Citation Journal Impact Factor as a Measure of Research Quality

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Abstract. The aim of this paper is to determine if the scientific papers published in high impact journals are not only of sufficient "a priori" quality to be accepted by such journals, but acquire further impact because they are cited by journals with at least a similar impact. A normalized impact factor (NIF) is proposed as a measure to compare the visibility of research conducted by different university departments working in different disciplines. This analysis is supplemented by a study of the distribution by quartiles of the journals involved. In addition, the quality of the journals citing the papers in the sample selected for the study is evaluated to determine research prestige. The feasibility of using citation journal impact in the evaluation as an incentive for research quality is posed in this work. This paper will be of interest to those institutions interested in quality research evaluation as well as those involved in science policy.

Key Words. University Departments' evaluation; Visibility; Citation Analysis; Impact Factor

1. Introduction

The development of a method for comparing institutions working in different areas is essential to the analysis of a university environment such as Spain's, with 48 public and 28 private universities. These institutions are evaluated as a whole on a regular basis, often to rank them on the grounds of their scientific activity [1, 2, 3]. Such exercises fail to take the enormous differences among universities into consideration, however. The factor with the greatest effect on the results of such global evaluations is more than likely the area of specialization, for scientists' habits and research results vary substantially from one subject matter to another. In a recent analysis of scientific activity in all Spanish public universities (measured as papers published and cited) on the basis of subject diversity, publishing profiles were found to differ depending on the degree of specialization [4].

This aspect has been studied together with the Impact Factor (IF) indicator. Traditionally, IF has been considered as an impact or quality measure, and all its advantages and limitations have been reviewed in the following studies [5, 6, 7, 8, 9, 10, 11].

In order to solve the IF limitations as well as the bias of comparing universities with different subject profiles, the solution proposed in the present study is to normalize the IF values provided by the ISI by applying a normalized impact factor (NIF). This indicator could then be used to analyze the impact of each department area's output, conduct an inter-area comparison and evaluate the overall impact of the university as a whole. Many "normalized" impact factors are available for scientific literature, such as those developed by the Centre for Science and Technology Studies (CWTS), discussed by Moed [12] in his latest book on citation analysis.

Journal positions by quartiles within the subject areas listed by Journal Citation Reports (JCR) were also analyzed to supplement the NIF information. These two analyses are complementary because IF distribution varies widely across disciplines: i.e., one subject area may have IF values with a very low standard deviation, indicating that they are concentrated around a central value, with all the journals exhibiting a similar NIF, whereas in others the standard deviation may be high, a reflection of substantial differences between NIF values. This makes the information provided by quartile distribution on a journal's position with respect to other journals dealing with the same subject matter particularly useful.

Nonetheless, while quality analysis based solely on a publishing journal's impact factor limits the conclusions that can be drawn respecting its popularity, it furnishes little information on its prestige. So, the quality of the journals where papers are cited (the "citing journals") is also a factor to be considered, according to some authors who think that the impact of the periodicals where a paper is cited should be considered along with the number of times it is cited [13, 14].

Consequently, this study aims to compare the impact both of a sample of papers and of the journals, in which they are cited, on the assumption that measuring the quality of the journals in which papers are cited is an optimal indicator for analyzing the quality of such papers.

The underlying premise is that scientific papers published in high impact journals are both of sufficient "a priori" quality to be accepted by such journals and acquire further impact because the journals where they are cited have a similar impact.

Consequently, the primary objective addressed in this study to verify this premise was to test the suitability of measuring the visibility of citing journals as a method for analyzing the visibility of the articles cited. This objective was pursued by focusing on the following more specific targets: on the one hand, to analyze journals where a given Spanish public university publishes its papers to determine both the NIF and their relative position in the JCR listing (quartile occupied in the respective subject area classification for the period studied); and

on the other, to analyze the citing journals' NIF and relative position by quartile, likewise in their subject area classification. Finally, the impact and visibility measures of the two series of periodicals were also compared.

