# ON-LINE MATHEMATICS REVIEWS AND PERFORMANCE IN INTRODUCTORY MICROECONOMICS

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## ABSTRACT

*We examine whether on-line remedial mathematics reviews can improve student performance in introductory microeconomics. In treatment sections, graded pre- and posttests were used to assess student understanding of graphing, systems of linear equations, area, slope, ratios and percentages. Students had on-line reviews and tutorials available between completing the tests. Pre- and posttest scores are positively and significantly related to course grade, more so than variables designating which mathematics courses have been taken by students. Ordered probit analysis suggests that each additional question answered correctly on the posttest over the initial pretest score is significantly related to final course grade, with students in the treatment sections earning on average 0.20 of a letter grade higher.*

## INTRODUCTION

Even at the introductory level, the abilities to think mathematically and reason abstractly have been shown to be important contributors to student success in economics, and many studies in economics education have attempted to control for students' mathematical backgrounds in their analysis. Durden and Ellis (1995) and Williams, Waldauer, and Duggal (1992) use Math SAT score as a measure of student mathematics ability and find that Math SAT score is positively and significantly correlated with student performance in economics courses. Anderson, Benjamin, and Fuss (1994), Brasfield, Harrison, and McCoy (1993), Brown and Leidholm (2002), Ely and Hittle (1990) and Lumsden and Scott (1987) include in their regressions of student performance the types of mathematics courses taken by students. These studies argue that the mathematics classes a student has taken are a reasonable proxy for student mathematics ability. Ballard and Johnson (2004) find that the mastery of very basic mathematics concepts is one of the most significant contributors to student success in introductory microeconomics; they argue that studies that emphasize whether a student has taken calculus does not measure the influence of calculus *per se*, but rather measures the fact that students taking calculus are more likely to have mastered the basic mathematics concepts important for introductory economics.

The results of these studies suggest potential gains in student mastery of economics concepts if greater emphasis is placed on students' mathematics skills. In this study, we verify the link between basic mathematics skills and performance in introductory microeconomics and examine the use of on-line mathematics reviews as a method to improve student performance. As economics courses are increasingly being offered wholly or partly via internet, the effectiveness of this alternative format for student learning is important to assess. Brown and Leidholm (2002) and Katz and Becker (1999) examine whether internet courses can effectively substitute for classroom learning in economics. In this study, we examine whether an internet mathematics component to a standard lecture-based classroom course can improve student performance. We identify the advantages of conducting the mathematics reviews on-line as: (a) it does not require students to take additional mathematics classes or satisfy more prerequisites, (b) it can be done simultaneously with the economics course, and (c) it does not use valuable class time.

While introductory microeconomics is not, in general, a heavily mathematical course, the recognition of economics as a mathematics-based discipline at the introductory level is important. Instructors who de-emphasize the quantitative aspects of economics still must present concepts such as elasticity and consumer surplus, which can prove difficult if students cannot mathematically conceptualize the ideas. Additionally, students who enter intermediate-level economics classes with little idea that economics is a mathematics-based discipline are functionally unprepared to be economics majors.

We collected information on the background, motivation, and mathematics preparation of 445 students enrolled in nine sections of introductory microeconomics at a regional Midwestern university. To ascertain the degree to which mathematics skills are correlated with performance and whether mathematics reviews can improve student performance, six sections of introductory microeconomics were assigned or given the opportunity to complete on-line tutorials with quizzes on basic mathematics, and earn class points on graded mathematics pre-and posttests. The three remaining sections served as controls. Students' scores on the mathematics pre- and posttests are significantly and positively correlated with final grades in the course, holding other factors constant. In addition, we find that students in the six treatment sections performed significantly better than their counterparts in the control sections, earning on average one-fifth of a letter grade higher in introductory economics. Further, each additional point earned on the mathematics posttest over the initial pretest score is positively and significantly related to course grade. The results suggest that one way to improve student performance in introductory microeconomics is to place more emphasis on improving students' basic mathematics skills.

