Math Skills and Everyday Problem Solving

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ABSTRACT

Given the importance of mathematics to economic education, we administer a test of basic math skills to 696 students enrolled in various college economics courses in order to understand the factors influencing a student's ability to apply basic math skills in practical settings. Students with strong elementary math skills perform significantly better in applied contexts and we find that taking more math classes in college improves a student's ability to apply mathematics substantially. Interestingly, our results suggest that students with greater personal financial responsibility in funding their education do significantly better in understanding and applying basic math skills.

Introduction

One of the more significant challenges facing instructors of economics is the lack of strong mathematical skills in a number of students enrolled in our college courses. The limitations are significant because understanding many of the economic models we teach assumes, at a minimum, a sound knowledge of high school level algebra. As a result, students who struggle with basic math skills tend to perform poorly. As we point out below, there are quite a few empirical studies that verify the positive effect of a strong math background on success in college economics courses. Recognizing the important link between math skills and course performance, the current study delves deeper into the issue by directly testing what factors influence a student's ability to apply basic math skills. Given the importance of basic mathematical knowledge in economic education, understanding these factors is critical.

We administer an exam which allows us to directly measure how well a student can apply basic math skills. The exam consists of two parts; the first part of the exam is a test of very basic math skills, while the second part consists of a series of three applied math problems. Using the score on part two as our outcome variable, we investigate the link between mastery of simple mathematical concepts and applied math problem solving ability while also controlling for a host of economic, social, and demographic variables collected on each student. Our findings establish a strong positive link between skills and application and underscore the importance of basic mathematical knowledge in economic education. Additionally, many of the control variables yield meaningful insights. We find for example, that student's with greater personal responsibility in funding their education perform significantly better on the exam.

Literature Review

A number of researchers have investigated the determinants of success in college economics courses. Among other things, many of the studies control for student math skills and find that the mathematical ability of students enrolled in economics courses has a positive effect on course performance. More specifically, many of the studies control for the effects of previous math experience or Math SAT scores on course performance. Durden and Ellis (1995) and Anderson, Benjamin, and Fuss (1994) find that a student's calculus experience is positively and significantly related to course performance. Moreover, Lumsden and Scott (1987) find that "A" students in previous math courses perform better on multiple choice exams. Anderson, Benjamin, and Fuss (1994) show that students who had completed a sequence of Business math courses did significantly better in their economics course and Willliams, Waldauer, and

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Douglas (1992) show that Math SAT scores are an important factor in a student's course performance.[2] Because these studies only account for higher level mathematics courses, Ballard and Johnson (2004) investigate the impacts of varying levels of math skills on course performance. They administer a test of basic math skills to several students enrolled in principles of microeconomics and use the score on this exam along with other math experience variables as determinants of course performance. One of the major conclusions of their paper is that among the controls for mathematical background, mastery of very elementary math skills as measured by performance on their administered exam is of utmost importance. The results of their research suggest that a substantial number of students lack the mastery of very elementary math concepts, such as calculating the slope of a line, necessary to perform well in an economics course. Hence, they suggest that professors identify students with weak basic math skills early on so that some type of remediation can be done to bring these students up to par.

The emphasis on elementary math skills by Ballard and Johnson (2004) provides some motivation for this paper. Ballard and Johnson (2004) study a group of students enrolled in principles of microeconomics who should have been exposed to college level algebra at a minimum. However, as Ely and Hittle (1990) point out, completing a math course does not necessarily mean that students have acquired the math skills. The fact that a significant number of students performed poorly on the test of basic math skills in Ballard and Johnson (2004) signals a serious deficiency and implies that many students who have completed minimum math requirements in college will not be able to apply these math concepts in an applied setting such as an economics course. To this end, instead of looking at course performance as the outcome, our paper more directly investigates the link between basic math skills and application using a two part mathematics exam which directly measures a student's ability to apply basic math concepts. We describe the exam and data as well as the econometric model in the next section.