2. Methodology

The case study was defined on the basis of the scientific output of ten Carlos III University of Madrid (UC3M) departments that routinely publish in journals included in ISI databases, taking the information required from the Web of Science.

The university's output was retrieved from the "Address" and "Reprint address" fields in the above database. Each department's production and the records on the respective citations were subsequently normalized.

The period covered was from 1997 to 2003 (extended to 2004 for the citations). The units selected were: from the university's Polytechnic School, Mathematics (MATH), Physics (PHY), Materials Science and Engineering and Chemical Engineering (MAT), Electrical, Electronic and Robot Engineering (ELEC), Mechanical Engineering (MECH), Computer Science (COMP), and Communications Technology (COMM), and from its Social and Legal Science Faculty, Economics (ECO), Business Administration (BUS) and Statistics (STAT).

The indicators used in the study were:

- Normalized impact factors (NIFs) for UC3M publishing and citing journals. This indicator is proposed to obtain the mean impact for department output when several areas are covered and relate it to the mean factors for each respective category. An index was calculated to render any journal's impact factor comparable to any other by relating its IF to the mean IF of the category to which it belongs, or to the mean of the mean IFs for several categories in the event of multidisciplinary journals. This indicator, which measures the real difference between an IF and the mean for the category, is unaffected by the concentration or deviation of the category's IF distribution.

  In this procedure, the following formule has been applied to find the NIF:

$$NIF = \frac{UC3MjournalIF}{\frac{\sum jrnlF\_category}{n}}$$

  where n= No. of journals in each category.

  The value found was then used to rescale each IF to the mean IF of the respective subject category; the result was a comparable inter-category IF. For journals having more than one subject category, their IF has been rescaled as follows:

$$NIF = \frac{UC3MjournalIF}{\left(\frac{\sum jrnIF\_category_1}{n_1} + \frac{\sum jrnIF\_category_2}{n_2} + ... + \frac{\sum jrnIF\_category_n}{n_n} \right)}{N}$$

where N = No. of subject categories.

A department's NIF for a specific year has been calculated as the mean NIF for all the papers produced by that area in the year in question.

The interpretation of the indicator is: if NIF>1, the journal had an IF higher than the mean; where NIF<1, its IF was lower than the mean; if NIF=1, the journal's IF concurred with the mean; if NIF=0, either no IF was available for the journal in the JCR for the respective year, or the value was 0. A few remarks on the NIF for the citing journals are in order:

» This analysis excluded both citing articles with no IF and department's output that was not cited, for their inclusion would have distorted the analysis of department prestige, inasmuch as it would have entailed taking "zero" citation NIFs into consideration. These data were analyzed separately so that information on uncited articles would not be lost.

» When an article was cited more than once, the NIF of the citing journals was not averaged; rather, the citations were aggregated: e.g., in the event of papers receiving several citations, instead of averaging them, each citation was considered individually. For this reason, the impact of citing journals carried more weight in articles with a large number of citations than the mean impact of papers with fewer citations. That is to say, account was taken of both the popularity and the prestige of scientific output.

- Relationship between the UC3M NIF and the NIF of its citing records. This indicator relates the impact of scientific output to the impact of the citations, associating the visibility of each department's published papers with the visibility of the journals citing such papers.
- Distribution of UC3M output and the respective citations by JCR quartile. This technique, commonly used in similar studies [15, 16], consists in dividing the list of publications (ranked by IF in descending order) into quartiles to compare journals in terms of their relative positions, regardless of the subject area or speciality involved. Where journals were assigned to more than one subject area and perhaps positioned in different quartiles in each, only the highest ranking quartile was used.
- Relationship between UC3M output quartiles and citation record quartiles. This indicator used percentage and absolute values to compare the impact of the citing journals to the impact of UC3M output. With this approach, the percentage of citations in each quartile was related to the percentage of pa-

pers in the respective quartile for the university as a whole. Correspondence analysis (CA) was used to analyze the relationship between citing and cited quartiles. This method aims to deduce the relationships between different categories by defining their similarities and grouping them accordingly [17]. The correspondence analysis values obtained were plotted on bubble charts where, in addition to the similarities between variables, a third measure is shown, namely the relative weight acquired by each value when analyzed.

