The Role of Algebra I Assessment in Improving Student Performance in Principles of Economics

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Abstract

Anecdotal evidence from Principles of Economics faculty suggests that many students fail to comprehend foundational material in economics due to gaps in their understanding of basic Algebra I concepts. To address this issue, Principles faculty at this institution administer a common Algebra I assessment at the start of each Fall semester. Students are not allowed the use of a calculator on this test although they are allowed to use calculators in the course on homework, quizzes and exams. The goal is to identify students weak in basic math skills early in the semester in order to give them remedial help to allow them to catch up to the rest of the class or to indicate to them that they are entirely inadequately prepared for the course.

This paper presents results from primary data collected on 1361 students registered for a Principles of Economics class for which the prerequisite is Algebra I. The dataset contains Algebra I assessment results, subsequent class performance, and other student characteristics including gender, private or public schooling, country of origin, students' own self-reports of their math ability. their GPA and their SAT Math scores.

Our results show that student performance on the Algebra I assessment is a good predictor of cumulative final exam scores in the Principles class. Would SAT Math scores have been an equally good predictor? Our results show that they are not. We suggest that use of a calculator on the SAT Math test may be allowing students to answer questions they otherwise would not be able to think through and solve. In other words, students know how to use a calculator solve problems but fail to understand underlying math concepts. It could also be the case that the multiple-choice format of the SAT Math test allows students to answer questions correctly without fully understanding what they are doing. The contribution of this paper is to emphasize the importance of basic math assessment without allowing the use of a calculator at the start of a Principles course rather than relying on SAT Math outcomes as a strong indicator of students' math ability.

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1. Introduction

Each year, students' college admissions are based in part on their SAT Math scores. The expectation of Economics faculty is that if students have been admitted into college, they should have the math skills necessary to navigate a Principles of Economics course. However, anecdotal evidence from frustrated Principles faculty suggests that this is not the case. Evidence from research in this area suggests that many students fail to comprehend foundational material in economics due to gaps in their understanding of basic math concepts (Mallik and Lodewijks 2010; Owen 2012) and that in addition to advanced math and good test scores, a student's score on a mathematics quiz has a statistically significant positive impact on performance in an economics course (Arnold and Straten 2012, Ballard and Johnson 2004, Benedict and Hoag 2002, Benedict and Hoag 2012, Schuhmann et al 2005).

To address this issue, Principles faculty at this institution administer a common Algebra I assessment at the start of the Fall semester. The questions are simple and cover only those skills required for a Principles class – percentage change, ratios, proportions, fractions and decimals, order of operations, place value, the area of a triangle, simple exponents and the graph of a straight line. Students are informed two weeks before class that an Algebra I assessment worth 10% of the course grade will be administered in Week One. They are pointed towards learning resources and told that calculators will not be allowed on the assessment. Any student who does not achieve an 80% (indicating mastery) on the first try has three other chances to pass the assessment during the first part of the semester. Math reviews are offered every other week in between assessment opportunities. Given that it is 10% of their course grade, students take passing the assessment quite seriously. Students who do not pass the assessment even after four attempts are strongly encouraged to take the class only after they have mastered the math prerequisite given the importance of remedial mathematics for learning economics (Lagerlöf and Seltzer 2009). In this manner, faculty can maintain the rigor of the class while ensuring that students are not falling behind.

This paper presents results from primary data collected on 1361 students registered for a Principles of Economics class for which the prerequisite is Algebra I. The dataset contains Algebra I assessment results, subsequent class performance, and other student characteristics including SAT Math scores. We analyze assessment results by gender, private or public schooling, country of origin and students' own self-reports of their math ability. Performance by component of the Algebra I assessment - arithmetic, algebra, geometry and graphing – is also analyzed. Finally, we present results on whether assessment scores predict course performance. Similar to prior research in this area (Ballard and Johnson 2004, Cohn et al 2001, Pozo and Stull 2006), our results indicate that assessment scores predict course performance, and that students are more motivated to learn the math (and therefore do better in the course) when it is a significant part of their grade in the course.

We then control for SAT math scores and report on the differences between assessment results and SAT math scores. Our results also suggest that the use of a calculator on the SAT may be allowing students to answer questions they otherwise would not be able to think through and solve. In other words, students know how to use a calculator but fail to understand underlying concepts (Bridgeman, Harvey and Braswell 1995). It could also be the case that the multiple-choice format of the SAT Math test allows students to answer questions correctly without fully understanding what they are doing (Becker and Johnston 1999; Rebeck and Asaarta 2012).

The contribution of this paper is to show that a basic math assessment is a better predictor of student performance in a Principles of Economics course than SAT Math scores. Rather than allowing just one attempt, we allowed students multiple attempts to pass the assessment with reviews in between. We emphasize the importance of disallowing the use of a calculator on the assessment and suggest some reasons that SAT Math outcomes may not be a strong indicator of students' math ability.

In Section 2 we describe the Algebra I assessment given to students and how the data was collected. In Section 3 we present our overall assessment results. In section 4 we analyze the explanatory power of students' SAT Math scores in predicting their performance on the Algebra I assessment. In section 5 we use students' scores on the SAT Math test as well as their performance on the Algebra I assessment to predict performance on the final exam in the Principles class. In Section 6 we present our conclusions.

2. The Algebra I Assessment and Data Collection

The Algebra I assessment was administered at the start of the Fall 2012 semester to 1361 students enrolled in a Principles of Microeconomics course at The George Washington University. To ensure that students would take the assessment seriously, the assessment counted towards 10% of each student's overall course grade. The assessment was made up of 20 questions covering four topics: arithmetic, algebra, geometry, and graphing. The distribution of points for each topic is given in Table 1 below. In general, the points were split relatively evenly between all four topics. A sample Assessment is provided at the end of the Appendix.

Table 1
Algebra I Assessment: Distribution of Points Across Sections

		Assessment Opportunity 1	Assessment Opportunity 2	Assessment Opportunity 3	Assessment Opportunity 4	Average Distribution
Section I	**Arithmetic**	7	6	6	6	0.31
Section II	**Algebra**	5	5	7	6	0.29
Section III	**Geometry**	4	4	4	4	0.20
Section IV	**Graphing**	4	5	3	4	0.20
Overall		20	20	20	20	1.00

Students were given four opportunities to pass the math assessment. These four opportunities were scheduled every other week in order to allow students to review basic math skills, as some may not have had a mathematics course in recent years. Students were directed to resources including McGraw-Hill's ALEKS (an online math tutorial system), K-12 Algebra and Geometry textbooks available online, and on-campus math review sessions offered weekly by teaching assistants.

