WHAT INFLUENCE DOES MATHEMATICS PREPARATION AND PERFORMANCE HAVE ON PERFORMANCE IN FIRST ECONOMICS CLASSES? [1]

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ABSTRACT

Using data from a Midwestern university, the authors examine whether math preparation, as measured by the ACT special mathematics score and the math placement from a preparation entrance exam for freshmen students, is associated with performance in one's first economics course. The results indicate that the level of math skills one brings to college has a statistically and economically significant effect on the performance in the economics course. This result is persistent, even when controlling for college math courses taken prior to the economics course. The authors conclude that mathematical maturity may be the relevant causal factor in one's first economic course performance, since higher level math placements tend to result in higher probabilities of As and Bs in one's economic class. In addition, it appears as though the first college algebra course, the business calculus course, and the mathematics courses for math majors or those planning to teach mathematics are the classes associated with higher economics grades. On the other hand, the elementary and intermediate algebra course are not helpful, and in fact, those students who did not take a math class prior to their economics courses performed better on average than those who took the basic algebra classes. These results suggest that at the least, some college algebra would benefit a student in the first economics course.

INTRODUCTION

Educators have long held the belief that successful learning relies on a series of building blocks. Students often begin with an introductory course that overviews the general concepts of a subject, and additional courses sequentially cultivate the students' expertise in that discipline. As with many other disciplines, economics students sequence from principles level courses, which typically require algebra level mathematical skills, to intermediate courses that focus on advanced technical skill development, and finally to higher level courses that develop increasingly complex applications of economic theory. Critical thinking skills are also developed (hopefully) in a sequential pattern, as students learn to apply normative analyses to ever more intricate questioning.

Despite this "building block" mentality, students often begin the economics principles courses with a wide degree of mathematical preparation. In the case of Bowling Green State University, students can take a principles level economics course with only a background in high school level algebra. However, students from different colleges and in different stages of their academic career will vary in their math preparation. For example, the College of Business (CBA) students must complete five to six credit hours in calculus in order to attain the Bachelor of Science in Business Administration (BSBA) degree.[2] Because calculus is not required for the principles of economics courses, sophomores typically begin such a course with algebra, while juniors and seniors are more likely to have completed a calculus class. Education majors specializing in Integrated Social Studies must take one math course that includes basic statistics and college algebra. Students from the College of Arts and Sciences and the College of Technology also have a low math requirement prior to taking an economics principles course. And, finally, students are often placed in a mathematics course in their first year at the university, so that those students with better high school preparation may begin their college mathematics courses at a higher level compared to those lacking such preparation.

Because economics educators face a diversity of mathematics preparation, because of the reliance on mathematical devices such as graphs in economics, and because economics courses are typically difficult for the average student,[3] we investigate whether the level of math preparation prior to college has an impact on the final grade in introductory and principles level economic courses. Using data provided from the authors' university, this paper analyzes whether the economics course grade is related to two different mathematics placement tests taken by students before they begin college classes. Because these tests have several versions and include questions related to different math skills, it allows us to more closely examine the effect of math preparation on performance, as compared to a more generic control for math skills, such as the overall ACT mathematics score. With our data, we can examine how basic, intermediate, college algebra, and trigonometry skills brought to college are related to final grades in first level economics courses.

As noted earlier, calculus is not required for any of the first level economics classes. But what mathematics usually occurs in these classes? These three courses are taught by both tenure track faculty and instructors (both full time and part time). Each instructor does something a little different, but the mathematics requirements are fairly standard. The primary tools are using and reading graphs, performing algebra and finding areas using very basic geometry rules. These are skills most students will have been exposed to in high school. How well they remember them is an issue. Further, the level of mathematics tools applied to the economics material is fairly even across instructors. One or two may use Aplia, but most simply rely on what students bring to the class. The level of mathematics used seems to be in line with the standard textbooks used, including Mankiw. Frank and Bernanke, and Case and Fair. Because the faculty do not rely on calculus for understanding the economics material, and there is no reason to think that calculus or any higher level mathematical skill would be especially useful at this particular institution in one's first economics course.

PREVIOUS RESEARCH ON MATHEMATICS ABILITY AND SUCCESS IN ECONOMICS

One goal of higher education is to prepare young adults for the intricacies of everyday decision-making. Students will face many situations that are rich in complexity, with no easy solutions. Such ill-defined problems are used to build the critical thinking skills faculty often include as part of the classroom experience. Mathematics is an important element of such development because solving mathematical problems helps students with transitional ability, the ability to take what they know and apply that to what they do not know. Experiments involving middle and high school students indicate that students who have practiced certain rudimentary algebra (Leader, 2004) or calculus skills (Walter, 2005) can apply those skills to advanced mathematical problems that the students previously did not experience. This idea of becoming a transitional problem-solver is directly related to mathematics education, where one becomes comfortable presenting the same information across verbal, graphical, and algebraic symbols (Gagatsis and Shiakalli, 2004). Mathematical maturity also matters. Researchers in the mathematics education field find that college preparatory mathematics leads to higher test scores in high school students' subsequent academic careers (e.g., Gamoran and Hannigan, 2000). The general conclusion is that mathematics maturity and understanding help students become better overall learners.