3. Results

3.1 General output and visibility data

By way of introduction to the findings on the relationship between publishing and citing journal visibility, Table I gives the data compiled on each UC3M department's scientific output and the respective citations, ordered by percentage of the latter. The percentage data refer to the respective totals (1462 papers analyzed, 4594 citations).

DEPARTMENT	% UC3M PAPERS	% UC3M CITATIONS	UNCITEDNESS RATE (%)	% SELF-CITATIONS	CITATIONS PER PAPER
MATH	22.63	38.47	23.35	29.16	5.33
PHY	14.30	22.56	23.70	21.26	4.95
MAT	11.04	8.93	49.08	46.97	2.53
STAT	9.76	7.91	39.58	16.94	2.54
ECO	11.31	7.11	43.71	9.42	1.97
MECH	5.76	5.12	36.47	24.89	2.79
ELEC	5.83	2.92	44.19	33.82	1.57
COMM	6.91	2.46	58.82	39.47	1.12
BUS	4.20	2.27	41.94	7.62	1.69
COMP	8.27	2.25	67.21	36.54	0.85

Table I. Output by department and distribution of citations

According to Table I, the Mathematics Department (MATH) accounted for the highest percentage of papers published and had the highest percentage of citations. It was also the department with the highest percentage of citations per paper and the smallest percentage of papers not cited. The Physics Department (PHY) ranked second in each of these indicators. In his analysis of the 100 largest European research universities [18], van Raan also found a relationship between high production and low number of uncited papers.

The department with the smallest portion of papers was Business Administration (BUS) with 4.20% of the documents published, followed by Electrical, Electronics and Robot Engineering (ELEC) and Mechanical Engineering (MECH), with 5.83% and 5.76%, respectively.

The smallest proportion of citations was recorded for the Computer Science Department (COMP), which also had a very high percentage (67.21%) of uncited papers. It was, moreover, the only department that had less than one citation per paper (0.85), as the rate for the remaining departments ranged from 1.12 to 5.33.

Despite the large number of non-uncited papers, these data did not differ substantially from Seglen's finding to the effect that over 50% of articles selected at random from the Science Citation Index had not been cited three years after publication [19].

Since the unit analyzed in this study was the department, self-citations were regarded to be a department's citations of its own papers. They were identified as the citation records in which Carlos III University of Madrid or the respective department was among the affiliations listed. Of the 4594 citations referring to UC3M papers, 1260 (27.42%) were included in papers authored by the university's own researchers. According to Table I, the highest percentage of self-citations was recorded for the Materials Science Department (MAT), where they accounted for nearly one half (46.97%) of the area's visibility. The three departments with the lowest self-citation indices, in turn, were: Business Economy (BUS), with 7.62%, Economics (ECO) with 9.42% and Statistics (STAT) with 16.94%.

Overall, the self-citation rate found in this study was lower than found for Spanish output as a whole in 1999, when the figure was 34% [20] and lower also than the 36% reported for Norwegian publications between 1981 and 1986 [21].

3.2 Normalized Impact Factor (NIF) for UC3M output and respective citations

The NIFs were found for the two series analyzed, i.e., journals publishing UC3M papers and the respective citing journals; the values for the period covered in the study are graphed in Figure 1.

The figure shows that the citing journal NIF was higher than the publishing journal figure in all the years analyzed. More specifically, the decline in the UC3M's impact in 2003 was not mirrored by the citing journals' NIF. The mean impact for the UC3M papers across the entire period analyzed was 1.43: i.e., 43% higher than the mean IFs of the journals in the respective categories.