To pass the assessment, students had to score 80% (16 correct out of the 20 possible points) or higher to indicate mastery of simple math skills. The pass rate was carefully chosen to allow students a few careless mistakes and to accommodate students who might be slower in their work. Each student was given 30 minutes to complete the assessment.

Once students passed, they earned the full 10% of their overall grade and did not have to take the assessment again. Students who scored 79% or below on an assessment attempt, did not pass the assessment and received zero percent. Students who did not pass the assessment after four attempts were encouraged to drop the class and retake it after first taking a class in remedial math.

Should students be allowed to use calculators on the assessment or not? While most faculty allow students to use calculators in their classes, it was decided that we wanted to know whether or not a student could answer the questions on the assessment without a calculator. What we wanted to know was not whether students could come up with an answer to a problem, but if they knew correctly *how* to come up with an answer to a problem. We ensured that questions were easy enough and that students were given ample time.

The dataset contains Algebra I assessment results for each attempt by a student, subsequent class performance, and other student characteristics including gender, private or public schooling, country of origin, students' own self-reports of their math ability and their SAT Math scores.

3. Algebra I Assessment Results and Summary Statistics

Overall, 11.5% of the 1361 students failed the Algebra I prerequisite assessment. On average, it took students that passed the assessment 1.59 attempts to pass.[3] For those who passed the assessment, the median number of attempts to pass was 1.

Failure Rates and Number of Attempts Required to Pass the Algebra I Assessment

Table 2 shows the failure rate and number of attempts required to pass by student characteristic. We also tested to see if differences among groups were statistically significant.[4] On average, women took longer to pass the assessment than men did, significant at the 1% level, with no significant difference in failure rates. Students of Asian ethnicity had the lowest failure rate and needed fewer attempts to pass as compared to all other ethnicities, significant at the 1% level. Black students had the highest failure rate and required more attempts to pass compared to all other ethnicities, both significant at the 1% level. Students of Hispanic ethnicity had a high failure rate (significant at the 10% level) and were second only to Black students in terms of the average number of attempts needed to pass (significant at the 1% level) as compared to all other ethnicities. International students did not differ significantly in terms of the failure rate and number of attempts to pass in comparison to their US counterparts. Interestingly, students from

[3] Please note that these are attempts to pass, not number of assessment opportunities given. Though each student was given the opportunity to take the assessment 4 times, they were not required to take every assessment offered to them.

[4] Significant results are explained, tables are available upon request.

China had a lower failure rate (significant at 10% level) and a smaller average number of attempts to pass (significant at 1% level) in comparison to all other students. Students from private high schools took longer to pass the assessment (significant at the 5% level) with no significant differences in failure rate. Upper-classmen had a higher failure rate than lower-classmen although upper-classmen took on average fewer attempts to pass the assessment (both significant at the 1% level).

Table 2

Failure Rate and Average Number of Attempts to Pass

	Total	Share of Responses	Number That Failed	Percent That Failed	Number of Attempts to pass
All Students	1361	-	156	11.5%	1.59
Male	661	51.88%	40	6.05%	1.52
Female	613	48.12%	40	6.53%	1.62
Total	1274	100%	80	6.29%[5]	1.57
White	785	58.11%	84	10.70%	1.59
Asian	125	9.25%	5	4.00%	1.32
Black	68	5.03%	15	22.06%	1.96
Hispanic	105	7.77%	16	15.24%	1.81
International	173	12.81%	16	9.25%	1.36
Other[6]	95	7.03%	13	13.68%	1.61
Total	1351	100%	149	12.49%	1.61
Public High School	668	52.72%	44	6.59%	1.54
Private High School	599	47.28%	35	5.84%	1.60
Total	1267	100%	79	6.22%	1.57
Freshman	1,153	88.22%	107	9.28%	1.60
Sophomore	110	8.42%	24	21.82%	1.64
Junior	29	2.22%	9	31.03%	1.25
Senior	15	1.15%	4	26.67%	1.27
Total	1307	100%	144	22.20%	1.40

Student Performance on the Assessment Compared to Their Self-Assessment of Math Skills

We looked at the number of attempts it took a student to pass the assessment. Those who passed the assessment on the first attempt were classified as Performance Group 1 (PG1). Students who passed on their second attempt were classified as Performance Group 2 (PG2), and so on. Students who did not pass the assessment were classified as Performance Group 5 (PG5). The

[5] The reason that the failure rate for gender and public v private high school are so low is because of non-response. Of the 82 students who did not report their gender, 87.5% failed the assessment. This is similar for public and private high schools where the failure rate for students that did not respond was 82.11%.

[6] This is a category used by the university. Ten students did not provide this information.

distribution of students by Performance Group is given in Table 3. Students in PG 1 and 2 were considered to be the "top performers" on the assessment.

Table 3
Performance Group Distribution

Performance Group	Total in Group	Share
PG1 – passed on 1st attempt	662	48.6%
PG2 – passed on 2nd attempt	417	30.6%
PG3 – passed on 3rd attempt	81	6.0%
PG4 – passed on 4th attempt	45	3.3%
PG5 – did not pass	156	11.5%
Total Number of Observations	1,361	100.0%

We then compared how students actually performed compared with their perception of their own mathematical ability (Table 4). When taking the assessment, students were asked to rank their mathematical skill level on a scale from 0 to 10, with 10 indicating that the student perceived he or she had very strong math skills and 0 indicating a self-perceived lack of math skills. 92% of students responded. From Table 4, it is clear that those who performed poorly on the assessment in terms of failure rate or were in Performance Groups 3, 4 or 5, perceived that they had weaker math skills than those who passed.[7] It is also interesting to note that students in those performance groups generally perceived their math skills as slightly above average.

Table 4
Average Math Skills Pass/Fail and by Performance Group

	Number of Responses	Total Number of Students	Response Rate	Average Self-Assessment of Math Skills
Total	1265	1361	92.95%	6.74
Pass	1186	1205	98.42%	6.84
Fail	79	156	50.64%	5.19
PG1 – passed on 1st attempt	650	662	98.19%	7.34
PG2 – passed on 2nd attempt	411	417	98.56%	6.33
PG3 – passed on 3rd attempt	81	81	100.00%	5.92
PG4 – passed on 4th attempt	44	45	97.78%	5.64
PG5 – did not pass	79	156	50.64%	5.19

[7] Note that students in Performance Group 5 (who failed the assessment altogether) had a notably lower response rate to this question, which hinders interpretation for this specific group.