In addition, a number of studies find that there are links between mathematical ability and performance in college or in life decision-making. Mathematical ability is highly associated with achievement in the sciences, engineering, business, and technology fields, where mathematical language and visual-spatial intelligence is foundational (e.g., Stavridou and Kakana, 2008). Applying mathematics to problems in physics can improve both the mathematical abilities and the comprehension of the physics (Giannetto and Vincent, 2002). The level of mathematics is also used to explain gender differences in achievement in the sciences and in gender choices of science occupations (Bolli, et. al, 1985). Researchers also find that numeracy ability is important for introduction to statistics courses in psychology (Gnaldi, 2006) and in making health and medical decisions (Raina and Brainerd, 2007). Thus, mathematical comprehension, even when it is as simple as understanding fractions, provides long term benefits for individuals.

The relationship between mathematics ability and subsequent performance in economics courses has also been investigated. However, the results are inconsistent across studies and do not provide economics departments with strong directions regarding the type and sequence of mathematics and economics courses. A detailed review of the major studies about mathematics and economics performance follows.

Brasfield et al. (1992) argue that students taking the calculus course have a stronger grade in both the micro and the macro principles of economics. The college algebra course does not improve performance at statistically significant levels. The analysis involved a regression (one for micro and one for macro) including GPA, class standing (hours completed), ACT, average grade in the course, the number of hours the student planned to study, and binary variables for whether the student completed each of college algebra and business calculus. This research suggests that if we wished to improve performance in the principles, we should require business calculus.

Milkman et al. (1995) completed a similar study. However, in this study, the students were given a pre-test (Test of Understanding College Economics, III, called TUCE) and a post test (the same one). As with the Brasfield study, the Milkman study used a similar list of independent variables. The study examines both the absolute level of performance and the change in performance between tests. In this case, college algebra was a statistically significant factor in the absolute performance level on the micro TUCE, but not for macro, and neither algebra nor calculus was a statistically significant factor on the difference between the post-test and the pre-test performance. This result is in stark contrast to the previous study. In addition, the authors suggest that the form of the dependent variable appears to be a significant issue. What it is we are trying to measure in the scope of learning is central to whether we want to require more mathematics or not.

Two additional studies are the primary literature on this topic. Siegfried et al. (1996) report that about half of the students taking principles of economics have had a college level calculus course before they took economics. It is clear that success in economics can be achieved without calculus, but that calculus is widely seen as a valuable tool for many economics students. Anderson et al. (1994) examine the predictors of academic success in principles of economics in a class that was essentially a yearlong principles class. The dependent variable is the final grade. The independent variables include how the student performed in various high school classes (this is a Canadian study, so the authors create an index using data on the best six classes in the students' 13th year of school). This high school grade index was statistically significant and positive. The subject areas were represented by binary variables indicating if the student took the class in their final year of high school and a second variable representing their grade in that class. The authors control for three different math classes: algebra, functions, and calculus. These math variables have a negative coefficient, but were not statistically significant. The math grade had a positive coefficient, but was not statistically significant. However, joint tests on the dummy variable and grade for each math class indicated that neither algebra nor functions has an impact, but that calculus does.

Ballard and Johnson (2004) report on their examination of the relationship between mathematics skills and performance in principles of microeconomics. The relationship was generated by an ordinary least squares regression where the dependent variables included both measures of mathematics skills and other control variables. The measures of mathematics skills included whether the student took a remedial mathematics course, whether the student took calculus, whether the student took remedial math and their score on a 10 question mathematics quiz. The dependent variable was percentage of correct answers on three multiple choice tests given during the semester (the same exams were administered in all sections). Whether the student had taken calculus and whether the student had taken a remedial math course were statistically significant, with the remedial course having a negative sign. The score on the math quiz was also statistically significant. If the four measures of quantitative ability are combined, a substantial effect is generated. The authors argue that the regression analysis indicates that mathematics skills involve several different facets. To focus only the math ACT or the math course taken will miss some parts of the mathematics skills that may support success in economics. Better algebra skills may be more important than more calculus concepts for success in economics. Finally, they conclude that quantitative skills are important for success in economics.

