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Differences in Results – Analysis of Mathematics Scores from Subsequent Academic Years

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***Abstract*—The paper provides results of long-term evolution of students' scores from the basic mathematics course at the University of Economics, Prague. Dataset used in this analysis contained information about 8964 students who took a course of Mathematics for Economists at the University of Economics, Prague in academic years 2013/2014–2017/2018. The results showed that students tend to score better in summer semester each year and there are differences between the scores from different academic years. These differences were observed for both, mid-term test scores and final test scores.**

Keywords—analysis of variance, linear regression, performance of students, results in mathematics

I. INTRODUCTION

Mathematics is one of the core courses in most of the Bachelor's degree programmes. The Department of Mathematics of the Faculty of Informatics and Statistics of the University of Economics, Prague is teaching one semester course of Mathematics for Economists for the students in different Bachelor's programmes of different faculties of the university. The aim of the course is to provide students with the basic knowledge of linear algebra and mathematical analysis. The content of the course is identical to the content of the textbook by Klůfa [5]. The evaluation of the course consists of a written mid-term test worth 20 points, a written final test worth 40 points and an oral exam worth 40 points. The points are then summed up and the final grade is determined based on the rules defined in Table I, which are common for all courses at the university. Each student has just one attempt to each part of the evaluation. However, if a student is classified by 4+ (Failed, eligible for retake), he/she can write the final test and participate in the oral exam once more.

TABLE I. GRADING RULES AT THE UNIVERSITY OF ECONOMICS, PRAGUE

Grade		Points
Excellent	1	90-100
Very good	2	75-89
Good	3	60-74
Failed, eligible for retake	4+	50-59
Failed	4	0-49

II. MOTIVATION AND GOAL

The introductory course of mathematics for economists underwent a major change in 2006. It was decided to reduce the course from two semesters to just one semester intensive course. Moreover, we decided not to use the old way of assessment, which composed of credit test and exam at the same time as well. In the first years after this change, students were writing just final exam test and underwent oral exam and the scores from both parts were combined for the determination of final grade.

However, in this setting, students were not motivated to study continuously throughout the semester and due to intensity of the course their results were poor. Hence, students themselves suggested in surveys to introduce some kind of testing or continuous assessment during the semester which would be part of the final evaluation and not just have an exam in the examination period. The solution of this situation was an introduction of the mid-term test score which students write when approximately 2/3 of the course material are covered. Students' results became far better after this change and the association between scores from the mid-term test scores and the final grades were discussed in [10].

Other factors that have major impact on performance of students were analysed by various authors, e.g., Ulrychová and Bílková [11] analysed the impact of gender on student's performance in mathematics; Kiwanuka et al. [2] analysed the impact of student's and classroom's characteristics on math self-confidence, perceived usefulness, and enjoyment of mathematics. Kolari, Savander-Ranne, and Viskari were interested in how students approach studying and which learning strategies they use [6]. Discussion how teacher qualities and course structure influence students' results is exposed in [1] and [13].

An extensive analysis was conducted by Ulrychová in [12], who analysed differences in mathematics results between students of University of Economics, Prague and students of the University of Finance and Administration in Prague. We analysed the differences between performance of students coming from different faculties of the University of Economics [8] and we also discussed the impact of exam date on the performance [9].

Several papers elaborate on the association of student's performance in mathematics and the way he/she was accepted to the degree programme, e.g. [3], [4].

The aim of this paper is to see whether any long-term trends in the performance of students can be observed, or whether each academic year is different. We analysed the mid-term test scores and final test scores from both semesters and from five consecutive academic years. This paper is an extension of our previous research, i.e., [8] and [9], where we only analysed scores from one academic year.

