**Research productivity of scientists in consolidated vs. non-consolidated teams: the case of Spanish University Geologists**

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**Abstract**

We present some results of an evaluation of research performance of Spanish Senior University researchers in Geology. We analyse to what extent productivity of individual researchers is influenced by the level of consolidation of the team they belong to. Methodology is based on the combination of a mail survey carried out among a defined set of researchers, and a bibliometric study of their scientific output. Differences among researchers have been investigated with regard to team size and composition, patterns of publication in domestic and foreign journals, productivity, co-authorship of papers, and impact of publications. Results indicate that not belonging to a research team represents a handicap at the time of publishing in top international journals. Researchers belonging to consolidated teams are more productive than their colleagues in non-consolidated teams, and these in turn more than individuals without team. Team size does not appear to be as important for scientific productivity as the number of researchers within the team that reached a stable job position. Analysis of the impact factor of journals has not revealed differences among researchers with regard to the visibility of their papers.

## Introduction

Scientists productivity and, in general the whole of their research activity, is influenced by a wide range of factors, such as individual characteristics and context aspects. Among the former, age, psychological aspects, educational background, or gender, can be quoted. Among the latter, social and political context, financing or characteristics of the research team the scientist belongs to (size, composition, degree of consolidation and cohesiveness, leadership, etcetera), are included.

These factors are extensively treated in recent literature, both from a scientometric as well as from a sociological viewpoint. *Dundar and Lewis*[1] overview the literature on research productivity available since 1970 examining individual, departmental and institutional factors affecting the university productivity. In their paper, they also examine the relationship between academic research productivity and institutional factors in USA universities. The series of articles included on a study published in 1979 by UNESCO[2] review different factors that might influence or relate to the performance of research units, such as "*R&D activities; research methods; scientific exchanges and contacts with other units; evaluation methods; planning of the work and choice of research themes; availability of resources; amounts and patterns of influence; supervision; remuneration and career advancement; working climate; and numerous demographic variables like age, experience, staff size, staff turnover, institutional setting, and scientific discipline*"[3]. *Prpi≡*[4] explores patterns and factors of the scientific productivity of eminent Croatian scientists. *Ramesh-Babu and Sing*[5] identified and analysed nearly 200 variables influencing research productivity selecting, after statistical analysis, eleven factors affecting research productivity of scientists. *Scott Long and McGinnis*[6] considered the effects of organisational context over scientific productivity, analysing the productivity and position of a sample of both academic and non-academic scientists. *Johnston*[7] has examined the effects of resource concentration on research performance. Relationship between the size of the teams and their productivity is one of the topics that has caused more interest, generating different results, sometimes contradictory[8]. *Cohen*[9] reviews empirical studies about the relationship between size, age and productivity of scientific and technical research teams.

Over the last few years, scientific research has been more and more carried out within groups or teams of scientists, rather than by separate individuals. It can be assured that teamwork, collaboration and interdisciplinarity are some of the principal characteristics of modern science. In this framework, factors as research team characteristics or collaboration degree, are eventual parameters to be considered when analysing conditionings of researchers' productivity.

Team stability and cohesiveness are factors that play a key role in determining research patterns, productivity and successful performance of scientists. The importance of team cohesiveness as determinant of the productivity and research patterns of scientists, has been considered by *Stankiewicz*[10], who emphasises that size/productivity correlation is strongly determined by the cohesiveness of the team, as well as by the experience of the team leader.

In most scientometric studies that deal with these topics, performance and productivity of research teams are analysed through a strictly bibliometric approach, using as data source the scientific output gathered by databases of the Institute for Scientific Information (ISI), as the Science Citation Index (SCI). However, some approaches to evaluation of performance of research units or teams have been carried out by means of a combination of bibliometrics and other research techniques (peer review, scientist's surveying), showing the complementarity of peer review and bibliometric studies (see, for instance, *Nederhof and Van Raan*[11]).

A key issue in these studies is the way in which research teams are defined. In bibliometric studies, teams are usually defined in terms of co-authorship or cross-citation. On the other hand, in what *Cohen*[9] calls "input-based" studies, teams are defined "by existing administrative arrangements, such as laboratories, research institutes", etc.

In this paper, we present some results of an evaluation of research performance of Spanish Senior University researchers in Geology. We analyse to what extent productivity of individual researchers is influenced by the level of consolidation of the team they belong to. This study is part of a project which objective is to explore to what extent being part of a consolidated, well-established team, affects

research performance, productivity and patterns of publication of scientists. Our aim is to contribute to answer some relevant questions concerning science policy and management issues: Does team consolidation raises productive potential of team members? Does it affect their performance and research habits?

**Methods**

Methodology proposed in this study is based on the combination of a mail survey carried out among a defined set of Spanish University geologists, and a bibliometric study of scientific output of these authors.