Other studies also provide some insight into the relationship between math preparation and performance in economics principles classes. Roger Reid (1993) demonstrates that the grade students earn in a college principles course is affected in a statistically significant and positive way by having taking a mathematics class in their senior year in high school. The mathematics variable is a dummy representing the taking of some math class, without indicating the level of the math class taken. Myatt and Waddell (1990) test whether a high school economics course improves performance in college economics. As part of this study, the authors include a dummy variable for whether math was taken in the senior year of high school or not and a variable for the grade in the highest level math class taken. Taking math and the grade were statistically significant factors in predicting the final grade (in percentages). When the sample included only those who had economics in high school, the math grade had a statistically significant positive coefficient, and the dummy for having taken math as a senior was positive but not statistically significant. Kassens Uhl and Fleming (2007) use a sample of Roanoke College students and examine whether student performance is associated with human capital variables, time variables, indicating how the individual spent time studying or doing other activities, a math score from a quiz taken during the first week of class, and the number of prior mathematics courses taken. The results of an ordered probit indicate that students with better mathematics skills performed better in their economics classes. Finally, in two different but related studies, Cohn et. al use data gathered from experiments and find that graphs may not contribute to short-term performance in principles courses (2001), but that because a later statistical analysis indicates a positive but statistically insignificant association between a measure of performance and the student belief that graphs were helpful in learning economics (2004), the authors conclude that they cannot argue against the use of graphs. Instead, they argue for better student preparation and a better combination of verbal and graphical representation of economic concepts on the part of the instructor.

These studies on the effect of mathematics on economics performance suggest that mathematics may play a role in performance in the principles of economics. However, the impact may depend on the output measure used. Further, it is not clear whether the impact comes from the taking of the math course, the performance in the math course, or the skills one brings to the college arena.

DATA DESCRIPTION

Our analysis employs observations from the fall semester economics courses between 2002 and 2006. We elected a dataset with only fall semesters because students taking the standard principles sequence were required to take microeconomics before macroeconomics and we would therefore be more likely to get those students in their first economics course. In addition to the two principles level courses, we also offer an introduction to economics course. Students required to take one economics course could take either the introduction or the micro principles. Deletions occurred if a student recently transferred to BGSU and therefore did not have a math placement code or a previous semester's GPA, or if they were missing some other control variable, such as ACT scores. These deletions resulted in a sample size of 2,823.[4]

For the estimation of math preparation and final grade, we use an ordered probit model. Grades are arranged from 0 to 4, with 0 associated with the lowest grade of F and 4 associated with the highest grade of A. We estimate the probability of receiving a grade with the independent variables that have been used in many studies of economic performance. These variables include measures of academic achievement, including high school GPA and college GPA in the previous semester, gender, whether the individual was situated in the College of Business, whether the student has a proclivity for economics, mathematics or technical problem solving, either as an economics or finance major, as a mathematics or actuarial science major, or a computer science major,[5] and binary controls for type of economics course taken, including the micro and macro course.

Several variables represent math preparation. We normally see the ACT mathematics score employed as a control for mathematics preparation (Ballard and Johnson, 2004) and we do the same. However, we believe that the overall ACT math score only tells us that "more math preparation is better for economics" and not "which math skills are better for economics?" Therefore, we include two other sets of variables.

First, we substitute the ACT mathematics subscores for the overall ACT math score. These subscores present information about the individual's preparation in elementary algebra, college algebra, and trigonometry and geometry and these scores are aggregated up to the ACT Math section score (See Table 1A).

Table 1A. ACT Subtest Content		
Test	Broad Content	Material Covered
ACTSEA	Elementary algebra	Basic operations, factoring, linear equations
ACTSAG	Algebra and coordinate geometry	Functions, exponents, arithmetic and geometric series, matrices, complex numbers
ACTSGT	Plane geometry and trigonometry	Circles, rectangles, area, triangles, trig equations
Source: ACT Compass http://www.act.org/compass/		

The second set of control for mathematics preparation comes from the math preparation test provided by the authors' institution. Freshmen entering the university are required to take placement tests in mathematics. Until recently, the test was administered when the student came to campus in the summer for registration and orientation. Based primarily on the placement score and the overall ACT math score, a placement for the student in a college math class was determined.

The mathematics department uses a set of tests developed by the American Mathematical Association. Each student selects one of three tests, based on their preparation. Table 1 shows the expected preparation for each test. Test A examines arithmetic, number sense, and pre-algebra. Test B predominantly tests algebra skills with some arithmetic skills. This test overlaps with both Test A and Test C. Test C examines for readiness in calculus, graphing, algebra, and trigonometry. Depending on the score on the test and the Math ACT, the student would be placed as shown in Table 1B. We are not given the score of the placement exam, but we are provided with the code that associates a student with the highest possible mathematics course s/he could first take at the university. Thus, we know something about how well prepared the student is for different types of mathematics.

