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GINI INDEX AS AN IRREGULARITY ANALYSIS TOOL OF STUDENTS' MARKS DISTRIBUTION IN A QUALITY ASSURANCE PROCESS AT UNIVERSITY

WSKAŹNIK GINIEGO JAKO NARZĘDZIE ANALIZY NIERÓWNOMIERNOŚCI ROZKŁADU OCEN STUDENTÓW W PROCESIE ZAPEWNIANIA JAKOŚCI KSZTAŁCENIA NA UCZELNI WYŻSZEJ

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Summary. The amended Law on Higher Education has forced universities to implement a number of pro-quality changes in the educational system, including building programs of study based on learning outcomes, determining the specific teaching methods, and specifying ways to assess the degree of student achievements. Universities are also obliged to build an internal system of quality assurance and improvement. This paper presents the results of the irregularities analysis in the students marks distribution using the Gini index (ratio) as a tool supporting this system. According to the authors, the use of this ratio can effectively help to identify those elements of the study program that may adversely affect its quality. In order to better illustrate the efficacy of this method, the Gini index was calculated and interpreted for distributions of student marks using example data from the USOS University of Economics in Wroclaw.

Key words: Gini index, analysis of inequality, student marks distribution, education quality.
Słowa kluczowe: wskaźnik Giniego, analiza nierównomierności, rozkład ocen, jakość kształcenia.

INTRODUCTION

The Act of 18 March 2011, which amended the Law on Higher Education, the Law on Academic Degrees and Titles and on Degrees and Title in Art, and certain other acts (Journal of Laws of 2005 No. 164, item. 1365 as amended), introduced a number of pro-quality changes in the development and evaluation of higher education programs. On the one hand, the amendment gave universities autonomy in developing degree programs, but on the other hand, imposed greater than ever responsibility for the quality of education. Under the new regulations, universities are obliged to include many new elements in the documentation of outcomes. The most important element seems to be a list of qualifications confirming that graduates have achieved specific learning outcomes in terms of knowledge, skills and social competence, in line with the National Qualifications Framework for Higher Education (KRK set out in a separate regulation – Rozporządzenie Ministra Nauki… 2011). This legislative framework refers

only to the academic aspect (including humanities, social sciences and engineering), leaving universities with great autonomy in designing their own programs and outcomes for specific fields of study conducted, individual subjects, and even certain thematic units (Saryusz-Wolski 2010).

In order to ensure proper functioning of the new solutions and to maintain high quality level of education, universities are obliged to develop and implement an internal quality assurance system for the analysis of learning outcomes. Such a system should, *inter alia,* clearly define the principles of students assessment, and with consistent implementation, should also enable effective control over the achievement of intended learning outcomes (Mirecka 2010).

An analysis of reports assessing the quality of education conducted by the Polish Accreditation Committee (PKA)[1] shows that the student assessment rules can be of particular concern to the Commission. In the course of their evaluation, the members of the Committee may examine, among other things, whether:

- there are procedures in place to analyze the degree of program implementation and results achieved by students,
- the departments are consistent in their analyses of the marks distribution and the learning outcomes achieved,
- the distribution of assessments in the investigation period is not uniform, in other words, if there are occurrences of over- or under-assessments.

In the effort to adjust to the evaluation criteria used by PKA, some universities have developed and implemented formal guidelines for conducting classes. They focus on the variation in student ratings (to follow a normal distribution), mainly through selection of adequate student assessment models, including methods for testing the knowledge of students and evaluating the results of this measurement.

The aim of this article is to look at the possibility of using the Gini index in the evaluation (grading) of students as a supporting tool of internal quality assurance system for higher education. To illustrate how the ration should be used by internal auditors responsible for the quality of university education, performance ratings achieved by students of the Faculty of Management, Information System and Finance (ZIF) at the University of Economics in Wroclaw in the academic year 2014/2015 were used.

The empirical research was preceded by:

- a study of literature and law, for changes to the education system in the national universities under the Bologna process,
- a review of reports from SAC with results of assessment of institutions and national universities from 2013–2015, in terms of uneven distributions of student grades and/or of evaluation of quality assurance systems implemented at these universities,
- a search for evidence in the internal documentation of sample universities that substantiates the need for diversification of student grades,
- an interview survey conducted with academic teachers (as a qualitative research method) regarding uneven distributions of student grades.

[1]Elaborated on the basis of reports PKA availableon the website http://www.pka.edu.pl/portfolio-item/baza-ocen/ /access date2015-11-03.

The aim of the preliminary research was to confirm the validity of the subject analysis of uneven distribution of student assessments in the context of the law, available scientific studies, and the evaluation principles adopted in the practice of universities and PKA.

