Final Project Paper

Quantitative analysis of student performance in Calculus I

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1 Abstract

Over 800 freshmen students entering in their first year at the University of Connecticut take the traditional Calculus I course offered in the department of Mathematics. This course focuses primarily on certain key topics such as limits, derivative, applications of derivatives and introduction to integral calculus. Grade data over the last seven years suggests that Calculus I has high number of students who receive a 'F' grade or a 'D' grade. There are other students who withdraw from this course with a letter grade 'W'. At the University these grades are clubbed together as 'DFW'. The 'DFW' rates for Calculus I over the last seven years has been steady at around 30%. The course is built on the foundation of basic concepts in Algebra, Geometry and Trigonometry. It is assumed at the University that students who take this course have the prerequisite knowledge of these fundamental concepts. Students' SAT and Advance Placement (AP) scores are used as a indicator to advice students on taking this course.

The goal of this article is to prove using quantitative analysis that SAT scores and AP scores are not a good predictor of student performance in Calculus I course.

2 Introduction

Department of Mathematics at the University of Connecticut offers traditional courses in differential (Calculus I) and integral (Calculus II) calculus for incoming freshmen every semester. These courses require the students to have a sound knowledge of precalculus material. Concepts in Algebra, Geometry and Trigonometry are the foundation for differential and integral calculus. Student grade data for the last seven years in the Calculus I course indicate that 30 % percent students get a 'F', 'D' or a 'W' in the course. This is indicative of very poor student performance in this course. High percentage of DFW rates transforms in students having to repeat this course several times. This in turn requires the department to use more resources to offer multiple sections of this course to accommodate for this high enrollment. This in turn translates to spending more money

on offering these course. It is there fore necessary to understand why students don't do well in this course so that a remedial action can be taken by the department. Entering freshmen undergo an advising session with their advisor. During this session the advisor has to recommend the students on picking courses for their first semester. Students who have their majors in the school of Engineering and CLAS (those who intend to pursue BS degree) require to take Calculus I and II. Typically it has been observed that the student advisor use SAT and AP scores to recommend students on taking Calculus I. The goal of this study is the to investigate if AP and SAT scores are a good predictors of students' performance in the Calculus I course. To conduct this study, the author has chosen to look at the sample of students from Fall 2012 who were enrolled in Calculus I course.

3 Research Questions

This study is motivatived by the following research questions.

- Is there statistically significant difference in student grades based on Gender and Major?
- Does AP and SAT scores predict the student performance in Pretest, Midterm 1 and Midterm 2 and this statistically significant?
- Does the Pretest predict student performance in Midterm 1 and Midterm 2 and is this statistically significant?.

4 Data Collection and Research Methodology

There are three parts to collecting data.

- Pretest data that is collected at the beginning of the semester.
- Midterm 1 and Midterm 2 data collected during the semester.
- Data obtained through university data base.

At the beginning of the semester a precalculus test was administered to all the students who were enrolled in Calculus I. This test quizzed the students on the basic concepts in algebra, arithmetic

and trigonometry. Scores on each of the equations were recorded. It is the authors' hypotheses that the pretest will be a better indicator of how students will do in their midterm 1 over and above SAT and AP scores. This will be tested during the analysis of the data.

During the semester there were two midterms which were administered to all the students enrolled in the course. The data from these exams has been recorded. The midterm 1 and midterm 2 assessed students understanding of concepts in calculus and how well the students to apply their precalculus skills to the material in calculus. Thus a detailed item analysis was performed over the semester to see if student performance could be predicted using the scores on questions which needed the students to use precalculus knowledge. This analysis is not presented in this article. Demographic data such as student gender, major, AP and SAT scores was obtained through the university data base. It is important to note that this data was not available for all students.

Once all the data was collected, linear and logistic regression analysis was used to determine the strength of correlation between the test scores and various categorical predictors such as gender and major and continuous predictors such as AP, SAT and pretest scores.