## DESCRIPTION OF THE DATA

Using a survey, data was gathered on students enrolled in nine sections of introductory microeconomics during the Fall 2002, Spring 2003, and Fall 2003 semesters at a regional-Midwestern university. The nine sections all had enrollments of roughly 50 students each. Professor 1 taught six sections (two sections each during the three semesters) and Professor 2 taught three sections (all during the Fall Semester 2002). Students were asked to provide background and demographic information including their gender, race, age, university class status, study habits, attendance patterns, mathematics background, grade point average (GPA), and ACT score. See Table 1 for a summary. While we rely primarily on student reported data, we find little evidence that our students overstated their GPA or ACT scores, comparing our means and standard deviations to those of the university as a whole.

Our sample consists of 445 students, a sub-sample of the 457 students that were enrolled. The students were primarily sophomores (64.8%) and juniors (18.0%) with a mean GPA of 2.90 and a mean ACT score of 22.6. The sections were 46.8% female, and 95.6% of students classified their race as "white." Nearly 88% of students were taking the class because it was required for their major.

To enroll in introductory microeconomics, students must score sufficiently well on a mathematics placement exam or have taken pre-calculus. However, this prerequisite is not enforced. Of the sample, at the time of taking introductory microeconomics, 7.7% of students had been required to take remedial mathematics; 72.8% had taken a pre-calculus course; 53.6% had taken calculus or business calculus; and 7.3% had taken a mathematics course more advanced than calculus. In addition, 83% of the students were currently taking a mathematics course or had taken one during the previous semester. Only 7.5% of students had not taken a mathematics class in two or more years. Women were more likely to have been required to take remedial mathematics than men ($p < 0.05$), and were less likely to have taken calculus ($p < 0.001$).

On some survey questions, students occasionally chose an invalid option or left the question blank. For these students, we replace the missing values with sample mean values in an effort to preserve the sample size. In addition, some of the students were absent on the first day of class— the day the survey was given—and four students who completed the survey did not complete the course and do not have a final grade. In total, we are missing information on 2.6% of the students enrolled in the nine sections. There is the possibility of selectivity bias in our survey sample if the missing students are systematically different from the students in the sample (Chan, Shum, and Wright, 1997). While we lack information on the non-survey students, we do know that they performed relatively worse in the course than students who took the survey. If we compare the distribution of grades between the survey sample and the entire class sample, it is evident that grades are relatively consistent over the mid-range (from a 1.5 to a 3.5), but that there are statistically significant differences in the tails of the distribution. Students who completed the survey and were in the sample were more likely to earn a 4.0 in the course, and students who missed filling out the survey were more likely to have failed the class (both with $p < 0.01$).

We argue the inclusion of the missing students in the study would actually strengthen our results. Consider an equation determining attendance:

$$Attendance_i = a + Sum_j\,(\,b_j\,x_{ij} + u_i)$$

where, for every individual $i$, $a$ is a constant, $b_j$ is a vector of coefficients on the exogenous variables $x_i$, and $u_i$ is the error term. We argue that the error, $u$, in this equation is positively correlated with the error in an equation determining student final grade:

$$Grade_i = d + Sum_j\,(g_j x_{ij} + e_i)$$

In the grade equation, $d$ represents the constant, and $g_j$ represents the vector of $j$ coefficients on the same explanatory variables, $x_i$, where $e_i$ is the error term. Such a relationship would indicate that the students who are more likely to attend class (and thus were more likely to complete the survey) are also more likely to get higher grades and have better mathematics skills. The negative correlation between mathematics skills and the error term, *e*, would cause the coefficient on the "treatment section" dummy variable to be underestimated. In other words, the error from the attendance equation effectively operates as an omitted explanatory variable in the grade equation, causing downward bias in the estimated coefficient for the treatment-section dummy variable. Therefore, although the sample of students who took the survey was not drawn randomly from the class as a whole, we argue that this does not significantly affect our conclusions.