A set of binary variables indicate at which mathematics level students could begin their mathematics course of study, including college algebra I and II, precalculus, basic calculus (which is required for business students), a higher level of precalculus, required for those student taking higher level math courses in the future, and a calculus course that includes trigonometry and analytical geometry. Apriori, we are not sure which of the math skills will be associated with success in one's economics course. Perhaps it is less about calculus and more about intermediate algebra, since introductory and principles courses do not use calculus, but do present graphs and simple equations.

Table 1B. Math Placement Rules & Skills Tested Bowling Green State University				
Minimum High School Background	***Test***	***Sub-sections***	***Possible placements***	
Less than two years of high school algebra or two years with less than C	A	Prealgebra Elementary algebra Intermediate algebra	MATH 095 MATH 112 MATH 122	Intermediate Algebra College Algebra I College Algebra II
Two years of high school algebra with a C or better, but no trigonometry	B	Intermediate algebra College algebra	MATH 112 MATH 122 MATH 126 MATH 128 Mathematics MATH 129	College Algebra I College Algebra II Basic Calculus Precalculus Trigonometry
Some trigonometry	C	College algebra Advanced algebra Trigonometry	MATH 128 Mathematics MATH 130 Mathematics MATH 126 MATH 131 Analytical	Precalculus Precalculus Basic Calculus Calculus and Geometry
Source: University X Mathematics Department.				

Table 2 presents the descriptive statistics for the sample. The average economics grade for all students was a 2.19, which is typical for the department in any given year. The students who elected to take economics had an average grade point average in the previous semester of 2.92. Only 43% were females, a percentage not reflective of the gender composition of the university, but is in line with the typical class in economics at this university. Further, the majority of students take principles of microeconomics course as their first economics course.[6] Twenty-four percent of the students scored their highest placement in the required business calculus course, while another 34% placed either into college algebra I (21%) or II (13%). This distribution is typical of the students who end up in economics, where a majority of the students in principles levels courses tend to be business majors who have had some mathematics preparation in high school but fewer place into the calc/trig course (11%) or the higher level precalculus course (8%). Note also that the ACT subscore averages are not very different from one another.

Table 2. Descriptive Statistics of the Variables

Variable	***Description***	***Mean***	***Std. Dev.***
Grade	0 if F, 1 if D, 2 if C, 3 if B, 4 if A	2.19	1.04
GPA	College GPA in previous semester	2.92	0.61
High School GPA	High School GPA	3.17	0.66
College of Business	1 if from College of Business	0.44	0.50
Econ/Finance Major	1 if an economics or finance major	0.05	0.21
Math/Actuarial Science Major	1 if a math or actuarial science major	0.02	0.13
Computer Major	1 if a computer science major	0.01	0.10
Female	1 if female	0.43	0.49
White	1 if white	0.88	0.32
Introductory Economics	1 if course is Introductory Economics	0.24	0.42
Principles of Micro	1 if course is Principles of Microeconomics	0.58	0.49
Principles of Macro	1 if course is Principles of Macroeconomics	0.19	0.39
ACT Math	Overall ACT Math Score	22.10	4.05
ACT untimed placement tests for mathematics			
ACTSEA	ACT Elementary Algebra Score	11.95	2.77
ACTSAG	ACT Algebra Score	10.98	2.29
ACTSGT	ACT Geometry and Trigonometry Score	11.24	2.37
University mathematics placements			
College Algebra I	1 if highest placement was in College Algebra	0.21	0.41
College Algebra II	1 if highest placement was in Intermediate Alg.	0.13	0.34
Pre-Calculus	1 if highest placement was in Pre-	0.17	0.38

Table 2. Descriptive Statistics of the Variables			
Variable	***Description***	***Mean***	***Std. Dev.***
	Calculus		
Basic Calculus (Business)	1 if highest placement was in Basic Calculus	0.24	0.43
Precalculus for Higher Level Math	1 if highest placement was in a precalculus course	0.08	0.27
Calculus or Trig	1 if highest placement was in calculus/trig	0.11	0.31
Highest Mathematics Course in College Prior to Economics			
No College Math	1 if no college math before first economics course.	0.13	0.34
Elementary & Intermediate Algebra	1 if the student took a beginning math class.	0.23	0.42
College Algebra I	1 if College Algebra .	0.05	0.22
College Algebra II	1 if College Algebra II.	0.08	0.26
Basic Calculus (Business Students)	1 if Business Calculus.	0.36	0.48
Precalculus or Trig. For Math	1 if Precalculus or Trigonometry for Mathematics.	0.04	0.15
Calculus & Analytical Geometry	1 if Calc. with Anal. Geom.	0.05	0.22
Advanced Calc. & Anal. Geometry	1 if Advanced Calc. with Geometry.	0.01	0.17
Math for Math Majors/Educators	1 if math for math majors or educators taken.	0.04	0.19
Higher Level Mathematics (Discrete Analysis, Linear Algebra)	1 if higher level mathematics.	0.003	0.06
Data source: Authors' university. SAS statistical software used to develop the statistics.			

