RELATION BETWEEN UNIVERSITY STUDY RESULTS AND WAYS OF ACCEPTANCE STUDENTS

Jindřich Klůfa

Abstract

Relation between the study results in mathematics and ways of acceptance students at University of Economics in Prague is studied in present paper. The analysed data are the results of students in the basic course Mathematics for Economists at the Faculty of Informatics and Statistics in winter semester of the academic year 2019/2020. The applicants can be accepted to study at the Faculty of Informatics and Statistics on the basis of tests in mathematics and English, which are used at University of Economics, on the basis of excellent results in entrance examinations mock at the university, on the basis of the national comparative exams (the tests of general academic prerequisites), on the basis of excellent results in mathematics and English at grammar school and other way (excellent results in mathematical Olympiad etc.). Different methods of mathematical statistics were used for the analysis. Results of this paper can be used for improvement of the admission process at University of Economics in coming years.

Key words: Entrance examinations, course Mathematics for Economists, statistical methods.

JEL Code: C12, I21

Introduction

The basic course Mathematics for Economists (ident 4MM101) at University of Economics in Prague consists of linear algebra and mathematical analysis. Examinations in the course include mid-term test, final test and oral examination. These tests are standard tests, the multiple choice question tests (see e.g. (Klůfa, 2015b), (Klůfa, 2016)) in this course are not used. The number of points in the mid-term test can be in interval [0,20], the number of points in the final test can be in interval [0,40] and the number of points in the oral examination can be in interval [0,40] (see e.g. (Otavová and Sýkorová, 2016)). This course is mandatory for

the Faculty of Informatics and Statistics, Faculty of Finance and Accounting, Faculty of Business Administration and Faculty of International Relations.

The students can be accepted to study at the Faculty of Informatics and Statistics on the basis of tests in mathematics and English, which are used at University of Economics (denoted VSE tests) – see (Klůfa, 2015a), on the basis of excellent results in entrance examinations mock at the university (denoted EEM), on the basis of the national comparative exams - the tests of general academic prerequisites (denoted SCIO tests), on the basis of excellent results in mathematics and English at grammar school (denoted GrSch) and other way (excellent results in mathematical Olympiad etc.).

Relation between the study results in course Mathematics for Economists and the ways of acceptance students at the Faculty of Informatics and Statistics is studied in present paper. The same problem at the Faculty of Mathematics and Physics Charles University is studied in (Zvára and Anděl, 2001). Relationship between admission grades and academic achievement is also in (Sulphey et al., 2018). Similar problems are studied in (Kučera, Svatošová and Pelikán, 2015) - Czech University of Life Sciences, (He et al., 2015) - the Faculty of Medicine of Juntendo University, (Klůfa, 2015c), (Loster and Langhamrová, 2012), (Hrubý, 2016), (Klůfa, 2015d), (Kaspříková and Klůfa, 2011), (Ječmínek et al., 2018). Results of this paper can be used for improvement of the admission process at University of Economics in coming years.

1 Comparison the ways of acceptance students

The analysed data (the number of points in the final test in mathematics) are the results of 183 students in the basic course Mathematics for Economists at the Faculty of Informatics and Statistics in winter semester of the academic year 2019/2020. These data were sorted according to 5 ways of acceptance students. Basic descriptive statistics of distribution of the number of points in the final test in mathematics are in Table 1 (see also Figure 1).