We have two additional concerns regarding the data. First, some students in the sample do not have an ACT score. For students who took the SAT instead, the university's admissions scale was used to convert the SAT scores to ACT scores. However, there also were a number of transfer students and special scholarship students enrolled in the sections who were never required to take the ACT exam before being admitted to the university. Since we do not want to drop these students from the analysis, we replace their missing ACT scores with predicted ACT scores. The predicted values were found by a simple regression of ACT on explanatory variables, including student academic performance, student individual characteristics, and family background.

A second concern is that the division of students between the control and treatment sections was not random; students selectively enrolled in sections of microeconomics and students with fewer credits had fewer choices of sections, though students did not know of the experiment in advance of the first day of class. In an effort to control for this non-random assignment, we collected information as to whether the student was enrolled in his or her first-choice section and the student's preferred sleeping habits. Overall, 87.1% of students enrolled in their preferred section, and fewer than 7.4% of the students were enrolled in sections they considered "too early." However, both variables have insignificant coefficients and *t*-statistics in the performance regressions and are thus not included in the final reported results.

**Table 1: Summary of the Data**

| Variable | Percent | Mean | Standard Deviation |
|---|---|---|---|
| Female | 46.77 | | |
| Male | 53.23 | | |
| Age | | 20.47 | 3.43 |
| Freshmen | 10.24 | | |

**Table 1: Summary of the Data**

| Variable | Percent | Mean | Standard Deviation |
|---|---|---|---|
| Sophomores | 64.81 | | |
| Juniors | 18.01 | | |
| Seniors | 4.9 | | |
| Other | 2.04 | | |
| White | 95.55 | | |
| Non-white | 4.45 | | |
| Hours Work per Week | | 12.57 | 11.69 |
| Hours in Extra-curricular Activities | | 4.9 | 5.41 |
| Weekly Hours Study all Classes | | 11.1 | 6.37 |
| Course is Required for Major | 87.63 | | |
| Not Required for Major | 12.37 | | |
| Took Economics in High School | 46.55 | | |
| Did Not Take in High School | 53.45 | | |
| Took Econ at Another College | 9.58 | | |
| Did Not Take at Another College | 90.42 | | |
| Never Skip Class | 58.13 | | |
| Hardly Ever Skip Class | 38.08 | | |
| Don't Usually Class | 3.57 | | |
| Often Skip Class | 0.22 | | |
| Almost Always Skip Class | 0 | | |
| GPA | | 2.9 | 0.53 |

| Table 1: Summary of the Data | | | |
|---|---|---|---|
| Variable | Percent | Mean | Standard Deviation |
| ACT Score | | 22.64 | 3.08 |
| First Choice of Sections | 87.08 | | |
| Not First Choice of Sections | 12.92 | | |
| Naturally Awake Before 8am | 14.92 | | |
| Awake between 8 and 9am | 53.67 | | |
| Awake between 10 and 11am | 24.05 | | |
| Awake in the Afternoon | 7.35 | | |
| Required to take Remedial Math | 7.73 | | |
| Not Required to take Remedial | 92.27 | | |
| Have Taken Pre-calculus | 72.83 | | |
| Have Not Taken Pre-calculus | 27.17 | | |
| Have Taken Calculus | 53.63 | | |
| Have Not Taken Calculus | 46.37 | | |
| Have Taken Advanced Math | 7.26 | | |
| Have Not Taken Advanced Math | 92.74 | | |
| Currently Taking a Math Class | 40.05 | | |
| Took Math Last Semester | 42.39 | | |
| Took Math Last Year | 10.07 | | |
| Took Math 2 Years Ago | 3.04 | | |

| Table 1: Summary of the Data | | | |
|---|---|---|---|
| Variable | Percent | Mean | Standard Deviation |
| Took Math More than 2 Yrs. Ago | 4.45 | | |
| Took the On-Line Math Pretest | 60.33 | 26.71 | 4.5 |
| Did not Take the Math Pretest | 39.67 | | |
| Took the On-line Math Posttest | 41.67 | 27.73 | 5.8 |
| Did not Take the Math Posttest | 58.33 | | |