Data and Methodology

In our research, we are interested in determining what factors influence a student's ability to apply basic math knowledge in applied settings. We do so by administering a two part math exam to 696 students enrolled in various economics courses ranging from principles to upper level applied courses. Table 1 contains the set of questions that the students were given in the first part of the exam. This part of the exam contains a set of 15 multiple choice questions designed to test basic math skills that students should have mastered in high school or in a college algebra class. The questions are the same as those used by Ballard and Johnson (2004) in their test of basic math skills. In the second part of the exam, shown in Table 2, students were given a series of three problems containing practical everyday uses of basic mathematical knowledge. The scores on the two parts allow us to directly correlate a student's basic math aptitude with their ability to solve simple applications of mathematics.

The econometric model used in the paper is represented as

$$y_i = \beta_0 + \beta_1 x_1 + \sum_j \beta_j x_j + e_i$$

where the dependent variable (y) is the score on the applied part of the test and the independent variable (x_1) is the score on the mathematical part of the test. Additionally, we use a set of control variables that can influence the results on the second part of the test. The control variables include a number of economic, social and demographic characteristics of the students taking the exam. The data for these variables are based on a survey that each student was asked to complete along with the exam. Table 3 presents the descriptive statistics for the test scores and control variables. We have a number of important economic and social controls to use in this model, and the data seem to contain a wide spectrum of students.

[2]In addition to the studies described in the text, other studies that show the importance of mathematics in learning economics include Brasfield, McCoy, and Milkman (1992), Cohn and Cohn (1994), Cohn, Cohn, Hult, Balch, and Bradley (1998, 2000), and Cohn, Cohn, Balch, and Bradley (2001).

Empirical Results

Table 4 presents the results from our model discussed above. Since many of the independent variables are highly correlated, we present a set of four models with different specifications. All four models include our key independent variable, the student's exam 1 score which controls for the basic mathematical skills of each student. Also, included in each model is the student's G.P.A. in order to control for their overall cognitive ability. Regardless of the model specification, the results show students with greater basic math skills (i.e. higher part 1 scores) and higher G.P.A.'s perform significantly better on the applied portion of the test.

In Models 1 and 2 we include variables to control for each student's educational background. Model 1 controls for the student's major college, classification, and whether they attended a private high school, while model 2 controls for the student's previous math courses. Compared with freshmen and sophomores, juniors and seniors performed significantly better on the exam and students enrolled in the colleges of Business, Arts and Sciences, and Engineering tended to outperform those in the colleges of Education and Health. There is some evidence in the empirical literature of a private school effect on student cognitive ability.[3] However, we find no evidence that students from private high schools perform significantly different than students from public schools. Finally, the results indicate that students who took advanced math courses performed significantly better on the test, while the effect was negative for students who had only taken algebra. It is important to mention that there is a positive correlation between the performance on test one and the mathematical courses students took which could be reducing the positive impact of math courses on student performance.

In the last two models of Table 4, we add controls for various demographic and economic characteristics of each student. Model 3 accounts for the student's race and gender as well as their personal and family income, while model 4 controls for the source of school financing (e.g. scholarships and loans). When we add the demographic variables to Model 3, many of the educational background variables become statistically insignificant. However, since many of these variables are correlated, it is likely that their effects are being captured by the demographic variables. Moreover, we evaluated a range of additional demographic and economic variables not reported in the tables; however their impact is not sufficiently robust to alter the specification of the econometric model. Among the variables we eliminated are: students coming from community colleges, students coming from the local area, the United States and Foreign countries, marital status of students, age, hours worked and part time or full time worker. The results of Model 3 suggest that, ceteris paribus, whites and Asians outperformed African Americans on the applied portion of the exam, while the difference between African Americans and Latinos is not statistically significant. Moreover, the results indicate that male students performed significantly better than females and students with no work obligations did better than students who worked part or full time. Interestingly, we find that as family income increases, students performed significantly worse on the exam.

In model 4 we considered the source of a student's education finance. That is, was the student's education paid for by themselves (myself), parents (Parents), another family member (Other Family), scholarships (Scholarship), loans (Loans) or another source of financing (Other). The only significant variables are Parents and Other Family, which have a negative sign, indicating that students whose families pay for their education performed much more poorly on the test than students who had to resort to other sources of financing. The source of financing can be correlated with the African American and Latino variables, perhaps due to things like minority geared scholarships. The source of financing is correlated with personal and family income and we did not include these variables in this econometric model (Model 4).

