STATISTICAL LITERACY ON REGRESSION ANALYSIS IN BRAZILIAN ECONOMICS COURSES: HOW ARE THINGS GOING?

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This research aims to analyze what Brazilian economics students know about regression analysis, based on the different types of knowledge/skills in statistical literacy proposed by Gal (2002). For this, we used one question of the main assessment instrument of Brazilian higher education: the National Exam for the Assessment of Student Performance. Skills using formulas and statistical algorithms were not the most important knowledge required to answer the question. Students needed to express an opinion using only results from hypothesis tests; students did not have requisite information to conduct the tests themselves. Given the low percentage of correct answers on this question, we hypothesize that the statistical literacy perspective has not been developed within the scope of Brazilian economics courses.

INTRODUCTION

Statistics is prominent in economics courses and is offered in a significant number of economics course modules. Within economics courses, the strong presence of regression analysis content in the curricula is indisputable. Yet, for a long time, studies have reported students' learning gaps in statistics (Angrist & Pischke, 2017; Arkes, 2020; Becker & Greene, 2001; Bekkerman, 2015; Kennedy, 1998; Sowey, 1983).

These studies point out that students find it difficult to understand regression models conceptually. The teaching/learning process of this content, in general, does not seem to be guided by the statistical skills expected of a 21st-century citizen. As a result, there seems to be little alignment with the vision of statistical literacy emphasized by Iddo Gal. This research aims to analyze what Brazilian economics students know about regression analysis, based on the different types of knowledge/skills in statistical literacy proposed by Gal (2002).

To this end, we analyzed students' achievement level for one question on the National Exam for the Assessment of Student Performance (Exame Nacional de Desempenho dos Estudantes–ENADE; Ministério da Educação, 2018). ENADE is the main Brazilian instrument for assessing and monitoring higher education learning. The exam assesses students according to the contents, competencies, and abilities outlined in the curricular guidelines for courses in higher education.

This study is part of a more extensive research project being developed for a PhD thesis within the scope of statistics education. The research is linked to the Postgraduate Program in Mathematics and Technological Education at the Federal University of Pernambuco.

STATISTICAL LITERACY

Due to the greater prominence of statistics in schools and universities, its teaching and learning began to appear as an object of research. Thus, relatively recently, the field of statistics education emerged as a field of study.

In the last few decades, one of the research paradigms animating discussions in this new field of studies is statistical literacy (SL). For Gal et al. (2020), statistical literacy "encompasses how people deal with the mathematical, quantitative and statistical demands of adult life, and is seen as an important outcome of schooling and as a fundamental skill for all adults" (p. 377).

Gal (2002) systematized an SL model that established conditions for an adult citizen's statistical literacy. The model is based on two interrelated components, cognitive and dispositional. The cognitive component includes the mathematical and statistical content necessary to understand data and information about the data provided. According to Gal's model, knowledge of mathematics and statistics content is not important by itself. On the contrary, knowledge and skills associated with the abilities to read and interpret information at different levels and in different formats are important, such as knowledge of the context and critical reading questions.

Yet, the second dispositional component is relevant for citizens to take an active stance and become more than mere consumers of information. The dispositional component adds three subjectively related elements: beliefs, critical stance, and actions. These elements denote how a subject's behavior

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affects their views of statistical information. At a subjective level, the SL behaviors that are socially constructed and agreed upon can be revealed.