Student Performance on the Assessment Compared to Their GPA

We also compared how students actually performed on the assessment with their GPA for Fall 2012 (Table 5). On average, students who passed the assessment had a higher semester and cumulative GPA and those with higher mathematical skill levels (as measured by Performance Group) had a higher GPA. This gives additional validity to the value of the math assessment and our performance groupings.

Table 5

Average Term and Cumulative GPA

	Average Semester GPA	Average Cumulative GPA
Total for all 1361 students	3.08	3.09
Pass	3.12	3.13
Fail	2.75	2.78
PG1 – passed on 1st attempt	3.24	3.24
PG2 – passed on 2nd attempt	3.00	3.01
PG3 – passed on 3rd attempt	2.89	2.90
PG4 – passed on 4th attempt	2.85	2.89
PG5 – did not pass	2.75	2.78

4. Is there a Relationship Between Students' SAT Math Scores and Their Scores on the Algebra I Assessment?

Did we have to go to the trouble of creating, administering and analyzing an Algebra I Assessment when we could have used students' SAT Math scores as an indicator of students' math ability instead? The SAT Math covers four areas of mathematics, including arithmetic, algebra and functions, geometry, and data analysis. Given the similarity in the topic areas covered and the fact that we asked simpler questions on the Algebra I assessment, in theory, a student's SAT Math score should be able to predict the student's performance on the Algebra I assessment. However, basic analysis of average SAT Math scores by students' performance on the math assessment as shown in Table 6 leads us to believe that this may not be the case.

Table 6

Average SAT Math and First Algebra I Assessment scores[8]

			SAT Math		First Assessment	
	Total #	Share	Average Score	Low Score	Average Score	Low Score
Pass	908	89.90%	655.89	420	15.43	3.0
Fail	102	10.10%	601.27	440	10.37	1.0
Total	1010[9]	100%				
PG1 – passed on 1st attempt	515	50.99%	684.27	540	17.62	16.0
PG2 – passed on 2nd attempt	303	30.00%	629.57	470	13.06	4.5
PG3 – passed on 3rd attempt	60	5.94%	591.17	480	12.36	7.0
PG4 – passed on 4th attempt	30	2.97%	564.00	420	10.54	1.0
PG5 – did not pass	102	10.10%	601.28	440		
Total	1010	100%				

Although the average SAT Math score is higher for students that passed as compared to those that failed, the distribution of SAT Math scores of students who failed the assessment includes both high and low scores, as can be seen in the lower half of Figure 1. The lowest SAT Math score for students that failed the Algebra I assessment was higher (440) than for those that passed the assessment (420). The relationship between SAT Math scores and Algebra I assessment performance as gauged by Performance Groups is even less clear as shown in Figure 2. Students in PG5 (who failed the assessment) scored higher on average on the SAT Math test than students that were in PG3 and PG4 (who passed the assessment on the third and fourth tries).

Figure 1
SAT Math Score Distribution by Pass (Top) and Fail (Bottom)

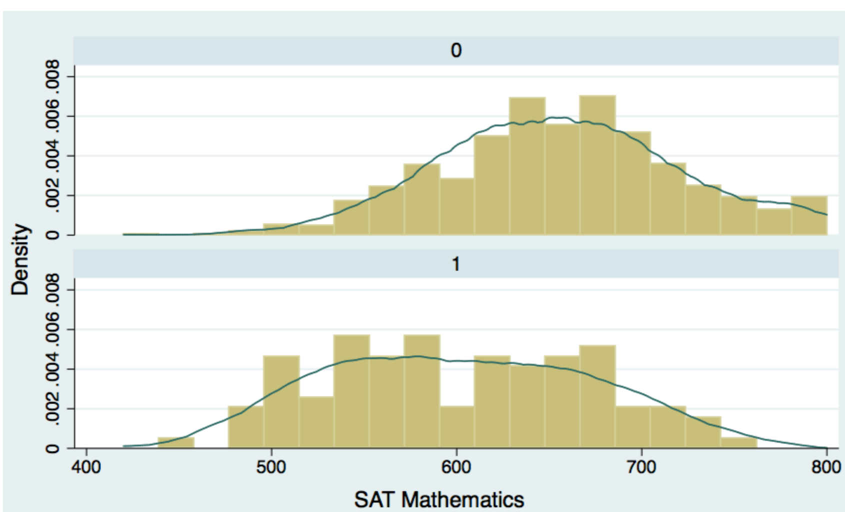
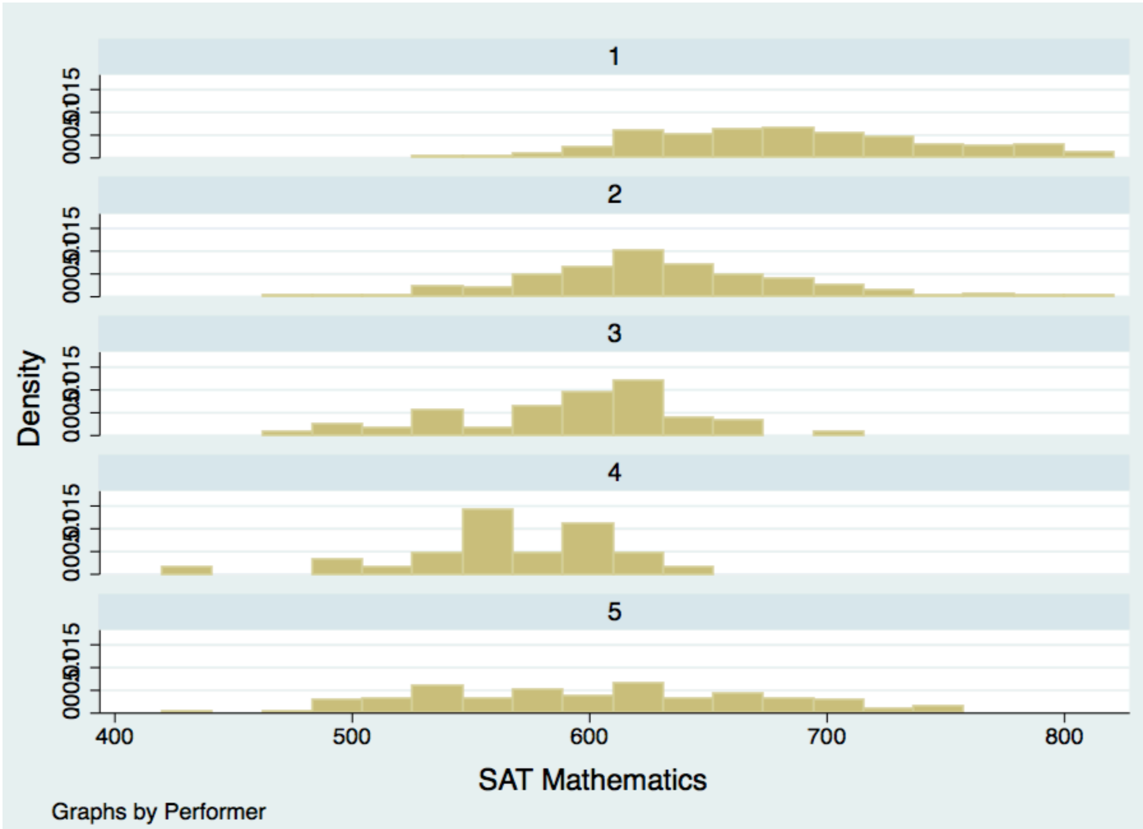