In this paper, research teams are not defined in terms of co-authorship, but rather in the sense of *Cohen's* input-based studies[9]. Nevertheless, in our opinion they cannot be considered only in terms of administrative arrangements. In this sense, we do not believe that a mere collection of researchers, with some kind of hierarchical scheme or not, working in the same administrative unit, can be always considered as a research team. This approach, as stated by *Johnston*[7], fails to take into account, firstly that "*research groups are not necessarily homogeneous*", and may "*be organised in different ways according to the technical demands of research"*, and secondly "*the dynamics of groups themselves*". Thereby, we think of research team as a collection or cluster of researchers and technical support personnel belonging to a single research unit (laboratory, department, etceteras), with common scientific interests and objectives, working on one or more common research lines, and sharing tasks in order to achieve said objectives. A research team might be considered as a consolidated, well-established one, when it has reached a certain size, composition, duration, autonomy, funding, member's involvement, cohesiveness, intra and inter-team collaboration , and competitiveness. Nevertheless, we might not forget that these characteristics might vary according to the team context (scientific field, institutional sector, country, etcetera), thus making difficult to define "consolidation" of a research team. In this sense, it is as well to use well-defined samples consisting of well described units and to adequately characterise the organisational and institutional backgrounds of said samples, in order to avoid "*conceptual ambiguities that can make interpretation difficult*"[10].

The surveyed data correspond to a sub-sample of a survey carried out among Spanish researchers in Earth Sciences. A total of 383 scientists, belonging to 132 different research centres from all sectors involved in R&D in this field in Spain, were surveyed about different aspects of their research activity during a five-years period. Geologists represent nearly half of the sample (49.3%), followed by researchers in Environment, Environmental Engineering and Technology, and Hydrology. On the other hand, 35.6% of respondent belong to University faculties, and 49.6% are university lecturers (for a more detailed

description of the sample, see Rey and Sempere[12,13]). Given this diversity, an in order to eliminate possible differences among research activities on the basis of the organisational context in which they are performed, in this study we select, as a sample, University scientists doing research work in the Geology field, as stated by them in the survey. Researchers from polytechnics have been excluded, as their research and publication patterns are presumed to be quite different to that of faculty scientists. Data were collected in some of the seven thematic blocks of the broader, specially created, 27-point questionnaire, which surveys different aspects of respondents' research activity, including publishing and collaboration patterns. Selected questions from the original questionnaire are shown in Appendix.

Our basic structural units for analysis are individual scientists, not research teams. We asked the respondents to ascribe themselves to one of the following categories: a) C researchers, i.e. those working within Consolidated, well-established teams; b) NC researchers, i.e. those belonging to Non-Consolidated, not well-established teams; c) researchers that are not members of any research team, who either work with different teams in different projects; and d) researchers who usually work alone. Researchers on categories c) and d) were further combined into a unique NT (No Team) category. Both sets of researchers have in common that they do not belong to any particular team, neither consolidated nor non-consolidated. Furthermore, we believe little information is lost, as there is only one respondent in the latter category, what otherwise is reasonable given the current interdisciplinarity and collaborative character of the scientific field here studied. Those respondents who indicated more than one category in Q6 where re- assigned according to answer in Q7. Scientists with multiple responses in Q6 and value 'zero' in all sections of Q7 where considered as NT. Questionnaires were ruled out when the team class the researcher belonged to was not clear. This is seen for instance, when there are multiple responses in Q6 and a 'not null' value in Q7, so it was not possible to determine to which answer of question 6 correspond team members of Q7. After data revision and re-codification, the sample size is of 93 individuals.

Bibliometric analysis was carried out starting from bibliographic information retrieved from the CD-ROM version of a multidisciplinary domestic database (ICYT), a multidisciplinary international database (SCI), and an international database specialised in Earth Sciences (GeoRef). ICYT, the Spanish Index on Science

and Technology[14], is the database produced by the Spanish Council for Scientific Research (CSIC). It contains over 130,000 records covering S&T literature published in over 500 Spanish journals since 1979. The Science Citation Index[15] (SCI), produced by the ISI, constitutes a usual bibliometric tool widely used in scientific evaluation studies. Finally, GeoRef, the Geological Reference File[16], is the American Geological Institute's database, containing over 2.2 million references to Geoscience journal articles, books, maps, conference papers, reports and theses, from North America since 1785 and other areas of the world since 1933. The scientific output of the respondents during the five-years period analysed was retrieved from all of the databases.

Differences among researchers have been investigated with regard to: a) Team size and composition (average number of members per category); b) Patterns of publication in domestic and foreign journals; c) Productivity, i.e. number of documents (journal articles, conference papers, scientific and technical reports, patents, maps, books, book chapters and others) per author; d) Co-authorship of papers, through the co-authorship index, i.e. the average number of authors per paper; and e) Impact of publications: The Expected Impact Factor (EIF) has been assigned to author's articles published in journals covered by the SCI, being the EIF of each article the corresponding IF of the publication journal (in the year when it was published, as shown by the ISI's Journal Citation Reports).

We use the whole count method for counting papers. Statistical analyses were carried out with SPSS 10.0 for Windows statistical package. Figures are shown as 'average ± standard deviation (range)'. Differences were considered as significant with a $\alpha<0.05$. Non-parametric tests for sample comparisons were used, as data did not follow a normal distribution. For quantitative variables, the Kruskal-Wallys H test and the Mann-Whitney U test were performed. For qualitative variables, Chi-square values were obtained through exact methods, using the Monte Carlo test. When relationship between quantitative variables exists, K-Means cluster analysis has been carried out, standardising the variables and not including the 'team consolidation level' variable on the analysis. The 'cluster membership' variable is saved as a new qualitative variable. The correspondent Chi-square test and, if appropriate, a correspondence analysis was performed with variables 'cluster membership' and 'team consolidation level'.