METHOD

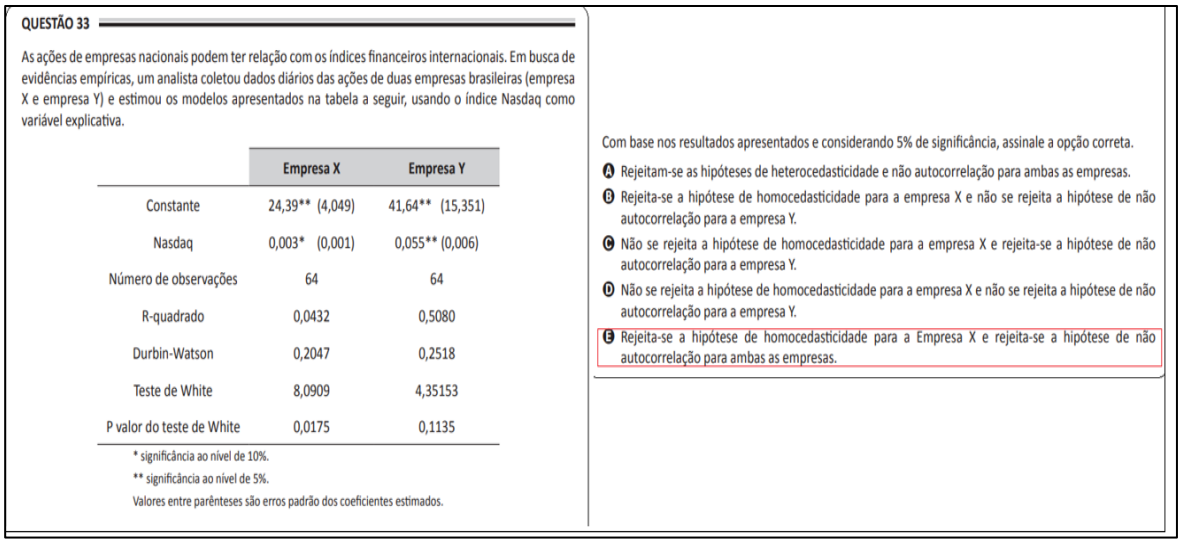
In the case of economics courses, the last ENADE for which data are available occurred in November 2018 (Ministério da Educação, 2018). The exam was administered to 9,580 students who expected to graduate by July 2019, with students distributed among 195 undergraduate economics courses from across Brazil.

For this paper, among the eight questions that involved statistics, we chose one question from this ENADE, question 33. This question was chosen because it had the lowest percentage of correct responses on the exam and thus can expose students' main types of difficulties in their learning of statistics. Students who obtained a score of zero in ENADE were excluded. Thus, responses from 7,764 students were left for investigation.

For analysis, we interpreted the SL skills required by the question and treated the statement and the distractors (incorrect answer choices that imply different types of reasoning) as an approximation of a given professional situation experienced by an economist. We used this to interpret the cognitive components of Gal's (2002) model required to answer the question. The methodological challenge was more significant for the dispositional component because it deals with subjective aspects. To identify elements for the dispositional component, we referenced already-known behavioral traits, which somewhat related to the narrative of the distractors. They represent an expectation of belief, attitude, or critical stance in the face of the (professional) situation revealed by the question.

RESULTS

The question (Figure 1) represented regression models in a financial market context. Specifically, the question reported an empirical investigation about a possible relationship between the stock price of national companies and international financial indices.



QUESTÃO 33

As ações de empresas nacionais podem ter relação com os índices financeiros internacionais. Em busca de evidências empíricas, um analista coletou dados diários das ações de duas empresas brasileiras (empresa X e empresa Y) e estimou os modelos apresentados na tabela a seguir, usando o índice Nasdaq como variável explicativa.

	Empresa X	Empresa Y
Constante	24,39** (4,049)	41,64** (15,351)
Nasdaq	0,003* (0,001)	0,055** (0,006)
Número de observações	64	64
R-quadrado	0,0432	0,5080
Durbin-Watson	0,2047	0,2518
Teste de White	8,0909	4,35153
P valor do teste de White	0,0175	0,1135

* significância ao nível de 10%.
** significância ao nível de 5%.
Valores entre parênteses são erros padrão dos coeficientes estimados.

Com base nos resultados apresentados e considerando 5% de significância, assinale a opção correta.

