MEASUREMENT, ANALYSIS AND EVALUATION OF ACADEMIC PUBLICATIONS AND CITATIONS

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ABSTRACT

This study is about the measurement, analysis and evaluation of academic publications and citations. The main objective is to compile publication and citation data and do comprehensive statistical analysis to answer the types of questions relevant to evaluation of publications and citations.

For data collection and analysis, eight different fields and countries are selected to constitute a sample. The data are collected from ISI Web of Science – main database about academic publications and citations – and from university web pages. Using the raw data, some measures are defined to evaluate given fields and academic units. Most important measures are: average number of publications per faculty/author, average number of authorships per paper, and average number of citations per publication.

The study showed that some measures are highly correlated. For example; as the number of authors per paper increases, average number of citations per paper increases. It is also discovered that fields have significantly different characteristics in some aspects. For example both collaboration and average number of publications per author/faculty are high in biology where articles are not very long on the average. Industrial engineering publications show significant differences with biology in all characteristics analyzed.

In case of multi- authorship it is difficult to define the 'number of publications per author.' It is observed that there are two extremes for interpreting 'average number of publications per author'. Our research proposes a new *K-measure* to deal with the two extremes. *K-measure* is a kind of weighted average of the two extremes.

Our research also suggests a way to use H-index – a highly popular performance measure –more appropriately to evaluate academic performance. This enables us to compare academic units that are of different sizes.

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1. INTRODUCTION

Publications and citations they receive are critical performance criteria in academia. Average number of publications per author and average citation per publication are two common measures for evaluation. However, measurement and evaluation is not trivial. Many things should be taken into consideration such as the nature of field, type and quality of publication medium, per paper authorship.

Different disciplines require different perspectives. In some fields, collaboration is indispensable; however, there are fields where individual work is more appropriate. Similarly, characteristics of the publications differ from field to field. In some fields 2-3 page papers are quite common; on the other hand this number can be 20 or more in some other fields. Such issues necessitate different evaluation criteria for different fields.

Measuring the quality of academic publications is a great concern for academicians since it affects their careers through tenure and promotion [3]. Since number of citations reflects the number of times individual scientists consider a given document important enough to cite it in their own work, the number of citations their papers receive is very important. The reputations of the journals they publish in may also be a criterion for the quality of a publication.

Multi-author papers constitute another difficulty in measurement and evaluation. The contribution level of each author is not easy to determine. Since the length of publication list is a performance criterion in research assessment and funding decisions, the authors tend to participate in as many articles as possible. This can be termed as authorship inflation that leads to an increase in the average number of authorships per paper, but not necessarily to an increase in the number of papers per active scientist [4].

Moreover, considering evaluation criteria researchers may choose different publishing strategies, which can be classified as ‘quantity’ of publishing strategy and ‘quality’ of publishing. Most extreme case of the former is salami-style publishing. Salami style publishing can be defined as cutting slices from a single long paper and publishing each slice in a separate paper. Aim of this publishing strategy is increasing the number of publications. The extreme form of the latter strategy is aiming to publish as many papers as possible in journals with a high journal impact factor [4].

The main objective of this study is to compile extensive publication and citation data and do comprehensive statistical analysis to answer the types of questions relevant to evaluation of publications and citations. These questions include how to evaluate different disciplines and compare them, what the main criteria are etc.

2. DATA GATHERED

Data gathering process is one of the main steps of this research. Since there are not many previous studies on this subject, there is no processed data and collection of the raw data is extremely difficult.

2.1. Raw Data

While gathering raw data eight particular fields are selected from different countries that are selected to be representative of the world. These are engineering, industrial engineering, biology, mathematics, physics, psychology, economics and medicine. Engineering is considered without separating into departments. Moreover, countries, which are chosen, are USA, China, India, Russia, European Union (Belgium, France, Germany, Italy, Luxembourg, Netherlands, Denmark, United Kingdom, Greece, Spain, Ireland, Portugal, Austria, Finland and Sweden), Australia and Turkey.

Raw data that is gathered can be listed as the following:

- Number of publication
- Number of authors
- Total number of authorships
- Sum of times cited
- Number of pages per publication
- H-index (to be defined later)
- Total number of faculty

Here difference between 'number of authors' and 'total number of authorships' must be defined clearly. What is meant by 'number of authors' is number of distinct authors of each publication sample taken to analyze. Furthermore, 'total number of authorships' means sum of number of authors of all publications in a sample. For instance, when 2 scientists write 10 publications together, 'number of authors' is 2 because there are 2 distinct authors. However, 'total number of authorships' is 20 because each publication in the sample of 10 papers is written by 2 authors and summation of number of authors for all publications is 20.

All raw data except 'Total number of faculty' is collected for years 2000, 2003 and 2006. It is based on 961,610 publications provided by ISI Web of Science which is a huge database about publications and citations. It is an online academic database provided by Thomson Scientific. It covers about 8,700 leading journals of science, technology, social sciences, arts, and humanities [9].

Data of number of pages of publications is also collected in order to see whether it is a sign of quality. For instance one of the aims is to examine the effect of number of pages on the number of citations received.

'Total number of faculty' is another raw data that requires excessive amount of effort to collect. While gathering this data a sample of about 50 universities is determined for each field. %60 of the universities selected for each field are from USA,

%20 from European Countries and %20 from other countries. Data is collected from sample universities web pages for 2006.

2.2. Defined Measures

In order to make statistical data analysis and to use in dynamic simulation model some measures are defined using raw data accordingly. It is believed that these measures help to identify differences between the selected fields. Defined measures and formulas that are used to calculate these measures are explained in detail below.

Average Number of Publications per Author

This measure is one of the most important measures that must be defined carefully because there are two different approaches to evaluate. These two approaches are the extreme cases of evaluating units such as countries and departments according to their average number of publication per author. These two extremes can be defined as punishing extreme and generous extreme and these extremes can be calculated in the following ways.

- Punishing Extreme: Number of publications / Number of authors
- Generous Extreme: Total number of authorships/ Number of authors

Referring to 2 scientists and 10 papers example, which is used to define 'total number of authorships' in page 9, these extremes can be explained better. If 2 scientists write 10 papers together, according to punishing extreme average number of publications per author will be 5. However, one may ask these scientists about their number of publications and they both may claim that they have 10 publications each. Generous extreme corresponds to this case. Since total number of authorship is 20 and number of authors is 2, average number of publication per author is 10 according to generous extreme.

Average number of publications per faculty

As mentioned before number of faculty members has been found from university web pages and the measure is found by:

Number of publications / number of faculty

Average number of authors per publication

Total number of authorships / Number of publications

Average number of citations per paper

Sum of times cited values are the citations that 2000-year publications (for each field and country) received up to now. The measure is found by:

Sum of times cited / Number of publications

Adapted impact factor

Impact factor is a measure that is normally used to evaluate journals and can be calculated based on a three-year period [8]. For this project impact factor is adapted to evaluate academic units such as departments, universities etc. For example, adapted impact factor of a department for 2002 can be found as the following:

A = the number of citations that articles published in 2000-2001 has received in 2002.
B = the number of articles published in 2000 and 2001.

2002 impact factor of the department = A/B.

Data is collected to see the results of adapted impact factor. 2000 and 2001 publications of engineering, industrial engineering, mathematics, economics, physics, biology, psychology are searched in Web of Science for the countries previously selected. Afterwards the citations that these papers received in 2002 are found with the help of *Citation Report* option.

3. STATISTICAL DATA ANALYSIS

In order to understand data and make informed decisions about defined measures and difference between fields, extensive statistical analyses are made. It is aimed to derive a mathematical representation of the relationship between measures.

3.1. Correlations between Defined Measures

After calculating defined measures, relations between these measures are found with the correlation tests. Hypothesis test that is used for correlation is the following.

$$H0: r = 0$$
$$H1: r \neq 0 \quad \text{where } r \text{ is the correlation}$$

Correlation test between all defined measures are completed using MINITAB Statistical Software. The concept of correlations between defined measures is particularly noteworthy.

Correlations: avg authors per paper , avg citations per paper, H-index, Impact factor

Cell Contents: Pearson correlation
P-Value

	avg authors per paper	avg citation per paper	H-index
avg citation per paper	0.623 0.000		
H-index	0.562 0.000	0.633 0.000	
Impact factor	0.714 0.000	0.925 0.000	0.806 0.000

Figure 1: Correlation Matrix between different measures

According to Figure 1, it can be concluded that average number of authors per paper and average citation per paper are positively correlated and when the former increases, the latter increases. This is parallel to the findings of Wolfgang Glänzel and András Schubert, who say that the number of citations a paper receives is on the average strongly dependent of the number of co-authors [5]. Moreover, when average citation per paper increases, H-index and Impact Factor increases. So as a result, in can be said that growing collaboration is destined to high values of H-index and Impact Factor.