1.1 Kruskal-Wallis test

Now we shall compare the ways of acceptance applicants to study Faculty of Informatics and Statistics. We shall test null hypothesis

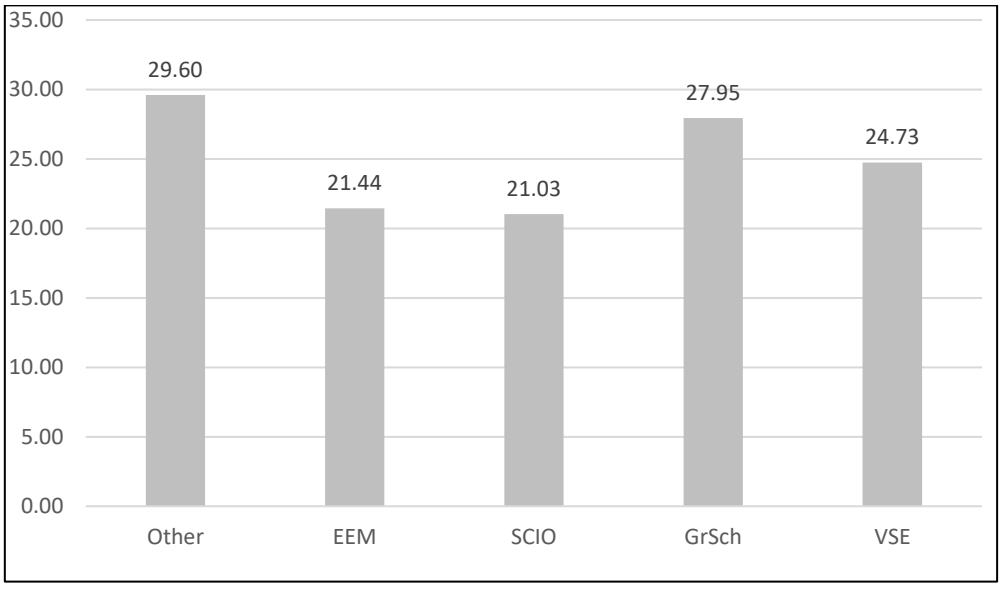
Ho: distribution of number of points in the final test in mathematics is the same for all ways of acceptance students

Tab. 1: Basic descriptive statistics for number of points in the final test in mathematics

Ways of acceptance	Other	EEM	SCIO	GrSch	VSE
Average number of points	29.6000	21.4444	21.0294	27.9474	24.7320
Median	29	22	23	30,5	27
Mode	Not specified	Not specified	29	38	28
Standard deviation	5.814	14.423	10.429	9.954	10.164
Variance	33.8000	208.0278	108.7567	99.0782	103.3024
$x_{max} - x_{min}$	13	40	36	33	39
x_{min}	23	0	3	7	1
x_{max}	36	40	39	40	40
Kurtosis	-2.6678	-1.4658	-1.0267	-1.1775	-0.4629
Skewness	0.0733	-0.0605	-0.2001	-0.4544	-0.5912
Sum	148	193	715	1026	2399
Frequency n_j	5	9	34	38	97

Source: own calculation

Fig. 1: Average number of points in the final test in mathematics in course 4MM101



Source: own construction

To verify the validity of the hypothesis we use Kruskal-Wallis nonparametric test. We use the statistic *H* as follows (see e.g. (Anděl, 1978))

$$H = \frac{12}{n(n+1)} \sum_{j=1}^{k} \frac{R_j^2}{n_j} - 3(n+1)$$

where *k* is the number of groups ($k = 5$), n_j is the size of the *j*th group (last row in the Tab. 1), *n* is the total sample size ($n = 183$) and R_j is the rank sum for the *j*th group (all 183 test points are ranked, the same values have an average rank). This statistic has asymptotically χ^2 distribution for $k - 1 = 4$ degrees of freedom. If

$$H > \chi_\alpha^2(k-1)$$

where $\chi_\alpha^2(k-1)$ is the critical value of χ^2 distribution for $(k-1)$ degrees of freedom, null hypothesis is rejected at significance level, which is approximately equal to α.