A Rejeitam-se as hipóteses de heterocedasticidade e não autocorrelação para ambas as empresas.
B Rejeita-se a hipótese de homocedasticidade para a empresa X e não se rejeita a hipótese de não autocorrelação para a empresa Y.
C Não se rejeita a hipótese de homocedasticidade para a empresa X e rejeita-se a hipótese de não autocorrelação para a empresa Y.
D Não se rejeita a hipótese de homocedasticidade para a empresa X e não se rejeita a hipótese de não autocorrelação para a empresa Y.
E Rejeita-se a hipótese de homocedasticidade para a Empresa X e rejeita-se a hipótese de não autocorrelação para ambas as empresas.

Figure 1. Question 33 from the 2018 ENADE

The main prompt for the question can be translated as follows: *The actions of national companies may be related to international financial indices. In search of empirical evidence, an analyst collected daily data on the actions of two Brazilian companies (company X and company Y) and estimated the models presented in the following table, using the NASDAQ as an explanatory variable.*

The prompt includes the following question stem: *Based on the results presented and considering a 5% significance level, select the correct option.* The correct answer and distractors are as follows.

A. *The hypotheses of heteroscedasticity and non-autocorrelation for both companies are rejected.*
B. *The hypothesis of homoscedasticity for company X is rejected and the hypothesis of non-autocorrelation for company Y is not rejected.*
C. *The hypothesis of homoscedasticity for company X is not rejected and the hypothesis of non-autocorrelation for company Y is rejected.*
D. *The hypothesis of homoscedasticity for company X is not rejected and the hypothesis of non-autocorrelation for company Y is not rejected.*
E. *The hypothesis of homoscedasticity for company X is rejected and the hypothesis of non-autocorrelation for both companies is rejected*.

To validate the assumption about a relationship between the stock price of national companies and international financial indices, the daily quotations for shares of companies X and Y and the index of an international stock exchange (NASDAQ) were investigated. The investigation narrative was based on the construction of a regression model for each company to assess the degree of dependence of the price of company shares on international indices. Furthermore, the quality of the models obtained was evaluated through the R^2 coefficient of determination, and results from three significance tests were presented: (a) test for the coefficients of the models; (b) test for the absence of error autocorrelation (Durbin-Watson test), and (c) test for the presence of homoscedasticity (White test).

All results were displayed in a two-way table. The correct answer and distractors referred exclusively to analysis of statistical significance for results from the Durbin-Watson (TDW) and White (TW) tests. By analyzing the distractors of the question, one can see that all refer to interpreting the results of hypothesis tests for two important theoretical assumptions related to the "errors" of a regression model: homoscedasticity and non-autocorrelation. Homoscedasticity guarantees that error in the relationship between the independent variables and the dependent variable is the same for all values of the independent variables, and autocorrelation checks whether those errors are independent. The assumptions of homoscedasticity and non-autocorrelation, therefore, represent the null hypotheses of the TW and TDW tests, respectively. Naturally, heteroscedasticity and autocorrelation are the alternative hypotheses.

According to the information in the question, only the model of company X did not present homoscedasticity (rejection of the null hypothesis), because its *p*-value (0.013) was lower than the established significance level (5%). As far as TDW is concerned, there is no display of *p*-values, only of test statistics. However, when those statistics are close to zero, there may be some indication of autocorrelation in the model. Hence, distractor E (highlighted in red in Figure 1) is the correct answer.

The SL skills involved in the professional situation represented by Question 33 are detailed below, according to the methodological strategy developed for this study.