As part of the research, quantitative data from USOS Wroclaw University of Economics databases for the academic year 2014/2015 were collected and analyzed.

This article consists of an introduction, three sections, and a summary. The first part explains the essence of the problem and the results of preliminary empirical research on uneven distribution of student grades. The second part introduces methods of testing uneven distribution of data, describes the data source and outlines the authors' method of analysis of uneven distribution of student grades based on empirical data. The paper concludes with a summary outlining main conclusions of the study, indicating potential areas of the method's application and directions for further research.

METHODS AND MATERIALS

Marks given to students should be utilitarian in nature, purposeful, systemizable, objectively defined and assigned[2]. According to Toruński and Wyrębek (2009) effective use of assessments should provide feedback and answer questions about the legitimacy of the methods and models used. Thus the incorrect, i.e., inconsistent and devoid of proper structure, implementation of the evaluation process can impair the objectivity of the process and adversely affect the quality of education. So if the evaluation process is structured and evaluation factors do not significantly impact subjective factors, the probability distribution of these assessments should be close to the normal distribution, also called the Gaussian distribution. This assumption was adopted by some national universities in the framework of their internal quality assurance system. For example, at the Faculty of Biotechnology and Horticulture University of Agriculture in Krakow, the Faculty adopted a normal approximation to assure and evaluate the quality of their formal guidelines regarding the variation in student grades (the Faculty Council Resolution No. 32/2013/14 dated 20 January 2014).

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In practice, it happens that students in one group achieve similar results or even the same result. This could mean that the evaluation process was "corrupted", and the results may be biased. If all students of in one class receive a pass mark (or the same mark), this reflects a concentrated distribution of marks. However, a more desirable result is a situation when the outcomes are more normally distributed around the mean and this is considered a more "even" distribution of outcomes.

Under normal circumstances, receiving identical assessments by students in one subject might indicate the presence of qualitative deficiencies of the educational process. An interview conducted among 10 experienced teachers revealed some potential causes of uneven distributions of marks and possible sources of their formation (Fig. 1).

[2]In contrast to emotional evaluations which give unstable and often unrepeatable results and depend on subjective factors, such as relations between the evaluator and the person being evaluated (Kotarbiński 1986).