Some other measures are analyzed in terms of the correlation among them. The results of them can be seen in Appendix A, Table A. For example, it is wondered whether there is correlation between number of pages of publications and the citations they get. For this purpose, data is obtained for some fields and countries selected. In each row, there were the number of pages, number of authors and number of citations of each paper. The results said that there is not a correlation between number of pages and number of citations received (Table A.2 in Appendix A).

3.2. Analysis of Fields

One of the crucial aims of this project is to observe the difference between fields. For that reason, behaviors of the selected fields in terms of some measures are observed and it is concluded that some fields are similar in some aspects; on the other hand, some show significantly different behaviors.

Determined measures to observe the behaviors between different fields are listed below:

- Average number of publications per faculty
- Average number of authorships per publication
- Average number of publications per author (for both punishing and generous extremes)
- Average number of pages per publication

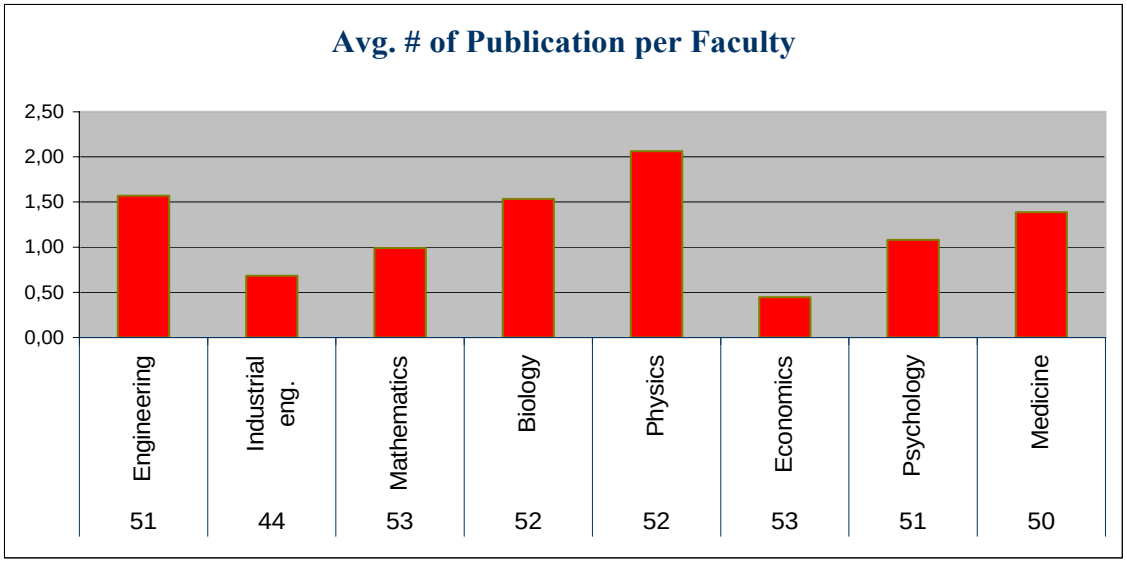

Figure 2: Average Number of Publications per Faculty (Web Search)

As it can be observed in Figure 2, average number of publications per faculty measure differs in a large range. Physics department has the maximum value which is 2, 06 and for economics average number of publications per faculty is 0, 45 which is the lowest among all fields. As a reminder these measure is calculated using the total number of faculty data, which are, collected from sample universities web pages. Values, which are written under the fields' name, show the sample size of selected universities.

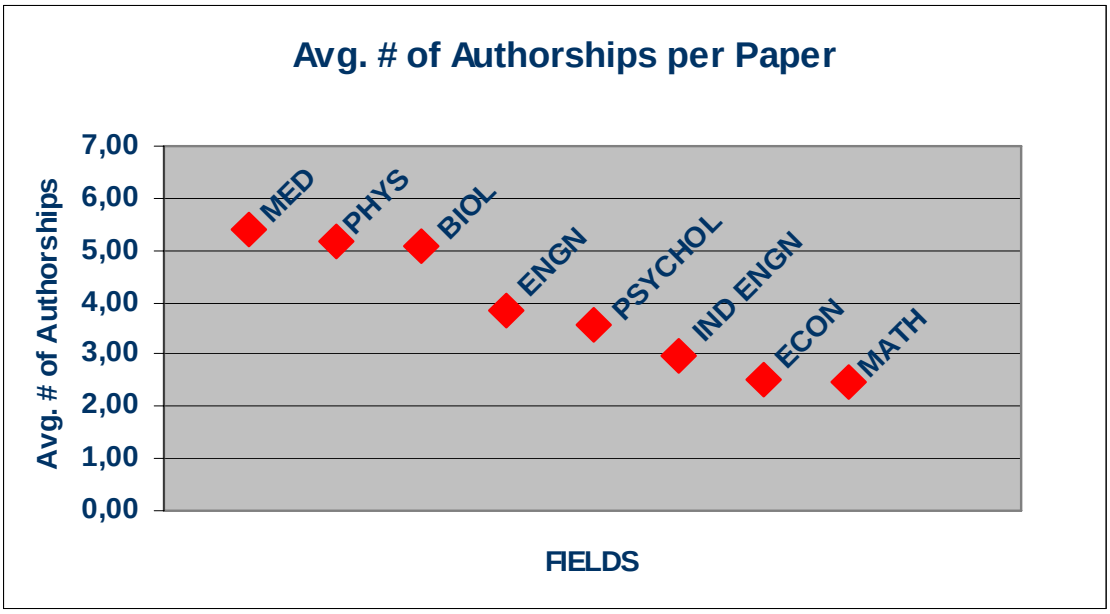

Figure 3: Average Number of Authorships per Publication (ISI)

According to average number of authorships per publication measure, it is observed that Medicine, Physics and Biology fields have highest values, which are in between 5 and 6. On the other hand, Economics and Mathematics are the fields, which have lowest average number of authorships per publication value, which are in between 2 and 3. Besides in the project an investigation is done about the average number of co-authors per paper to see whether collaboration is growing or not. It is seen that collaboration is becoming more prevalent according to the past (Figure A.1 in Appendix A). Henk F. Moed says that scientific collaboration and authorship inflation results with rising authorships per paper [4].

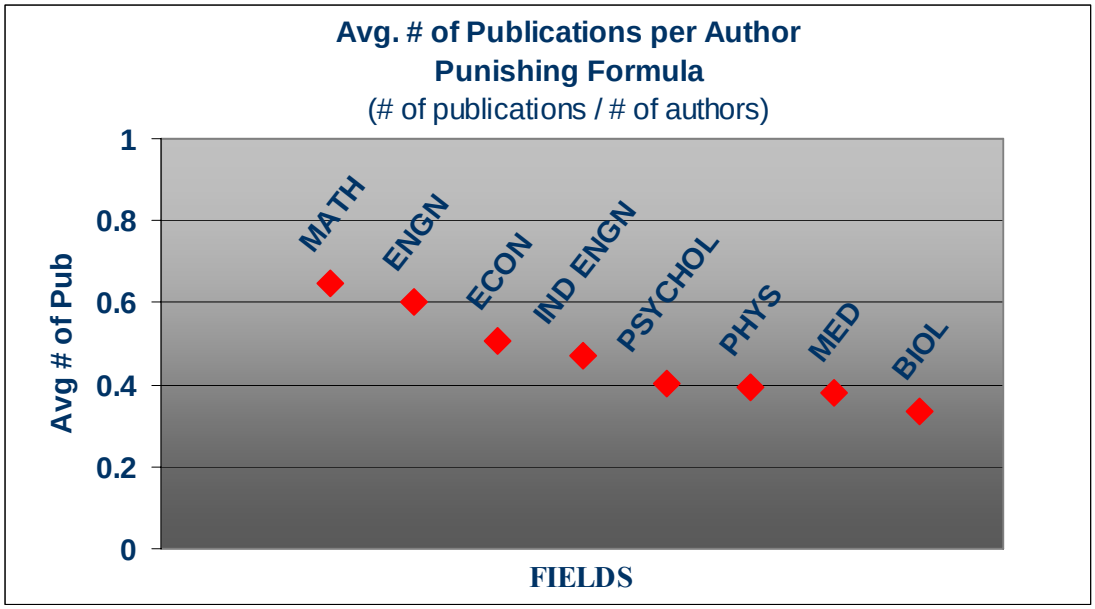

Figure 4: Average Number of Publication per Author (Punishing Formula)