## Results

### *Team size and composition*

Most of scientists surveyed (66.7%) are members of consolidated, well-established teams, while 16.1% belong to non-consolidated teams, and 17.2% are not members of any research team.

Teams are composed by more than 8 members on average, being most of them Doctors (the Spanish equivalent to PhDs). Significant differences have been found, as indicated in Table 1. Team size has been found to be significantly higher in consolidated than in non-consolidated teams, being differences mainly due to the number of doctors in the permanent staff.

*Table 1: Average number of members in research teams.*

| *Category* | *C* | *NC* | *Total* |
|---|---|---|---|
| Doctor/PhD (in the permanent staff)* | 5.6±2.3 (1-18) | 3.2±1.6 (1-7) | 5.1±2.4 |
| Bachelor /Engineer (in the permanent staff) | 1.1±1.5 (0-20) | 0.5±0.7(0-2) | 1.0±1.4 |
| Post-doctoral fellow | 0.5±0.8 (0-3) | 0.3±0.6 (0-2) | 0.4±0.8 |
| Pre-doctoral fellow | 1.7±1.7 (0-7) | 1.0±1.8 (0-2) | 1.6±1.6 |
| Other | 0.9±1.7 (0-14) | 0.7±1.3 (0-5) | 0.9±1.6 |
| Total * | 9.4±3.4 (4-40) | 5.6±2.3 (3-10) | 8.6±3.5 |

* Significant differences

### *Patterns of publication in domestic and foreign journals*

Taken responses to question 15 (Q15) of the survey (see Appendix), data revealed that most of researchers surveyed (91.4%) usually publish in both domestic and foreign journals, being this publishing pattern more frequent in C and NC researchers (95.2% and 93.3% of respondents, respectively) than in NT ones (75%), as shown in Table 2.

Significant differences among the three types of researchers have been found. The pattern showed by the correspondence analysis between both variables (Figure 1) indicates that differences would exist among researchers belonging to teams, either consolidated or non-consolidated, and those not belonging to any team. Nevertheless, in view of the reduced size of the sample, it is as well to be cautious with the interpretation of data. In this sense, it would be desirable -in order to confirm the dependency pointed out by the exact test- to increase the sample size, or else, in this case, to work with other variables.



*Table 2: Publication patterns in domestic and foreign journals, according to responses to survey's question 15.*

| | *% of researchers* | | | |
|---|---|---|---|---|
| | *C n=62* | *NC n=15* | *NT n=16* | *Total n=93* |
| I always publish in domestic journals (D) | 1.6 | 0.0 | 18.7 | 4.3 |
| I always publish in foreign journals (F) | 1.6 | 6.7 | 0.0 | 2.1 |
| I publish in both (DF) | 95.2 | 93.3 | 75.0 | 91.4 |
| No response | 1.6 | 0.0 | 6.3 | 2.1 |
| Total | 100 | 100 | 100 | 100 |

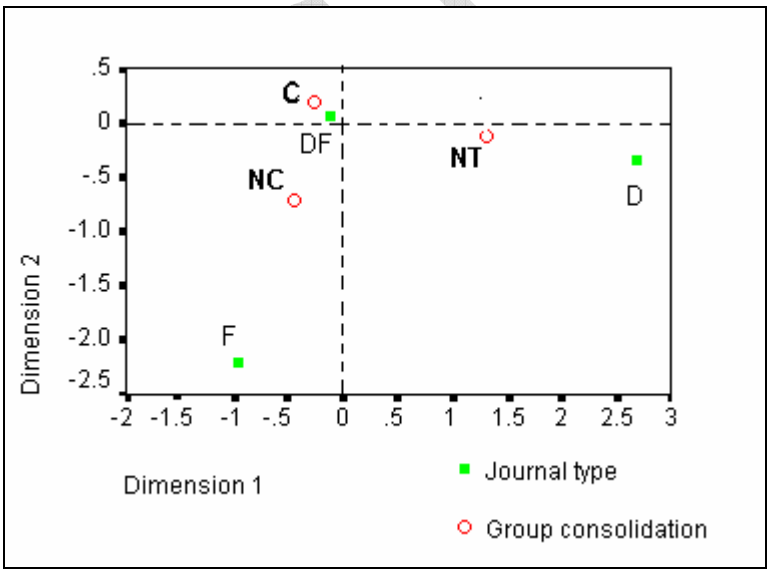



*Figure 1: CA row and column profile plot for 'publication patterns in domestic and foreign journals', according to responses to survey's question 15. Both dimensions explain 46.3% of total variation, dimension 1 accounting for 89.9% of the total association between the rows and columns.*

Along these lines, we performed the same analysis with data from responses to Q13. Values of Q13 were re-coded into a new variable containing same values as Q15 (D, F, DF). Results are slightly different to that obtained in the previous case (see Table 3), although correspondence analysis shows a very similar picture (Figure 2).