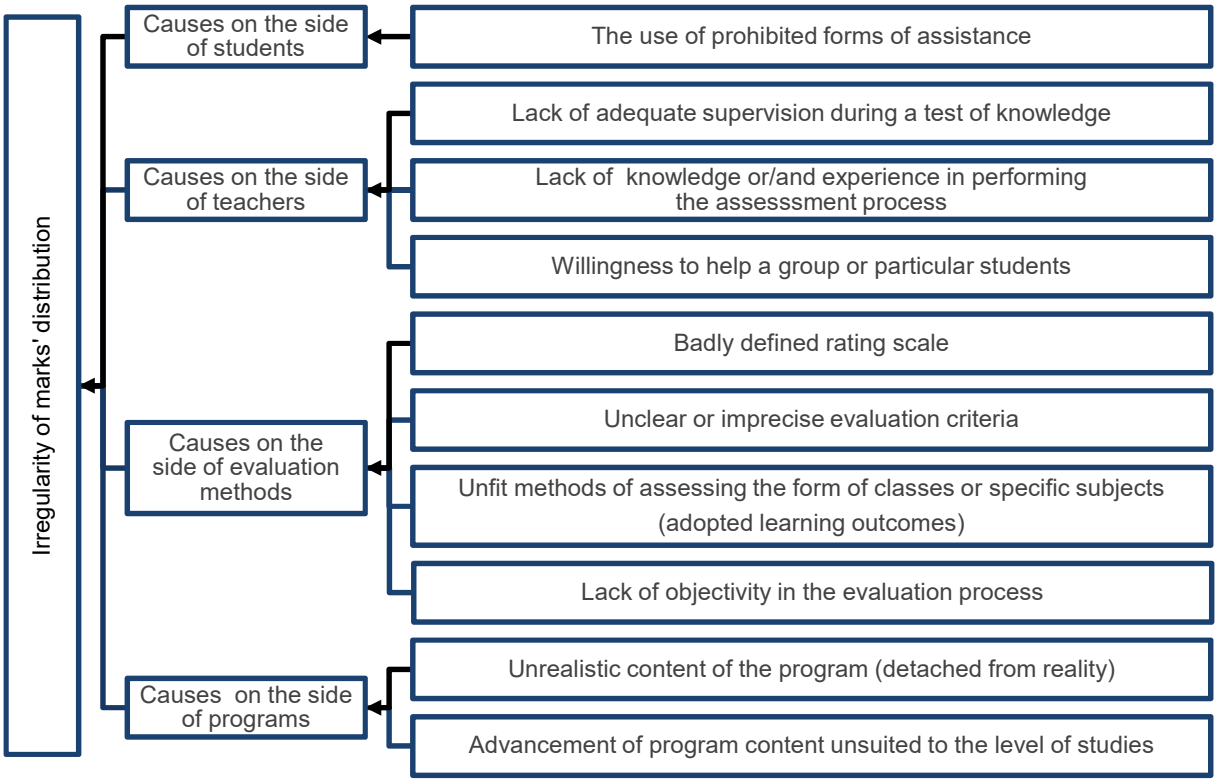


Fig. 1. Potential causes of irregular distribution of marks and their sources
Source: own elaboration based on interview results.

As indicated in the paper, it is valid to study the distribution of marks received by students within the teaching and learning processes of pro-quality systems of higher education. The main reason for conducting this type of analysis is the PKA' s approach totesting the quality of education in universities. Another equally important reason is the possibility of quick evaluation of instructors or groups of students which evoke suspicions of misconduct, for reasons presented in Fig.1. Naturally, the authors are aware that same ratings can be achived e.g., an excellent mark received by all students in one group, thanks to the common commitment of teachers and students. However, such situations are exceptional, and the results of the analysis should not form the basis of an overly negative assessment of the educational process – the results of should only inform of quality problems if any should occur.

The measure of dispersion of phenomena can be computed using a variety of statistics and parameters, hence the selection of methods for evaluation of the quality of the teaching is n important consideration.

METHODS OF TESTING IRREGULARITY OF DATA DISTRUBUTION

Non-uniformity has accompanied mankind since its inception, especially in the spheres of economic and social sciences. In the case of economic phenomena, non-uniformity relates to, e.g., the profitability of goods, the level of company assets, and the cost-production. In the area of social sciences, it relates to, e.g., income inequality, the country's wealth, and discrepancy

in the quality of life across the country. In the context of the analysis of these phenomena, there are a number of measures of variability or dispersion. For example, Aczel includes: the range, variance, standard deviation, and inter-quartile interval (Aczel 2011). Wierzbiński considers additional measures of diversity: average deviation and volatility dispersion (Wierzbiński 2006).

Buga and Kassyk-Rokicka (2003) consider an even wider range of parameters than Aczel and Wierzbiński to assess irregularity. In the chapter entitled "Measures of variability, asymmetry and concentration", the authors draw attention to an indicator of the concentration strength (relative frequency) of a particular outcome occurring in the studied phenomenon based on a measure of equality (inequality) along a cumulative distribution function (cdf). It is calculated on the basis of the ratio between the surface area of the figure between the line of concentration/line of equality (a straight line inclined to the X axis at an angle of 45°) and the Lorenz curve (a line determined on the basis of data on the cumulative percentage of the number of variables with the same intensity and the cumulative percentage of the value of these variables).

Zimny (2010) also observes the phenomenon of concentration and defines three separate groups of indicators used to measure it, i.e., variability (dispersion), asymmetry, and concentration. Further, Zimny includes indicators of kurtosis and the concentration ratio with the last group. The quoted author states that concentration is the uneven division of phenomena in the community (Zimny 2010). If all the units of the community are equally represented, then concentration does not occur. However, if only one unit of the community is represented, then complete concentration occurs.

Researchers of social phenomena have employed the same approaches to measurement of diversity as statisticians. They have consolidated and standardized indicators to measure the phenomenon of diversity and, above all, to measure it in relation to time and space. For measuring the concentration (diversification), Antczak and Żółtaszek (2009) propose to use spatial concentration ratios, Lorenz (location factor) and Gini coefficients, the Hirschman--Herfindahl, Theil, and Isard index. The use of these measures is warranted by specific characteristics such as (Antczak and Żółtaszek 2009):

- comparability between sectors,
- comparability between geographical areas,
- insensitivity to changes in the definition of spatial units,
- insensitivity to changes in the definition of sectors,
- adoption of certain known values that enable the verification of the null hypothesis concerning the lack of a systematic part in the analysis of the concentration and location of activity,
- possibility to determine whether there are significant differences between the two sites (areas, periods, sectors),
- possibility to analyze the volatility of estimates in the case of alternative hypotheses.

Based on the analysis of the characteristics of the listed parameters, the authors concluded that the study of inequality is possible by using the kurtosis and the Gini coefficient. The first indicator shows how the test is different from that of the normal distribution. The authors, however, are not convinced to believe that student marks should correspond to normal distribution.

