Differential Impact in PLTL

Analyzing PLTL Data with Comparative Linear Regression

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It has been noted[1] that in one large study the positive impact of PLTL decreases as prior ability (as measured by GPA) increases. This has implications for not only the practice of PLTL but also research on PLTL: 1. arguing in favor of the type I model of PLTL - one in which PLTL sessions are a regular part of the course & all student are expected to attend; and 2: cautioning against research models which would select against students of lower prior achievement & introducing bias into their analysis.

This "differential" impact of PLTL is often comes up in discussions, but to my knowledge, has never been a focus of study. Differential impact can be seen in the study of of PLTL in Organic Chemistry by Wamser [2], Figure 1. Wamser examined the exam scores of students versus their prior cumulative GPA. I imagine, being a research chemist, he was inclined to plot the values and regression lines. Two things leap out - the PLTL line lies above the non-PLTL line. Furthermore, the slope of the PLTL line is smaller, and the lines appear to nearly intersect at high GPA values.

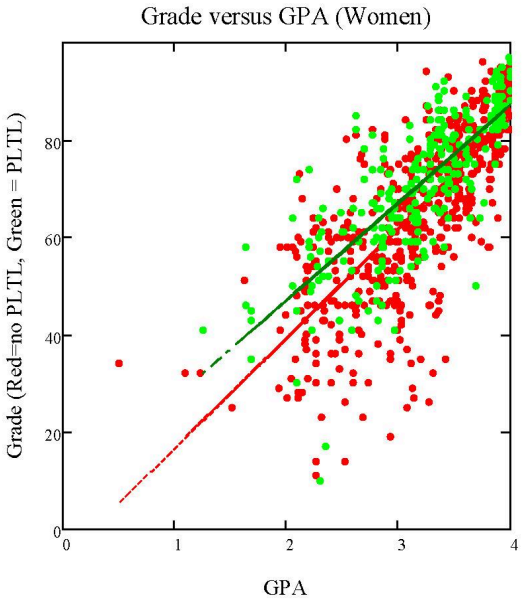

Figure 1. Exam score versus prior GPA

[1] Gosser, David. (2011) *The PLTL Boost: A Critical Review of Research*. Progressions, Summer
[2] Wamser, C. (2006) *Performance, Success, and Persistence in the Course. J. Chem. Educ. 83, 10, 1562*

What was interesting is, and went unmarked upon, is that in this same study a multilinear regression resulted in parallel lines, seemingly contradicting the graphical evidence. The reason for this is that in the basic multilinear model categorical data are differentiated by an intercept term & and assume identical slopes. This was discussed in the PLTL meta study[2] PLTL boost and in a monograph[3]. In the case of comparing lines Zar[4] has outlined a method with which one can can compare two lines[5], and in particular compare two y values at the same x value. This is of interest to us in exploring the difference in student performance across ability measures.

We take as the basis for our simulations the slope and intercepts[2] and added Gaussian noise commensurate with r^2 value found in the original data (sd = 12 pts) . Figure 1 show the data points, Figure 2 the data points and regression lines. Again, the differential impact is easily discerned.