*Table 3: Publication patterns in domestic and foreign journals, according to survey's question 13*

| *Articles published* | *% of researchers* | | | |
|---|---|---|---|---|
| | *C* | *NC* | *NT* | *Total* |
| Only in domestic journals (D) | 3.2 | 6.7 | 31.2 | 8.6 |
| Only in foreign journals (F) | 3.2 | 13.3 | 0.0 | 4.3 |
| In both (DF) | 91.9 | 73.3 | 62.5 | 83.8 |
| No response | 1.6 | 6.7 | 6.2 | 3.2 |
| Total | 100 | 100 | 100 | 100 |

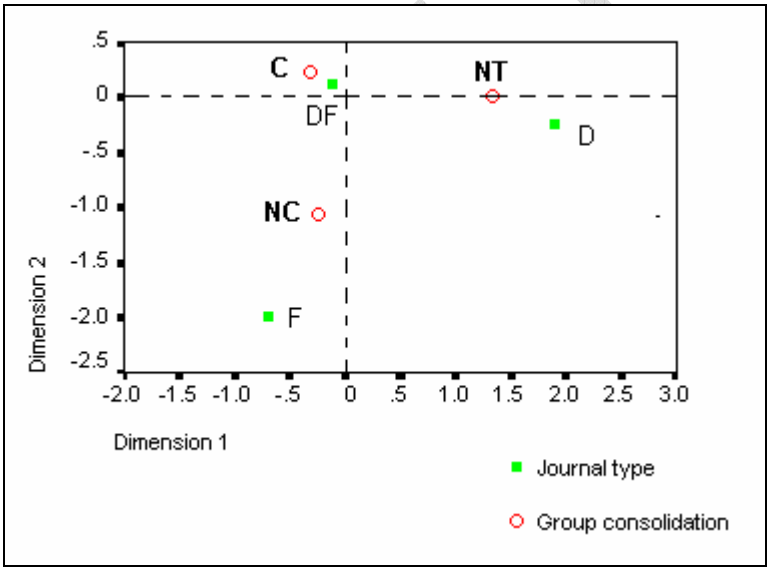



*Figure 2: CA row and column profile plot for 'publication patterns in domestic and foreign journals', according to responses to survey's question 13. Both dimensions explain 59.0% of total variation, dimension 1 accounting for 79.5% of the total association between the rows and columns.*

Going further, we performed the analysis with data from bibliographic databases. Starting from the number of articles published in domestic and foreign journals, a new variable was created taken the same values as Q15, as we did with data from Q13. According to these data, percentage of researchers publishing in both types of journals significantly decrease with regard to results obtained from the survey. This is particularly noticeably in the case of NC researchers, a third of whom published only in foreign journals during the five-year period analysed (see Table 4). As in previous cases, significant differences have been found among the three types of researchers. The correspondence analysis between both variables (see Figure 3) shows a more clear association among categories.

*Table 4: Publication patterns in domestic and foreign journals, according to bibliographic databases.*

| *Articles published* | *% of researchers* | | | |
|---|---|---|---|---|
| | *C* | *NC* | *NT* | *Total* |
| Only in domestic journals (D) | 16.1 | 26.7 | 31.2 | 20.4 |
| Only in foreign journals (F) | 12.9 | 33.3 | 6.2 | 15.1 |
| In both (DF) | 66.1 | 20.0 | 50.0 | 55.9 |
| In none of them | 4.8 | 20.0 | 12.5 | 8.6 |
| Total | 100 | 100 | 100 | 100 |

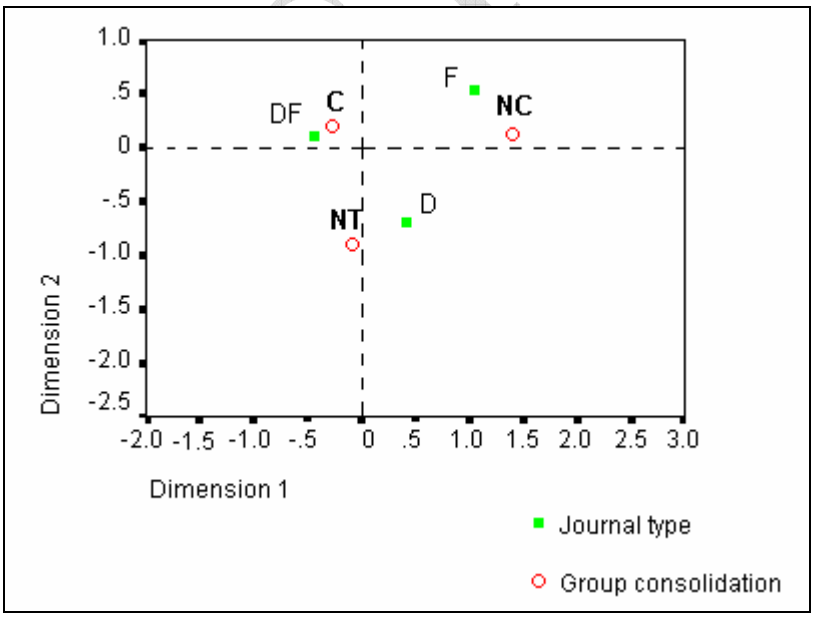



*Figure 3: CA row and column profile plot for 'publication patterns in domestic and foreign journals', according to bibliographic databases. Both dimensions explain 49.2% of total variation, dimension 1 accounting for 80.4% of the total association between the rows and columns.*

In all of three previous figures, the horizontal dimension, i.e. that accounting for the largest part of the association between rows and columns, seems to be largely determined by C and NC versus NT (this is best showed by Figures 1 and 2), being NC and NT the points that make a relative larger contribution to the chi-square statistic and the inertia of dimension 1.