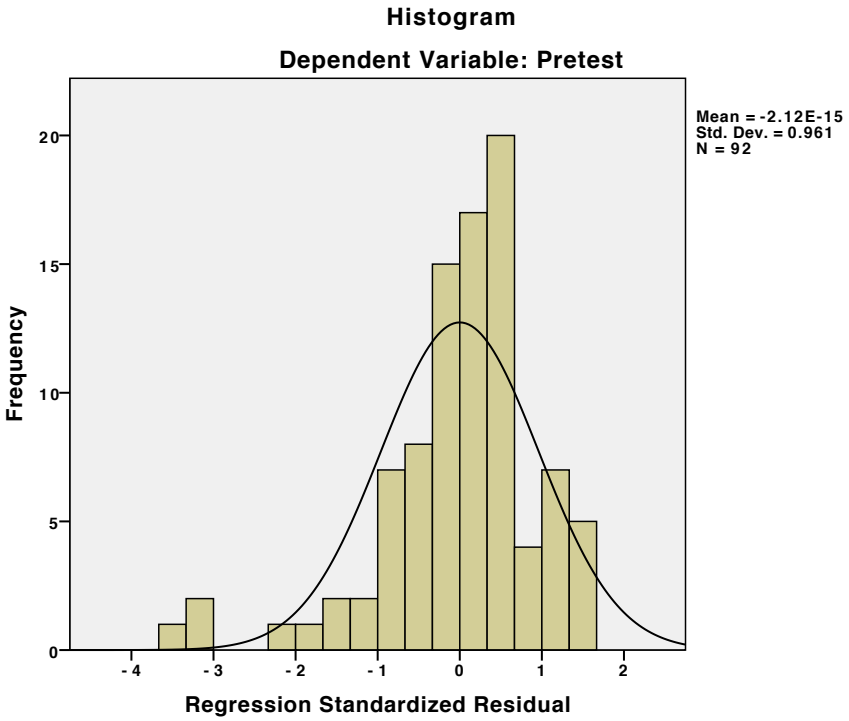
4.1 Data Mining and Regression Diagnostics

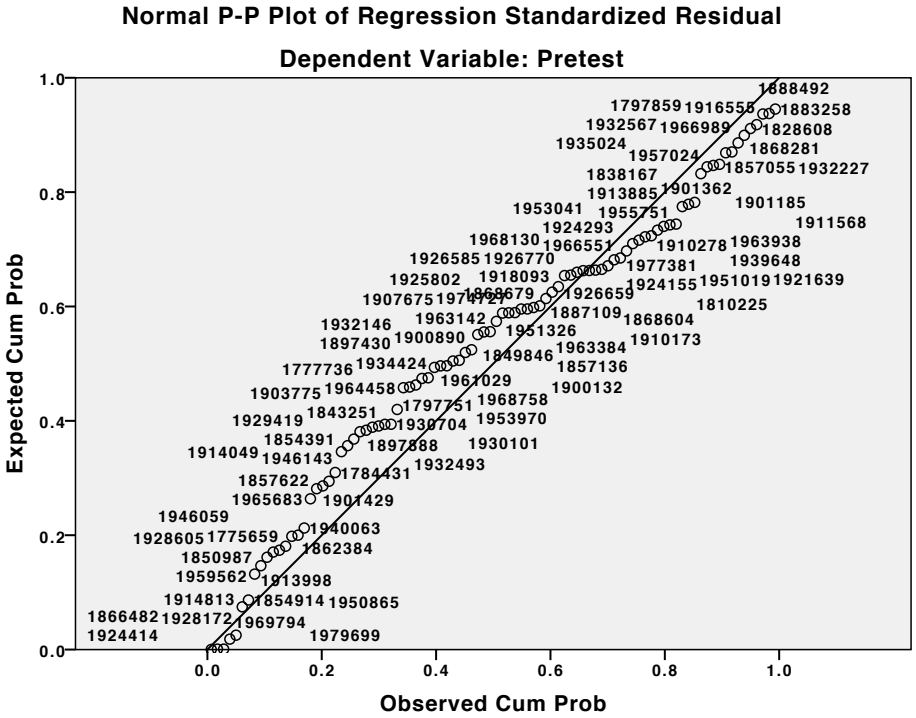
All the data was obtained in an Microsoft Excel format. There were four files which contained pretest, midterm1 midterm 2 and demographic data. These files were first opened in SPSS and then sorted in ascending order of the PSID. Once sorted, these files were merged to get a master data file. All the analysis was conducted on this master file.