Figure 2

[8] A full table with scores by other student characteristics is given in Table 1 in the Appendix
[9] Only 1,010 students took the Assessment the first time it was administered.

SAT Math Score Distribution by Performance Group



To test if SAT Math scores have predictive power in determining a student's Algebra I assessment score, we estimated three regressions based on three different definitions of performance on the Algebra I assessment.

<u>Regression 1: Ordered Probit</u>
For the first regression, we defined a student's performance on the math assessment by their Performance Group, and estimated an ordered probit (as we have more than two outcomes of an ordinal dependent variable) of students' Performance Group on their SAT Math score. This allows us to use available information from each assessment attempt a student made to see how well SAT Math scores predict the overall performance of students on the Algebra I assessment.

The functional form of the model is as follows[10]:

$$PerformerGroup_i = \alpha + \beta SAT_i^M + \vartheta {SAT_i^M}^2 + \gamma Char_i + \varepsilon_i$$

Where $PerformerGroup_i$ is the Performance Group that student *i* belongs to, SAT_i^M is student *i*'s SAT Math score, ${SAT_i^M}^2$ is the square of the SAT Math score of student *i,* and $Char_i$ is a list of

[10] The model is specified with the SAT term squared because of potential decreasing return to the SAT Math score (which we found to be the case in the OLS regression). This can be seen clearly in Figure 1 in the Appendix which shows the relationship between the SAT Math score and the score on the first Algebra I assessment opportunity.

characteristics of student *i*, including gender, ethnicity, public or private high school, and year in college.

Table 2 in the Appendix shows the results of the ordered probit. We see that SAT Math is statistically significant at the 5% level. The predicted probabilities of being in a given Performance Group are given in Table 7 below for 5 different students: the student with the lowest SAT Math score, the student with the 10^{th} percentile SAT Math score, the student with the 1^{st} quartile SAT Math, the student with the median SAT Math score, and the student with the 3^{rd} quartile SAT Math, holding all other variables at the median. Students with the lowest SAT Math score have the highest probability of being in Performance Group 5 (failed the Algebra I assessment). Students with the 10^{th} percentile and 25^{th} percentile SAT Math scores have the highest probability of being in Performance Group 2 (passed the Algebra I assessment on the second attempt), and students with the median and 75^{th} percentile SAT Math scores have the highest probability of being in Performance Group 1 (passed the Algebra I assessment on the first attempt). Though this does follow the logical ranking we would expect, the fact that the student with the 10^{th} percentile SAT Math score has the highest probability of being in the 2^{nd} performance group indicates that SAT Math scores do not do a good job of predicting performance on the Algebra I assessment.

Table 7
Predicted Probability of Being in a Performance Group

SAT Math Score	Probability of being in PG1	Probability of being in PG2	Probability of being in PG3	Probability of being in PG4	Probability of being in PG5
Lowest (420)	0.11%	3.66%	5.61%	6.06%	84.62%
10th Percentile (570)	18.12%	46.28%	15.25%	7.41%	13.01%
Q1 (610)	33.65%	46.80%	10.17%	4.10%	5.28%
Median (650)	51.26%	39.26%	5.66%	1.90%	1.92%
Q3 (700)	70.85%	25.78%	2.27%	0.62%	0.48%

Regression 2: Probit

Our second analysis of the explanatory power of SAT Math scores in determining a students performance on the Algebra I assessment will be to estimate a probit regression of whether a student was classified as a top performer based on his or her SAT Math score. Even though the SAT Math does not predict a student's Performance Group with great accuracy, this will allow us to see if the SAT Math has more predictive power in determining those students who have the best math skills. The functional form is as follows:

$$TopPerformer_i = \alpha + \beta SAT_i^M + \vartheta SAT_i^{M\,2} + \gamma Char_i + \varepsilon_i$$

Where $TopPerformer_i$ is a dummy variable indicating whether student *i* passed on their first or second attempt at the Algebra I assessment, SAT_i^M is student *i*'s SAT Math score, $SAT_i^{M\,2}$ is the square of student *i*'s SAT Math score, and $Char_i$ is a list of characteristics of student *i*, including gender, ethnicity, public or private high school, and year in college.

Table 3 in the Appendix shows the results of the probit regression. Both SAT Math and SAT Math squared are statistically significant at the 1% and 5% levels. The predicted probabilities of passing on the 1st or 2nd assessment attempt are given in Table 8 below for 5 different students: the student with the lowest SAT Math score, the 10th percentile SAT Math score, the first quartile SAT Math score, the median SAT Math score, and the third quartile SAT Math score, holding all other variables at the median. The last column of Table 8 includes information on how an increase of 10 points on students' SAT Math score is predicted to improve the student's probability of passing on the first or second assessment attempt. The results imply that for the student with the lowest SAT Math score of 420, the predicted probability of passing on the 1st or 2nd attempt is 0.12%. Improving the SAT Math score of this student by 10 points is predicted to increase the probability of passing on the 1st or 2nd assessment attempt by 0.13 percentage points, meaning that this student would have a 0.25% chance of passing the assessment on the 1st or 2nd attempt. The student with the 10th percentile SAT Math score is predicted to have a 45% chance of passing the assessment. Increasing the SAT Math score of this student by 10 points is predicted to increase the probability of passing by 6.04 percentage points, implying that the student would have a 51.15% chance of passing on the 1st or 2nd attempt. That the student with the lowest SAT Math score has such a small change in the probability of passing due to a 10 point increase in the SAT Math and that the student with the 10th percentile SAT Math score has such a high probability of passing again implies that the SAT Math score does not have much predictive power in determining a students performance on the Algebra I assessment.