## PRETESTS, POSTTESTS, AND TUTORIALS

To test the effectiveness of the mathematics reviews in improving student performance, three of the nine sections of introductory microeconomics were assigned to be controls, and did not have access to the mathematics review materials. The remaining six sections were either required to, or could voluntarily, use the review materials. We began by assessing student mathematics skills in the six treatment sections with a mathematics pretest. Students could supplement the basic review of the pretest with tutorials and homework assignments during the first three weeks of the semester. Professor 1 assigned the mathematics pre- and post-tests as homework, allowing students to keep the highest number of points earned on the tests in her four treatment sections. Professor 2 gave students the option of completing the pre- and post-test, keeping the greatest number of points earned as extra credit in his two treatment sections.

All review materials were made available to students on-line, through the economics course management and content web company, Aplia™ (see www.aplia.com). None of the review material was discussed in class, other than providing general instruction for logging-on, etc. Each pre- and posttest contained 35 questions divided among five key topics: (1) reading graphs, (2) solving systems of linear equations, (3) manipulating ratios and fractions, (4) calculating areas, and (5) finding slopes. (Note: this differs from Ballard and Johnson (2004) who used a pretest of only 10 questions covering topics 2 through 5, above.) The tests contained some standard multiple-choice questions and some questions that relied on interactive graphing technology. For example, students were asked to place a point at a particular *x*-*y* coordinate pair, to plot a line, or to change the slope of a line to a particular value.

Students were given one week to complete the pretest. Students who chose to review the mathematics concepts in more detail could complete up to five tutorials, covering the five major basic mathematics concepts. Each tutorial contained a 10 to 15 minute explanation of the mathematics concepts, with sample problems. Students also had the option of doing practice homework problems relating to each of the five concepts, and students could review their answers to the pretest, comparing them against the correct answers and detailed explanations. Students were given two weeks to work with this review material. Following that two-week period, the students had the option of completing a posttest on the same mathematics concepts. Students were awarded the highest number of points earned on either the pre- or the posttest.

Professor 1 had 162 students who took the pretest out of an eligible 200 students (81%); of those, 142 students opted to take the posttest. Professor 2 had 49 of an eligible 103 students (47.6%) take the pretest, and 33 of these students opted to take the posttest. Additionally, 30 of Professor 1's students and 8 of Professor 2'sstudents opted to only take the posttest. The average score on the pretest was 26.7 out of 35 and the average score on posttest was 27.7 out of 35; the difference is statistically significant ($p < 0.001$). There was no statistically significant difference in test scores across professors on either the pre-test or the post-test. Of those students who took the pre- and posttests, 22.6% of students did worse on the posttest than the pretest (the average being 5.43 fewer questions answered correctly). This may be attributed to a handful of students who began the posttest, completed a few questions, and then quit, perhaps deciding that the opportunity cost of finishing the entire posttest was too high.

In addition, 9.5% of students did exactly the same on the pre- and posttests, and 67.9% of students did better. The average improvement across all students who took both the posttest and the pretest was 1.9 more questions answered correctly. We attempt to calibrate the pre- and post-tests by switching the order in which they were given during the Fall 2003 semester. That semester, the post-test was given as the pre-test and the pre-test served as the post-test, and there was no noticeable differences in means.

An examination of simple correlation coefficients indicates that students who performed better on the pre- and posttests also received higher grades in the class. See Table 2. Further, while students with higher GPAs did better on the pre- and posttests overall, students with lower ACT scores saw more improvement between the pre- and the posttest. In addition, the correlation coefficient between GPA and the posttest is smaller than the correlation coefficient between GPA and the pretest. The same relationship is observed for correlation coefficients between ACT score and the pre- and posttests. This may indicate that students who are less prepared than their counterparts are not necessarily permanently disadvantaged; they can gain the skills they lack through review work.