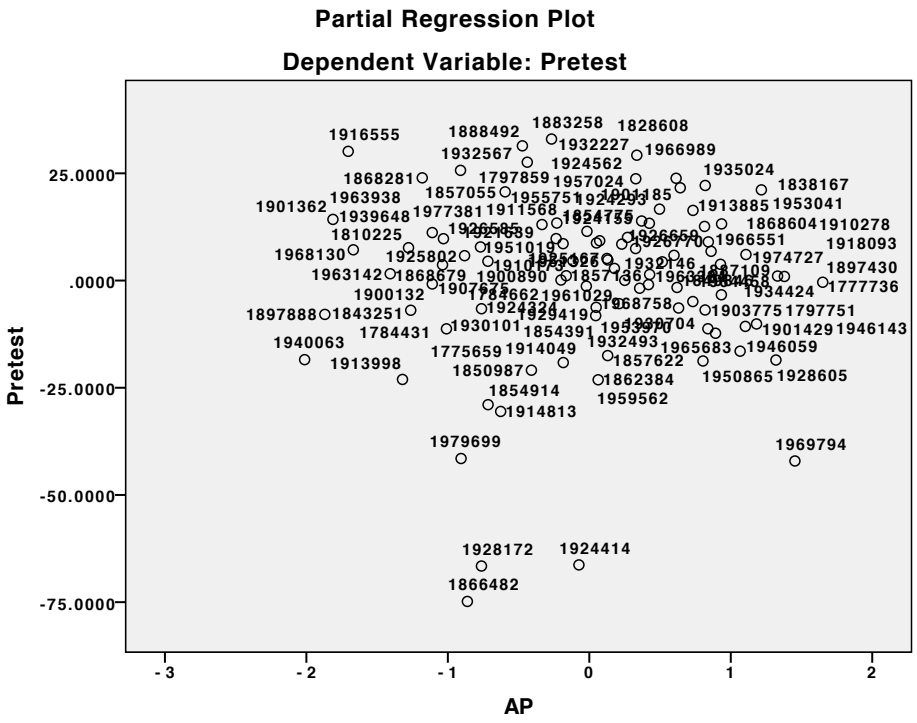
Merged data was carefully reviewed and discrepancies resolved before running the regression diagnostics. After looking at the data for majors it was decided that the majors will be clubbed together by school. Thus all engineering majors were coded as 1, all majors that fell under the CLAS were coded as 2, all other majors were coded as 3. Categorical predictors gender and major were then recoded using simple contrast for the purpose of regression analysis.

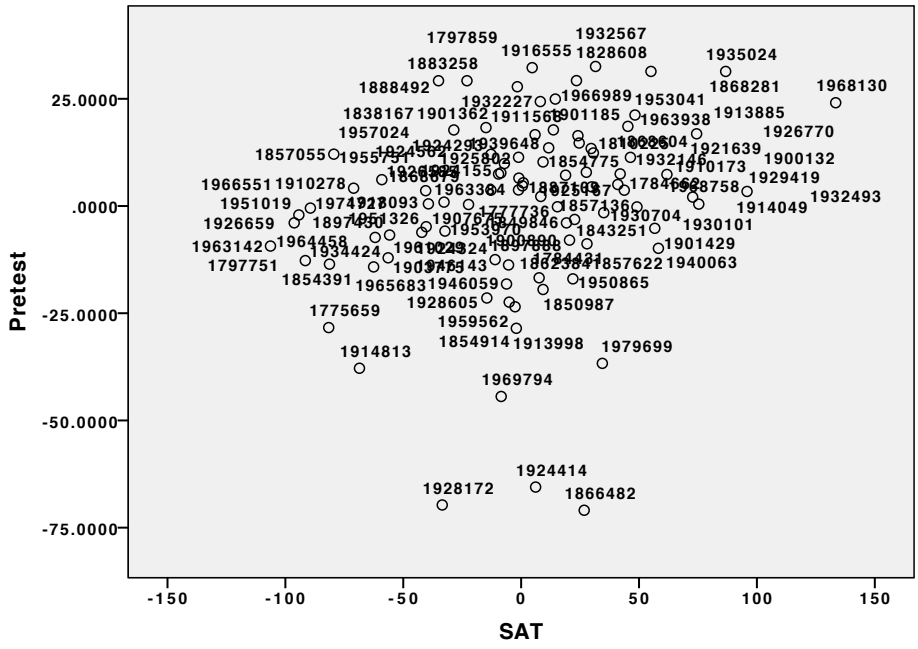
Below are the results from the regression diagnostics.