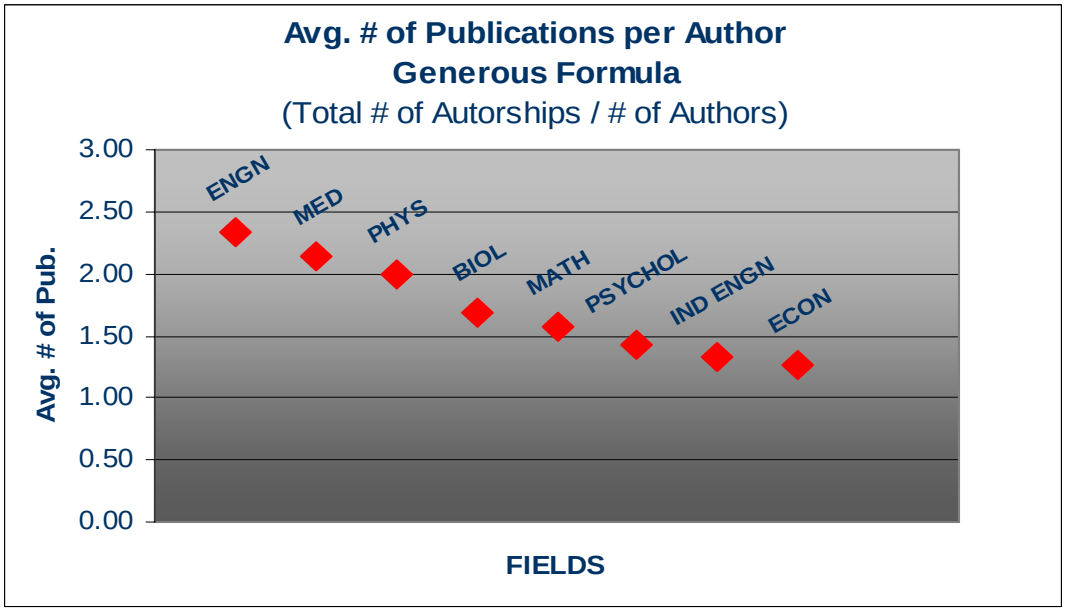

Figure 5: Average Number of Publication per Author (Generous Formula)

As it is expected, Physics, Medicine and Biology fields which have high average number of authorships are punished according to punishing extreme and these fields are at the bottom of the graph (Figure 4). However, these departments have the highest values according to generous extreme. To make a remark, it can be realized that fields that have social characteristics tend to have low levels according to generous extreme because of less collaboration (Figure 5).

To provide better understanding of average number of publication per author value, average of the two extreme is calculated and result is presented in Figure 6. On

the average Engineering has the highest value and Industrial Engineering has a low value.

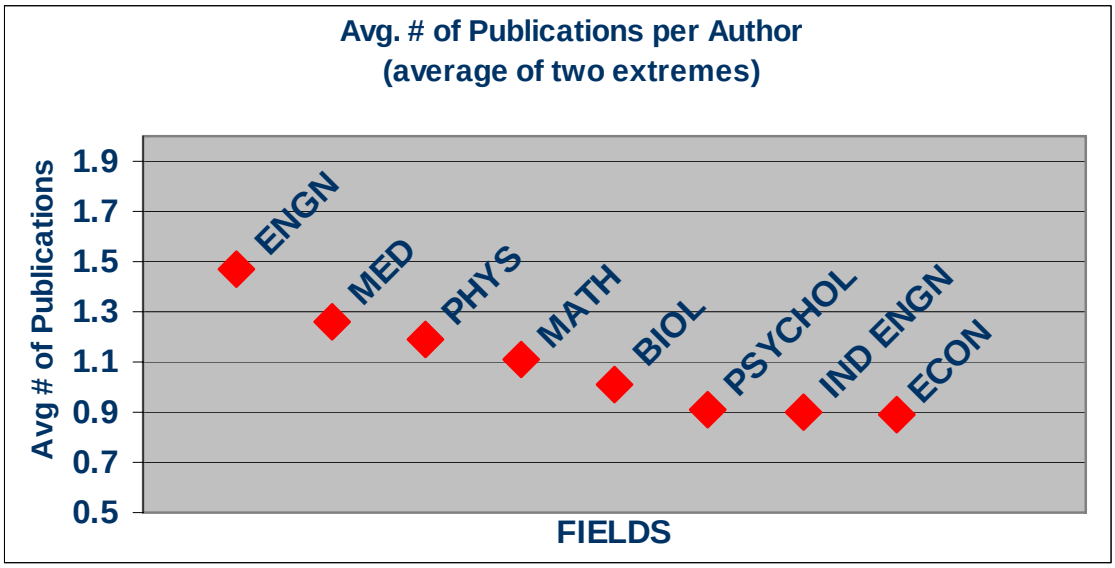

Figure 6: Average Number of Publications per Author

3.3. Statistical Tests for Fields Averages

Graphs in the previous pages are presented to show similarities or differences between fields. Here, aim is to observe how significant these similarities or differences are. For this reason t-tests are completed for all measures and all fields with hypothesize below, where m1, m2 are the means of fields that are tested in terms of a measure.

$$H0: m1 - m2 = 0$$
$$H1: m1 - m2 \neq 0$$

For example, according to average number of publication per author MINITAB result is provided for the fields Engineering and Medicine. Means of Engineering and Medicine fields in terms of this measure is 1.244 and 1,229 respectively. P value of test is 0.941 and H0 cannot be rejected (Table 1). Therefore, it can be concluded that these fields are not significantly different according to average number of publication per author.

Table 1: Two-Sample T-Test for Engineering and Medicine

Two-Sample T-Test and CI: ENGN, MED

	N	**Mean**	**StDev**	**SE Mean**
Engn	24	1.244	0.470	0.096
Med	8	1.229	0.463	0.16

Difference = mu (Engn) - mu (Med)
Estimate for difference: 0.014437
T-Test of difference = 0 (vs not =): T-Value = 0.08 **P-Value = 0.941**

Results of average number of publication per author measure are shown in the Figure 7 to present the significance level of similarities between all fields. Other test results for all measures can be seen in Table A.3 in Appendix A.

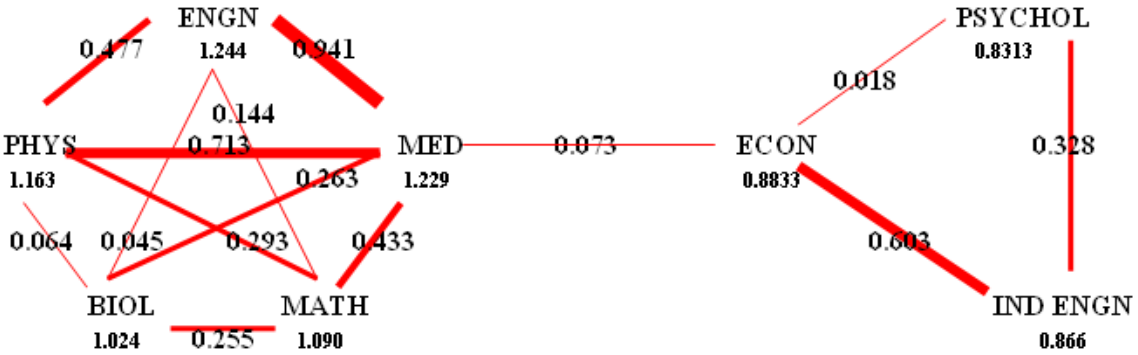

Figure 7: T- test Results for Average Number of Publications per Author

3.4. Where does Bogazici University stand?

Figure 8 shows the comparison of Bogazici University with world average for seven fields. Number of publications data is taken from ISI Web of Science and the number of faculties is gathered from university web pages. Both of them are for year 2006. For all the fields selected Bogazici University is below the world average.

In Figure 9, comparison is made in terms of average number of citations per paper. 2000-2007 citations of the papers published in year 2000 is used. In the Figure mathematics department of Bogazici University shows an unexpected behavior. Number of citations per paper is 50.50 in Bogazici University where the world average is 6,03. When the papers composing these statistics is observed, it is seen that, only two papers are published in year 2000 and these two papers received totaly 101 citations up to year 2006. So it is a result of this very small number of papers.