III. Data description

Data used in the analysis come from the students of the University of Economics, Prague, who took the course in the academic years 2013/2014, 2014/2015, 2015/2016, 2016/2017, 2017/2018. The scores from the mid-term test and the final test were used for this analysis and only first attempt to the final test exam was taken into consideration. In total, 8964 students from five faculties of the university (Faculty of Finance and Accounting – F1, Faculty of International Relations – F2, Faculty of Business Administration – F3, Faculty of Informatics and Statistics – F4, and Faculty of Economics – F5), took the course in the abovementioned academic years.

IV. Statistical methods and Software

Descriptive statistics were calculated for mid-term and final test scores for each year and semester. Boxplots were then generated to visualize these descriptive statistics.

A linear regression model was used to verify whether mid-term and final test scores differ across academic years. Hence, two regression models were fitted, one for the mid-term test score and one for the final test score. The score in both models was used as a dependent variable while semester, academic year and interaction between them were used as independent variables. Analysis of variance type III tests were used to assess whether test scores depend on these predictors. All tests were performed at 5% level of significance. More details about linear regression models and analysis of variance can be found in [7].

The statistical analyses were performed in statistical software R 3.5.2 and its packages.

V. Results

A. Descriptive Statistics

The descriptive statistics for the mid-term test and the final test are presented in Table II and Table III respectively, while Fig. 1 and Fig. 2 present boxplots for the two tests. It can be observed that students tend to score better in summer semester compared to winter semester and this phenomenon can be observed across all academic years and in both, final and mid-term test scores.

TABLE II. Descriptive Statistics for Mid-term Test Score by Semester and Academic Year

Academic Year	Semester	N	Mean	Std. Dev.	Min.	1st Quartile	Median	3rd Quartile	Max.
2013/2014	Winter	1318	12.45	5.14	0	9	13	16	20
	Summer	938	13.32	4.86	0	10	14	17	20
	Total	2256	12.81	5.04	0	9	14	17	20
2014/2015	Winter	1179	11.62	5.37	0	8	12	16	20
	Summer	803	12.75	5.09	0	9	13	17	20
	Total	1982	12.08	5.29	0	8	12	16	20
2015/2016	Winter	1168	11.19	5.46	0	7	12	16	20
	Summer	670	12.47	5.29	0	8	13	17	20
	Total	1838	11.66	5.43	0	8	12	16	20
2016/2017	Winter	853	11.89	5.45	0	8	12	16	20
	Summer	620	12.12	5.11	0	8	13	16	20
	Total	1473	11.99	5.31	0	8	12	16	20
2017/2018	Winter	814	11.96	5.50	0	8	13	16	20
	Summer	601	12.07	4.86	0	9	13	16	20
	Total	1415	12.01	5.24	0	8	13	16	20