While table 4 highlights the variables that are statistically significant, it is also useful to understand the importance of each variable. Hence, in Table 5, we calculate how the average score on part two of the exam changes because of a change in one standard deviation on each independent variable in order to understand the effect of each variable on a student's performance. The baseline results for each model appear in the first row of the table. The baseline results reflect a sophomore African American female who is not in any specific college, has taken no college math courses, comes from a public high school, does not work, and her GPA, age, and family and personal incomes are the average for the distribution. Relative to the

[3] See for example Murname (1986), Rouse (1996), and Neal (1997).

baseline, increasing GPA by one standard deviation increases the performance on the second part of the exam between 6.4% and 10.3%. In the case of prior mathematics knowledge, as captured by the performance in the first part of the test, an improvement of one standard deviation in the score on part one leads to a 27% to 29% increase on the score of the second part. This positive impact is robust to different specifications of the econometric model and it is reinforced by the results that show that students who took advanced math courses perform significantly better on the test, while the effect was negative for students who had only taken algebra.

The regression results from Table 4 indicated that upper classmen (i.e. juniors and seniors) and graduate students perform significantly better on the applied portion of the exam compared with freshmen and sophomores. The simulations in Model 2 of Table 5 show that relative to the baseline, students from the College of Computing Sciences and Engineering and the College of Arts and Sciences scored about 26% higher on the exam, students from the Business School scored 17.1% higher, and students from the College of Health did not perform significantly better on the exam. Collectively, what these comparisons seem to indicate is that students from degree programs with higher mathematics requirements are better able to solve simple everyday applications of mathematics.

Model 3 of Table 5 captures the effects of race and gender. In the simulations, we interact race and gender and observe that African American and Latino females perform the worst. Relative to the baseline group (i.e. African American females),white and Asian males had the greatest gains, with their scores about 60% higher. They were followed by White and Asian females, who both scored about 35% higher on the exam. The achievement gap between African American females and African American and Latino males was the smallest, with the latter two groups scoring 18% higher.

Model 3, as well as model 4 also captures the effects of important economic characteristics. The results (Model 3) show that students who work full or part time scored 21.6% higher on the exam and when we increase by one standard deviation the family income, we observe a 8.6% decrease in exam scores on average. In model 4, when controlling for the source of school financing, we find that that students whose families pay for their education scored 10 to 17% lower on the exam than students who had to resort to other sources of financing. The overarching implication here seems to be that students with greater personal responsibility in funding their education are motivated to perform better academically.

Summary and Conclusions

We investigate the factors influencing a student's ability to solve a series of practical everyday problems, which require a sound understanding of basic math skills. Understanding these factors is of particular importance to economics instructors who need students to grasp basic mathematical concepts in order to understand economic modeling and analysis. To examine the issue, we gave a two part examination to 696 students enrolled in various college economics courses. The first part of the exam was used to assess the student's basic math aptitude, while the second part of the exam consisted of three problems designed to test how well a student could apply basic math skills. A number of social, economic, and demographic variables, collected through a survey from each student, were used as controls in the econometric models, to explain the student's score on the second part of the exam.

We find that the score on part 1 of the exam has a significant and positive effect on the student's score on part 2 of the exam confirming the fact that students who have mastered basic high school math skills are better able to rely upon those skills in applied settings. The importance of this result is magnified when we consider that an increase of one standard deviation in the part 1 score results in a 27 to 29 % increase in the part 2 score. Coupled with the result that shows students in colleges with higher math requirements (e.g. Engineering) perform significantly better on second part of the exam, this finding suggests that by taking more math classes in college, students can greatly improve their problem solving abilities. Of course, regardless of the math background or college the student is enrolled in, students with higher GPAs perform better on the exam. Nevertheless, given the use of mathematics in economic modeling and analysis, if we can convince our students to strengthen their basic math skills by taking more math classes, the results imply that we would greatly enhance the quality of their economic education. This result underscores the findings of Ballard and Johnson (2004), which suggest that students who have taken calculus perform better in economics classes not necessarily because of their knowledge of calculus, but rather because they have more likely mastered basic math concepts through more exposure to mathematics.