i) Scatter plots and Histogram.






Partial Regression Plot
Dependent Variable: Pretest
Pretest
AP
25.0000
.0000
-25.0000
-50.0000
-75.0000
-3
-2
-1
0
1
2
1916555
1888492
1883258
1828608
1932567
1932227
1966989
1924562
1935024
1868281
1797859
1957024
1838167
1857055
1963938
1901362
1939648
1977381
1911568
1913885
1953041
1810225
1966551
1918093
1968130
1925802
1974727
1897430
1963142
1868679
1900890
1777736
1900132
1934424
1897888
1843251
1784662
1961029
1903775
1797751
1784431
1930101
1854391
1901429
1946143
1940063
1775659
1914049
1932493
1965683
1946059
1913998
1857622
1850987
1862384
1950865
1928605
1854914
1959562
1914813
1979699
1969794
1928172
1924414
1866482


Partial Regression Plot
Dependent Variable: Pretest
Pretest
SAT
25.0000
.0000
-25.0000
-50.0000
-75.0000
-150
-100
-50
0
50
100
150
1797859
1932567
1916555
1828608
1935024
1883258
1888492
1868281
1968130
1966989
1932227
1953041
1838167
1901362
1913885
1957024
1926770
1857055
1921639
1900132
1966551
1910278
1929419
1951019
1914049
1932493
1926659
1930101
1963142
1964458
1901429
1797751
1854391
1965683
1946059
1950865
1940063
1775659
1928605
1850987
1959562
1854914
1913998
1979699
1914813
1969794
1924414
1928172
1866482

ii) Outlier Statistics

Outlier Statistics[a]

		Case Number	PSID	Statistic	Sig. F
Stud. Deleted Residual	1	266	1866482	-3.994	
	2	493	1924414	-3.494	
	3	522	1928172	-3.480	
	4	787	1969794	-2.302	
	5	830	1979699	-2.052	
	6	310	1883258	1.869	
	7	330	1888492	1.623	
	8	457	1916555	1.619	
	9	447	1914813	-1.544	
	10	207	1854914	-1.469	
Cook's Distance	1	310	1883258	.137	.997
	2	266	1866482	.112	.999
	3	787	1969794	.096	.999
	4	522	1928172	.085	1.000
	5	493	1924414	.079	1.000
	6	160	1838167	.067	1.000
	7	207	1854914	.039	1.000
	8	447	1914813	.038	1.000
	9	457	1916555	.033	1.000
	10	330	1888492	.032	1.000
Centered Leverage Value	1	160	1838167	.280	
	2	59	1777736	.236	
	3	310	1883258	.233	
	4	270	1867587	.199	
	5	769	1966384	.196	
	6	420	1910521	.168	
	7	602	1940290	.167	
	8	210	1855216	.163	
	9	780	1968130	.163	
	10	170	1840646	.151	

a. Dependent Variable: Pretest

The diagnostic analysis provided with PSID who looked like they are outliers. After further investigation of the data it was observed that these cases had missing data on AP and/or SAT scores. These cases were then excluded from analysis where AP and SAT scores were used as predictors of performance on Prestest.

5 Analysis and Conclusion

5.1 Analysis of Variance

At first Comparison of means (Analysis of Variance) was carried out to predict pretest and MTT (Midterm 1 plus Midterm 2) using categorical predictors as gender and Majors.