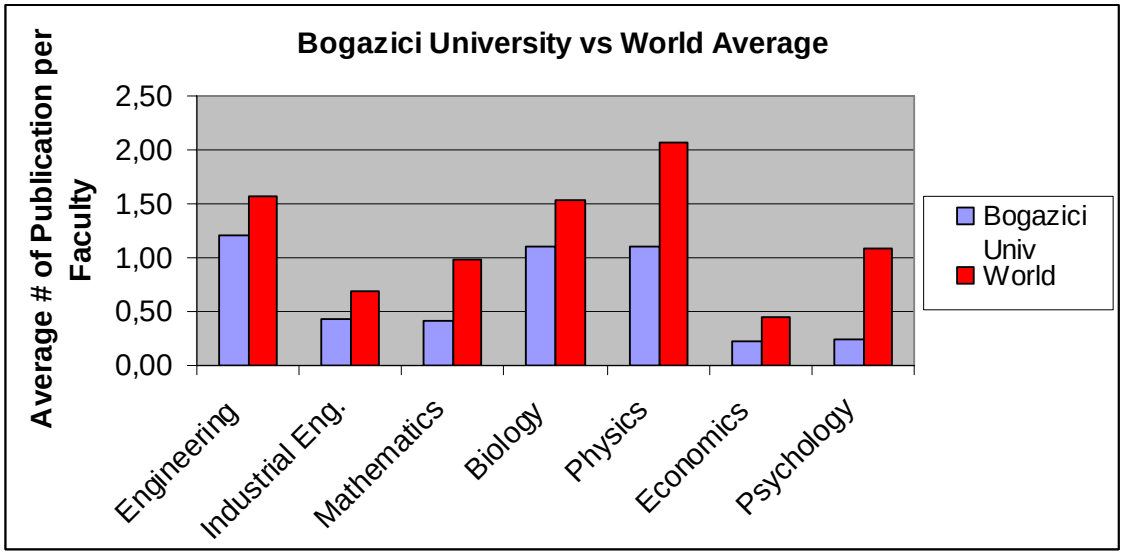

Figure 8: Average Number of Publications per Faculty – Bogazici vs. World

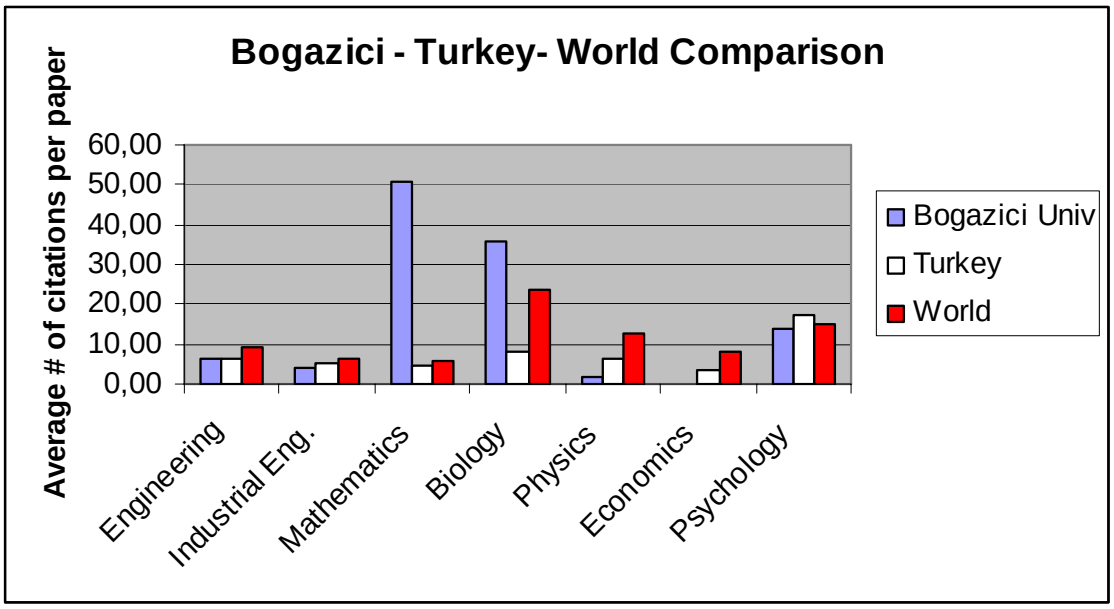

Figure 9: Average Number of Citations per Paper – Bogazici-Turkey-World

3.5. A Suggested *k-Measure*

As defined earlier, the average number of publications per author is measured in two different ways. One way of doing this measurement is dividing the number of publications by the number of authors. This methodology does not consider the co-authorship issue. Therefore, the average number of publications of an author is found very small. This methodology punishes the co-authorship by giving an extremely small number.

On the other hand, the same measure can be found by dividing the total number of authorships by number of publishing authors. In this case, a very high number is found. This can be considered as the generous extreme.

In order to find average number of publications per author in a reliable way, a new methodology is needed which will provide a number which is between the two extremes. The new suggested methodology is as follows:

p: punishing extreme (number of publications/ number of publishing authors)
g: generous extreme (total number of authorships/ number of publishing authors)
c: number of citations per paper
$\overline{C}$: grand average of citations per paper in the particular field
σ: standard deviation of citations per paper in the particular field

$$\text{avg \# of publications per author} = k*g + (1-k)*p$$

where k is defined as;

$$k = \begin{cases} 0 & c \leq \overline{C} - 3\sigma \\ a*c + b & \overline{C} - 3\sigma < c < \overline{C} + 3\sigma \\ 1 & c \geq \overline{C} + 3\sigma \end{cases}$$

In the above formulation, a weighted average of the numbers p and g is taken. As can be observed from the formulation, if k is a small number, then the measure will be close to punishing extreme. Similarly, if k is a large number, then the measure will be close to generous extreme. It is a fact that, being close to generous or punishing extreme is something relevant to quality. If the papers of an author are good-quality papers, then the author deserves to get generous extreme value as his average number of publications. In the same way, if the papers are not qualified ones, then the number of publications of the author will be close to punishing extreme value. As the quality measure, number of citations a paper gets is taken. Certainly citations provide the qualitative factor that is so glaringly absent from simple publication counts [1].

$\overline{C}$ is the grand average of citations per paper in a particular field. It is necessary to compute $\overline{C}$ because as explained in detail before, every field should be evaluated in itself. So every c should be compared with $\overline{C}$ of its field.

It is decided that, if the average number of citations the papers of an author get is same with the world grand average of that field ($\overline{C}$), then he/she can have the k value 0.5 which means his average number of publications is calculated by just taking the average of p and g.

Additionally, it is decided that if "c" (number of citations per paper) is 3σ higher than the grand average, k value can be 1, meaning; the author is so good that he/she desires to get the generous extreme as the average number of publications.

With the help of the two points explained, a line is fitted. k value for any "c" is read from that line.

The graphs of *k-measure* for all selected fields and the detailed calculations are included in Appendix A, Figure A.2-A.14 and Table A.4 - A.9. Citations are the all citations for the 2000 publications.

Example 3.1

Average number of publications of engineering faculty of Bogazici University is chosen to be evaluated. Citations are the all citations for the 2000 publications.

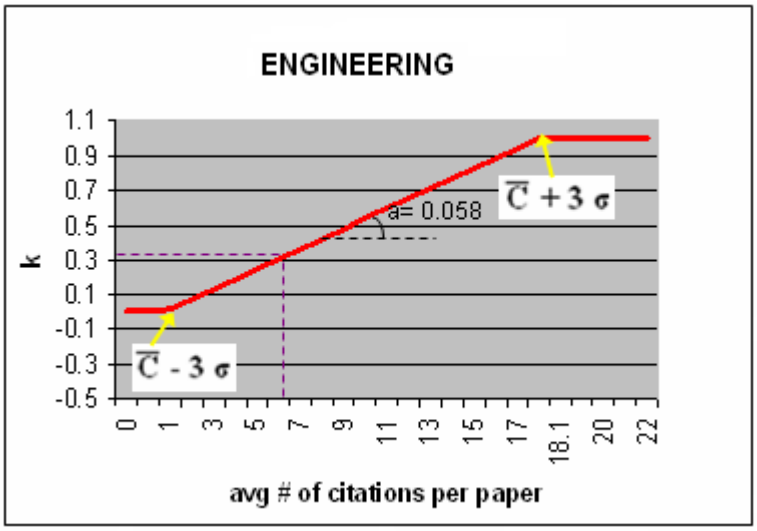

Figure 10: k- value Calculation for Engineering Department

In Figure 10, $\overline{C}$ is 9.40 which means; the number of citations a paper gets on the average in the world for the field engineering is 9.40. Standard deviation (σ) is 2.89. $\overline{C}$+3σ=18.1 corresponds to k value 1. That means if c is greater or equal to 18.1, k value will be 1. Similarly, if c is smaller or equal to $\overline{C}$-3σ=0.73, then k will be 0. "c" of Bogazici University Engineering Department is 6.48. This value corresponds to 0.33 according to the graph. Calculations are shown below.