Finally, income and other demographic and social variables are important. One of the more interesting results we find is that size of family income is negatively related to the exam score, while the size of personal income has a positive effect. What this may suggest is that student's with a greater personal financial responsibility are more motivated to learn and apply concepts than students who depend on financing from parents or other family members.

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Table 1
Test of Basic Math Skills

1. A round-trip airline ticket to Las Vegas is normally $200. This week, the ticket is 15% off. What is the price of the round-trip ticket to Las Vegas this week?
(a) $185 (b) $180 (c) $175 (d) $170 (e) $140

2. If the tax per cup of coffee is $0.30 and the number of cups of coffee sold is 5, then the total tax revenue is _________.
(a) $ 0.30 (b) $ 1.50 (c) $ 1.50 per cup (d) $ 5.30 (e) $ 0.06 per cup

3. Add these two fractions:

$$\frac{1}{2}+\frac{3}{4}=$$

(a) 5/4 (b) 1 (c) 4/6 (d) 1/2 (e) 7/4

4. Perform the following multiplication:

$$\frac{1}{2}*\frac{4}{7}=$$

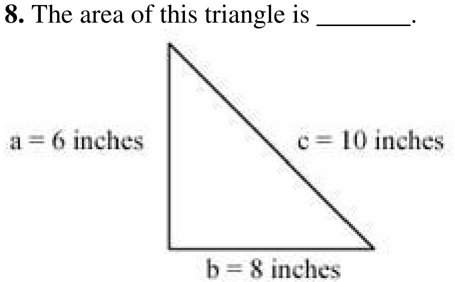
(a) 5/9 (b) 4/9 (c) 5/14 (d) 2/7 (e) 7/8

5. Solve the following equation for P: 3P = P + 12
(a) P = 4 (b) P = 3 (c) P = 6 (d) P = -3

6. Solve the following system of equations for y.
y = x – 2
y = 2x
(a) -1 (b) -2 (c) -4 (d) 0 (e) 3/2

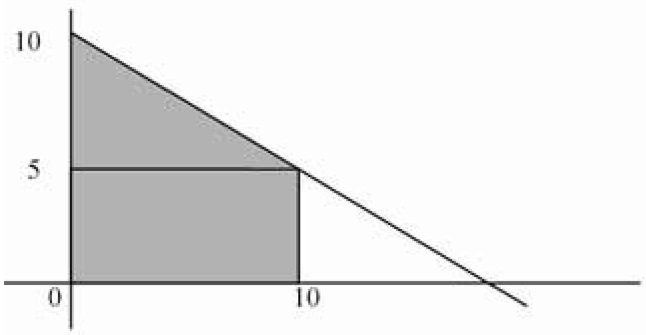
7. Suppose that x = a / b. Then if x = 2 and a = 4, solve for b.
(a) 1 (b) 2 (c) 4 (d) 8 (e) 1/2

8. The area of this triangle is _______.



(a) 24 square inches (b) 24 inches (c) 48 inches (d) 48 square inches (e) 100 square inches

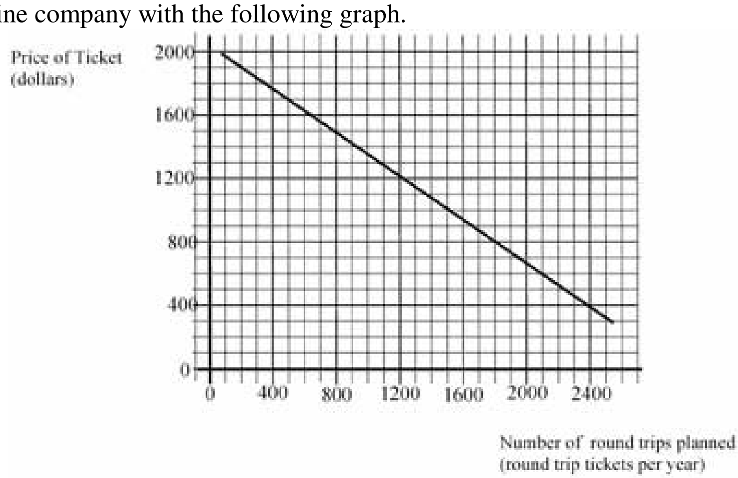
9. In this graph, calculate the shaded area.