Tab. 2: Rank sum and rank average for the ways of acceptace students

Ways of acceptance	Frequency n_i	Rank sum R_j	Rank average $\bar{R}_j$
Other	5	571.5	114.300
EEM	9	728.5	80.9444
SCIO	34	2489	73.2059
GrSch	38	4143.5	109.0395
VSE	97	8910	91.8557

Source: own calculation

Using Table 2 we can calculate $H = 9.917$. The critical value of χ^2 distribution for 4 degrees of freedom and significance level 0.05 is $\chi_{0.05}^2(4) = 9.488$. Since

$$H > 9.488,$$

null hypothesis is rejected at significance level, which is approximately equal to 0.05. There are significant differences between the ways of acceptance students to study Faculty of Informatics and Statistics.

1.2 Nemenyi test

Since the Kruskal-Wallis test showed there is a significant difference between the ways of acceptance students, we use the Nemenyi test to determine which groups are significantly different. According to the Nemenyi test, the two rank averages (last column in the Tab. 2) are significantly different if

$$\left|\bar{R}_i - \bar{R}_j\right| > q_{crit}\sqrt{\left(\frac{1}{n_i}+\frac{1}{n_j}\right)\frac{n(n+1)}{24}} \qquad (1)$$

where q_{crit} is the critical value of Studentized range distribution for infinity degrees of freedom (for $\alpha = 0.05$ and $k = 5$ is $q_{crit} = 3.858$). Results of the multiple comparison are in Table 3.

Tab. 3: Nemenyi method

Ways of acceptance	Ways of acceptance	Difference $\left\|\bar{R}_i - \bar{R}_j\right\|$	Right hand of formula (1)	Significant difference
Other	EEM	33.36	80.60	NO
Other	SCIO	41.09	69.21	NO
Other	GrSch	5.26	68.75	NO
Other	VSE	22.44	66.27	NO
EEM	SCIO	7.74	54.17	NO
EEM	GrSch	28.10	53.57	NO
EEM	VSE	10.91	50.35	NO
SCIO	GrSch	35.83	34.11	YES
SCIO	VSE	18.65	28.80	NO
GrSch	VSE	17.18	27.66	NO

Source: own calculation

From Table 3 it is seen that a significant difference at 5% significant level is only between SCIO and GrSch. All other pairs of the rank averages are not significantly different.

Remark. Since the Bartlett's test for homogeneity of variances did not show any significant differences[1] between variances in Table 1 (see 6th row of Table 1), we can use for comparison the ways of acceptance students also ANOVA (Kruskal-Wallis nonparametric test is asymptotic test and frequency n_1 is only 5). We shall test null hypothesis Ho: mean number of points in the final test in mathematics is the same for all ways of acceptance students. The

[1] The Bartlett statistic (see e.g. (Anděl, 1978)) B=4.126 is less than $\chi^2_{0.05}(4) = 9.488$

results of ANOVA were obtained using MS Excel – see Table 4. Since $F = 2.520 > 2.442$, null hypothesis is rejected at 5% significance level (also at 4.3% significance level – see *p* value). The differences between average number of points in the final test in mathematics in Table 1 (see also Figure 1) are statistically significant. This result confirms the result of the Kruskal-Wallis test.

Tab. 4: Results of ANOVA

Source of variability	SS	Degrees of freedom	Fraction	*F*	*p* value	*F* crit
Between groups	1074.299	4	268.5748	2.519925	0.042865	2.42241
Within groups (residual)	18971.32	178	106.5804			
Sum	20045.62	182				

Source: own calculation

Conclusion

From results of this paper follows that the differences between average number of points in the final test in mathematics (see Figure 1) are statistically significant, i.e. there are significant differences between ways of acceptance students to study Faculty of Informatics and Statistics. But based on our data (the results of 183 students), we can only say that there is a significant difference between the results in mathematics of students which were admitted to study on the basis of SCIO tests and the results in mathematics of students which were admitted to study on the basis of excellent results in mathematics and English at grammar school (the results in math of students which were accepted to study on the basis of excellent results in mathematics and English at grammar school are better than the results in math of students which were admitted to study on the basis of SCIO tests). For a detailed analysis of admission methods to the Faculty of Informatics and Statistics, it will be useful to study the results of exams in other courses.