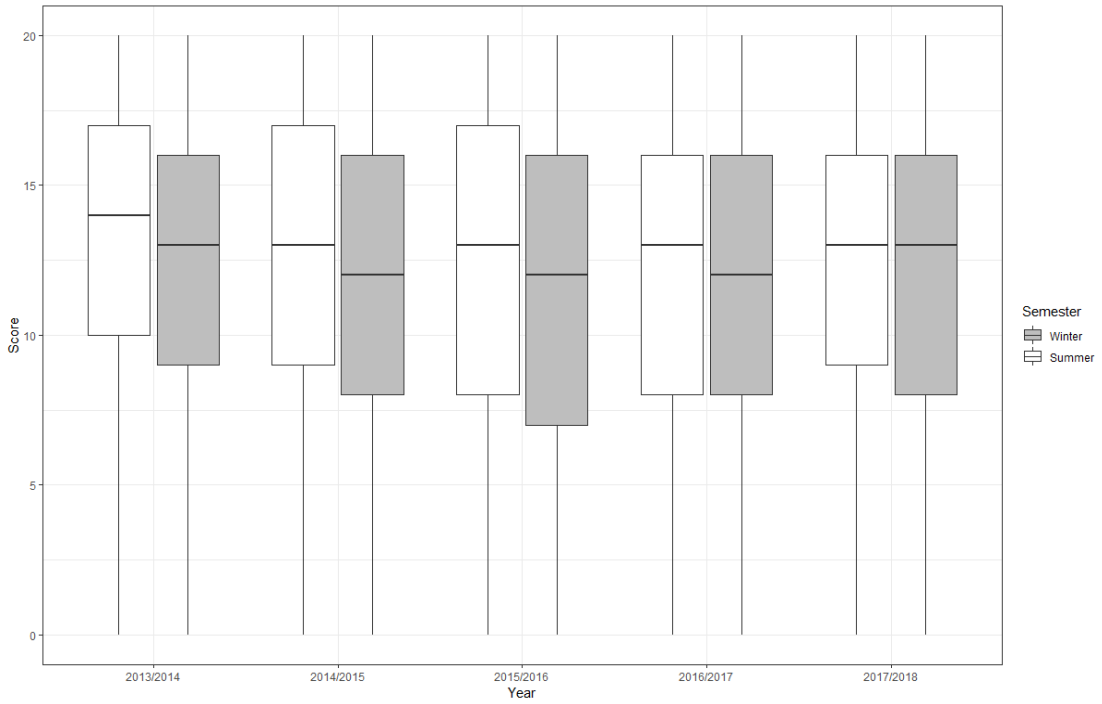

Fig. 1. : Boxplots for mid-term test score by semester and academic year

TABLE III. DESCRIPTIVE STATISTICS FOR FINAL TEST SCORE BY SEMESTER AND ACADEMIC YEAR

Academic Year	Semester	N	Mean	Std. Dev.	Min.	1st Quartile	Median	3rd Quartile	Max.
2013/2014	Winter	1318	24.28	10.19	0	17	25	32	40
	Summer	938	25.70	9.50	0	19	27	33.88	40
	Total	2256	24.87	9.93	0	18	26	33	40
2014/2015	Winter	1179	26.05	9.72	0	20	27	34	40
	Summer	803	27.83	8.80	0	22	29	35	40
	Total	1982	26.77	9.39	0	21	28	35	40
2015/2016	Winter	1168	24.91	9.61	0	19	26	32	40
	Summer	670	26.37	9.21	0	21	27	34	40
	Total	1838	25.44	9.49	0	20	26	33	40
2016/2017	Winter	853	24.78	10.22	0	18	26	33	40
	Summer	620	26.22	9.34	0	20	28	33	40
	Total	1473	25.39	9.88	0	19	27	33	40
2017/2018	Winter	814	24.07	9.94	0	18	25	32	40
	Summer	601	24.67	8.73	1	19	26	31	40
	Total	1415	24.33	9.45	0	18	25	32	40