Table 8
Predicted Probability of Passing on the 1st or 2nd Assessment Attempt

	SAT Math Score	Probability of Passing	Percentage point increase in probability of passing after 10 point increase in SAT Math score
Lowest Score	420	0.12%	0.13% point
10th Percentile	570	45.11%	6.04% point
Q1	610	67.42%	4.54% point
Median	650	82.63%	2.65% point
Q3	700	92.35%	1.11% point

Regression 3: OLS

Our last analysis of the explanatory power of SAT Math scores in determining a student's performance on the Algebra I assessment will be to estimate an OLS regression of a student's performance on the first assessment based on his or her SAT Math score. We estimate the following functional form:

$$Score_i = \alpha + \beta SAT_i^M + \vartheta SAT_i^{M\,2} + \gamma Char_i + \varepsilon_i$$

Where $Score_i$ is the assessment score of student *i*, SAT_i^M is the SAT Math score of student *i*, $SAT_i^{M\,2}$ is the square of student *i*'s SAT Math score, and $Char_i$ is a list of characteristics of student *i*, including gender, ethnicity, public or private high school, and year of college.

Results of the OLS regression analysis can be found in Table 4 in the Appendix. Both the SAT Math and SAT Math squared are statistically significant at the 1% level. On average, students of Asian ethnicity are predicted to score 0.6 points higher on the 1st assessment than students of White ethnicity (significant at the 5% level). Students of Hispanic ethnicity are predicted to score on average 0.6 points lower on the 1st assessment than students of White ethnicity (significant at the 5% level). Somewhat surprisingly, students that went to private school are predicted to score on average 0.29 points lower on the 1st assessment than students that go to public school (significant at the 5% level). The adjusted R squared is 0.4, implying that the regression can explain 40% of the variation in students' Algebra I assessment scores.

In Table 9 below we calculate the predicted Algebra I assessment score for the student with the lowest SAT Math score (420), the student with the 1st quartile score (570), and the student with the median SAT Math score (650), holding all other variables at the median. We then calculate the predicted increase in the Algebra I assessment score given a 10 point and 100 point increase in the SAT Math score of these two students.

The student with the lowest SAT Math score is predicted to score a 5.57 out of 20 (or 27.85%) on the Algebra I assessment. A 10-point (or 1.25% out of 800 points) increase in the SAT Math for this student is predicted to increase the Algebra I assessment score of this student by 0.62 points (or 3.1% out of 20 points). The student with the median SAT Math score is predicted to score a 15.79 out of 20 (or 78.95%) on the Algebra I assessment. A 10-point increase (or 1.25% out of 800 points) in the SAT Math for this student is predicted to increase the Algebra I assessment score by 0.25 points (or 1.25% out of 20 points). These results imply that the SAT Math has explanatory power in determining the Algebra I assessment score of the first assessment.

Table 9

Predicted Algebra I Assessment Score Based on SAT Math Score

	Predicted Algebra I Assessment Score out of 20 points (% score in parenthesis)	Increase SAT Math score by 10 points (% point increase in parenthesis)	Increase SAT Math score by 100 points (% point increase in parenthesis)
Low SAT Math Score (420)	5.57 (27.85%)	0.62 (3.1% point increase)	5.47 (27.35% point increase)
1st Quartile (570)	13.14 (65.7%)	0.38 (1.91% point increase)	3.09 (15.46% point increase)
Median SAT Math (650)	15.79 (78.95%)	0.25 (1.25% point increase)	1.81 (9.05% point increase)

From the three regression results above, while the SAT Math does have some explanatory power in determining student performance on the first Algebra I assessment opportunity, it does not have a great deal of explanatory power in determining the performance of a student on the Algebra I assessment over all four attempts.

5. Predictive Power of the Algebra I Assessment and the SAT Math Test on the Final exam

That the SAT Math has little explanatory power in determining the overall Algebra I assessment performance of a student suggests that the SAT Math may have little explanatory power in predicting performance in Principles of Economics. To test whether this is the case, we analyze the predictive power of the SAT Math and performance on the Algebra I assessment in determining students' performance on the Principles of Economics cumulative final exam. To do this we will run a run an OLS regression of final exam scores on Algebra I assessment performance (as measured by Performance Group and score on the first Algebra I assessment opportunity), and SAT Math, controlling for a student's innate test-taking ability using SAT Verbal scores.[11] Since each professor teaches a different section and gives a different final exam, we include dummy variables and interaction dummy variables for each professor. The functional form will be as follows:

$$Final_i = \alpha + \sum_{j=1}^{4}\left(\rho_j PG_i^j\right) + \tau Score_i + \sigma Score_i^2 + \delta SAT_i^M + \psi SAT_i^{M\,2} + \sum_{j=1}^{4}\left(\sum_{z=2}^{3}\left(\alpha_z \Pr of_z + \rho_{jz} \Pr of_z * PG_i^j + \tau_z \Pr of_z * Score_i + \sigma_z \Pr of_z * Score_i^2 + \delta_z \Pr of_z * SAT_i^M + \psi_z \Pr of_z * SAT_i^{M\,2}\right)\right) + \gamma Char_i + \pi SAT_i^V + \varepsilon_i$$

Where $Final_i$ is student i's final exam score; PG_i^j is a dummy indicating if student i is in Performance Group j=1, 2, 3, or 4; $Score_i$ is the first assessment score of student i; $Score_i^2$ is the square of the first assessment score of student i; SAT_i^M is student i's SAT Math score; $SAT_i^{M\,2}$ is the square of the SAT Math score of student i; $Char_i$ is a list of characteristics of student i, including gender, ethnicity, public or private high school, and year in college, and SAT_i^V is student i's SAT Verbal score.

Results of this analysis can be found in Table 5 in the Appendix. One can see that students' performance on the Algebra I assessment, as measured by Performance Group, has a significant predicted impact on a students' final exam scores. Students in Performance Group 1 are predicted to score 12.12 percentage points higher than students that failed (significant at the 10% level). Students in Performance Group 2 are predicted to score 14.96 percentage points higher than students that failed (significant at the 5% level). Students in Performance Group 3 are predicted to score 11.59 percentage points higher than students that failed (significant at the 10% level). The performance of students in Performance Groups 4 and 5 are not predicted to be significantly different than each other. The overall Algebra I assessment score has a good deal of power to predict how well a student performs in the class.