Descriptive Statistics

Dependent Variable:Pretest

Gender	Major	Mean	Std. Deviation	N
0	Engineering	74.786325	16.2227695	18
	CLAS	67.873303	24.5048423	51
	other	50.000000	25.7224813	12
	Total	66.761633	24.0754227	81
1	Engineering	72.307692	23.0801685	80
	CLAS	65.952081	20.5188621	61
	other	61.025641	21.5958277	45
	Total	67.493797	22.2694211	186
Total	Engineering	72.762951	21.9293956	98
	CLAS	66.826923	22.3381695	112
	other	58.704453	22.7370382	57
	Total	67.271680	22.7892307	267

Tests of Between-Subjects Effects

Dependent Variable:Pretest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8505.369[a]	5	1701.074	3.425	.005
Intercept	732880.871	1	732880.871	1475.468	.000
Gender	209.439	1	209.439	.422	.517
maj	7503.129	2	3751.565	7.553	.001
Gender * maj	1340.325	2	670.162	1.349	.261
Error	129641.474	261	496.711		
Total	1346449.70	267			
Corrected Total	138146.843	266			

a. R Squared = .062 (Adjusted R Squared = .044)

It can be seen from the table above that there is statistically significant difference in the pretest within the majors with a $F = 7.553$ and $p = 0.001$. The gender effect is statistically not significant with a $F = 0.422$ and $p = 0.517$. There is also no statistically significant interaction effect between the major and gender as seen by the $F = 1.349$ and $p = 0.261$.

Descriptive Statistics

Dependent Variable:mtt

Gender	Major	Mean	Std. Deviation	N
0	Engineering	165.3158	25.39915	19
	CLAS	151.2679	25.66461	56
	other	154.4762	26.38109	21
	Total	154.7500	26.06874	96
1	Engineering	160.1791	26.67761	67
	CLAS	154.5412	28.05078	85
	other	143.5833	30.95146	48
	Total	153.8000	28.87123	200
Total	Engineering	161.3140	26.34042	86
	CLAS	153.2411	27.08239	141
	other	146.8986	29.87186	69
	Total	154.1081	27.95241	296

Tests of Between-Subjects Effects

Dependent Variable:mtt

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10643.592[a]	5	2128.718	2.808	.017
Intercept	5214696.98	1	5214696.98	6878.579	.000
Gender	982.431	1	982.431	1.296	.256
maj	6111.096	2	3055.548	4.030	.019
Gender * maj	2239.654	2	1119.827	1.477	.230
Error	219850.949	290	758.107		
Total	7260290.00	296			
Corrected Total	230494.541	295			

a. R Squared = .046 (Adjusted R Squared = .030)

MTT is the total of midterm1 and midterm 2.

It can be seen from the table above that there is statistically significant difference in the total score on midterm1 and midterm 2 scores within the majors with a $F = 4.030$ and $p = 0.019$. The gender effect is statistically not significant with a $F = 1.296$ and $p = 0.256$. There is also no statistically significant interaction effect between the major and gender as seen by the $F = 1.477$ and $p = 0.230$.

5.2 Regression analysis with Categorical predictors

Simple contrast coding was used to code the categorical predictors. This is a 2 by 3 model. The males were coded as 1/2 and females were coded as -1/2. The reference cell is the cell female gender and 'others' as major.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.229[a]	.052	.042	24.5450960

Model Summary

Model	Change Statistics				
	R Square Change	F Change	df1	df2	Sig. F Change
1	.052	4.887	5	443	.000

a. Predictors: (Constant), int2, mj2, Gender, int1, mj1

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14720.394	5	2944.079	4.887	.000[a]
	Residual	266890.550	443	602.462		
	Total	281610.943	448			

a. Predictors: (Constant), int2, mj2, Gender, int1, mj1
b. Dependent Variable: Pretest

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	67.243	1.433		46.941	.000
	Gender	.902	2.865	.018	.315	.753
	mj1	12.278	3.612	.203	3.399	.001
	mj2	5.643	2.867	.098	1.969	.050
	int1	-9.584	7.224	-.078	-1.327	.185
	int2	-9.026	5.734	-.079	-1.574	.116

a. Dependent Variable: Pretest