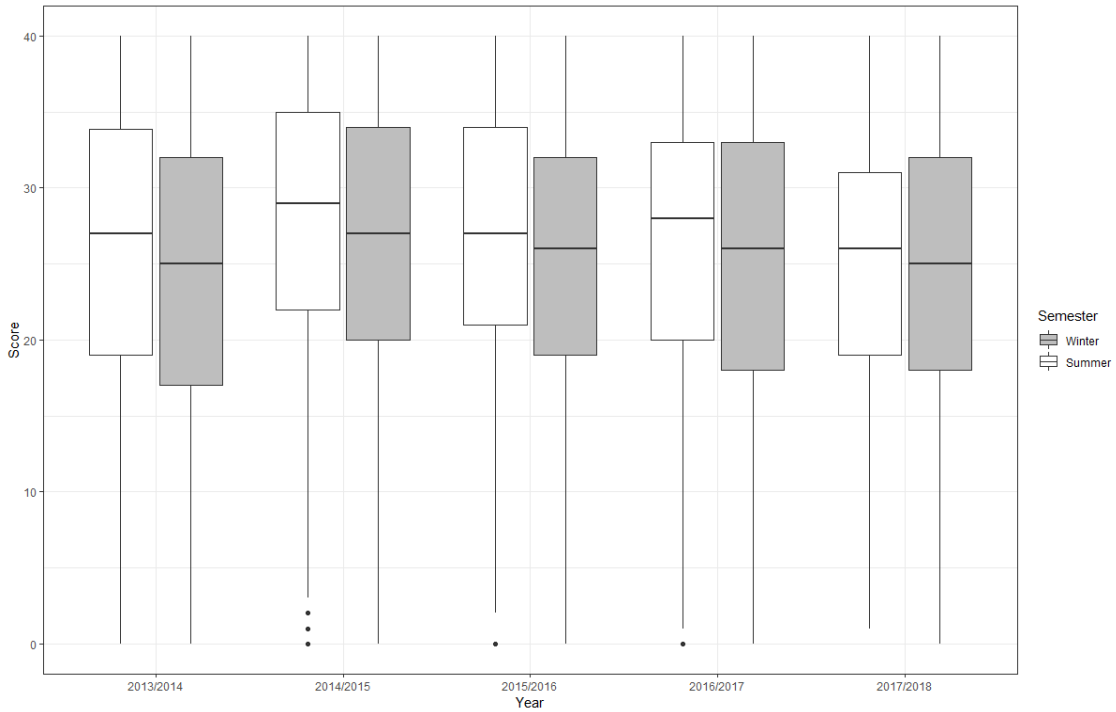

Fig. 2. Boxplots for final test score by semester and academic year

B. *Linear Regression Model*

Table IV shows the analysis of variance table from the linear regression model for mid-term test score and Table V shows the table for the final test score. Both tables present type III test results (F-statistics) and corresponding p-values. P-value smaller than 0.05 (5%) corresponds to significance of the factor, while p-value larger than 0.05 (5%) signifies that the factor is not statistically significant.

TABLE IV. ANOVA TABLE FOR MID-TERM TEST (TYPE III SUM OF SQUARES)

Source of variation	**Df**	**Sum of squares**	**F-statistic**	**P-value**
Academic Year	4	824	7.52	<0.0001
Semester	1	416	15.18	0.0001
Academic Year*Semester	4	431	3.93	0.0034
Errors	8954	245409		

TABLE V. ANOVA TABLE FOR FINAL TEST (TYPE III SUM OF SQUARES)

Source of variation	**Df**	**Sum of squares**	**F-statistic**	**P-value**
Academic Year	4	3777	10.21	<0.0001
Semester	1	1105	11.95	0.0006
Academic Year*Semester	4	292	0.79	0.5321
Errors	8954	827981		

VI. CONCLUSION

From the results it can be observed that students tend to score better in the summer semester than in winter semester in each academic year. This finding supports the conclusions from papers written in previous years [8], [9], which were based on data from one academic year only. Moreover, the effect of semester is statistically significant in both models (mid-term test score and final test score). A potential explanation of this phenomenon could be that students who take the course in the winter semester are in the first semester of their studies and therefore they are still getting used to the way of studying at the university. The other factor that might contribute to better scores of students in the summer semester is the fact that less students tend to take the course in that semester and hence there are less students in one lecture and the lecturer could interact more with them.

As the academic year turned out to be significant in both models, we can conclude that scores are different each year. However, the interaction between academic year and semester turned out to be significant only for the mid-term test score. This could be caused by the fact that different proportion of the course content was included in the mid-term test in different academic years and semesters, while the entire content of the course was always included in the final test in each academic year.

In conclusion, in this first long-term evaluation of differences between scores, we have shown that there are differences in mathematics scores in different academic

years and previously shown differences between semesters can be observed each year.

Extension of this paper is planned to be published, where we want to investigate long-term differences between scores of students from different faculties and long-term association between mid-term test scores, final-test scores and grades. Moreover, we would like to investigate other factors that can potentially influence performance of students.

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