It should also be stressed that the determination of differentiation of the distribution measures (eg. the standard deviation, variance, mean absolute deviation, coefficient of

variation, statistical range) in the case of student grades will only show the variation (dispersion) of characteristics around the central value. In addition, it should be taken into account that student assessment constitute ordinal variables, for which the calculation of the arithmetic mean and the standard deviation are not recommended.

The research presented in the paper focuses on the entire population of students of the Faculty of ZIF. Therefore, no verification of hypotheses using statistical tests was carried out. The statistical tests are used to study the differences between distributions (eg. Kruskal-Wallis) based on the statistical sample.

Considering the above, the Gini coefficient was selected to examine the differentiation of grades obtained by students of the Faculty of Management, IT Science and Finance (ZIF) at the University of Economics in Wroclaw[3].

THE SOURCE OF DATA AND PROPOSED METHOD OF IRREGULARITY ANALYSIS OF DISTRIBUTION OF STUDENT EVALUATION

The data for the analysis were gathered from a database query of the USOS system made in October 2015. In this manner, 37210 records were received containing student assessment data for the Faculty of ZIF at the University of Economics in Wroclaw. The data included the winter and summer semesters of academic year 2014/2015 and contained the following fields:

- the code and name of the field,
- the student's index (album) number,
- the field of study,
- the form of study,
- the semester number,
- the type of class code,
- the student group number,
- the name of lecturer,
- the student's evaluation/assessment/grade/mark for classes in the first period,
- the student's evaluation for classes in the second period.

The table of fields was placed in the file format ".xlsx". These data were prepared for the fulfillment of the statutory tasks of the Departmental Committee on Quality of Education. Elements of the selected fields are shown in Tables 1 and 2.

Table 1. Fields of study in USOS database

Field of study	Description
AG	Economic Analytics
FiR	Finance and Accounting
FiR (BSiF)	Finance and Accounting (Bachelor Studies in Finance)
FiR (MSiF)	Finance and Accounting (Master Studies in Finance)
IE	Information System and Econometrics
IwB	Information System in Business (Business Informatics)
IwB (BI)	Information System in Business (Business Informatics)
Logistics	–
Management	–
Management (BA)	Management (Business Administration)

[3]The choice of this instrument was made on the basis of test results of Z. Kes over the possibilities of using different indicators in assessing diversification of budgetary variances (materials not yet published).

Table 2. Forms of study in USOS database

Form of study	Description
N1	Part-time student – Bachelor's
N2	Part-time student – Master's
S1	Full-time student – Bachelor's
S2	Full-time student – Master's

Regarding student marks, the mean and standard deviation for the total population was 3.873 and 0.873, respectively. Table 3 provides additional information by semester and form of study.

Table 3. Characteristics of the evaluations of ZIF students

Form of study	Marks – Winter semester		Marks – Summer semester	
	average	standard deviation	average	standard deviation
N1	3.472	0.957	3.725	0.882
N2	3.907	0.817	4.112	0.762
S1	3.620	0.951	3.821	0.813
S2	4.044	0.833	4.209	0.721

As shown in Table 3, average evaluations of full-time students are greater and less dispersed than the ones for part-time students, and the average scores for master's degree students are greater and less dispersed than that for baccalaureate students. This method of data analysis, however, does not answer the question: What is the level of concentration (uniformity) of the student evaluations? According to the authors of this study, the answer to this question can be provided by applying the Gini coefficient.

The Gini coefficient determines the ratio of the cumulative share of the population arranged by value features to the cumulative distribution function (cdf) of these features (Lerman and Yitzhaki, 1984). It takes values from the interval [0,1]. Populations that may be called egalitarian, are characterized by a coefficient value close to 0, whereas in the case where only one variable assumes a significant value and the remaining ones adopt zero values, the coefficient gravitates towards 1. This factor is calculated using the egalitarian line (line of equality) and the Lorenz curve (Paradysz 2009). It is the ratio of the area between the two curves over the area beneath the egalitarian line (Formula 1):

$$GINI = \frac{P_1}{P_1 + P_2} \tag{1}$$

where:

P_1 – the field between the egalitarian line and curve concentration (Lorenz),

P_2 – the area under the curve concentration.

Graphic interpretation ofthe Gini coefficientis shown in Fig. 2.