EMPIRICAL ESTIMATION OF PERFORMANCE

Table 3 presents the results from the ordered probit regressions; Table 3A presents the marginal effects for the relevant variables. We estimate the base probability at the means of all continuous variables and assume the base case includes the economics/finance major, the business student, and the microeconomics course (Recall, over 58% of the sample takes principles of microeconomics). All other binary variables are set to zero. Except for the ACT Math variable, the coefficients in Column 4 of Table 3 are used in the calculations. Column 2 results are used to estimate the ACT Math effect. Marginal effects are calculated by increasing the continuous variables by one unit. Binary variables are "turned on" by setting them to one.

The regressions present reasonably consistent results, as noted by the statistically significant likelihood ratio statistics that test the overall fit of the models and by the consistency of the coefficient estimates across different specifications of the independent variable set.

The controls for demographic characteristics are in the direction expected. Compared to their male counterparts, females have a higher probability of receiving a D or F (by about 3 percentage points) and a lower probability of receiving an A or B grade (by almost 5 percentage points). The signs of these coefficients are consistent with other papers that control for gender (Anderson, Benjamin, and Fuss, 1994; Benedict and Hoag, 2002).

Table 3. Ordered Probit Results

Dependent Variable: Grade in Economics

Variable	*(1) Basic*	*(2) ACT Math*	*(3) ACT Special Math*	*(4) Freshman Placement Score*	*(5) College Math*
Intercept	-2.311*** (0.141)	-3.333*** (0.160)	-3.277*** (0.160)	-2.740*** (0.207)	-2.798*** (0.209)
GPA	1.179*** (0.040)	1.093*** (0.040)	1.094*** (0.040)	1.088*** (0.040)	1.097*** (0.014)
High School GPA	0.288*** (0.034)	0.160*** (0.036)	0.168*** (0.036)	0.135*** (0.036)	0.140*** (0.036)

Table 3. Ordered Probit Results					
Dependent Variable: Grade in Economics					
Variable	***(1) Basic***	***(2) ACT Math***	***(3) ACT Special Math***	***(4) Freshman Placement Score***	***(5) College Math***
College of Business	0.315*** (0.048)	0.257*** (0.049)	0.259*** (0.049)	0.246*** (0.049)	0.189*** (0.061)
Econ/Finance Major	0.182* (0.098)	0.176* (0.098)	0.182* (0.098)	0.168* (0.098)	0.170* (0.099)
Math/Actuarial Science Major	0.571*** (0.163)	0.335** (0.165)	0.338** (0.165)	0.302* (0.166)	0.137 (0.180)
Computer Major	0.678*** (0.205)	0.461** (0.208)	0.460** (0.208)	0.404* (0.209)	0.196 (229)
Female	-0.255*** (0.042)	-0.143*** (0.043)	-0.142*** (0.043)	-0.145*** (0.043)	-0.146*** (0.064)
White	0.167*** (0.062)	0.085 (0.063)	0.080 (0.063)	0.093 (0.063)	0.087 (0.064)
Principles of Micro	-0.273*** (0.054)	-0.319*** (0.055)	-0.315*** (0.055)	-0.325*** (0.055)	-0.306*** (0.056)
Principles of Macro	-0.453*** (0.070)	-0.561*** (0.071)	-0.552*** (0.071)	-0.566*** (0.071)	-0.562*** (0.073)
ACTMATH		0.083*** (0.005)			
ACT math subscores (untimed test results used for informational purposes)					
ACTSEA			0.044*** (0.010)	0.026** (0.011)	0.024** (0.012)
ACTSAG			0.040*** (0.012)	0.016 (0.013)	0.017 (0.013)
ACTSGT			0.069*** (0.011)	0.051*** (0.012)	0.051** (0.013)
Highest Level of Mathematics Placement from University Placement Exam					
College Algebra I				0.082 (0.094)	0.082 (0.096)