$\overline{C}$ = 9.40 σ = 2.89

p =0.43 g =1.42 c=6.48

$$k=\begin{cases} 0 & c \le 9.4 - 3*2.89 \\ 0.058 * c - 0.041 & 9.4 - 3*2.89 < c < 9.4 + 3*2.89 \\ 1 & c \ge 9.4 + 3*2.89 \end{cases}$$

k=0.058 * c - 0.041 = 0.33

By using this k value;

avg # of publications per author = k*g+(1-k)*p= 0.33*0.43+(1-0.33)*1.42= 0.759

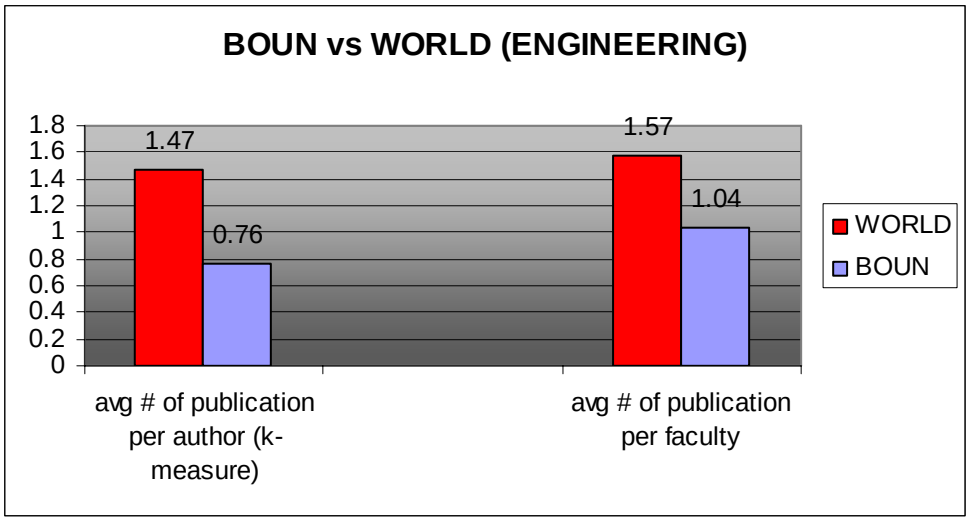

Figure 11: Comparison with k-measure (Boğaziçi vs World Engineering)

In Figures 11 and 12 comparisons are made between Bogazici University and World Average values using k-measure. Average number of publications per faculty is also shown for a better understanding.

The suggested evaluation method is to compare the *k-measure* of the particular academic unit with the world average. This can be done by taking the ratio of the two. As an example Bogazici University Engineering Faculty can be evaluated. Average number of publications per author is 0.759. World average for engineering is 1.47. Then 0.759/1.47 is 0.52 which says that Bogazici University Engineering Faculty publishes half of the world average. This evaluation method can be applied to any kind of academic unit such as departments, faculties, universities, countries for each field.

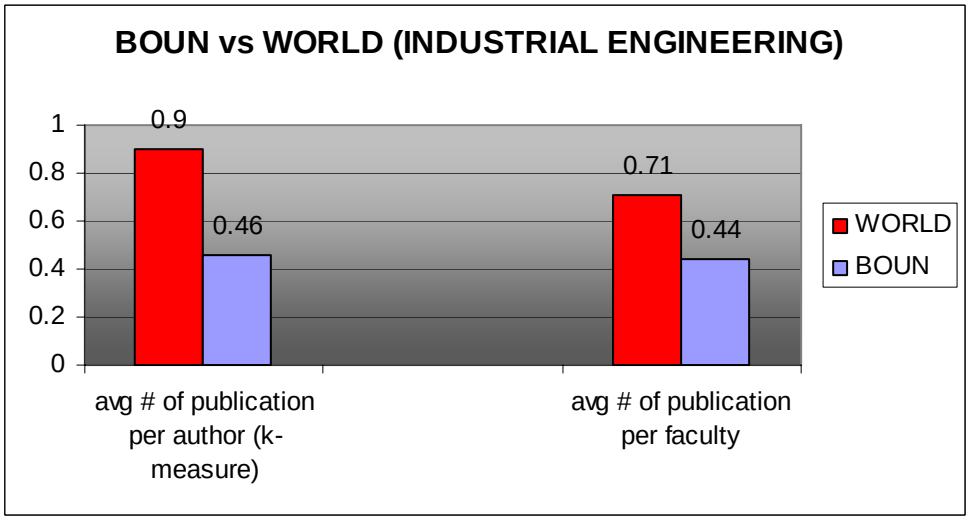

Figure 12: Comparison with k-measure (Boğaziçi vs World Industrial Engineering)

3.6. H-Index

The h-index is an index that quantifies scientific productivity of a scientist based on the number of papers published by the scientist and on how often these papers are cited in papers written by other scientists.

The index is calculated based on the distribution of citations received by a given researcher's publications. A scientist has index h if h of his papers have at least h citations each [7]. For a better understanding, here is an example:

A scientist has 10 published papers. The number of citations those papers received are 6, 7, 8, 6, 5, 8, 3, 4, 7, 5. As can be seen from the numbers, 6 of these papers received at least 6 citations. Therefore, the h-index of this author is 6.

3.6.1. Suggestion for H-Index

H-index can apply to the productivity of a group of scientists, such as a department, a university or a country as well. However, in such applications the size of the group can be a problem. It is a fact that if the size of the groups differs, the number of the publications will differ automatically which is very important in computing h-index. Therefore, if two groups such as two departments are to be compared with respect to their h-indexes, size factor should be taken into consideration.

The suggestion for overcoming the size problem is dividing the h-indexes by the number of group members.

In order to see the effect of sizes of the departments, the industrial engineering departments of the following universities are selected and shown with their number of faculty members. H-indexes and number of papers are taken from ISI Web of Science. Number of faculty members is gathered from university web pages. Data is for 2000-2006.

Table 2: h-indexes versus the Suggested h-index/ faculty

Industrial Engineering Department	h-index	Number of papers	Number of faculty members	(suggestion) h-index/faculty
Univ of California Berkeley	8	131	18	0.44
Columbia University	10	89	16	0.63
Northwestern University	10	112	18	0.56
Arizona State University	12	177	22	0.55
University of Pittsburgh	5	60	15	0.33
Bogazici University	6	51	16	0.38

As can be seen in Table 2, h-index of Arizona State University is the highest one. When the number of faculty members is observed, it is seen that the same university has the highest number of faculty members. Those faculty members produce a lot and therefore, the number of papers increases automatically. Increased number of papers affects the h-index directly. On the other hand, when the h-indexes are divided by the number of faculties, the position of Arizona State University changes as can be seen in the last column. In the last column, it is seen that, the best value belongs to Columbia University, which has a good number of papers with a low number of faculty members.

This sort of calculation is useful in the case of comparing two departments, which have the same h-index. For instance, Columbia University and Northwestern University both have h-index 10. Nevertheless, when the h-index/faculty values are observed, the difference is clear.

4. CONCLUSION

This study firstly generated valuable data about publications and citations. This is important because there are not many studies about this topic. The data collected is representative of the world publications. This contribution may help other studies in the same area of interest.

The data analysis results in many conclusions. One crucial point is that different fields have different characteristics in terms of academic publications. This study underlines these differences, based on statistical analysis. For example, average number of publications per author, average number of publications per faculty and number of authorships per paper are statistically different for different fields. It is not meaningful to compare average number of publications per author values of a medicine department and an economics department. Therefore, it is concluded that every field should be evaluated separately. In other words, if a particular measure of a discipline is to be evaluated, it must be compared to the worldwide average of that measure in the discipline.

Another ambiguous issue is how to evaluate papers with multiple authors. There are many discussions going on worldwide about this problem. In this study, a *k-measure* is suggested to identify average number of publications per author. *K-measure* says that if the publications are valuable, each author should be given relatively high points. On the other hand if these publications are not cited much, each author gets a smaller point. This measure should be applied to each field separately as a result of its design. After the average number of publications per author value is found, it is divided by the worldwide average of that field to be able make a comparison.

To conclude, this research can be a key stone for further studies. Several specific sub-topics can be chosen to dwell on with the help of the data gathered and analysis carried out. It is certainly true that measurement, analysis and evaluation of academic publications and citations is a very deep area and there are many points that necessitate much further research.

5. REFERENCES

1. Garfield, E. (1979). *Citation Indexing. Its theory and application in science, technology and humanities.* New York: Wiley.

2. ISI Higly Cited. *About Citations*. http://portal.isiknowledge.com/portal.cgi?DestApp=HCR&Func=Frame.

3. Mingers, J., Burrell, Q.L. (2006). *Modeling citation behavior in Management Science journals.* Information Processing and Management. Vol.42, No: 6. pp. 1454-1464.

4. Moed, H.F. (2005). *Citation Analysis in Research Evaluation.* Dordrecht (Great Britain): Springer.

5. Moed, H.F., Glänzel, W., and Schmoch, U. (2004) (eds.). *Handbook of quantitative science and technology research. The use of publication and patent statistics in studies of S&T systems*. Dordrecht (the Netherlands): Kluwer Academic Publishers.

6. Price, D.J.D. (1965). *Networks of Scientific Papers.* Science, Vol.149. pp. 510-514.

7. Vikipedia. *Hirsch Number*. http://en.wikipedia.org/wiki/Hirsch_number

8. Vikipedia. *Impact Factor*. http://en.wikipedia.org/wiki/Impact_factor.

9. Vikipedia. *Web of Science*. http://en.wikipedia.org/wiki/Web of Science.

10. Web of Science [electronic resource]. (1997-). Philadelphia, PA: Institute for Scientific Information.

APPENDIX

Table A.1: Correlations between Defined Measures

H_0: $\rho = 0$ versus H_1: $\rho \neq 0$ where ρ is the correlation between…	Correlation	P-value
avg # of authors per publication avg # of publications per author(punishing extreme)	-0.598	0.000
avg # of authors per publication avg # of publications per author(generous extreme)	0.482	0.000
avg # of authors per publication avg # of citations per publication	0.623	0.000
avg # of authors per publication H-index	0.562	0.000
avg # of authors per publication Impact factor	0.714	0.000
H-index avg # of citations per publication	0.633	0.000
H-index Impact factor	0.806	0.000
H-index New index	0.434	0.002
Impact factor New index	0.438	0.001

In Table A.13 for USA ENGN 23.144 papers, for USA BIOL 36,804 papers, for USA PHYS 15,704 papers and for JAPAN ENGN 13,726 papers are used. The first values in the cells are correlation coefficients and the second values are the p values for correlation hypothesis testing.