The SAT Math, on the other hand, has very little explanatory power in determining a student's

[11] The effect of a student's SAT Math score on the final exam score may also include the effect of a student's natural test-taking ability. We control for natural test-taking ability using students' SAT Verbal scores. We include only the SAT Verbal as it has a similar multiple choice test format as the SAT Math.

final exam score. If a student's SAT Math score increases by 10 points, his or her final exam score is predicted to increase by .019 points. Though the impact is statistically significant, the extremely small magnitude implies little predicted effect of the SAT Math on a student's performance on final exam. The first Algebra I assessment opportunity also has little explanatory power in determining a student's final exam score. When the first Algebra I assessment score increases by 1 point, the final exam score is predicted to increase by one tenth of a point.

The innate test taking ability of a student, accounted for by use of SAT Verbal scores, is predicted to have a positive and significant impact on a student's final exam score. Freshman are predicted to score 4 points lower than all other students on the final exam. Students of Asian ethnicity are predicted to score 4 points lower on the final exam than students of White ethnicity. Students of "other" ethnicity are predicted to score 4 points higher on the final exam than students of white ethnicity.

These results suggest that in determining the necessary math skills needed for a student to perform well in Principles of Economics, the Algebra I assessment has better predictive power than the SAT Math test.

6. Conclusion

Controlling for a student's innate test-taking ability, scores on the SAT Math test have little predictive power in (1) determining a student's performance on an Algebra I assessment created specifically to test students on the basic math skills necessary for success in Principles of Economics and (2) determining a students performance in the final exam for a Principles of Economics class.

There are two possibilities why this might be the case. First, the Algebra I assessment did not allow for the use of a calculator, whereas the SAT Math test does. Two of the three professors (accounting for more than 80% of all students) in this study allow calculator use on their final exam. If the explanatory power of the Algebra I assessment is driven by the fact that students were not allowed to use a calculator and the lack of explanatory power of the SAT Math test is driven by the fact that students were allowed to use a calculator, then our results imply that demonstration of basic math skills without the use of a calculator is necessary for students' success in Principles courses. In Economics it may be important for students to have a general sense of numeracy, the ability to intuitively understand what they are calculating and why, and what a solution means. We may be able to capture some of these skills only when asking students to solve simple math problems without the use of a calculator. See the Addendum at the end of this paper for some exploratory results on the effect of calculator use on performance of students on the Algebra I assessment).

Second, the format of the SAT Math test is multiple choice, whereas the math assessment is not. Many students solve basic math multiple-choice questions by using potential answers and working backwards to find the solution. It is possible that the SAT Math test may not be testing students on the basic skills due to this format. As stated in Rebeck and Asarta (2012)," A correctly answered multiple-choice item is not always an accurate signal of student understanding as even the best quality multiple-choice item can be answered correctly by a student who knows nothing about the topic but guesses correctly…… But a carefully written free-response item can require both a correct answer (if one exists) and a response that reveals the reasoning that takes place when the student answers the item."

In either case, if the SAT Math test is testing students on the basic math skills needed for college, it may not be accurately capturing weaknesses in basic math skills crucial to students of economics. Interestingly, one of the added benefits was that the Algebra I assessment serves as a strong signal of the rigor of the course and sets early expectations of the time and effort that will be required to do well. Our experience shows that students are more motivated to learn the math (and therefore do better in the course) when the assessment score is a significant part of their grade in the course.

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Appendix:

Table 1
Average SAT Math and First Algebra I Assessment scores

			SAT Math		First Assessment	
	Total #	Share	Average Score	Low Score	Average Score	Low Score
Pass	908	89.90%	655.89	420	15.43	3.0
Fail	102	10.10%	601.27	440	10.37	1.0
Total	1010[12]	100%				
PG1 – passed on 1st attempt	515	50.99%	684.27	540	17.62	16.0
PG2 – passed on 2nd attempt	303	30.00%	629.57	470	13.06	4.5
PG3 – passed on 3rd attempt	60	5.94%	591.17	480	12.36	7.0
PG4 – passed on 4th attempt	30	2.97%	564.00	420	10.54	1.0
PG5 – did not pass	102	10.10%	601.28	440	10.37	1.0
Total	1010	100%				
Freshman	876	89.48%	650.24	420	15.16	2.0
Sophomore	75	7.66%	647.73	510	14.49	1.0
Junior	17	1.74%	668.24	490	16.26	8.0
Senior	11	1.12%	660.91	500	16.83	11.0
Total	979	100%				
Male	492	51.84%	660.63	420	15.40	1.0
Female	457	48.16%	643.11	480	14.86	3.0
Total	949	100%				
White	571	56.93%	644.03	480	15.06	2.0
Asian	103	10.27%	690.78	530	16.72	9.5
Black	43	4.29%	592.56	420	12.62	1.0
Hispanic	84	8.38%	613.1	470	13.75	4.5
International	149	14.86%	685.6	500	16.28	5.5
Other	53	5.28%	649.62	440	14.77	5.0
Total	1003	100%				
Public High School	497	52.76%	657.57	420	15.33	1.0
Private High School	445	47.24%	646.73	490	14.93	3.0
Total	942	100%				

[12] Only 1,010 students took the Assessment the first time it was administered.

Figure 1
Nonlinear Relationship Between Students' SAT Math Scores and their Scores on the First Algebra I Assessment Opportunity