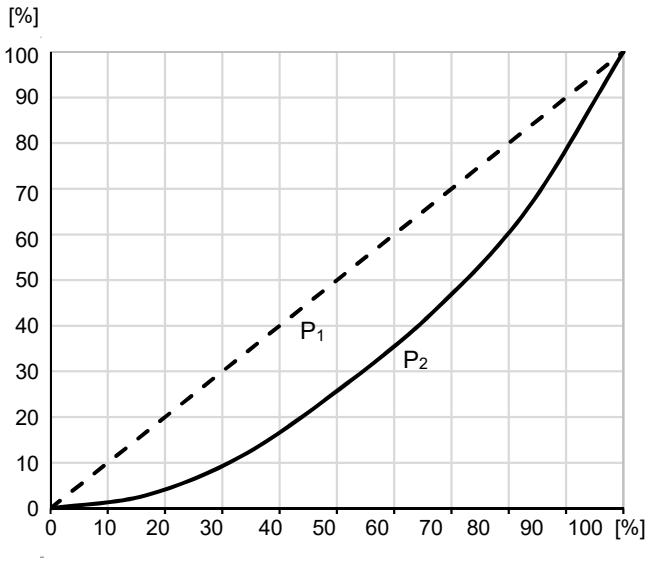
Due to the lack of a simple analytical method for determining the surface area between the egalitarian line and the concentration curve, the Gini coefficient can be computed using a trapezoidal and triangular approximation to the points forming the Lorenz curve. Panek (2007) gives the analytical form of this approximation as Formula 2:

$$GINI = 1 - \frac{1}{n^2 \bar{y}} \left(\sum_{i=1}^{n} (2(n-i)+1) y_i \right) \tag{2}$$

where:

n – sample size,

i – the position of an observation within a sequence of numbers (by increasing order),
y_i – the value of i-th variable,
$\bar{y}$ – the average value of the variable in the sample.



Y axe – cdf of features
X axe – cdf of occurrences
---- egalitarian line
—— concentration curve

Fig. 2. Determination of the Gini coefficient

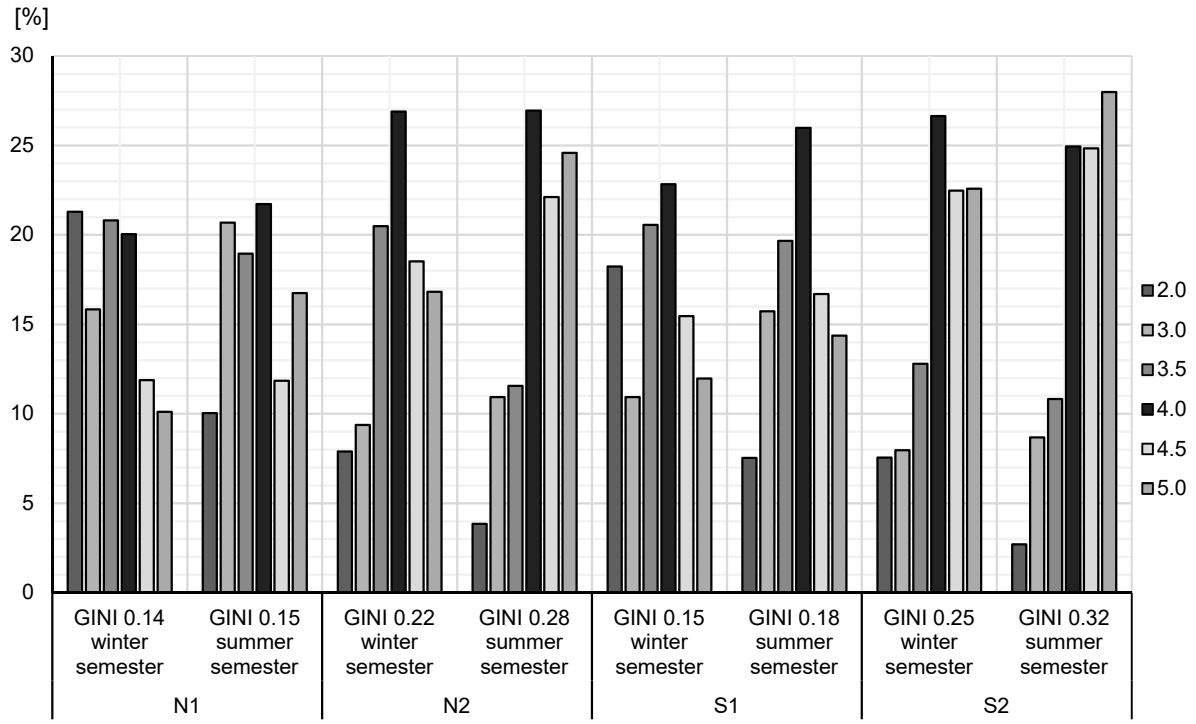
For purposes of this study, a low Gini coefficient represents low dispersion and lack of concentration of distribution of outcomes. A high Gini coefficient represents high concentration and inequality distribution of outcomes, possibly indicating a systematic problem or bias.