Table A.2: Correlation Matrices between various measures

USA ENGN 2000	times cited of each paper	number of pages of each paper
number of pages of each paper	-0.031 0.000	
number of authors of each paper	0.194 0.000	-0.142 0.000

USA BIOL 2000	times cited of each paper	number of pages of each paper
number of pages of each paper	0.032 0.000	
number of authors of each paper	0.229 0.000	-0.034 0.000

USA PHYS 2000	times cited of each paper	number of pages of each paper
number of pages of each paper	0.370 0.000	
number of authors of each paper	0.136 0.000	0.019 0.019

JAPAN ENGN 2000	times cited of each paper	number of pages of each paper
number of pages of each paper	-0.013 0.115	
number of authors of each paper	0.139 0.000	-0.116 0.000

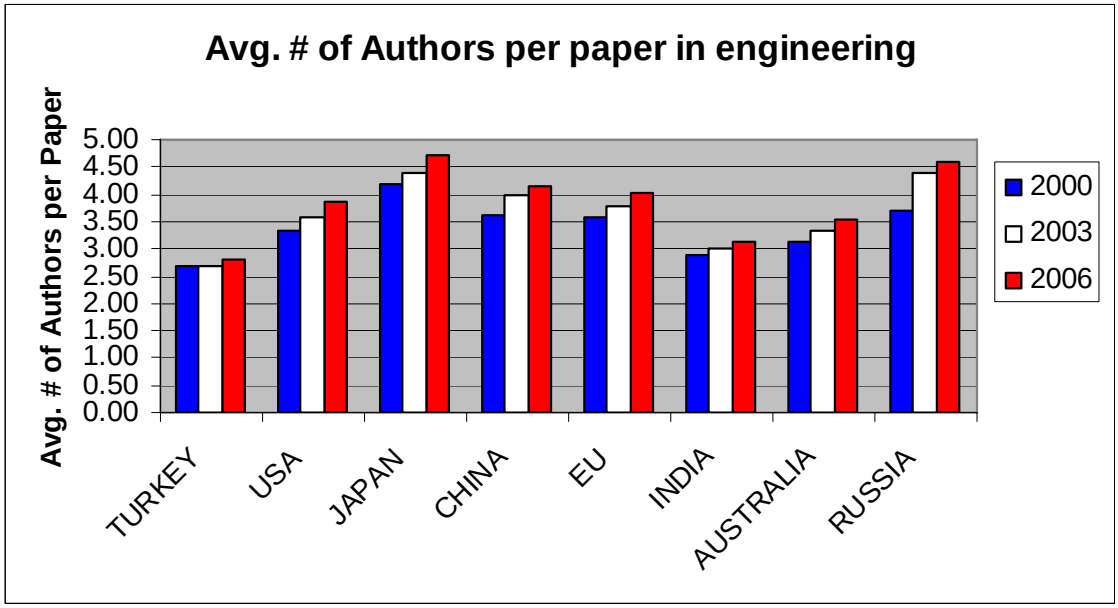

Figure A. 1: Average Number of Authors per Paper in Engineering

In Table A.3 p-values that are shown with blue are to indicate the similarity between the particular fields and red ones are for the differences

Table A.3: T test results

$H_0: \mu_1 - \mu_2 = 0$ versus $H: \mu_1 - \mu_2 \neq 0$		MED-BIOL	ENGN-MED	ENGN-IND ENGN	IND ENGN -BIOL
Avg. # of publication per author (punishing extreme) # of publications / # of authors	mean	0.382 0.3482	0.539 0.382	0.539 0.535	0.348 0.535
	p value	0.408	0.006	0.953	0.003
Avg. # of publication per author (generous extreme) total # of authorship / # of authors	mean	2.077 1.699	1.949 2.077	1.948 1.243	1.243 1.699
	p value	0.249	0.708	0.000	0.000
Avg. # of publication per faculty # of publications / # of faculty	mean	1.39 1.535	1.571 1.390	1.571 0.684	0.684 1.635
	p value	0.421	0.325	0.000	0.000
Avg. # of authors per publication total # of authorship / # of publications	mean	5.264 4.481	3.629 5.264	3.629 2.810	2.810 4.881
	p value	0.165	0.000	0.000	0.000
Avg # of pages per publication	mean	6.540 7.790	8.960 6.54	8.980 12.130	12.120 7.79
	p value	0.028	0.002	0.001	0.000

$H_0: \mu_1 - \mu_2 = 0$ versus $H: \mu_1 - \mu_2 \neq 0$		ECON-IND ENGN	PSYCHOL-IND ENGN	IND ENGN-MATH	MATH-PSYCHOL	PHYS-MED
Avg. # of publication per author (punishing extreme) # of publications / # of authors	mean	0.5166 0.535	0.3875 0.535	0.535 0.649	0.649 0.3875	0.418 0.382
	p value	0.747	0.015	0.064	0.000	0.421
Avg. # of publication per author (generous extreme) total # of authorship / # of authors	mean	1.25 1.243	1.275 1.243	1.243 1.53	1.53 1.275	1.909 2.077
	p value	0.896	0.591	0.000	0.000	0.602
Avg. # of publication per faculty # of publications / # of faculty	mean	0.447 0.684	1.082 0.684	0.684 0.992	0.992 1.082	2.065 1.39
	p value	0.020	0.002	0.012	0.450	0.001
Avg. # of authors per publication total # of authorship / # of publications	mean	2.493 2.81	3.457 2.81	2.810 2.386	2.386 3.457	4.686 5.264
	p value	0.050	0.003	0.005	0.000	0.059
Avg # of pages per publication	mean	12.130 13.42	12.130 10.75	12.130 14.15	14.150 10.75	7.840 6.54
	p value	0.240	0.078	0.080	0.007	0.021

***K-measure* – Engineering**

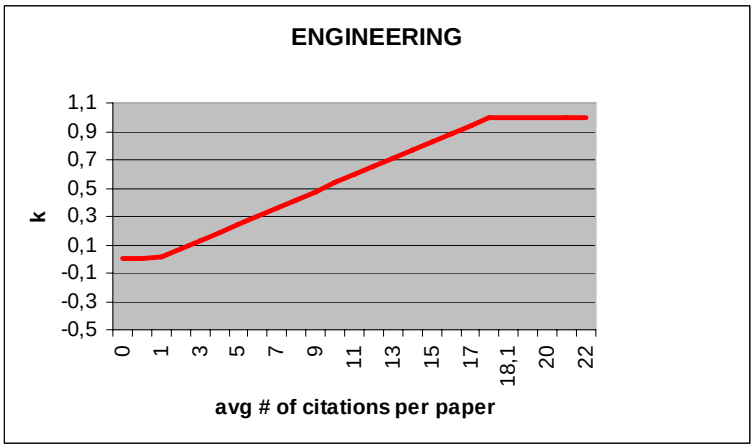

Figure A. 2: Suggested *k-measure* - Engineering

$$\overline{C}=9.40 \quad \sigma=2.89$$

$$k=\begin{cases} 0 & c \le 0.706 \\ 0.057*c - 0.04 & 0.706 < c < 18.09 \\ 1 & c \ge 18.09 \end{cases}$$

Table A.4: Calculation of Suggested *k-measure* - Engineering

Engineering			
	Bogazici University	**Turkey**	**World**
c= average # of citations	6,48	6,22	-
k	0,332068092	0,317115251	0,5
p	0,43	0,57	0,5696306
g	1,42	1,56	1,56
number of publications	0,758747411	0,883944098	1,0647147