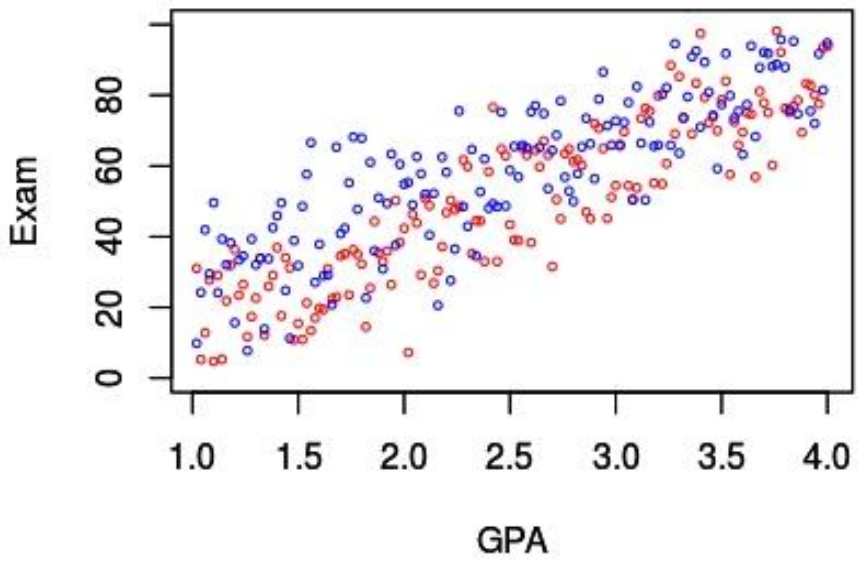

Figure 2. Scatterplot. No-PLTL = red, PLTL = blue.

[3] Gosser, D. (2015) *Peer-led Team Learning: Origins, Research, and Practice*. Linus Publications.
[4] Zar, J. (1984) Biostatistical Analysis.
[5] Non parallel lines can be accounted in multilinear regression by an interaction term, but the interpretation seems less direct than the method of Zar.

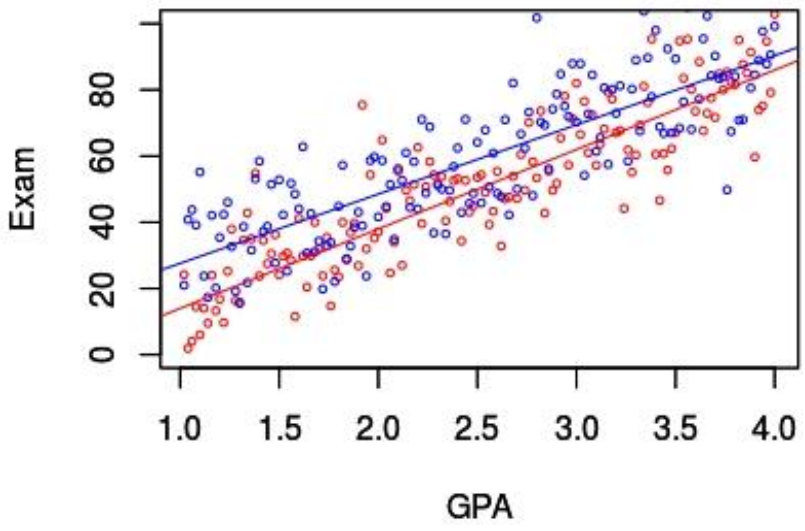

Figure 3. Scatter from Figure 2 with regression lines.

Following the method of Zar, we can calculate the t value to determine if two exam values (at a given GPA) are significantly different.

$$t = \frac{Y_1 - Y_2}{S_{Y1} - S_{Y2}}$$

Where the predicted Y_1 and Y_2 values (from separate linear regressions) for a particular value of x, and:

$$S_{Y1} - S_{Y2} = \sqrt{(S^2_{Y \bullet X}) * \left(\left(\frac{(X - X_1)^2}{\sum x_1^2}\right) + \frac{(X - X_2)^2}{\sum x_2^2}\right) + \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$$

$$S^2_{Y \bullet X} = \frac{Residual\ SS_1 + Residual\ SS_2}{DF_1 + DF_2}$$

Using the method of Zar, calculating the t value and determining the p values at gpa = 1 and gpa = 4.0 we find, in the analysis of our simulated data:

GPA = 1.0, $\Delta Exam = 9.5\ pts,$ p < 0.001
GPA = 4.0, $\Delta Exam = 5.4\ pts,$ p = 0.002

We find the differential improvement for GPA = 2.0 is nearly double that of GPA = 4.0. As expected, the p value decreases from high to low GPA as well.

βvalues reported by multilinear regression or anova programs can underestimate the impact of PLTL on students with lower prior achievement scores and overestimate the impact on higher scoring students.

By comparison, a simple t test of the two sets of exam scores results in p = 0.001.

It would be of great interest to see if the differential impact of PLTL found in this study is reproduced in other studies for which data is already available.

Statistical calculations were done using R, and appear in the supplementary material. An R tutorial can be found in this issue of Progressions (Fall, 2020).