The mean NIFs for the publishing journals were calculated for all years and broken down by unit of study for an exhaustive analysis of each department's impact and visibility. The same methodology was used to find the NIF for each

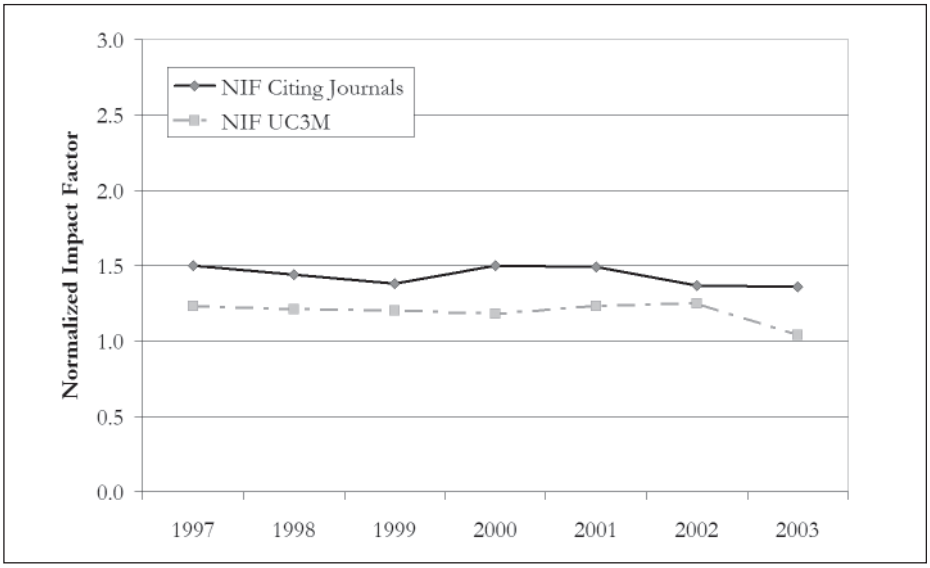

Fig. 1. Comparison of UC3M publishing and citing journal NIFs

department's citing journals. The difference between the two values was then calculated to verify the existence or otherwise of a relationship between publishing and citing journal NIFs. The results are set out in Table II.

Note that the UC3M departments whose citing journals had the highest NIF were the same departments whose papers exhibited the highest impact, namely Physics (PHY) and Mathematics (MATH). Not only did these two units publish in journals with the highest NIF – 1.59 for the former and 1.40 for the latter – ,

DEPART-MENT	NIF FOR AREA/DEPT PAPERS	NIF FOR CITING JOUR.	RATIO (CITING-PUBLIC.)
MATH	1.40	1.65	1.18
PHY	1.59	1.57	0.99
MAT	1.03	1.38	1.34
STAT	0.94	1.02	1.09
ECO	1.02	0.96	0.94
MECH	1.10	1.41	1.28
ELEC	1.12	1.22	1.09
COMM	1.14	1.28	1.12
BUS	0.87	1.13	1.30
COMP	0.81	1.08	1.33

Table II. Difference between citing journal and publishing journal NIF

but their papers were in turn cited in journals with the highest NIF: 1.57 for the Physics (PHY) and 1.65 for the Mathematics (MATH). In this same vein, the only departments having citing journals with a lower impact than their publishing journals were Economics (ECO) and Physics (PHY), although in the case of PHY the ratio between the two indices was 0.99.

The departments showing the greatest variation between the two indicators were Materials Engineering and Science and Chemical Engineering (MAT) and Mechanical Engineering (MECH). In both cases, their papers were cited by journals with a NIF of close to 1.4, but published in journals with a NIF of around 1. Moreover, several departments' publishing and citing journal NIFs barely differed; i.e., they published and were cited in journals with similar visibility. This group included Statistics (STAT), Electrical, Electronic and Robot Engineering (ELEC) and Communications Technology (COMM).