***Productivity***

Although not in all cases differences found are statistically significant, data show, in general, a higher scientific output per capita as the level of consolidation and stability of the team increases.

Table 5 displays the average number of documents per author during the analysed period, according to survey's data. No different productivity has been found among the three groups of scientists surveyed with regard to the total number of articles published, although researchers working in teams publish, on average, more papers than NT ones. Scientists working in teams (either consolidated or non-consolidated) published a significantly higher average number of articles in both journals from the USA and the EU, than NT researchers. As a result, the total number of articles in foreign journals is higher in the former, as is the ratio articles in foreign journals to total number of articles. NT scientists show, on the contrary, a significantly higher average percentage of articles in domestic journals.

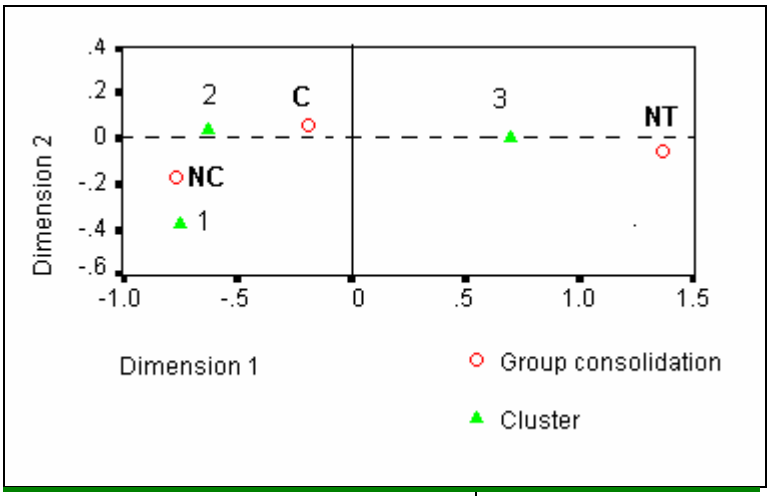
No significant differences have been found with regard to the number neither of other documents published, nor in the ratio of journal articles to the total number of documents.

*Table 5: Average number of documents per author, according to survey's question 13.*

| | C | NC | NT | Total |
|---|---|---|---|---|
| Journal articles (total) | 11.5±6.6(0-26) | 10.4±6.3(0-25) | 7.2±5.4(0-19) | 10.6±6.5 |
| -In domestic journals | 6.5±5.1(0-19) | 6.0±5.2(0-16) | 5.7±4.9(0-18) | 6.3±5.1 |
| -In foreign journals * | 5.4±4.2(0-18) | 4.5±3.2(0-11) | 1.6±1.6(0-5) | 4.6±3.9 |
| --USA journals * | 1.0±1.7(0-8) | 1.1±1.1(0-4) | 0.1±0.5(0-2) | 0.9±1.5 |
| --EU journals * | 3.5±2.4(0-10) | 3.2±2.3(0-8) | 1.2±1.4(0-4) | 3.0±2.3 |
| --Latin-American journals | 0.1±0.3(0-2) | 0 | 0.1±0.2(0-1) | 0.1±0.3 |
| --Other foreign journals | 0.4±0.8(0-4) | 0.4±0.6(0-2) | 0.1±0.3(0-1) | 0.3±0.7 |
| Domestic/total** | 0.5±0.2(0-1) | 0.5±0.3(0-1) | 0.8±0.2(0.5-1) | 0.6±0.3 |
| Foreign/total* | 0.5±0.2(0-1) | 0.5±0.3(0-1) | 0.2±0.2(0-0.5) | 0.4±0.3 |
| USA/total* | 0.1±0.1(0-0.44) | 0.2±0.2(0-0.5) | 0.01±0.05(0-0.2) | 0.1±0.1 |
| EU/total | 0.3±0.2(0-1) | 0.3±0.2(0-0.5) | 0.2±0.2(0-0.5) | 0.3±0.2 |
| Scientific and technical reports | 2.4±3.3(0-15) | 0.9±0.9(0-2) | 1.1±1.9(0-5) | 2.0±2.9 |
| Conference papers (national) | 5.6±4.2(0-16) | 4.6±2.7(0-8) | 3.9±3.5(0-12) | 5.2±3.9 |
| Conference papers (international) | 5.5±4.1(0-18) | 5.4±4.2(0-14) | 3.5±2.8(0-9) | 5.1±4.0 |
| International/total | 0.5±0.2(0-1) | 0.5±0.2(0.2-1) | 0.5±0.2(0-0.83) | 0.5±0.2 |
| Patents (national) | 0.02±0.1(0-1) | 0 | 0 | 0.01±0.1 |
| Patents (international) | 0.06±0.4(0-3) | 0 | 0 | 0.04±0.3 |
| Maps | 1.7±3.5(0-14) | 0.7±1.6(0-6) | 1.4±2.4(0-7) | 1.4±3.1 |
| Books | 0.9±1.0(0-3) | 0.7±1.1(0-4) | 0.6±1.3(0-5) | 0.8±1.1 |
| Book chapters | 2.7±2.2(0-9) | 2.5±2.5(0-9) | 1.4±2.1(0-7) | 2.4±2.3 |
| Other | 0.4±0.8(0-4) | 0.5±1.2(0-4) | 0.2±0.7(0-2) | 0.4±0.9 |
| Total | 29.1±13.5(4-64) | 28.4±15.7(4-59) | 20.1±12.5(5-41) | 27.3±14.0 |

