement that students must earn a minimum grade of C in MATHS 135 starting with the Fall 2006 semester.[19] Second, the College adopted a new prerequisite math sequence to replace the MATHS 135 sequence beginning with the Fall 2008 semester. This new sequence consists of MATHS 108, 111 and a new course, MATHS 136: Mathematics for Business (4 units), which includes three additional weeks of calculus applications for business compared to the MATHS 135 course it replaces. Pre-business students will now be required to take MATHS 111—which is also taken by math and science students and generally taught by tenure-track faculty. The minimum requirement of a C grade has been retained for MATHS 136. We anticipate that future student performance in business statistics under the new prerequisite math sequence will more closely resemble that associated with the MATHS 161 sequence than those previously observed for either the MATHS 135 or 132 sequences.

[19] Because our data set ended in Summer 2006, we are unable to directly examine the impact of this condition on student performance in the business statistics course.

Appendix: Variables and Definitions Used in Ordered Probit Model

Dependent Variable:

STAT: A ordered dummy variable (A = 11; A - = 10; …; F = 0) for the grade that the student received the *first* time that he/she enrolled in ECON 221.

Independent Variables:

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

ECON: The numeric grade (F = 0, D- = .7, …, A- = 3.7, A = 4) that the student received in the principles of microeconomics 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.

D131: A dummy variable identifying whether the student took MATHS 131 as the prerequisite math course for ECON 221 (Yes = 1; 0 otherwise).

D135: A dummy variable identifying whether the student took MATHS 135 as the prerequisite math course for ECON 221 (Yes = 1; 0 otherwise).

D161: A dummy variable identifying whether the student took MATHS 161 as the prerequisite math course for ECON 221 (Yes = 1; 0 otherwise).

D165: A dummy variable identifying whether the student took MATHS 165 as the prerequisite math course for ECON 221 (Yes = 1; 0 otherwise).

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

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