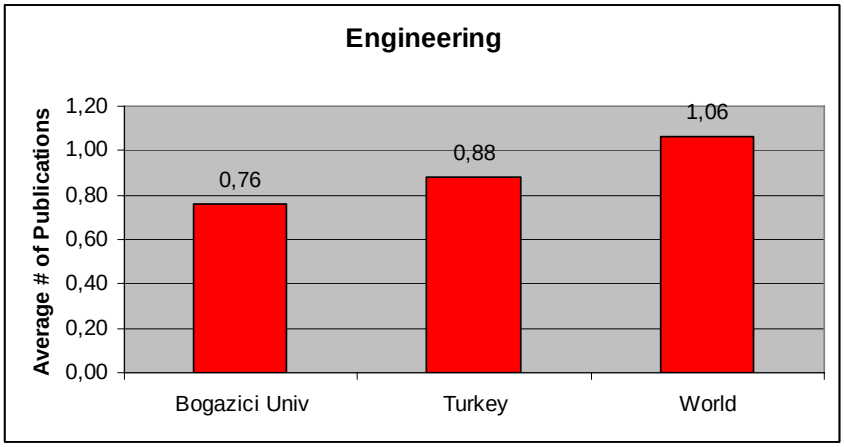

Figure A. 3: Comparisons with *k-measure* - Engineering

***K-measure* – Industrial Engineering**

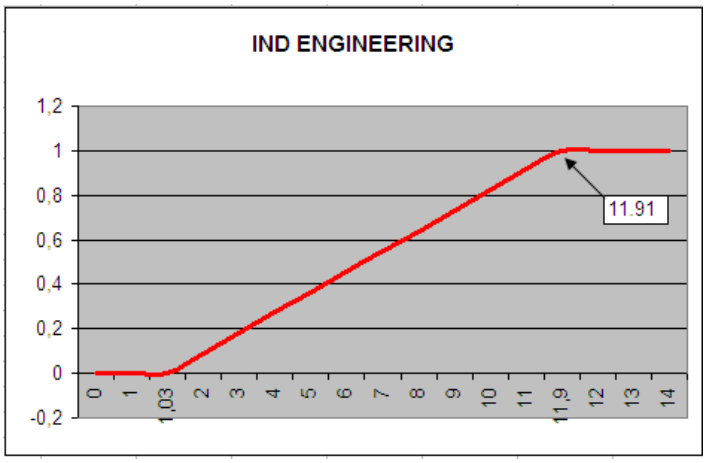

Figure A. 4: Suggested *k-measure* -Industrial Engineering

$$\overline{C}=6.47 \quad \sigma=1.81$$

$$k=\begin{cases} 0 & c \le 1.03 \\ 0.09*c - 0.09 & 1.03 < c < 11.91 \\ 1 & c \ge 11.91 \end{cases}$$

Table A.5: Calculation of Suggested *k-measure* - Industrial Engineering

Industrial Engineering			
	Bogazici University	Turkey	World
c= average # of citations	4,09	5,15	-
k	0,281250001	0,37867647	0,5
p	0,34	0,51	0,47
g	0,77	1,35	1,33
number of publications	0,4609375	0,82808824	0,9

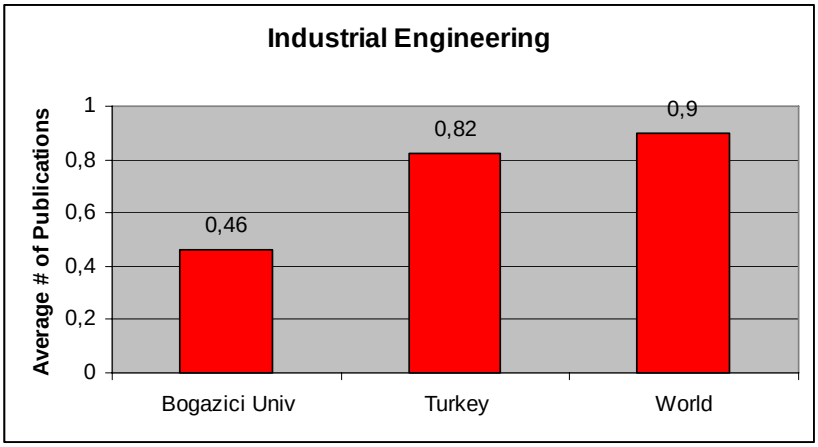

Figure A. 5: Comparisons with *k-measure* – Industrial Engineering

***K-measure* - Mathematics**

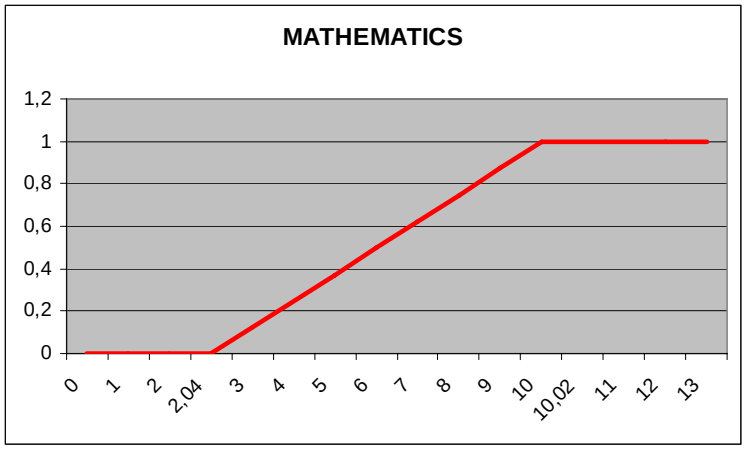

Figure A. 6: Suggested *k-measure* - Mathematics

$$\bar{c} = 6.03 \quad \sigma = 1.375$$

$$k = \begin{cases} 0 & c \leq 2.04 \\ 0.125*c-0.256 & 1.03 < c < 10.02 \\ 1 & c \geq 10.02 \end{cases}$$

Table A.6: Calculation of Suggested *k-measure* - Mathematics

Mathematics			
	Bogazici University	**Turkey**	**World**
c= average # of citations	50,5	4,37	-
k	1	0,291979949	0,5
p	0,44	0,714950828	0,65
g	1,05	1,403566605	1,58
number of publications	1,05	0,916012827	1,11

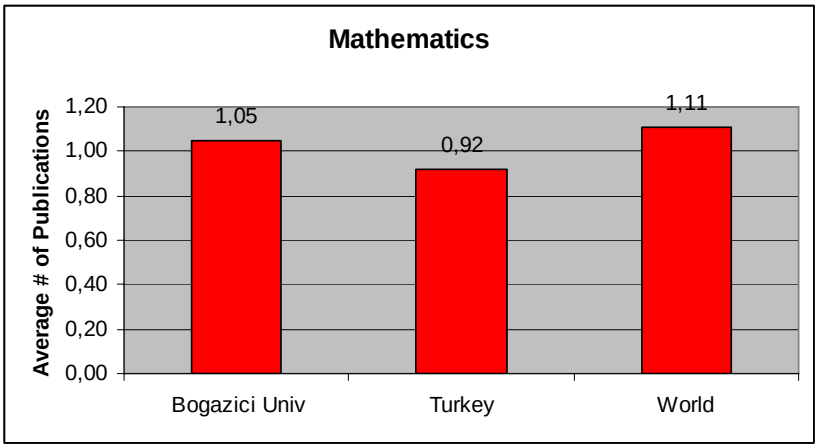

Figure A. 7: Comparisons with *k-measure* - Mathematics

***K-measure* - Psychology**

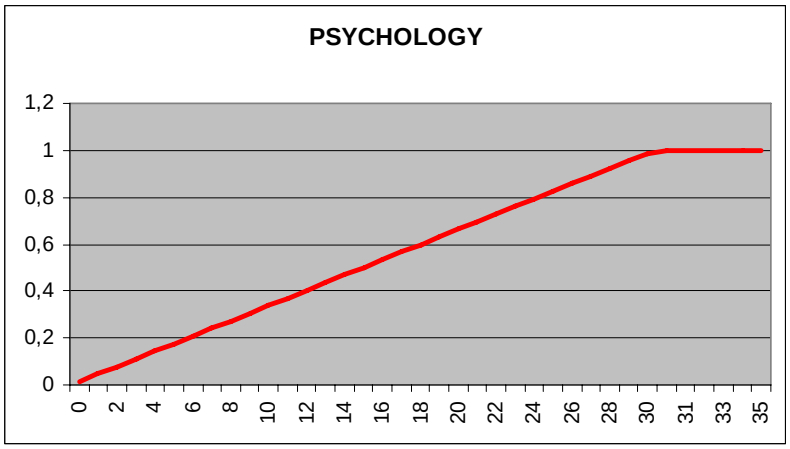

Figure A. 8: Suggested *k-measure* for Psychology Department

$$\overline{C}=14.9 \quad \sigma=5.15$$

$$k=\begin{cases} 0 & c \le 0.014 \\ 0{,}058*c-0{,}040 & 0.014 < c < 30.04 \\ 1 & c \ge 30.04 \end{cases}$$

Table A.7: Calculation of Suggested *k-measure* - Psychology

Psychology			
	Bogazici University	**Turkey**	**World**
c= average # of citations	14	17,11	-
k	0,764550263	0,943409246	0,5
p	0,31	0,39	0,40
g	1,06	1,24	1,42
number of publications	0,883412697	1,193611405	0,911059234