3.3 Relationship between publishing journal quartiles and citing journal quartiles

This section relates the quartiles occupied by the journals publishing university research to the quartiles in which the journals citing these articles are positioned. In this regard, Figure 2 shows each department's percentage output by quartiles, while the quartile distribution of the citing journals is illustrated in Figure 3.

The graph in Figure 2 shows that the departments with the highest proportion of papers in the first quartile were Physics (PHY), Mechanical Engineering (MECH) and Mathematics (MATH), in that order; 70% of the Physics Depart-

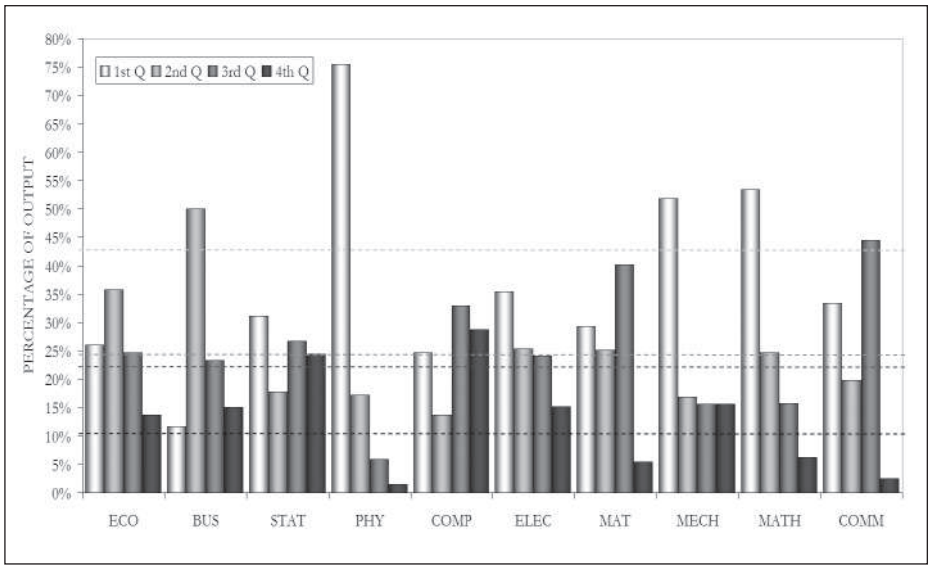

Fig. 2. Department output. Distribution by quartiles

ment output, in fact, was published in first quartile journals. A substantial difference was also observed between the first and second quartile in Mechanical Engineering (MECH), which accounted for 52% and 16% of the department's production, respectively.

Business Administration (BUS) showed low first quartile visibility and was the department with the lowest percentage of publications in this quartile, while half of its output was in the second quartile. Economics (ECO) followed a similar pattern, but with a much larger (double in fact) percentage of first quartile papers and a smaller share of second quartile papers than Business Administration (BUS). The third and fourth quartile percentages were similar for these two social science departments.

Computer Science (COMP) output was concentrated in the third and fourth quartiles, with less than 25% of its papers published in first quartile and less than 15% in second quartile journals.

Figure 3, which gives the quartile distribution of citing journals, shows that Physics (PHY), Mechanical Engineering (MECH) and Mathematics (MATH) had a larger proportion of first quartile citations than the other UC3M departments. Around 70% – 72% for Mechanical Engineering (MECH) – of the references to papers produced by these three departments appeared in first quartile journals.

Other departments in which first quartile citations prevailed were: Computer Science (COMP), Electrical, Electronic and Robot Engineering (ELEC), Materials Science (MAT), Communications Technology (COMM) and Statistics (STAT).