Acknowledgment

The paper was processed with contribution of long term support of scientific work on Faculty of Informatics and Statistics, University of Economics, Prague (IP 400040).

References

Anděl, J. (1978) *Matematická statistika*. Praha: SNTL/ALFA.

He, S.; Kempe, K.; Tomiki, Y.; Nishizuka, M.; Suzuki, T.; Dambara, T., Okada, T. (2015) Correlations between Entrance Examination Scores and Academic Performance Following Admission, *Juntendo Medical Journal*, pp. 1-7. https://doi.org/10.14789/jmj.61.142

Hrubý, M. (2016) Feedback improvement of question objects, *International Journal of Continuing Engineering Education and Lifelong Learning*, vol. 26, no 2, pp. 183–195. https://doi.org/10.1504/IJCEELL.2016.076010

Ječmínek, J., Kukalová, G., Moravec, L, Filipová. D. B. (2018) *Tax courses exams results at FEM CULS Prague evaluation, Efficiency and Responsibility in Education, Proceedings of the 15th International Conference*, Prague, pp. 132–139.

Kaspříková, N., Klůfa, J. (2011) *Calculation of LTPD single sampling plans for inspection by variables and its software implementation, The 5th International Days of Statistics and Economics*, Prague, pp. 266-276.

Klůfa, J. (2015a) *Analysis of entrance examinations, Efficiency and Responsibility in Education, Proceedings of the 12th International Conference*, Prague, pp. 250–256.

Klůfa, J. (2015b) Dependence of the Results of Entrance Examinations on Test Variants. *Procedia - Social and Behavioural Sciences*, vol. 174, pp. 3565-3571. http://dx.doi.org/10.1016/j.sbspro.2015.01.1073

Klůfa, J. (2015c) Comparison of the ways of acceptance students at university. *Journal on Efficiency and Responsibility in Education and Science*, vol. 8, no 3, pp. 72-76. https://doi.org/10.7160/eriesj.2015.080304

Klůfa, J. (2015d) Economic aspects of the LTPD single sampling inspection plans. *Agricultural Economics-Zemědělská ekonomika,* vol. 61, no 7, pp. 326-331. https://doi.org/10.17221/186/2014-AGRICECON

Klůfa, J. (2016) *Analysis of the differences between results of test variants, Efficiency and Responsibility in Education, Proceedings of the 13th International Conference*, Prague, pp. 279–285.

Kučera, P., Svatošová, L., Pelikán, M. (2015) *University study results as related to the admission exam results, Efficiency and Responsibility in Education, Proceedings of the 12th International Conference*, Prague, pp. 318–324.

Loster, T., Langhamrová, J. (2012) *Disparities between regions of the Czech Republic for non-business aspects of labour market, The 6th International Days of Statistics and Economics*, Prague, pp. 689-702.

Otavová, M., Sýkorová, I. (2016) Differences in results obtained by students of different faculties. *Journal on Efficiency and Responsibility in Education and Science*, vol. 9, no 1, pp. 1-6. DOI: 10.7160/eriesj.2016.090101

Sulphey, M.M, AlKahtani, N.S., Abdul Malik Syed, A.M. (2018) Relationship between admission grades and academic achievement, *Entrepreneurship and Sustainability Issues,* vol. 5, no. 3, pp. 648-658. http://doi.org/10.9770/jesi.2018.5.3(17)

Zvára, K., Anděl, J. (2001) Souvislost výsledku přijímacího řízení s úspěšností studia na MFF, *Pokroky matematiky, fyziky a astronomie*, vol. 46, no. 6, pp. 304-312. http://dml.cz/dmlcz/141097

Contact

Prof. RNDr. Jindřich Klůfa, CSc.
University of Economics in Prague,
Department of Mathematics,
W. Churchill Sq. 4, 13067 Prague 3
klufa@vse.cz