(a) 25 square units (b) 35 square units (c) 50 square units (d) 75 square units
(e) 100 square units

10. You want to retile your kitchen. The kitchen measures 9 feet by 9 feet. Tile costs $2 per square foot. What is the minimum you can spend on tile for the kitchen?
(a) $18 (b) $36 (c) $40.50 (d) $81 (e) $162

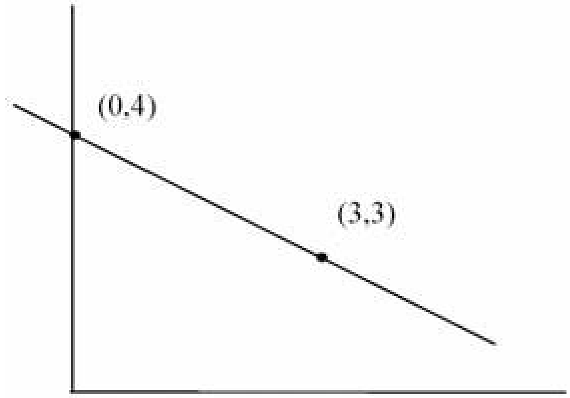
11. An airline company wants to know what business people are willing to pay to fly from Los Angeles to New York. They hire a market research firm that asks business people how many times they would plan to fly to New York in the next year at various prices. The market research firm presents the airline company with the following graph.



If the price of a round trip airline ticket from Los Angeles to New York was $800, how many round trips would you expect business people to take to New York?

(a) 400 round trips (b) 1500 round trips (c) 1800 round trips (d) 2400 round trips
(e) none

12. Find the slope of the line represented in the graph.



(a) 4/3 (b) -4/3 (c) 1/3 (d) -1/3 (e) 3/4 (f) -3

13. What is the slope of the following line? Assume that Y is measured on the vertical axis, and X is measured on the horizontal axis.

2X + 3Y = 5

(a) 2 (b) 3 (c) 5 (d) -2/3 e) 3/2

14. What is the intercept on the y axis of this line?

$$Y = 2 + \frac{3}{2} X$$

(a) 3/2 (b) -3/2 (c) 2 (d) X (e) Y

15. It costs 25 dollars to rent a car, plus $0.30 for each mile you drive. Let C represent the cost of renting a car if you drive it x miles. Write an equation that describes the relationship between the variables C and x.

(a) C = 25 + 0.30x (b) C = 25.30x (c) C = 25 + 0.30 + x (d) 25C = 0.30x
(e) 0.30C + 25 = x

Table 2
Applications of Basic Math Skills

1. At the close of the stock market on Monday, the value of a certain stock was $12.00 per share. By the close on Tuesday, the value of the stock went up 50% per share. At close on Wednesday, the value of the stock was down 5% per share from Tuesday's closing value.

Complete Parts A, B and C

Part A: Determine the value of the stock at closing on Tuesday and Wednesday. Show all work necessary to justify your answer

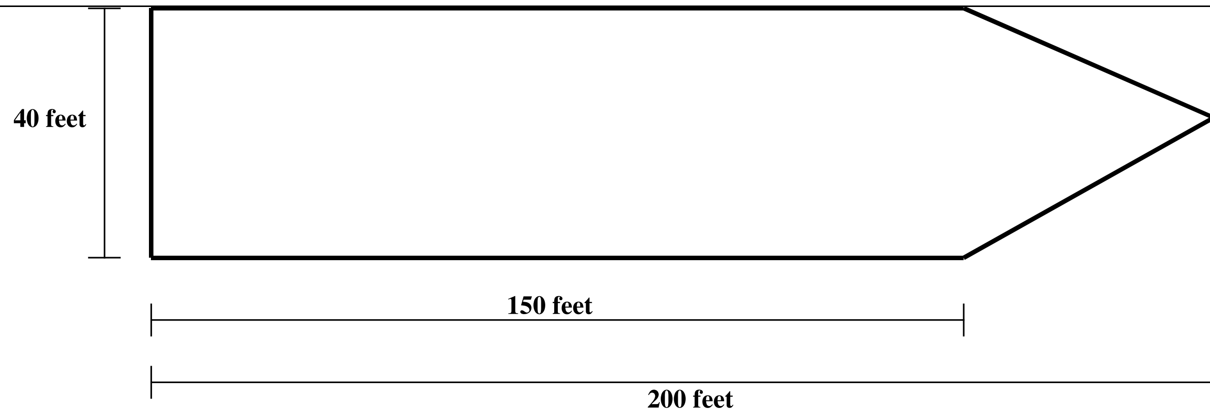
Value on Tuesday:____________________ Value on Wednesday:___________________

Part B: Determine the total percent change in the value of the stock from Monday to Wednesday. Show all work necessary to justify your answer

Part C: Make a line graph that shows the trend in the value of the stock at the close of the stock market on Monday, Tuesday and Wednesday.