Marcinkowska et al. (2008) report that the Gini index is a measure recommended by the United Nations and is used in studies of social assistance and poverty. A cited advantage of this measurement is that it is a synthetic measure and may be calculated based on data with a high degree of aggregation. A cited disadvantage is that for the purpose of measuring the effectiveness of a social policy index value, it must be related to the value calculated for another (additional) period or group.

The analysis of uneven distribution of marks was made based on data collected from the USOS system. The study used only records containing a numerical rating from the first term (general assessment on a passed/ not passed basis was omitted). The survey took into account multiple criteria, including: subjects, teachers, degree, semester, form of studies, and fields of study. In the case of small sample sizes (less than 25 observations) occurring in a group distinguished on the basis of the criterion, calculations were not performed. The results of the analysis are provided in the next section.

THE RESULTS OF THE ANALYSIS OF IRREGULAR DISTRIBITION OF GRADES

In the first stage of the analysis distribution of marks was evaluated by form of study. The distributions were further segmented by winter and summer semester. The results are shown in Fig. 3.



2.0 (unsatisfactory)
3.0 (satisfactory/sufficient)
3.5 (satisfactory plus)
4.0 (good)
4.5 (good plus)
5.0 (very good)

Fig. 3. Distribution of student evaluations by semester and form of study. To enable the comparability of distributions of the number of evaluations, the graph shows the percentage of evaluations relative to the total

Figure 3 shows the distributions of evaluations for specific categories of students and the value of the Gini index. It is worth emphasizing the increasing concentration values moving from baccalaureate to post-baccalaureate students and from winter to summer semesters. This movement is in conjunction with increases in the share of evaluations of good or very good, and decreases in the share of unsatisfactory grades and sufficient. What is apparent here is the 'learning effect,' which affects not only the time spent on some activities, but also the student performance score. Thus, in this case, the increases in the concentration of marks may be the result of deficiencies in education quality, as well as the effect of the learning curve and elimination of students (e.g., less successful students who do not pursue post-baccalaureate studies) with lower marks that bring down the average rating.

Another criterion for student evaluations was field of study. This is graphically depicted in Fig. 4.

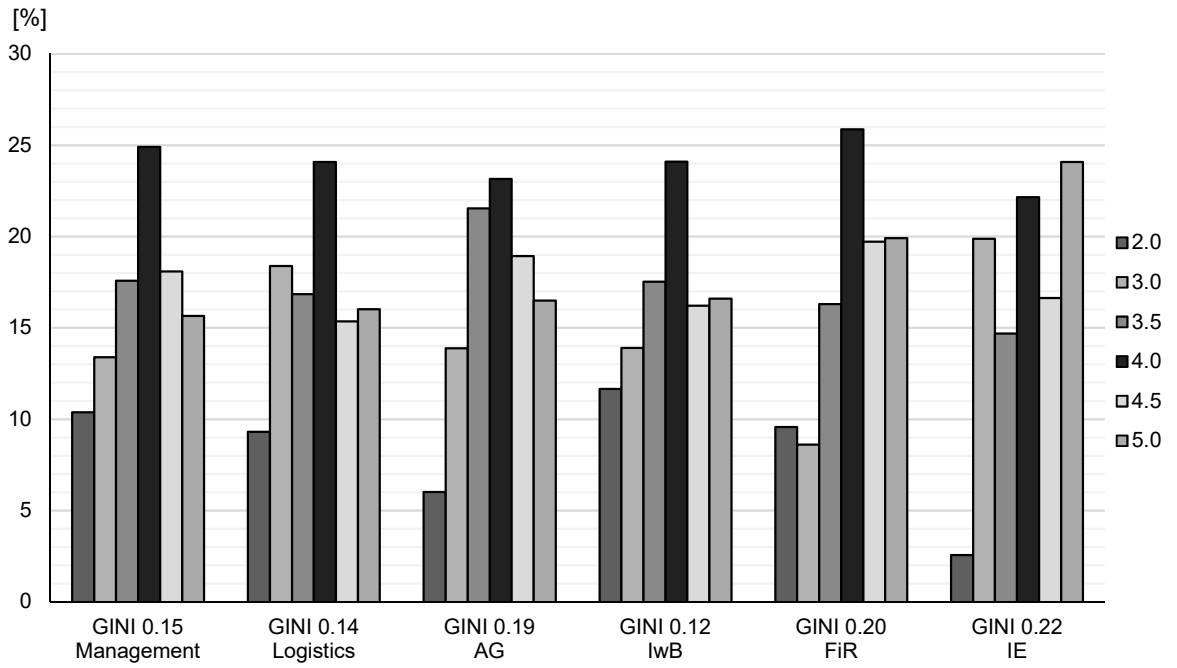


Fig. 4. Distribution of student evaluations by field of study. To enable the comparability of distributions of the number of assessments, the graph shows the percentage of evaluations in the aggregate

In the case of distributions of student evaluations across individual fields of study, there do not appear to be any noticeable differences between them. However, each distribution appears to be right-skewed, favoring very good marks over bad ones.