Significant differences: * (C=NC)>NT; ** NT>(C=NC)

Cluster analysis of the number of articles in USA and EU journals, together with the ratio of articles in foreign journals to the total number of articles, is displayed in Figure 4. Significant differences have been found on the belonging of scientists to clusters according to team consolidation level. NT researchers appear related with lower values in all parameters (cluster 3) opposite to authors belonging to teams, associated to clusters 1 and 2. Differences among groups seems to be mainly produced by the number of articles in USA journals (the variable that differ the most across the three clusters).




| | *Cluster* | | |
|---|---|---|---|
| | *1* | *2* | *3* |
| Articles in USA journals | 3.5 | 0.1 | -0.4 |
| Articles in EU journals | 1.3 | 0.6 | -0.7 |
| Articles in foreign journals / Total articles | 1.4 | 0.4 | -0.7 |

*Figure 4: CA row and column plot for cluster membership according to the number of articles in USA and EU journals, and ratio articles in foreign journals to total number of articles. Source: surveys question 13. Table shows final cluster centres. Cluster 1 shows the highest values for all variables, being the differences more relevant for the number of articles in USA journals (ANOVA F=68.8; EU journals F=44.6; foreign/total articles F=37.5), that in cluster 1 is 3.5 standard deviation units above the mean for all researchers. Both dimensions of the CA plot explain 44.6% of total variation, dimension 1 accounting for 100% of it.*

Productivity has also been analysed through bibliographic information retrieved from SCI, GeoRef and ICYT. Only journal articles have been considered. Foreign journals have been grouped not only by editing country or region, but also depending on their presence or not in the SCI. We retrieved a total of 542 articles by Spanish University geologists considered in this study during the period analysed. SCI journals published 53.7% of these articles, while 42.2% appeared in domestic (non-SCI) journals and 4.1 % in foreign non-SCI journals.

Table 6 shows the average number of articles per author .The first aspect that stands out while analysing scientific output is that, in absolute figures, it is ostensibly smaller than the revealed by survey's data. Not the case of correspondent relative values of published articles in national and foreign journals with regard to the total. A likely explanation for this imbalance is the not fully exhaustive coverage of scientific journals by these databases; thus many articles counted by respondents are not referenced by databases. Nevertheless, both groups of data allow us to observe some trends. Firstly,

and agreeing with survey results, a higher productivity of researchers belonging to teams, consolidated or not, can be observed, whether we consider the total of their scientific output or whether we count the different types of documents separately. Moreover, C researchers seem to be slightly more productive than their NC colleagues are, even though not in all cases statistically significant differences have been found between both groups. Secondly, relative values also reveal differences among NT researchers and the rest of their colleagues, the latter seeming to have a greater disposition (or aptitude) to publish abroad, as indicated by the higher proportion of articles in foreign journals. Once again, NC scientists show a higher percentage or articles in foreign journals than their C colleagues, although differences are not statistically significant.

*Table 6: Average number of articles per author, according to bibliographic databases.*

| | C | NC | NT | Total |
|---|---|---|---|---|
| Journal articles (total) ** | 5.9±5.1(0-23) | 3.9±6.0(0-23) | 3.1±2.3(0-7) | 5.1±5.0 |
| - In domestic journals | 3.1±3.4(0-17) | 2.5±4.0(0-14) | 2.2±2.1(0-7) | 2.8±3.3 |
| - In foreign journals * | 2.7±2.8(0-13) | 1.9±3.0(0-9) | 0.8±0.8(0-2) | 2.3±2.7 |
| - SCI journals * | 2.4±2.6(0-12) | 1.6±2.6(0-8) | 0.7±0.8(0-2) | 2.0±2.5 |
| - Non-SCI journals | 0.3±0.6(0-3) | 0.1±0.3(0-1) | 0.1±0.2(0-1) | 0.3±0.6 |
| - USA journals | 0.7±1.3(0-21) | 0.4±0.9(0-20) | 0 | 0.6±1.2 |
| - EU·journals | 1.9±2.1(0-42) | 1.9±2.8(0-9) | 0.9±0.8(0-2) | 1.8±2.1 |
| - Other foreign journals | 0.2±0.5(0-16) | 0 | 0 | 0.1±0.4 |
| Domestic/Total | 0.5±0.3(0-1) | 0.5±0.5(0-1) | 0.7±0.3(0-1) | 0.5±0.3 |
| Foreign/Total | 0.5±0.3(0-1) | 0.5±0.5(0-1) | 0.3±0.3(0-1) | 0.5±0.3 |
| SCI/Total | 0.4±0.3(0-1) | 0.5±0.5(0-1) | 0.3±0.3(0-1) | 0.4±0.3 |
| USA/Total | 0.1±0.2(0-0.7) | 0.1±0.3(0-1) | 0 | 0.1±0.2 |
| EU/Total | 0.3±0.3(0-1) | 0.4±0.4(0-1) | 0.3±0.3(0-1) | 0.3±0.3 |

Significant differences: * C>NT; ** C>(NC=NT);

***Co-authorship of papers***

As shown by precedent results, some differences have been detected on productivity among C, NC and NT researchers, with regard to articles published in foreign journals. A possible reason for these differences could be derived from differences in the number of signing authors, that would favour a higher productivity of those researchers belonging to larger teams (in our case, consolidated ones).