Be sure to include a Title for the graph, label for the axes, appropriate consistent scales and accurately graphed data.

2. Jackie wants to determine the number of gallons of paint needed to paint the entire deck of a cargo ship. A sketch of the deck is shown below:



How many square feet will be painted? ________________

3. The drama club plans to sell cans of orange soda and lemon-lime soda at its annual theater event. The club has enough money to buy a total of 288 cans of soda and has decided to buy twice as many cans of lemon-lime soda as orange soda.

Determine the number of cans of each flavor of soda the drama club will buy for the event. Show your work.

Number of cans of orange soda ________________________

Number of cans of lemon-lime soda ______________

Table 3
Descriptive Statistics

Variable	Number	Mean/Proportion	Std. Dev.	Min	Max
Performance on Exams					
Log Test 2 Score	695	19.14	8.34	3	37
Log Test 1 Score	695	11.35	2.45	3	15
Educational Background Variables					
Log GPA	650	3.07	0.47	1.5	4
Classification					
Freshman	35	0.05			
Sophomore	174	0.25			
Junior	216	0.31			
Senior	139	0.20			
Graduate	132	0.19			
Major College					
Coggin College of Business	522	0.75			
College of Health	14	0.02			
Arts and Sciences	35	0.05			
Computer and Engineering	21	0.03			
Other/Don't know	104	0.15			
Attended Community College					
Yes	473	0.68			
No	223	0.32			
Full time Student					
Yes	550	0.79			
No	146	0.21			
Went to Private High School					
Yes	125	0.18			
No	571	0.72			
Highest Level of Math					
Business Calculus	320	0.46			
Statistics	111	0.16			
High School Math	7	0.01			
Algebra	77	0.11			
Advanced Math	77	0.11			
Demographic Variables					
Age	689	23.55	6.13	17.00	57.00
Gender					
Male	369	0.53			
Female	327	0.47			
Race/Ethnicity					
White	536	0.77			
African American	56	0.08			
Latin	28	0.04			
Asian	42	0.06			

Table 3
Descriptive Statistics (continued)

Variable	Number	Mean/Proportion	Std. Dev.	Min	Max
Demographic Variables (contd)					
Married					
Yes	104	0.15			
No	592	0.85			
Local Resident					
Yes	271	0.39			
No	425	0.61			
In State Resident					
Yes	480	0.69			
No	216	0.31			
International Student					
Yes	125	0.18			
No	571	0.72			
Live on Campus					
Yes	77	0.11			
No	619	0.89			
Economic Variables					
Income					
Personal Income	461	25023.64	23254.03	1600.00	250000.00
Family Income	387	104862.30	104658.30	5000.00	1000000.00
Work Status					
Work Part Time	327	0.47			
Work Full Time	230	0.33			
Do not Work	139	0.20			
Log Hours of Work	549	30.13	12.15	4.00	85.00
Source of School Finance					
Pay education myself	271	0.39			
Pay education parents	258	0.37			
Paid by Other Family Member	21	0.03			
Scholarship	244	0.35			
Loan	125	0.18			