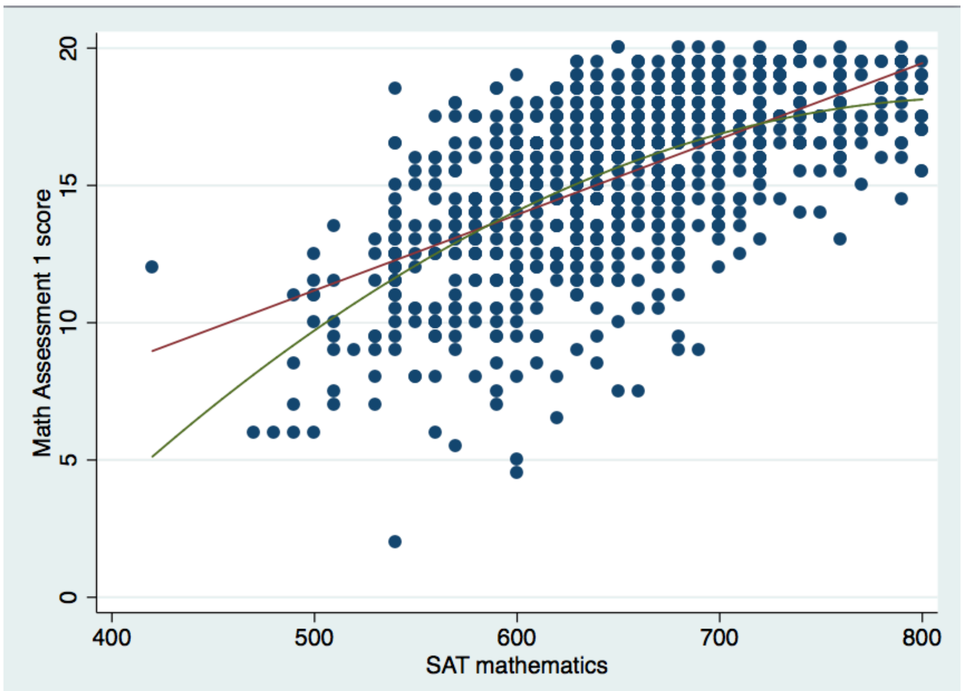

Table 2
Ordered Probit by Performance Group

VARIABLES	Performance Group
SAT Math	-0.0252**
	(0.0102)
SAT Math squared	1.10e-05
	(7.98e-06)
Gender	-0.0396
	(0.0844)
Private High School	0.0496
	(0.0833)
Freshman	-0.149
	(0.163)
Asian	-0.199
	(0.160)
Black	0.292
	(0.201)
Hispanic	0.133
	(0.129)
International	-0.155
	(0.128)
Other Ethnicity	-0.192
	(0.161)
Constant	-11.85***
	(3.231)
Constant	-10.57***
	(3.226)
Constant	-10.11***
	(3.224)
Constant	-9.813***
	(3.223)
Observations	881
Robust standard errors in parentheses	*** p<0.01, ** p<0.05, * p<0.1

Table 3
Probit Top Performer

VARIABLES	Top Performer
SAT Mathematics	0.0461***
	(0.0159)
SAT Math squared	-2.69e-05**
	(1.27e-05)
Gender	-0.0661
	(0.126)
Private High School	0.0287
	(0.124)
Freshman	0.356*
	(0.200)
Asian	-0.0889
	(0.224)
Black	-0.365
	(0.263)
Hispanic	0.174
	(0.223)
International	0.357
	(0.229)
Other Ethnicity	0.519
	(0.350)
Constant	-17.66***
	(4.975)
Observations	881
Robust standard errors in parenthesis	*** p<0.01, ** p<0.05, * p<0.1

Table 4
OLS Score on First Algebra 1 Assessment Opportunity

VARIABLES	Score on assessment given Aug 30-31
SAT Mathematics	0.130***
	(0.0198)
SAT Math squared	-8.00e-05***
	(1.49e-05)
Gender	-0.110
	(0.167)
Private High School	-0.289*
	(0.174)
Freshman	0.0848
	(0.304)
Asian	0.621***
	(0.228)
Black	-0.125
	(0.458)
Hispanic	-0.594*
	(0.324)
International	0.367
	(0.250)
Other Ethnicity	0.230
	(0.377)
Constant	-35.14***
	(6.586)
Observations	881
Adjusted R-squared	0.402
Robust standard errors in parentheses	*** p<0.01, ** p<0.05, * p<0.1

Table 5
Predictive Power of Performance on Algebra I Assessment and SAT Math

VARIABLES	Final Exam Score (% points)
Performance Group 1	12.12*
	(7.023)
Performance Group 2	14.96**
	(6.814)
Performance Group 3	11.59*
	(7.030)
Performance Group 4	12.41
	(7.691)
SAT Mathematics	-0.205
	(0.128)
SAT Math squared	0.000190**
	(9.59e-05)
Score on first Algebra I assessment opportunity	-2.136
	(1.722)
Score on first Algebra I assessment opportunity squared	0.119**
	(0.0591)
SAT Verbal	0.0289***
	(0.00750)
Professor 3	-106.2
	(102.0)
Interaction Performance Group 1 and Professor 2	-7.339
	(81.97)
Interaction Performance Group 2 and Professor 2	-10.09
	(82.28)
Interaction Performance Group 3 and Professor 2	-6.054
	(81.98)
Interaction Performance Group 4 and Professor 2	-15.06
	(80.53)
Interaction term Professor 2 and SAT Math Score	0.0323
	(0.244)
Interaction term Professor 2 and SAT Math Score Squared	-3.74e-05
	(0.000179)
Interaction Performance Group 1 and Professor 3	-6.932
	(9.908)
Interaction Performance Group 2 and Professor 3	-13.28
	(8.822)

Interaction Performance Group 3 and Professor 3	-8.176
	(9.186)
Interaction Performance Group 4 and Professor 3	-11.19
	(10.06)
Interaction term Professor 3 and SAT Math Score	0.436
	(0.327)
Interaction term Professor 3 and SAT Math Score Squared	-0.000345
	(0.000246)
Interaction term Professor 2 and 1st assessment score	2.695
	(3.188)
Interaction term Professor 3 and 1st assessment score	-0.531
	(3.337)
Interaction term Professor 2 and 1st assessment score squared	-0.106
	(0.116)
Interaction term Professor 3 and 1st assessment score squared	-0.0141
	(0.129)
Gender	-1.043
	(0.941)
Private High School	-1.635
	(1.009)
Freshman	-4.271***
	-1.509
Asian	-4.391***
	(1.641)
Black	-2.82
	-2.446
Hispanic	0.0717
	-1.994
International	2.571
	-1.715
Other Ethnicity	4.802**
	-2.043
Constant	94.56**
	-41.13
Observations	751
Adjusted R-squared	0.296
Robust standard errors in parentheses	*** p<0.01, ** p<0.05, * p<0.1