- *Literacy Skills*: Interpretation of statistical significance based on hypothesis tests for certain theoretical assumptions of the regression models was required, based on information arranged in a two-way table.
- *Statistical Knowledge*: To correctly answer the question, students would need knowledge of linear regression models, homoscedasticity, autocorrelation of errors, hypothesis tests, significance level, and significance.
- *Mathematical Knowledge*: Students need skills related to basic operations with decimal numbers and percentages.
- *Context Knowledge*: Students need knowledge about financial markets. In particular, with financial globalization, the performance of stock exchanges becomes increasingly dependent on existing movements in markets in other countries. The NASDAQ exchange is an important North American stock exchange specialized mainly in listing large companies in the technology sector. It is the second largest stock exchange globally, second only, in market value, to the New York Stock Exchange.
- *Critical Questioning*: The estimated models for the two companies showed markedly different predictive quality. There was also no company profile information provided for company X and company Y (e.g., size, industry, revenue, etc.). Those factors make an adequate comparative analysis difficult. The possible lack of representativeness of the samples might also raise questions. The financial market is known to present intense variability, which requires a larger sample size for most investigations.

- *Dispositional Elements*: Regression models were constructed using under-representative samples. Furthermore, we noted the common practice of considering the coefficients of a model as significant based only on the *p*-value, without taking into account the magnitude of the effects suggested by these coefficients. This becomes clearer when the coefficient of the "NASDAQ" variable for company X is interpreted (0.003).

The distractors involved understanding the results of hypothesis tests considering the absence (or not) of autocorrelation and homoscedasticity in the estimated models. Probably due to this similarity, there was a relative balance between the three most chosen distractors (Table 1): "C" (24.91%); "D" (22.27%); and "B" (21.60%).

Table 1. Distribution of student responses—Question 33—ENADE, 2018

Position	Distractor	Frequency	Percentage
Correct Response	E	1,370	17.65
Errors	C	1,934	24.91
	D	1,729	22.27
	B	1,677	21.60
	A	951	12.25
Missing	-	103	1.33
TOTAL		7,764	100.00

Despite not having to perform calculations, students had a low general performance on the item. Only 17.65% of undergraduates answered the question correctly ("E"), which is a critical indication that most of the assessed students have difficulties with basic inferential concepts regarding hypothesis testing in linear regression models.

Why does this happen? There are several possible reasons. According to Becker and Greene (2001), both economics and other social sciences students (namely, administration and accounting) have difficulty with the probabilistic concepts involved in hypothesis tests, in addition to the application of statistical significance. According to the authors, there is a concern with the accuracy of the statistical result (significance), neglecting the magnitude of the suggested effects.

Furthermore, Batanero et al. (2017) recognize the difficulty of teaching regression, because the learning process is based on the simultaneous understanding of multiple statistical concepts. Thus, even if the algorithms for hypothesis tests are accessible at an elementary mathematical level, this does not necessarily imply conceptual understanding because it requires knowledge of sampling, variability, and probability distributions. According to Garfield et al. (2015), understanding how these concepts are articulated is at the heart of statistical learning at all levels of education.

CONCLUSION

This study aimed to analyze the Brazilian economics students' statistical learning of regression analysis from the perspective of Gal's (2002) statistical literacy model. For this, we used the most important large-scale exam to assess Brazilian higher learning, ENADE.

We found that the chosen question represented a professional scenario in which skills with formulas and statistical algorithms were not the most important knowledge required to answer the question correctly. The students needed to express an opinion on the results of the hypothesis tests related to given theoretical assumptions about regression model errors constructed in the context of the financial market.

It was possible to identify some critical questions for the item, notably related to the sample quality and the lack of comparability between the models built. In a way, those aspects are associated with "blind trust" in the econometric model, neglecting the quality of the sample used and other qualitative factors.

Although those dispositional elements are not directly linked to the student performance in the question, their existence was taken from a broader cultural perspective. In general terms, they probably reflect the teaching practices in Brazilian economics courses. Thus, the fact that less than 20% of the undergraduates were successful with answering the question indicates that those practices seem to be more technique-oriented than oriented towards solving economic problems.

This discussion shows it is urgent to adopt the statistical literacy perspective in the teaching process, which could provide Brazilian economists with the necessary skills for empirical work with data, one of their main professional demands.

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