The next stage of the analysis assessed the distributions of marks in terms of individual teachers lecturing at the ZIF. This is graphically depicted in Fig. 5.

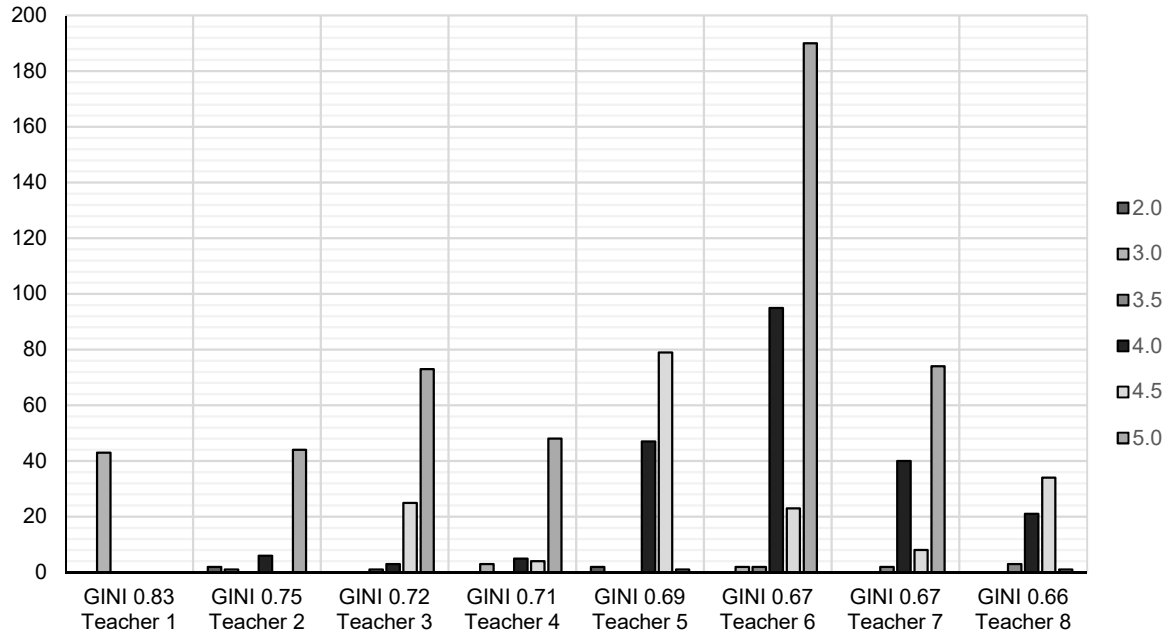


Fig. 5. Distribution (count) of student evalutions by teacher. The vertical axis is the number of grades of a given type

Figure 5 shows only a portion of the data (the top eight teachers ranked by highest Gini coefficient) and represents the most irregular distributions. In the case of a teacher using only one type of student performance evaluation, e.g., all students received the same mark of 3.0 (satisfactory), the Gini coefficient is 0.83 (which is the maximum value for a sample where five out of six observations are identical). For the teachers represented in this graph, it is clear that they predominantly use only one or two types of grades (In most cases this is a very good mark). As previously indicated, such situations can be associated with a poor assessment system, but may also be the result of other factors. It is therefore necessary to consider the possibility of evaluating teachers who grade students in this way.

The last stage of the analysis assessed the irregularity of the distribution of marks within individual subjects. The results are shown in Fig. 6.