In Economics (ECO), the quartile distribution for citations differed substantially from the overall pattern, for most (30.38%) of its citations was positioned in the third,

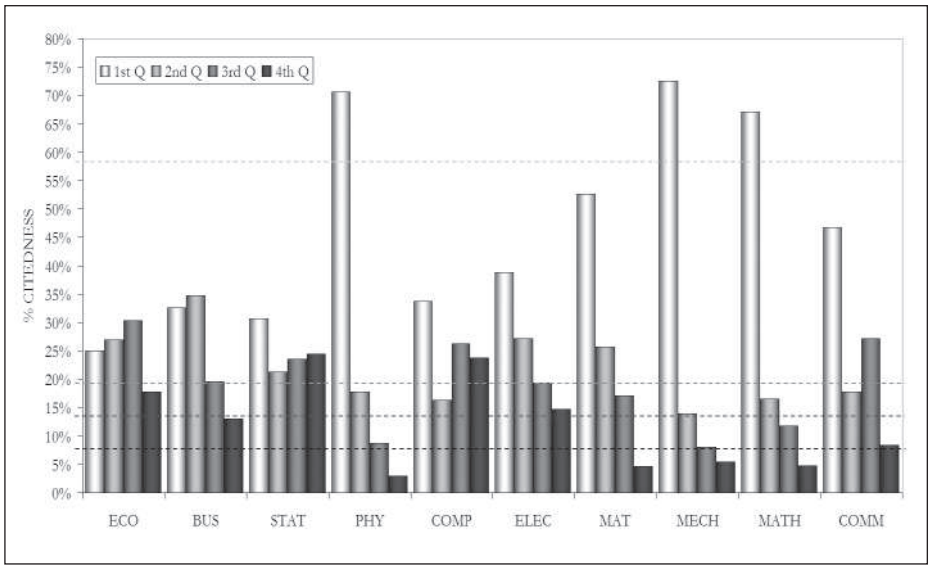

Fig. 3. Department citations. Distribution by quartiles

		CITING JOURNALS			
		1ST Q	2ND Q	3RD Q	4TH Q
UC3M PUBLISHING JOURNALS	1ST QUARTILE	69.87%	15.72%	9.75%	4.65%
	2ND QUARTILE	40.05%	28.15%	19.89%	11.91%
	3RD QUARTILE	24.63%	26.83%	34.88%	13.66%
	4TH QUARTILE	28.37%	23.40%	24.82%	23.40%

Table IV. Relationship between citing journal and publishing journal quartiles

followed by the second (26.90%) and first (25%) quartiles. Most (35%) of the Business Administration (BUS) paper citations, in turn, were found in second quartile journals, although followed closely by first quartile periodicals (32%).

The two variables are analyzed jointly in Table IV, in which the rows denote publishing journal quartiles and the columns citing journal quartiles. The value in each cell indicates the percentage of citations appearing in journals in a given quartile with respect to the total number of citations received by papers published in journals in that quartile.

The chi-square value obtained, throughout the absolute values, 591.95 [v=9; 16.92 at 95% probability], evinced the existence of a correlation between the quartiles of the journals where UC3M researchers publish their papers and the quartiles of the journals where such papers are subsequently cited.

According to Table IV, 69.87% of the citations of university papers published in first quartile journals were found in first, 15.72% in second, 9.75% in third and 4.65% in fourth quartile journals.

The highest proportion of citations of second quartile papers (40.05%) also appeared in first quartile journals, followed in descending order by 2nd, 3rd and 4th quartile citing journals.

Most of the third quartile paper citations (34.88%) appeared in third quartile journals. The next largest proportion of citations of papers in this quartile was found in second quartile journals, followed by first and fourth quartile journals, in that order.

Finally, the citations of papers published in fourth quartile journals were distributed rather evenly across citing journal quartiles, ranging from 23.40% in the 2nd and 4th to 28.37% in the first quartile.

Correspondence analysis explains the relationship between two variables. Here it was used to determine the relationship between the quartile in which each department published its results (small circles with departments' labels and number of quartile in Figure 4) and the quartiles citing its papers (big circles and labels composed by C-citing- and the quartile in Figure 4).