To test the reliability of student performance on the pre- and posttests we use Cronbach's alpha with test items of GPA, ACT score, grade in the course, pretest and posttest scores. We find the item-test correlations are roughly the same for all items, the lowest belonging to ACT score and the highest belonging to GPA. An alpha of 0.6680 is calculated for the pretest; the posttest alpha is 0.6860. This suggests that student performance on the mathematics tests is reasonably well-correlated with their general academic performance.

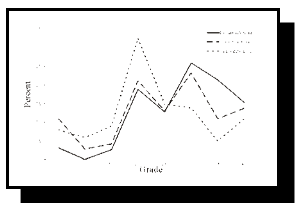
**Table 2: Correlation Coefficients**

| Variable | Grade | GPA | ACT | Pretest Score | Posttest Score | Improvement |
|---|---|---|---|---|---|---|
| Grade | 1.0000 | | | | | |
| GPA | 0.5827 | 1.0000 | | | | |
| ACT | 0.4095 | 0.4634 | 1.0000 | | | |
| Pretest Score | 0.3570 | 0.2727 | 0.2905 | 1.0000 | | |
| Posttest Score | 0.4128 | 0.2490 | 0.2058 | 0.2859 | 1.0000 | |
| Improvement | 0.0895 | 0.0095 | -0.0429 | -0.5232 | 0.6670 | 1.0000 |

## ANALYSIS OF THE DATA

The students in the experimental and control sections for each professor in the study had the same lectures, homework, and exams. Students were not allowed to keep their exams, so as not to influence student performance across sections or semesters. In Figure 1, the grade distributions for all nine sections are examined. Students are grouped into three categories: those who were in the control sections and did not have an option to do the mathematics reviews and tutorials (Control Series), those who were in Professor 2's treatment sections with the option to do the mathematics reviews and tutorials (Optional Series), and those in Professor 1's sections for whom the mathematics reviews were required (Required Series). It is apparent that the students in the required treatment sections were more likely to earn a B or better in the class. Students in the control sections earned consistently lower grades than those in the required treatment sections; this result is particularly evident at the tails of the grading distribution. For the optional sections, the results are less clear. Overall, *t*-tests of means suggest that students in the treatment sections earned on average 0.45 of a letter grade higher than students in the control sections ($p < 0.01$), not controlling for other factors.

**Figure 1: Distribution of Grades**




While completing the mathematics tests and reviews is correlated with higher grades in introductory microeconomics, we are concerned about whether we are measuring student motivation or the actual effects of the review. We run a series of regressions to determine if the treatment sections actually perform better than the control sections, taking into account exogenous influences. The dependent variable in this study is "grade," which indicates the grade a student received overall in the course, on a 4.0 scale.

The model we use is the education production function, as developed by Allison (1979) and Hanushek (1979). This model suggests knowledge is produced out of a variety of student motivational and background variables as well as university and professor specific variables. A calculation of the variance inflation factors suggests we do not have a multicollinearity problem with our explanatory variables. Our dependent variable, "grade", is an ordered categorical variable, and therefore we primarily use ordered-probit estimation techniques. We suggest the grade for each student, *i*, depends on a student's background (gender, race, age), the effort put into the class, innate intelligence, and mathematics ability.

$$Grade_i = f\,(background_i,\ effort_i,\ intelligence_i,\ math\ ability_i)$$

We proxy student effort with variables including how often they report skipping class, hours spent studying per week, and hours spent working for pay per week. Intelligence is proxied with student GPA and ACT score. We also include a vector of control variables for the semester and the professor. Student mathematics ability is measured variously by the mathematics courses a student has taken as well as their performance on the mathematics pre- and posttests. Although we have a wide variety of data on students, such as previous economics experiences, whether economics is required for their major, etc., we found that those variables are not significantly related to student grades, and they did not pass an *F*-test of inclusion in the regressions. Additional results and tests are available upon request.