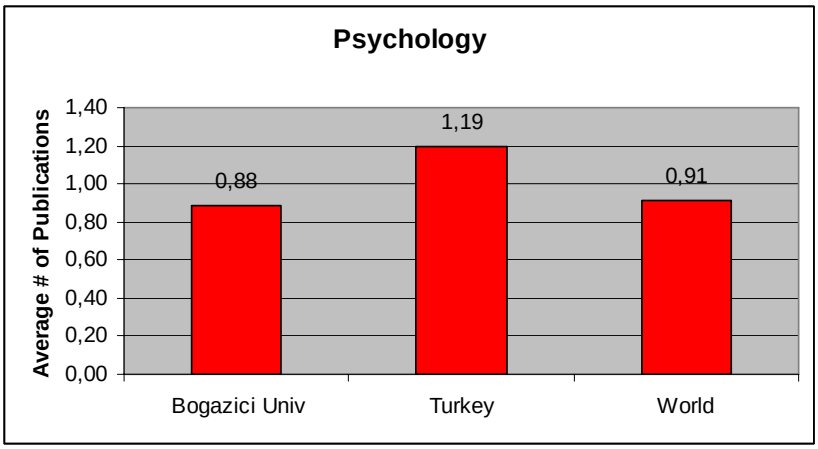

Figure A. 9: Comparisons with *k-measure*- Psychology

***K-measure* - Physics**

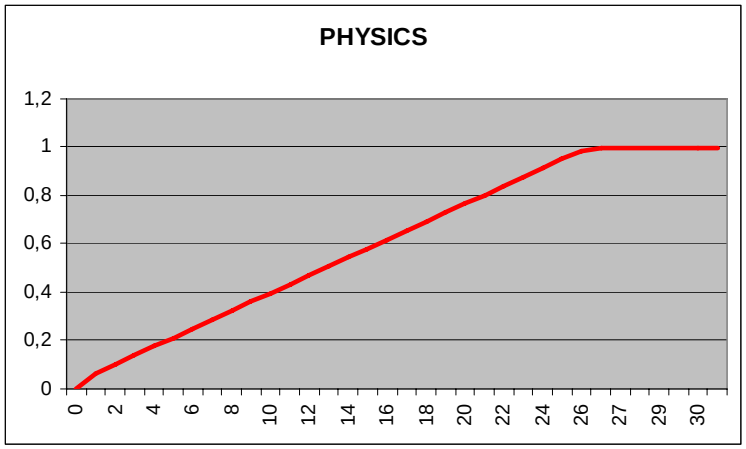

Figure A. 10: Suggested *k-measure* - Physics

$$\bar{c}=12.81 \quad \sigma=4.51$$

$$k=\begin{cases} 0 & c \le 0 \\ 0{,}037*c+0{,}027 & 0< c <26.36 \\ 1 & c \ge 26.36 \end{cases}$$

Table A.8: Calculation of Suggested *k-measure* - Physics

Physics			
	Bogazici University	**Turkey**	**World**
c= average # of citations	1,75	6,62	-
k	0,091881919	0,271586716	0,5
p	0,37	0,50	0,39
g	1,22	1,74	1,99
number of publications	0,448099631	0,838568083	1,192187432

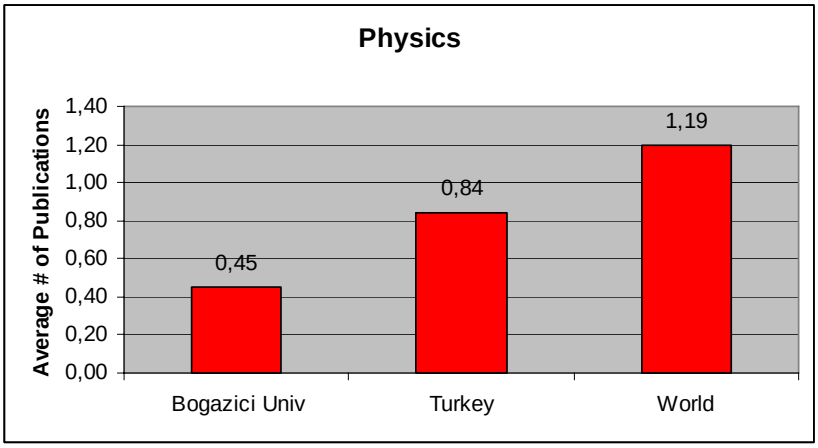

Figure A. 11: Comparisons with *k-measure* - Physics

***K-measure* - Biology**

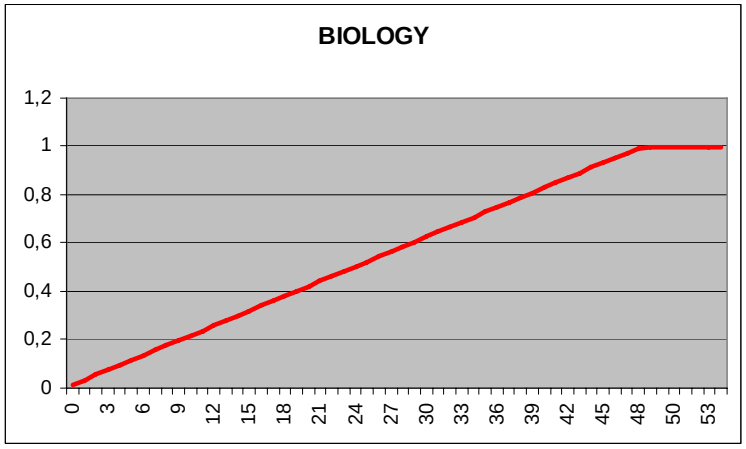

Figure A. 12: Suggested *k-measure*- Biology

$$\overline{C}=23.84 \quad \sigma=8.17$$

$$k=\begin{cases} 0 & c \le 0 \\ 0{,}02*c+0{,}01 & 0< c <48.34 \\ 1 & c \ge 48.34 \end{cases}$$

Table A.9: Calculation of Suggested *k-measure* - Biology

Biology			
	Bogazici University	**Turkey**	**World**
c= average # of citations	36	8,28	-
k	0,748165296	0,182446388	0,5
p	0,1	0,30	0,33
g	1,16	1,51	1,69
number of publications	0,893055214	0,522743206	1,012686924

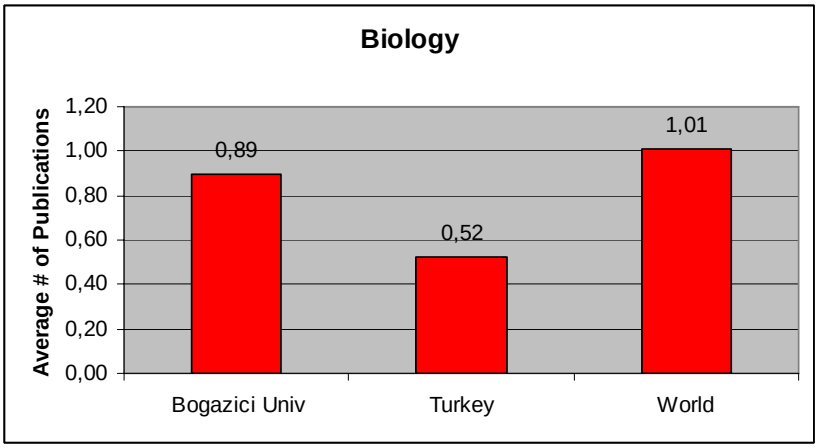

Figure A. 13: Comparisons with *k-measure* - Biology

***K-measure* - Economics**

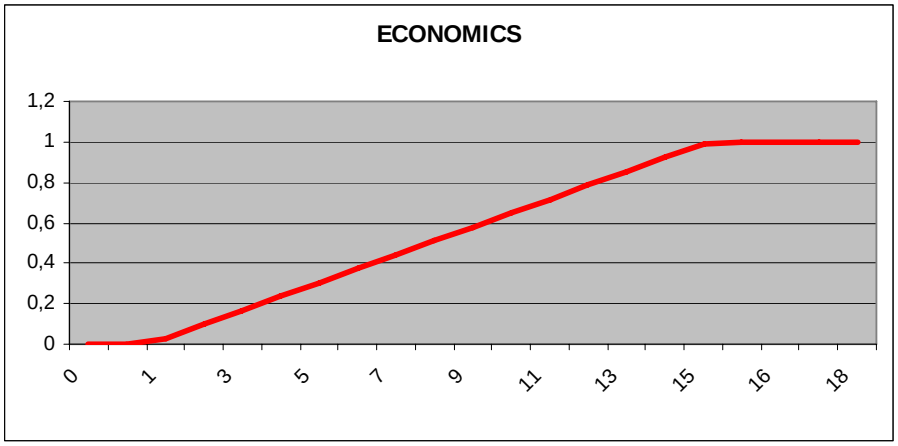

Figure A. 14: Suggested *k-measure* - Economics

$\overline{C}$=7.84 σ=2.43

$$k=\begin{cases} 0 & c \le 0.55 \\ 0{,}06*c-0{,}03 & 0.55< c <15.13 \\ 1 & c \ge 15.13 \end{cases}$$

Comparison graph of Economics does not exist because there are no Boğaziçi publications in 2000.