Table 3. Ordered Probit Results					
Dependent Variable: Grade in Economics					
Variable	***(1) Basic***	***(2) ACT Math***	***(3) ACT Special Math***	***(4) Freshman Placement Score***	***(5) College Math***
College Algebra II				0.203* (0.105)	0.171 (0.108)
Pre-Calculus				0.268*** (0.106)	0.209* (0.110)
Basic Calculus (Business)				0.360*** (0.113)	0.300** (0.118)
Precalculus for Higher Level Math				0.400*** (0.144)	0.342** (0.149)
Calculus or Trig				0.679*** (0.150)	0.637*** (0.158)
Highest Level of Mathematics Taken Prior to First Economics Class					
No College Math Prior to Econ					0.163** (0.072)
College Algebra I					0.209** (0.102)
College Algebra II					-0.056 (0.090)
Basic Calculus (Business Students)					0.188** (0.075)
Precalculus or Trigonometry for Mathematics					0.162 (0.115)
Calculus & Analytical Geometry					0.049 (0.113)
Advanced Calculus & Analytical Geometry					0.096 (0.194)
Math for Math Majors/Educators					0.416*** (0.136)
Higher Level Mathematics					0.528

Table 3. Ordered Probit Results					
Dependent Variable: Grade in Economics					
Variable	***(1) Basic***	***(2) ACT Math***	***(3) ACT Special Math***	***(4) Freshman Placement Score***	***(5) College Math***
(Discrete Analysis, Linear Algebra)					(0.389)
μ_1	1.060*** (0.042)	1.079*** (0.043)	1.080*** (0.043)	1.081*** (0.043)	1.086*** (0.043)
μ_2	2.407*** (0.050)	2.474*** (0.052)	2.475*** (0.052)	2.483*** (0.052)	2.494*** (0.052)
μ_3	3.623*** (0.061)	3.766*** 0.064)	3.764*** (0.064)	3.783*** (0.064)	2.494*** (0.052)
Log-L	1372.90***	1570.10***	1567.70***	1594.00***	1616.4***
Data Source: Authors' university. SAS statistical software is employed in the analysis. Statistical significance as follows: *** → α = .01, **→ α = .05, *→ α = .10. Standard errors in parentheses.					

The college grade point average in the previous semester is an important determinant of the economics grade. A 0.10 point increase in the college GPA increases the probability of receiving an A by 1.7 percentage points and the probability of receiving a B by 2.6 percentage points. The probability of receiving a D or F falls by 2.6 percentage points. This result is also consistent with pervious work on performance in economics courses (Park and Kerr, 1990; Anderson, Benjamin, and Fuss, 1994). As discussed earlier, it is likely that GPA represents several characteristics of the individual, including ability and work ethic, and we would expect that those students with higher GPAs would perform better in their economics classes. Likewise, the high school GPA is positively associated with higher grades in a student's first economics course, although the marginal effect is small.

Table 3A: Marginal Effects of Major Factors					
Grade	***A***	***B***	***C***	***D***	***F***
Base Probability	0.078	0.375	0.447	0.091	0.009
	Percentage Point Changes in the Base Probability				
Female	-0.019	-0.038	0.029	0.024	0.004
GPA	0.017	0.026	-0.026	-0.015	-0.002
High School GPA	0.004	0.007	-0.006	-0.004	-0.001
ACT Math	0.018	0.014	-0.023	-0.008	-0.001
ACTSEA	0.004	0.007	-0.006	-0.004	-0.001
ACTSAG	0.002	0.004	-0.004	-0.003	0.000
ACTSGT	0.008	0.013	-0.012	-0.008	-0.001
College Algebra I	0.013	0.020	-0.019	-0.012	-0.002
College Algebra II	0.034	0.047	-0.050	-0.027	-0.004
Precalculus	0.047	0.060	-0.067	-0.035	-0.005
Basic Calculus (Business)	0.067	0.076	-0.093	-0.044	-0.006
HiPrep Pre Calc	0.076	0.082	-0.105	-0.0473	-0.006
Calc& Trig	0.152	0.108	-0.185	-0.067	-0.008

The authors estimate the base probabilities at the means of all continuous variables, for those who are business students, and economics/finance majors, and for those in the microeconomics course (micro is set to 1) because the student sample is primarily associated with this course (Recall, over 58% of the sample takes principles of microeconomics). All other binary variables are set to zero. Except for the ACT Math variable, the coefficients in Column 4 of Table 3 are used in the calculations, as are base probabilities. Column 2 results are used to estimate the ACT Math effect and base probabilities are not reported in this table, but are available from the authors. Marginal effects are calculated by increasing the continuous variables by one unit. Binary variables are "turned on" by setting them to one.