Initially, we seek to verify a relationship between basic mathematics skills and performance in introductory microeconomics. In Table 3, the results from two initial ordered probit regressions of course grade on the explanatory variables and student scores on the pre- and posttests are reported. The most important determinants of student grade are college GPA and ACT score. We find no significant differences between the grades of men and women, nor do we find significant differences by university class-levels. These results are consistent across a variety of regression specifications. Variables controlling for student motivation, such as self-reported skipping and hours spent working per week are also not statistically significant. We do find significant differences in grading across professors: Professor 2 gave lower grades on average than Professor 1 ($p < 0.001$). However, there is no significant difference in grades given by the same professor across semesters ($p = 0.56$).

Both a student's pretest score and posttest score are positively and significantly related to course grade. All else equal, for every additional question a student answered correctly on the pretest, students increased the probability of earning a higher letter grade. For example, a student scoring a 30 on the pretest is predicted to earn 0.6 of a letter grade higher than a student who scored a 20 on the pretest. These results are consistent with Ballard and Johnson (2004), who also find basic mathematics skills to be significantly related to performance in introductory microeconomics. Unlike previous studies, we find that neither having taken calculus nor having taken remedial mathematics are as significantly related to course grade as the pre- and posttest scores. This suggests that there may be a specific group of mathematics skills which are particularly important for microeconomics students, rather than general mathematics knowledge.

| Table 3: Raw Math Pre- and Posttest Scores and Grades in Microeconomics | | |
|---|---|---|
| Variable | Regression 1—Pretest and Grade | Regression 2—Posttest and Grade |
| Female | 0.147 (-0.88) | 0.104 (-0.57) |
| Minority | -0.558 (-1.63)* | -0.608 (-1.55) |
| Freshmen | -0.046 (-0.19) | 0.148 (0.55) |
| Junior | 0.373 (1.77)* | 0364 (1.57) |
| Senior | -0.762 (-1.82)* | -0.777 (-1.54) |
| Other | 0.476 (0.53) | 0.360 (0.39) |
| Skip Class | -0.988 (-0.60) | -0.396 (-1.90)* |
| Hours Study Per Week | -0.001 (-0.07) | -0.003 (-0.21) |
| Hours Work Per Week | 0.004 (0.56) | 0.009 (1.18) |
| GPA | 1.283 (6.63)*** | 1.224 (5.85)*** |
| ACT Score | 0.083 (2.73)*** | 0.057 (1.64)* |
| Took Remedial Math | -0.411 (-1.42) | -0.329 (-0.95) |
| Took Calculus | 0.282 (1.70) | 0.305 (1.63)* |
| Spring 2003 | 0.054 (0.25) | 0.035 (0.13) |
| Fall 2003 | -0.384 (-1.43) | -0.103 (-0.41) |
| Professor 2 | -0.915 (-3.93)*** | -0.953 (-3.41)*** |
| Pretest Score | 0.067 (3.52)*** | -- |
| Posttest Score | -- | 0.057 (3.59)*** |
| Number of Observations | 209 | 174 |
| R-squared | 0.2036 | 0.2006 |
| Dependent Variable is Course Grade. Significance is indicated as * = 10%, ** = 5%, and *** = 1%. The comparison category for "University Class" is sophomores and the comparison category for "Semester" is Fall 2002. | | |

We find that students who were required to take remedial mathematics had slightly lower grades in introductory microeconomics. This is consistent with the findings of Ballard and Johnson (2004), though the remedial mathematics dummy variable is not significant in our regressions. Also as expected, we find that taking calculus is positively related to performance in introductory microeconomics. This result is consistent with previous studies (e.g., Brown and Leidholm, 2002).

In the next series of regressions, we examine whether students can improve their performance in economics by improving their mathematics skills through on-line reviews. The results are reported in Table 4. As before, grade earned in microeconomics is our dependent variable. In columns 1 and 2, we simply include a binary dummy variable indicating whether a student was assigned to a mathematics treatment or control section. In columns 3 and 4, we look more closely at student performance on the mathematics pre- and posttests and their performance in introductory microeconomics. We include a student's pretest score as a control for initial mathematics ability and examine whether an improvement on the posttest score, compared to the pretest, is associated with a higher grade in introductory microeconomics.