Table 4 Econometric Model: Dependent Variable Score Test 2

Variables	Model 1	Model 2	Model 3	Model 4
Test 1	0.987 *** (0.1162)	0.931 *** (0.1136)	1.042 *** (0.1393)	1.007 *** (0.1219)
Lgpa	0.408 *** (0.1453)	0.581 *** (0.1443)	0.530 *** (0.1930)	0.384 ** (0.1479)
Graduate	0.296 *** (0.0668)	______	0.222 ** (0.0948)	0.269 *** (0.0757)
Freshman	0.151 (0.1076)	______	0.190 (0.1504)	0.128 (0.1044)
Junior	0.163 ** (0.0634)	______	0.142 * (0.0819)	0.1478 ** (0.0644)
Senior	0.129 * (0.0716)	______	0.125 (0.0936)	0.125 * (0.0722)
Business	0.157 ** (0.0754)	______	0.043 (0.1138)	0.142 * (0.0751)
Arts and Sciences	0.230 ** (0.1072)	______	0.112 (0.1456)	0.207 * (0.1093)
Health	-0.246 (0.2784)	______	-0.418 (0.3315)	-0.228 (0.2794)
Engineering	0.238 * (0.1290)	______	0.018 (0.2286)	0.221 * (0.1291)
Private HS	0.063 (0.0523)	______	0.058 (0.0671)	0.076 (0.0536)
Business Calculus	______	0.073 (0.0516)	______	______
Algebra	______	-0.177 * (0.0965)	______	______
Advanced Math	______	0.119 * (0.0657)	______	______
Lincper	______	______	0.062 (0.0393)	______
Lincfam	______	______	-0.124 *** (0.0404)	______
White	______	______	0.301) *** (0.1099)	______
Male	______	______	0.169 *** (0.0607)	______
Latino	______	______	0.0974 (0.1545)	______
Asian	______	______	0.2996 ** (0.1234)	______
Don't work	______	______	0.1953 ** (0.0790)	______
Myself	______	______	______	0.042 (0.0458)
Parents	______	______	______	-0.107 ** (0.0495)
Other Family	______	______	______	-0.193 * (0.0991)
Scholarships	______	______	______	0.032 (0.0530)
Loan	______	______	______	-0.025 (0.0540)
Constant	-0.326 (0.3044)	-0.1284 (0.2840)	-0.010 (0.7067)	-0.308 (0.3203)
	F (11,597)= 14.47 R2=0.25, N=609	F (5,603)=27.25 R2=0.21, N=609	F(18,284)= 11.31 R2=0.39, N=303	F(16,592)=10.44 R2=0.26, N=609

Standard errors in parentheses. ***, **, and * denote statistical significance at 1, 5, and 10 %, respectively.

Table 5 Marginal Effect of Changes in Independent Variables

	Model 1	% Change	Model 2	% Change	Model 3	% Change	Model 4	% Change
Baseline	12.1		15.6		5.4		12.6	
CCB	14.2	17.1%			5.4	0.0%	14.6	15.3%
LAS	15.3	25.8%			5.4	0.0%	15.5	23.0%
Health	12.1	0.0%			5.4	0.0%	12.6	0.0%
Computer	15.4	26.9%			5.4	0.0%	15.8	24.8%
Freshman	12.1	0.0%			5.4	0.0%	12.6	0.0%
Sophomore								
Junior	14.3	17.7%			6.2	15.2%	14.3	13.3%
Senior	13.8	13.8%			5.4	0.0%	14.6	15.3%
Graduate	16.3	34.5%			6.7	24.8%	16.5	30.9%
GPA	13.0	0.0%	17.2	9.8%	5.8	8.9%	13.4	6.4%
Test 1	15.6	17.7%	19.8	26.6%	7.0	30.2%	16.3	29.0%
Business Calc			15.6	0.0%				
Algebra			13.1	-16.2%				
Advanced Math			17.6	12.6%				
Don’t Work					6.5	21.6%		
White Female					7.2	35.1%		
Latino Female					5.4	0.0%		
Asian Female					7.2	34.9%		
White Male					8.6	60.0%		
Latino Male					6.4	18.5%		
Asian Male					8.6	59.8%		
Afr. Am. Male					6.4	18.5%		
IncomeFam					4.9	-8.6%		
IncomePer								
Private HS	12.1	0.0%			5.4	0.0%	12.6	0.0%
Myself							12.6	0.0%
Parents							11.3	-10.2%
Other Fam							10.4	-17.6%
Scholarship							12.6	0.0%

*The baseline model results are the average math score as predicted by each model specification. The scores are based upon the performance of an African American female sophomore student that does not belong to any specific college, did not take any math courses, comes from a public High school, does not work, and her GPA, age, family and personal incomes are the average for that group.