Our primary interest is how mathematics preparation is associated with performance in the class. Before we review these results, note that when the ACT mathematics score is included instead of the math preparation examination, a marginal increase in the ACT Math score increases the probability that an individual will receive an A or B and reduce the probability of receiving a lower grade. When we substitute the ACT subscores for the overall ACT math score, all three coefficients related to these scores are statistically significant and positive, but the impact of each score on the economics grade is very small, from 0.2 to 0.8 of a percentage point. However, when we include the math placement level for the incoming freshman at the university, the placement reveals a strong, positive impact. One can see that as a student's mathematical skill reaches high levels, from the first level of college algebra to the highest level of calculus course, the probability of receiving an A or B grade increases as well, compared to the benchmark case of elementary algebra. For example, those who place into the required business calculus class have a 6.7 percentage point higher average probability of an A and a 7.6 percentage point higher average probability of a B compared to those whose highest placement is elementary algebra. For those who place into the highest level of mathematics, the average probability of receiving an A is 15.2 percentage points and a B is 10.8 percentage points higher than those who place into elementary algebra. Note that in these cases much of the movement to the highest grades comes from the C grade, suggesting that higher math ability does not particularly prevent individuals from flunking their economics courses, although the average probability of receiving a D does fall anywhere from 1.2 to 6.7 percentage points.

Are these results indicative of particular or specific mathematics skills or general mathematics ability? This is a difficult question to answer. However, we suggest that the math placement results represent something more than natural ability for several reasons. First, when we control for ability through the two GPA variables, the math placement variables are also statistically and economically significant in the regression. Second, when the model includes the ACT subscores and the math placement variables, all but one of the subscore coefficients remain statistically significant. The impact of the subscores is reduced, however, when the placement variables are included, due to some collinearity among the variables,[7] suggesting that there is some overlapping effect among the variables, but not entirely.

We next test whether math skills developed in college have an effect on the performance in the first economics course. Column (5) of Table 3 presents the model that includes all of the previous variables, plus controls for the highest mathematics course taken by the student prior to the economics class. The benchmark case is elementary and intermediate algebra. Table 3B presents the marginal effects of these courses. We find that except for College Algebra II and the benchmark case, some college math prior to economics helps the student better perform in the class, although a number of courses are associated with statistically insignificant coefficients. However, business calculus and mathematics for math majors and future educators seem to have a substantial impact, both statistically and economically. Those students who have completed a mathematics class for majors/educators have a higher average probability of receiving an A of 12.6 percentage points, and a 12.2 higher average probability of receiving a B, compared to those in elementary and intermediate algebra (the benchmark case). Likewise, students completing a business calculus class have a higher average probability of receiving an A of 7 percentage points and a B of 9.1 percentage points, compared to the benchmark case. Note that when these math courses are included in the model, most of the ACT subscores and math placement variables are still statistically significant, with little change in size, suggesting that the math skills brought to college are important for the student when taking economics.

Table 3B. Marginal Effects of College Math Courses on Economics Grades

Economics Grade	***A***	***B***	***C***	***D***	***F***
Base Probability	*0.065*	*0.352*	*0.468*	*0.104*	*0.011*
No College Math Prior to Econ	0.026	0.043	-0.039	-0.026	-0.004
College Algebra I	0.034	0.053	-0.051	-0.032	-0.005
College Algebra II	-0.005	-0.013	0.007	0.009	0.002
Basic Calculus (Business)	0.070	0.091	-0.101	-0.053	-0.008
Precalculus or Trigonometry for Mathematics	0.065	0.087	-0.094	-0.051	-0.007
Calculus & Analytical Geometry	0.042	0.064	-0.063	-0.038	-0.006
Advanced Calculus & Analytical Geometry	0.051	0.074	-0.076	-0.043	-0.006
Math for Math Majors/Educators	0.126	0.122	-0.166	-0.072	-0.009
Higher Level Mathematics (Discrete Analysis, Linear Algebra)	0.158	0.130	-0.199	-0.079	-0.010

Data Source: Authors' university
To estimate the Math Course effect, Column 5 of Table 3 is used. All average differences are in relation to the University's Elementary and Intermediate Algebra courses.

CONCLUSIONS

Using a unique control for mathematics preparation prior to the college experience, this study examines whether math preparation and specific math skills help students be successful in an economics course. The results of the analysis suggest: (1) Ceteris paribus, those individuals with the background that qualified them to take higher levels of mathematic courses were more likely to receive As and Bs in their first economics course, compared to those students who had relatively less math preparation from high school and subsequently placed no higher than in elementary or intermediate algebra. (2) The positive effect on grades grew as the placement level grew, and those whose highest placement was in the calculus course that included analytic geometry and trigonometry had the highest average probabilities of receiving an A or B grade in their first economics courses. (3) The effect of the ACT math subscores indicate that students who received higher scores in elementary algebra, college algebra, or trigonometry and geometry have a higher probability of receiving A and B grades in their economics courses. Again, the higher the level of ability in mathematics, e.g., trigonometry and geometry, the more likely the student will perform well in economics. (4) Taking college-level business calculus or higher level mathematics has an economically and statistically significant impact on performance in one's economics class.