This itemized analysis by department shows that in most cases, when a department published its papers in first quartile journals, its citations were predominantly published in first quartile periodicals. Figure 4 shows how close the Mechanical

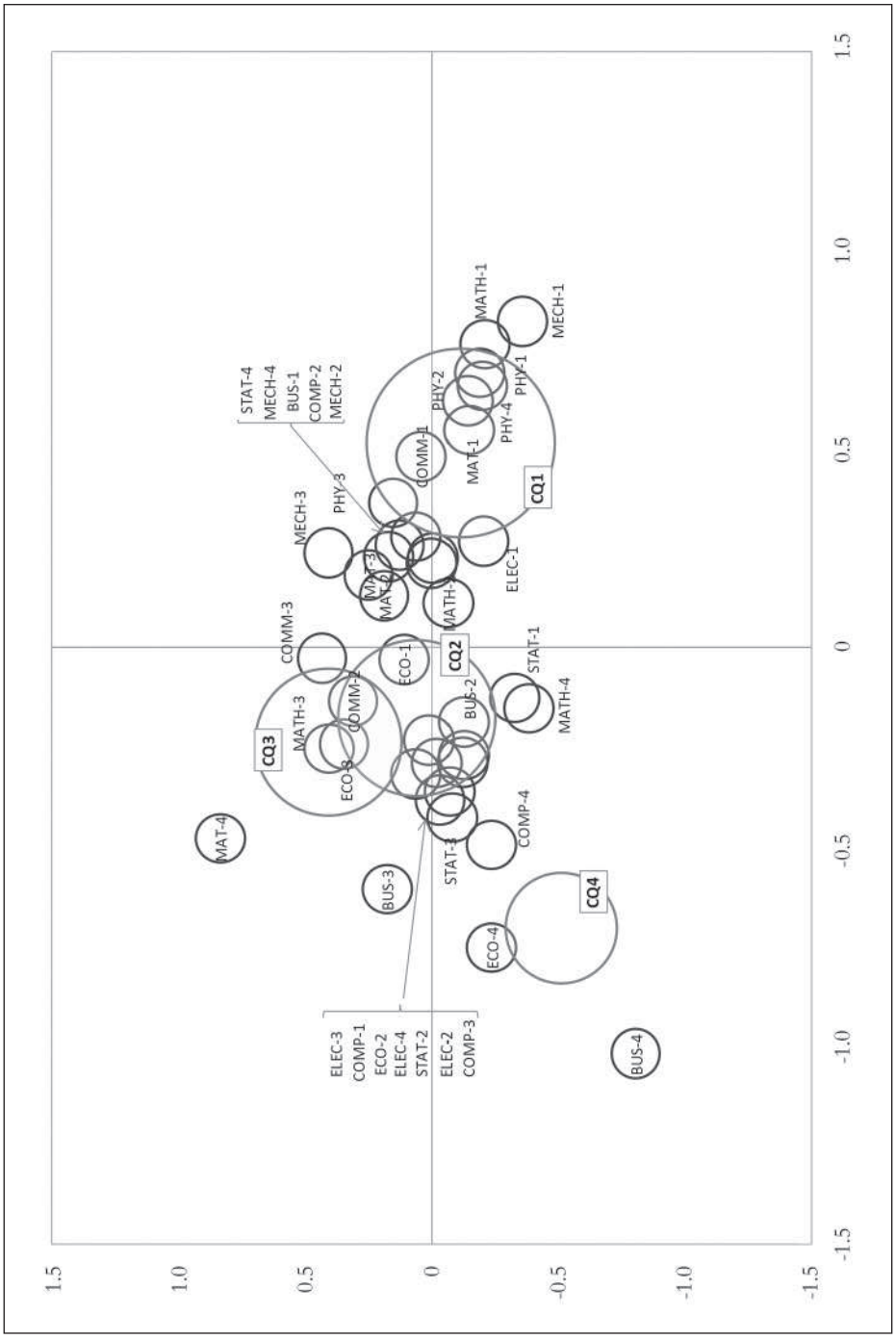

Fig. 4. CA. UC3M production quartiles vs citing journal quartiles

Engineering (MECH), Mathematics (MATH) and Communications Technology (COMM) departments were to the first quartile of citing journals.