Analysis of the co-authorship index of articles published in SCI journals does not reveal, nevertheless, significant differences among the different scientist types. However, articles by NT researchers, who in previous section where shown as less productive, show the highest index –NT= 4.75±2.60(1-8); C= 4.34±1.69(1-10); NC=3.84±1.59(1-9) –.

***Impact of publications***

Sixty-four of the 93 researchers surveyed (68.8%) published at least one article in SCI journals during the period analysed. Percentage of authors publishing in these journals is remarkably higher in researchers of consolidated teams (above 75%) than in the rest of scientists (around 55%).

Average EIF of articles published by C researchers is significantly higher than the corresponding to NC and NT ones. Nevertheless, these articles are published in journals included in different scientific fields, so the consideration of the whole set of articles is not proper[17]. For this reason, we analysed the EIF of articles published in journals under 'Geology' and 'Geosciences' categories of the JCR, thematically homogeneous categories whose journals show a similar range of IF values. These papers represent a 36.1% of the total number of articles published in SCI journals by scientists surveyed. Analysis of its IF does not reveal significant differences, even though researchers in teams show, in general, a higher average EIF and a maximum EIF, than NT ones (see Table 7).

*Table 7: Average Expected Impact Factor of articles published in SCI journals*

| | *JCR subject categories* | | |
|---|---|---|---|
| | *Geology + Geosciences n=105* | *Geology n=47* | *Geosciences n=59* |
| C | 1.000±0.505 (0.259-2.667) | 0.975±0.486 (0.404-2.319) | 1.023±0.518 (0.259-2.667) |
| NC | 0.928±0.454 (0.418-1.892) | 0.700±0.321 (0.418-1.255) | 1.327±0.384 (1.027-1.892) |
| NT | 0.846±0.299 (0.259-1.276) | 0.774±0.117 (0.679-0.966) | 0.954±0.469 (0.259-1.276) |
| Total | 0.978±0.483 (0.259-2.667) | 0.908±0.443 (0.404-2.319) | 1.039±0.507 (0.259-2.667) |

**Discussion and conclusions**

In this paper, we studied productivity, measured in terms of scientific publications, as one of the multiple dimensions that constitute the criteria of effectiveness and performance of researchers and research units. It should not be forgotten that scientific productivity is a multidimensional concept and that the effectiveness of research units is determined by many factors[1,18]. Indicators used in this study reveal individual scientists' productivity, without pretending in any way to do inferences about its quality.

At the time of interpreting results and establishing possible comparisons with other studies, the unit of analysis (in our case, individual researchers) and criteria used to characterise research teams and its consolidation level (based on the individual appreciation of researchers surveyed) must be taken into account. Thus, special attention must be paid to possible comparisons with other studies in which research teams are used as analysis unit, especially in those cases in which they are identified and defined through co-authorship of papers.

On the other side, specific characteristics of the population studied (researchers in the Geology field) and their context (Spanish University, Spanish R&D System) must be taken into account. In this respect, the research field appears to be a particularly relevant factor that could influence the activity of teams[10]. Earth Sciences, and particularly Geology, are scientific fields where applied research and that of local/national interest represent a very important part. On the Spanish case, the variety and geological complexion of the territory has favoured the development of this discipline. Furthermore, it has aroused the interest of numerous foreign researchers, principally French, Dutch, German and British, favouring the collaboration of Spanish scientists with prestigious international teams[19]. This character of Spanish geological research has promoted the creation and maintenance of numerous scientific journals of known prestige, covered by the main international databases specialised on Geology and Earth Sciences. These journals have been holders of great part of the results of geological research carried out in and about Spanish territory[13]. On the other hand, researchers of this study constitute a group with a high consolidation and stability level, as it corresponds to the already

mentioned tradition of this field in our country, and as results of this study indicate (use as data that two thirds of researchers surveyed belong to consolidated, well-established teams). Finally, in what respect Spanish R&D System characteristics, and in particular scientific political actions that most directly affect researchers, it is worth considering criteria established for the assessment of research activity of scientists, that can significantly influence their performance and research habits. In Spain, as in many other countries, these criteria are based on the consideration, principally of articles of scientific value published in SCI journals.

Although research teams themselves are not our analysis unit, as mentioned before, their size and composition are variables that can influence its components' productivity, so it is worth taking them into account before arguing other aspects. As expected, size of consolidated, well-established teams, is significantly larger than that of non-consolidated ones, mainly due to the higher number of doctors in the permanent staff, i.e. of scientists with the higher professional consolidation level among University staff. At first, it would be expected the combination of larger size and greater consolidation of the teams to have led to not only on its own benefit (in higher team output) but also on its components', resulting in a higher personal productivity. As stated by *Stankiewicz*[10], it could be considered that *"because larger groups* -in our case, consolidated ones- *are likely to have larger total outputs, their members have better chances to put their names on several publications even though the per capita output of such groups may be quite modest"*. If this worked out, co-authorship index of articles by C researchers should be higher than that of those signed by NC and NT researchers, but this does not occur on the analysed sample. Therefore, it seems more suitable to hypothesise that the higher consolidation of the team would result in a greater facility to establish contacts and collaborations, either national or international, that could benefit all members of the team, fostering their participation on funded projects and favouring their potential to publish in international mainstream journals. As *Stankiewicz* says, "*the larger and the older the group* -and in this case, we could say the more consolidated-, *the more likely it is to evolve elaborate structures and contain larger numbers of experienced scientists, and it will probably have bigger facilities to achieve resources at the disposal of the team's members*", as well as to initiate collaborations and to participate in research projects,

specially at the international level. In any case, results show that team size does not appear to be as important as the number of researchers within the team that reached a stable and secure job position.