Table 6

Average SAT Math, First Algebra I assessment, Final exam, and SAT verbal scores

			SAT Math		Assessment Aug 30-31		Final		SAT Verbal	
	Total #	**Share**	**Average**	**Low**	**Average**	**Low**	**Average**	**Minimum (excluding zero)**	**Average**	**Low**
Pass	908	0.90	655.89	420	15.43	3	68.09	25	639.98	410
Fail	102	0.10	601.27	440	10.37	1	48.62	19	628.33	440
Total	**1010**									
PG 1	515		684.27	540	17.62	16	71.13	34	641.28	410
PG 2	303		629.57	470	13.06	4.5	65.52	25	637.93	440
PG 3	60		591.17	480	12.36	7	62.45	28	637.65	500
PG 4	30		564	420	10.54	1	52.32	19	631.59	440
PG 5	102		601.28	440						
Total	**1010**									
Freshman	876	0.89	650.24	420	15.16	2	67.26	19	638.67	410
Sophomore	75	0.08	647.73	510	14.49	1	66.61	30	642.13	410
Junior	17	0.02	668.24	490	16.26	8	73.44	50.75	638.82	470
Senior	11	0.01	660.91	500	16.83	11	74.92	58.5	662.73	530
Total	**979**									
Male	492	0.52	660.63	420	15.4	1	67.92	19	640.53	410
Female	457	0.48	643.11	480	14.86	3	66.93	28.5	639.37	410
Total	**949**									
White	571	0.57	644.03	480	15.06	2	67.86	19	658.9	490
Asian	103	0.10	690.78	530	16.72	9.5	66.2	28.5	637.09	430
Black	43	0.04	592.56	420	12.62	1	59.73	35.5	608.6	490
Hispanic	84	0.08	613.1	470	13.75	4.5	64.5	28.5	636.19	470
International	149	0.15	685.6	500	16.28	5.5	69.31	30	561.74	410
Other	53	0.05	649.62	440	14.77	5	68.32	31.5	671.7	530
Total	**1003**									
Public	497	0.53	657.57	420	15.33	1	68.44	28.5	650.91	410
Private	445	0.47	646.73	490	14.93	3	66.49	19	627.26	410
Total	**942**									

<u>Addendum</u>
Preliminary Results of the Effect of Calculator Use on Performance of students on the Algebra I Assessment

To explore whether the difference in predictive power of the Algebra I assessment and the SAT Math test might be due to calculator use, Principles of Economics students were allowed to take the Algebra I assessment with a calculator in the Spring of 2013. Students were allowed to use any calculator of their choice including TI-84s and TI-83s with many functional capabilities. The same instructor had students take a similar Algebra I assessment in the Spring of 2012 without the use of a calculator. Figures 1 and 2 below show the distributions scores on the 1st Algebra I assessment opportunity for the Spring of 2012 and 2013 as well as the kernel densities. Table 9 gives some summary statistics of students overall performance on the assessment in each year.

Figure 1

Spring 2012 *(green line-mean, black line-cutoff to pass the assessment)*

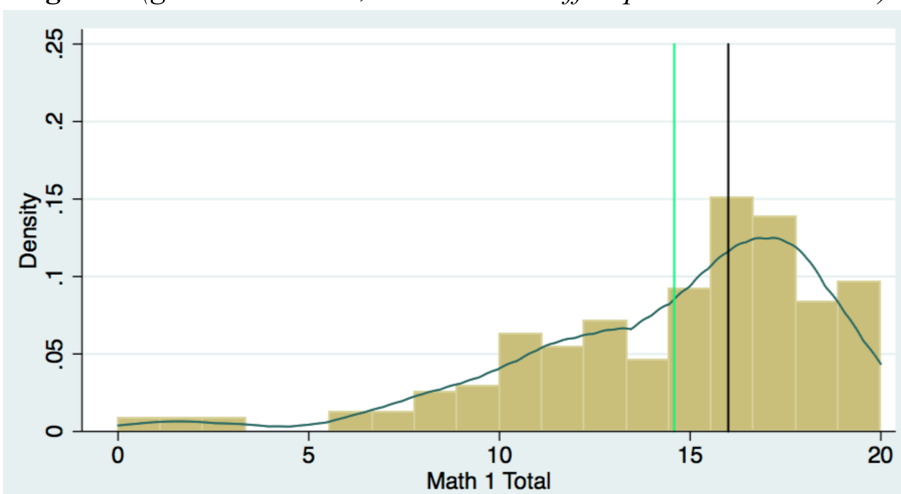

Figure 2

Spring 2013 *(green line-mean, black line-cutoff to pass the assessment)*

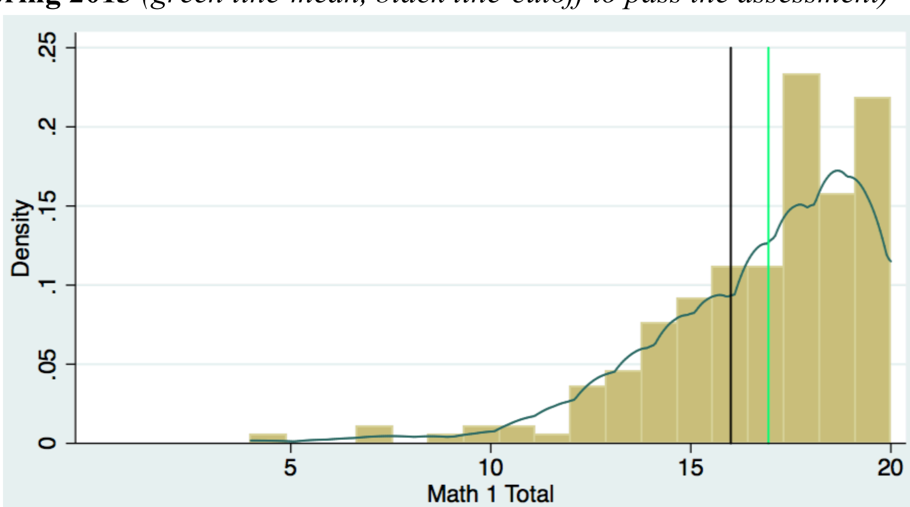

Table 1: Summary Statistics

Year	2012 (no calculators used)	2013 (calculators used)
Total number of students	242	248
Pass (%)	84.71%	87.50%
Fail (%)	15.29%	12.50%
Performance Group 1 (%)	52.89%	69.76%
Performance Group 2 (%)	23.97%	10.08%
Performance Group 3 (%)	7.44%	6.45%
Performance Group 4 (%)	0.41%	1.21%
Performance Group 5 (%)	15.29%	12.50%
Average Number of Times to Pass	1.47	1.30

These results suggest that being able to use a calculator does significantly affect students' performance on the Algebra I assessment. Note that those students that passed the assessment on the first attempt with a calculator are not necessarily the students who pass on the 2nd attempt without calculator use. It is possible that students that would have failed or needed more than two attempts to learn the basic concepts tested passed on the 1st attempt when using a calculator. However, these results are only suggestive, as the assessments used were not exactly the same instruments in 2012 and 2013. We are planning a more comprehensive experimental analysis of these results in the coming year.