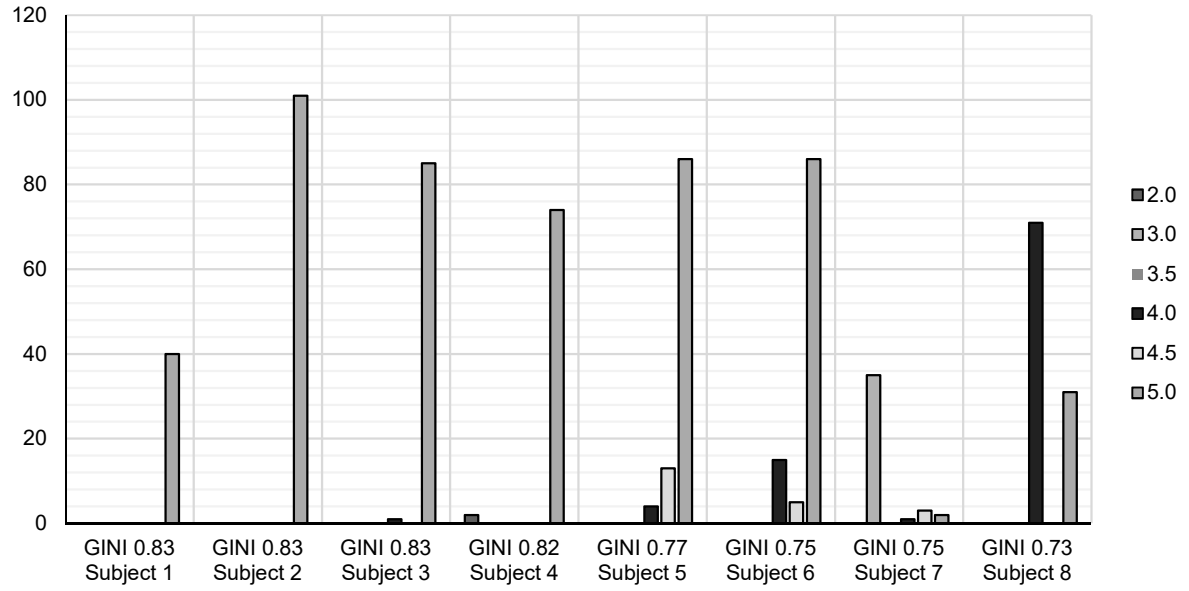


Fig. 6. Distribution (count) of student evaluations by subject. The vertical axis is the number of grades of a given type

Figure 6 shows only a portion of the data (the top eight subjects ranked by the highest Gini coefficient). The values of the Gini coefficients identified those subjects with the most significant concentrations of student evaluations. In most cases, these subjects were associated with very good grades, but there were also cases of predominantly satisfactory or good marks. The high Gini index values appear to be indicative of the need for an in-depth review of the evaluation system for the given subjects.

CONCLUSION

A decline in the amount of the State Budget allocated to financing higher education, in conjunction with lower student enrollment, has made pro-quality actions, which are partly imposed within the framework of the Bologna Process, an important factor in the survival and development of universities.

The objectives of maintaining high operational efficiency and a high quality education process have forced entities to seek various organizational and technical solutions, including, *inter alia*, the establishment of specialized roles and committees on quality of education (at the central level – college and the faculty), as well the implementation of various information and technical support systems.

The proposition of using the Gini index to evaluate irregular distributions of student evaluations is an attempt to improve the efficiency of internal audits and the overall quality of education. The results of this analysis clearly indicate the usefulness of the above mentioned indicator in the decision-making process. It has the advantage of providing a framework to test observations along many dimensions, including subjects, forms of study, and fields of study, as well as timeframes. The material presented in this study certainly does not exhaust the subject. The authors see the need for further, more detailed studies, including a comparison of the results using the Gini index to the results of other summary statistics, and an analysis of the results segmented into groups according to the form of classes, the kind of study, or the number of semester-hours for a given subject, etc.

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Streszczenie. Znowelizowana Ustawa Prawo o szkolnictwie wyższym wymusiła na uczelniach wyższych wdrożenie wielu projakościowych zmian w systemie kształcenia, w tym m.in. budowy programów studiów opartych na efektach kształcenia, określenia szczegółowych metod dydaktycznych umożliwiających osiągnięcie tych efektów przez studentów oraz sposobów oceny stopnia ich osiągnięcia. Uczelnie mają także obowiązek budowy wewnętrznego systemu zapewniania i doskonalenia jakości. W opracowaniu przedstawiono wyniki badań z zakresu analizy nierównomierności rozkładu ocen studentów, z wykorzystaniem wskaźnika Giniego jako narzędzia wspomagającego funkcjonowanie tego systemu. Według autorów stosowanie ww. wskaźnika może skutecznie wspomagać identyfikację tych elementów programu studiów, które mogą negatywnie oddziaływać na jakość. W celu lepszego zobrazowania istoty wskaźnika Giniego przedstawiono sposób jego obliczania i interpretacji w ramach analizy rozkładów ocen na przykładzie danych z systemu USOS Uniwersytetu Ekonomicznego we Wrocławiu.