As regards publication patterns in domestic and foreign journals, both bibliometric and survey's results coincide on indicating differences between the three groups of scientist. Although most of them publish in both kinds of journals, researchers without team seem to have a greater difficulty to publish in foreign ones. On the contrary, NC researchers are more closely associated with the habit of publishing exclusively in foreign journals. This could possibly be suggesting a change in publishing patterns through researchers' career, moving from great effort in publishing in foreign, mainstream journals at the start of their career, under pressure of evaluation criteria, to publishing more in domestic journals once they are professionally more consolidated and pressure for publishing in these journals starts to reduce. Pattern of NT researchers might indicate a natural evolution starting from and initial stage of great difficulty to publish in prestigious international journals, and progressively increasing of their publications in these journals due to an increase of their ability to publish in them, because of their own professional improvement as well as the increase of contacts and collaborations with teams more experienced and capacitated to publish in these journals.

This general view is corroborated by the productivity per capita. Even if not in all cases statistical analysis reveal significant differences, it is still true that, in general and excepting seldom occasions, researchers belonging to consolidated teams are more productive than their NC colleagues, and these in turn more than individuals without team. NT researchers are those who show a lower production of articles in foreign journals, North American and European mainly. Assuming that these researchers have, at first, the same interest in publishing in internationally-prestiged, mainstream journals, as their colleagues, these results would be indicating more difficulties for them to publish in these journals, so it could be considered that the not belonging to a team represents a handicap at the time of publishing in top international journals and therefore, to obtain a positive evaluation of their research activity that leads to larger economic incentives and better possibilities of professional promotion. On the other hand, NC researchers show a lower (not statistically significant) article production than their C colleagues do. This, together with their higher percentage of articles in foreign journals, may be

pointing that, even if belonging to non-consolidated teams could result in a lower per-capita productivity, it is not an obstacle to access to prestigious international journals in same conditions than their C colleagues.

Therefore, with regard to scientific output, it could be said that the not belonging to a team is a limiting factor, without appearing, however, that the consolidated or non-consolidated character of the team contributes to settle significant differences.

Another interesting topic remaining is whether greater consolidation of teams would lead to a greater research "quality" or rather to results with larger repercussion or visibility, measured in terms of citations and impact. Analysis of visibility of papers through their EIF has not revealed any significant differences that allow confirming that belonging or not to a research team, consolidated or not, would offer any advantage to researchers with regard to their visibility, although papers by authors belonging to teams show an average EIF slightly higher than that by NT ones. In this sense, analysis of citations received by authors studied (average citation count, fraction of highly cited papers), could throw some light in this aspect and reveal differences that EIF does not show.

Beside the previously mentioned, there are still further questions to be analysed and discussed. Is greater the quality of research carried out by consolidated teams? Are scientists in non-consolidated teams more inclined to start new research fronts or, on the contrary, they tend to continue research lines established by consolidated teams? Does team consolidation favour research collaboration? Does it favour participation of scientists in funded research projects? Do differences exist with regard to the basic or applied level of research? Do differences exist with regard to the local/national/international scope and interest of research? Do C researchers obtain more recognition? Do consolidated teams contribute more to the training of junior researchers?

To finish it should be emphasised, although it can seem obvious, that the above conclusions and interpretations must be considered with caution. Inferences that could not be certain if applied to other researchers and within other R&D frameworks should be avoided. We must also remember that

scientific productivity is being affected by many factors, only some of them considered in this paper, so the effects of possible interactions could vary results and interpretations.

**Appendix**

Selected questions of the survey 'Research activities in the R&D system in Earth Sciences in Spain: 1990-1994'.

**Q6. Are you member of a consolidated, well-established research team?**

- Yes, I belong to a consolidated, well-established team.
- No, my research team cannot be considered as a consolidated, well-established one.
- I am not member of any research team. Depending on the project, I work with different teams.
- I usually work alone.

**Q7. Please give the number of people that made up your research team (including yourself).**

- Doctors/PhDs (of the permanent staff).
- Bachelors/Engineers (of the permanent staff).
- Post-doctoral fellows.
- Pre-doctoral fellows.
- Other (please, specify).

**Q13. Please give the number of the following documents you produced (signed) during the reference period (1990-1994)**

- Journal articles (in Spanish journals).
- Journal articles (in US journals).
- Journal articles (in EU journals).
- Journal articles (in Latin-American journals).
- Journal articles (in other foreign journals).
- Scientific and technical reports.
- Conference papers (national).
- Conference papers (international).
- National patents.
- International patents.

- Maps.
- Books.
- Book chapters.
- Other (please specify).

**Q.15. Please mark the sentence/s that better describe your habits of publication in scientific journals**

- I always publish in Spanish journals.
- I always publish in foreign journals.
- I publish in Spanish as well as in foreign journals.

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