The outcome of this analysis does not lead to an easy interpretation. Precisely how well one can actually do the mathematics does not appear to be so important, because marginal increases in the ACT subscores have little impact. Further, while it does appear that native ability (as measured by the overall ACT math score) matters, exposure to mathematical ideas appear to be more important in improving performance in economics. Despite the fact that higher level mathematical skills are not employed in the principles and survey courses, exposure to higher level mathematics is associated with higher grades in the first economics course, other factors held constant.

Thus, it appears that for the student, being exposed to more mathematics in high school is the important point. It does not appear that algebra skills matter, where one focuses on getting the answer. Calculus prepares the student, too, but now the student must see the function, how things are related, and the student will be exposed to marginal analysis (e.g., total and marginal revenue concepts). What seems to prepare the student most is the abstract reasoning associated with geometry or trigonometry.

These results suggest to us that mathematical maturity will help the typical student perform better in their first economics course. However, economics departments have little say in what math courses are taken at the high school level. But, we do have control on entrance requirements for courses. Thus, one possible policy implication might be to require students to take more mathematics before taking economics on the grounds that students gain some maturity that helps them perform better in economics. In fact, this study suggests that the current required business calculus course aids the student in their understanding of economics and perhaps it should be a prerequisite for the principles levels classes.

Broadly speaking, our results suggest the importance of high school students selecting the proper mathematics courses for success later in college, both in mathematics and in other disciplines such as economics. Getter the word back to high schools is not easy, but is one possible way to proceed. For example, many states have graduation requirements that include a mathematics component. Working with agencies that set such standards would be one approach, although we can envision a number of political and bureaucratic problems with such an approach.

An additional problem is that students coming into our economics classes are often taking the class as part of a general education requirement or because an accrediting agency has recommended more economics, such as in education. What can be done for students in these areas where calculus may be not a reasonable requirement? It might make sense to offer some added help to these students to brush up on some mathematics and to add some simple calculus concepts through help sessions or computer learning packages.[8]

Finally, we also see an avenue for future research. It may be that universities would see that added quantitative strength would improve performance in other areas in addition to economics and may be well worth the cost of any program that enhances mathematics skills. It would be interesting to compare those institutions with programs that require a high level of math skill, such as engineering, to schools without such programs, to see how students in fair in a variety of programs. The larger pool of observations and the cross-comparison can tell us more about the effect of mathematical maturity on student performance in economics and other classes.

ENDNOTES

1 Thanks to Dr. David Meel of BGSU's Department of Mathematics and Statistics for providing the placement exams and for helping us understand the placement process at BGSU. Robert Zhang provided data in addition to the placement test data, a monumental job, for which we offer thanks. Julie Dibling provided some additional data as did Kelly Dove. We give our thanks for their help in our endeavor. The authors also thank session participants at the 2009 Midwest Economics Association meetings. No mistakes that may remain are due to these individuals. Please send all correspondence to Professor Hoag.

[2] Bowling Green State University Undergraduate Catalog, 2001-2003 provides the degree requirements information.

[3] From time to time the university provides a report on the average grade by discipline in the lower division courses, as well as the upper division courses. One consistent outcome is that at both levels, the courses labeled ECON have among the lowest grade point averages in the university. This information is not circulated among the students. We suspect that many economics departments across the country face the same situation.

[4] Of the 5429 observations, 759 had no ACT Math score, 516 were missing key university variables, including the dependent variable, 380 had no ACT math subscores, 664 had no math placement scores, 252 were double counts (in other words, they were in economics more than once in the sample). These deductions left a total of 2,858 observations.

[5] We tested other controls for a student's major and did not find that these controls were statistically significant. Thus, we opted for the most parsimonious model and included only three controls for major that had a logical and statistically significant impact on the first ordered probit regression.

[6] The department typically requires micro before macro, but exceptions do occur.

[7] An OLS regression of the ACT math scores on the placement variables yields an adjusted R^2 of 0.52 to 0.54 and the coefficients on all of the placement variables are statistically significant, indicating correlation. Results are available from the authors.

[8] An alternative solution to this problem is to alter the direction of presentation for students in the principles level courses so that the material is accessible to students with weaker mathematics backgrounds. There are now textbooks on the market that eschew graphs and math, hoping to make economics comprehensible for the math-phobic individual. So, why not change the course and make the material more accessible? After all, almost no one would argue that knowledge of economics is irrelevant.

While this is an attractive argument, our view is that there is something inherent in economics that calls for mathematical analysis. Further, disciplines that require economics for its analytical skill development would not find such a course useful. And, the bigger issue is that the tools of economics need mathematics. Somehow, the analysis of supply and demand is most deeply understood with a graphical analysis. The authors do not see a way to overcome this simple fact.

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