**Table 4: Regression Results**

| Variable | Regression 1 | Regression 2 | Regression 3 | Regression 4 |
|---|---|---|---|---|
| Female | 0.109 (1.25) | 0.121 (1.10) | -0.322 (-1.50) | -0.431 (-1.78)* |
| Minority | -0.203 (-1.03) | -0.293 (-1.19) | -0.824 (-2.04)** | -0.722 (-1.60)* |
| Freshmen | 0.034 (0.23) | 0.129 (0.68) | 0.122 (0.41) | 0.053 (0.16) |
| Junior | 0.115 (1.03) | 0.182 (1.29) | 0.465 (1.73)* | 0.430 (1.43) |
| Senior | -0.003 (-0.01) | -0.015 (-0.06) | -0.836 (-1.60)* | -0.971 (-1.72) |
| Other | 0.398 (1.20) | 0.576 (1.31) | 0.137 (0.15) | 0.524 (0.55) |
| Skip Class | -0.193 (-2.39)** | -0.231 (-2.28)** | -0.210 (-1.00) | -0.250 (-1.08)* |
| Study | 0.003 (0.54) | 0.006 (0.69) | -0.015 (-1.06) | 0.003 (0.06) |
| Work | 0.000 (0.02) | 0.001 (0.20) | 0.011 (1.23) | 0.006 (0.67) |
| GPA | 0.857 (9.18)*** | 1.239 (9.89)*** | 1.323 (5.56)*** | 1.425 (5.15)*** |
| ACT Score | 0.030 (2.04)** | 0.054 (2.87)*** | 0.071 (1.85)* | 0.003 (0.06) |
| Took Remedial Math | -0.088 (-0.59) | -0.122 (-0.65) | -0.823 (-1.96)** | -0.769 (-1.80)* |
| Took Calculus | 0.210 (2.43)** | 0.290 (2.66)*** | 0.411 (1.88)* | 0.453 (1.79)* |
| Spring 2003 | -0.061 (-0.44) | -0.064 (-0.37) | 0.059 (0.21) | 0.121 (0.42) |
| Fall 2003 | -0.107 (-0.88) | -0.222 (-1.46) | -0.355 (-1.14) | -0.195 (-0.61) |
| Professor 2 | -0.621(-5.59)*** | -0.881(-6.15)*** | -0.982(-3.14)*** | -- |

| Table 4: Regression Results | | | | |
|---|---|---|---|---|
| Variable | Regression 1 | Regression 2 | Regression 3 | Regression 4 |
| Treatment Group | 0.206 (2.24)** | 0.161 (1.39) | -- | -- |
| Pretest Score | -- | -- | 0.119 (4.21)*** | 0.144 (4.14)*** |
| Improvement | -- | -- | 0.062 (3.08)*** | 0.092 (3.29)*** |
| Constant | 0.367(0.67) | -- | -- | -- |
| Observations | 445 | 445 | 136 | 111 |
| R-squared | 0.3829 | 0.1473 | 0.2439 | 0.2519 |
| Dependent Variable is Course Grade. Significance is indicated as * = 10%, ** = 5%, and *** = 1%. The comparison category for "University Class" is sophomores and the comparison category for "Semester" is Fall 2002. | | | | |

We consider two regression specifications, both with "grade" as the dependent variable. In regressions 1 and 2, reported in Table 4, we include a binary dummy variable to indicate whether a student was enrolled in a treatment or control section, and find that Ordinary Least Squares (OLS) and Ordered Probit techniques produce similar results. In all cases, we check a variety of interaction terms and nonlinearity specifications, but find that these have no significant impact on our regression. In addition, we also enter dummy variables for each individual treatment section, but find that these are also not statistically significant. GPA, ACT score, and Professor 2 remain the most significant explanatory variables, as we saw in Table 3. In the OLS analysis we find that on average, students in the treatment sections earned 0.20 of a grade point higher than students in the control sections (whereas the ordered probit approach finds them to have a higher probability of earning a better grade in the course). This result was significant in the OLS estimation, but not in the ordered probit regression, due to the higher specification requirements for probit estimation.