Another significant finding was that regardless of the quartile in which they were published, Physics (PHY) and Mechanical Engineering (MECH) papers were primarily cited in first quartile journals. The Economics (ECO) and Business Administration (BUS) department papers, in turn, were cited by journals in the same quartile as the publishing journals.

4. Discussion and Conclusions

The findings of this study show that the methodology proposed is suitable for evaluating institutional quality on the grounds of citing journal impact.

The year-by-year analysis of the findings for the present sample shows that on the whole, UC3M papers were published in journals with a higher than average IF, i.e., a Normalized Impact Factor (NIF) higher than one. Moreover, these papers were cited in journals with a high NIF, on the order of 1.4, in all the years studied. The department breakdown shows the Physics (PHY) and Mathematics (MATH) areas to be particularly prominent in this regard, for while they published in journals with a high NIF, their papers were cited in journals with an even higher factor.

This study revealed that the departments exhibiting the largest difference between publishing and citing journal NIFs were not the ones that published in high impact journals. The reason is obvious, because if an article is published in a journal with a very high impact factor, the possibility of its being cited in journals with even higher IFs is smaller than if it were published in a lower impact journal. Consequently, –while the papers authored by Physics (PHY) and Mathematics (MATH) had the highest impact, they were not the departments with the most favourable difference between citing and publishing journal NIF.

The comparison between the publishing and citing journal quartiles for the various departments showed that the majority of the citations referring to papers published in first quartile appeared in journals in the same quartile. Most of the citations for papers published by the Physics (PHY) and Mechanical Engineering (MECH) departments appeared in first quartile journals, while 68% of the Mathematics (MATH) department citations were also found in the first quartile. The lowest visibility was recorded for Economics (ECO), Statistics (STAT), Business Administration (BUS) and Computer Science (COMP) departments.

In any event, researcher concern about the impact of the journals where they publish may be counterproductive in certain cases, if the journals preferred are not the ones read by the target audience [22]. Indeed, failure to reach the right researchers may determine a smaller number of citations and therefore lower im-

pact. For this reason, researchers should be cautious when choosing the vehicle for transmitting their findings, in addition to seeking publication in high impact journals. The recent trend in scientific evaluation to assess citations makes it preferable to publish in journals whose content and readership are well suited to the type of research addressed.

Lastly, the feasibility of using citing journal impact as an incentive for research quality should be explored. Spanish evaluation agencies, for instance, presently measure researchers' careers in terms of the impact of the journals where they publish their papers; as a result, papers may be published in high impact journals but never cited. In other words, is research quality measured more objectively in terms of the IF of the journal where an article is published or of the number of times it is cited? This study found that departments such as Physics (PHY), Mathematics (MATH) and Mechanical Engineering (MECH), that publish in high impact journals, normally had a higher rate of citations per paper; moreover, their citing journals had a higher impact than the periodicals chosen for publication. Therefore, taking assessment one step further and evaluating the quality of citing journals would not initially appear to jeopardize the sample analyzed. Nonetheless, this practice is regarded to be more suitable to meso- and macro-studies. Inasmuch as citations are sometimes affected by sociological factors, individual researchers may encounter difficulties if their research is assessed on the grounds of citation quality.

Along the lines proposed by Bollen [13], the present paper confirms the premise that even though a given paper may be frequently cited, the quality of such citations may not necessarily be high, whereas other papers may be cited more sparingly, but in high impact journals. This poses the question of whether it is preferable to be profusely cited in mediocre journals or more occasionally in high prestige periodicals. The former option may be a sign of popularity and an indication that the information is being widely used yet the latter is preferable, in principle, for the inference is that papers published in journals with a higher impact are consulted and cited by researchers of greater prestige.

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