Perhaps more informative are the regressions that control for initial mathematics ability with the pretest score. The regression reported in Regression 3 of Table 4 examines whether student improvement from the mathematics pretest to the posttest is associated with better performance in introductory microeconomics, including the full sample of treatment sections. In the regression reported in the last column of Table 4, we examine the same question, but only looking at Professor 1's students, for whom the pre- and posttests were required. We define "difference" as the posttest score minus the pretest score. As in previous studies, GPA and ACT score remain highly significant indicators of student performance in introductory economics. Students who had taken calculus did significantly better in economics and students who were required to take remedial mathematics did significantly worse, indicating again the importance of mathematics skills to introductory economics students.

Despite including the two variables for mathematics course background, we find both the pretest score and the difference in test scores are positively and highly significantly related to student performance in the class for the entire sample and the Professor 1 sub-sample. Controlling for initial mathematics skills, students of all levels find that improved mathematics skills are associated with the probability of earning higher grades. An examination of the tails of the distribution—those with poor and those with excellent initial mathematics skills—indicates that the benefits of the mathematics review accrue relatively evenly across all students.

In the economics education literature, there is some concern that women generally do worse in economics than men. It has been suggested that this is due in part to course content and grading policies and also because of the lack of female role models (Dynan and Rouse, 1997). Other studies identify that women have or perceive themselves to have weaker mathematics skills then men, and this negatively influences their course grade (Ballard and Johnson, 2005). We find women scored an average of 1.85 questions fewer correct on the mathematics pretest than men ($p < 0.001$), but that there was no statistically significant difference between the performance of men and women on the posttest. Women and men were equally likely to complete the pre- and posttests. Pair-wise comparisons indicate that women and men benefit equally from the mathematics reviews. Ultimately, we find little evidence that women performed worse in economics than men (see Regressions 1-3 in Table 4).

Thus, in general, we find that a student's gender is not statistically significantly related to course grade. However, if we include a measure of basic mathematics skills as a control by looking only at the improvement between pretest and posttest scores, women are predicted to earn higher grades. This is consistent with our earlier finding that women score more poorly than men on the pretest, but as well as men on the posttest. Thus, while the benefits to on-line remedial work seem to accrue generally to all students, there is perhaps some small additional benefit to women.

We also compare minority and non-minority students, but find that our sample of minority students is too small to draw any valid conclusions.

## CONCLUSIONS AND RECOMMENDATIONS

In this paper, we document the connection between basic mathematics skills and performance in introductory microeconomics and examine whether on-line mathematics reviews can be used to improve student performance in the course. The mathematics reviews encompassed pre- and posttests, designed to measure student knowledge of five basic mathematical concepts frequently used in introductory microeconomics: solving linear equations, reading and understanding graphs, manipulating fractions and ratios, calculating area, and finding the slopes of lines. In addition, students had the option of completing tutorials and homework on each topic between the pre- and posttest. All review material was available on-line, though Aplia™

We find that basic mathematics skills, as identified by our mathematics pre- and posttests, are positively and significantly related to higher course grades. A more careful examination of these skills shows that review of basic mathematics concepts can improve student grades. Students enrolled in the treatment sections with access to the on-line review material earned statistically significantly higher grades in the course than students enrolled in the control sections. Further, we find that for each additional question answered correctly on the mathematics posttest, compared to the pretest, students have a higher probability of earning a better grade in the course, regardless of the initial pretest score. These results suggest that one way to improve student mastery of introductory economics concepts is to address their basic mathematics deficiencies.

Basic mathematics skills can make a difference. Our analysis suggests that quantitative skills are important even at the introductory level in economics, and that remedial mathematics work, done concurrently with taking the economics, can improve student mastery of basic economics concepts. The results also suggest that there are alternative ways to make effective use of informational technology, including out-of-class assignments and reviews. With the use of on-line reviews, the burden of completing remedial mathematics work can be placed on the students, instead of using valuable class time.

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