Jointly published by Akadémiai Kiadó, Budapest and Springer, Dordrecht

Scientometrics, Vol. 66, No. 1 (2006) 199–218

Productivity, impact and publication habits by gender in the area of Materials Science

ELBA MAULEÓN, MARÍA BORDONS

Centro de Información y Documentación Científica (CINDOC), CSIC, Madrid (Spain)

A comparative analysis of the scientific performance of male and female scientists in the area of Materials Science at the Spanish Council for Scientific Research (CSIC) is presented. Publications of 333 scientists during 1996–2000 are downloaded from the international database Science Citation Index and the national one ICYT. Scientific performance of scientists is studied through different indicators of productivity (number of SCI and ICYT publications), international visibility (average impact factor of publications, percentage of documents in "top journals") and publication practices (%international publications, signing order of authors in the documents and different collaboration measures). Inter-gender differences in the research performance of scientists are studied. Influence of professional category and age are analysed. Although women are less productive than men, no significant differences in productivity are found within each professional category. However, a different life-cycle of productivity is found for men and woman and the most important inter-gender differences in productivity occur at the ages of 40-59.

Introduction

There is a growing concern in the most advanced countries about women and science issues and, more specifically, about the under-representation of women in scientific careers. As a sign of the importance of the topic we can mention that the third edition of the European Report on Science and Technology Indicators devoted a special section to Women and Science. As is stated in this report, gender equity is not only an ethical goal, but a requirement for the future competitiveness of countries which need the exploitation of all their human resources in science (*Third European Report*, 2003).

At the end of the 20th century around 31% of the researchers in the European Union were women, with variations among countries. It is well known that men and women are not equally distributed by disciplines or professional categories (LAAFIA, 2001). Women are more concentrated in medical sciences, social sciences and humanities, while they are scarcely present in engineering (horizontal segregation). Concerning the distribution of women throughout the scientific career ladders, her low participation at the top positions has been repeatedly described. The fact is that the higher the academic

Received June 22, 2005

Address for correspondence:
ELBA MAULEÓN
Centro de Información y Documentación Científica (CINDOC), CSIC
Joaquín Costa 22, 28002 Madrid, Spain
E-mail: elba@cindoc.csic.es

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rank, the lower the presence of women (vertical segregation). Although different educational, cultural and social factors have been described as contributing to the under-representation of women in science, further studies are required. In-depth studies which analyse the situation of women in science, identify factors that prevent them from progression in the academic career, and detect gender-specific patterns in research activity are especially needed (DEWANDRE, 2002).

At the European Union level, the Commission has developed different activities to promote gender equality in science. The inclusion of a sex variable in the analysis of science and technology indicators has been identified as a priority (ETAN, 2000), with the aim of obtaining internationally harmonised statistics and make inter-country comparisons possible. These statistics will allow to gain evidence of the situation of women in science in different countries and disciplines as well as to monitor future advances. Bibliometric studies have also been fostered since they can contribute to these goals by means of the analysis of scientific output of scientists (THE HELSINKI GROUP ON WOMEN AND SCIENCE, 2002).

The main problem that bibliometric studies have to face is how to identify male and female authors, provided that the sex is not included in bibliographic databases. Concerning this issue, different approaches have been used in the not very extensive literature on the topic. Firstly, in some studies indicators are obtained directly from the analysis of bibliographic databases. This is difficult, since only in a few countries the sex of the scientists can be deduced from their surnames (see for example LEWISON, 2001; WEBSTER, 2001). In most countries the sex has to be inferred from the first name, but very frequently it is not included in the bibliographic records, in which only the initial of the first name appears. Secondly, other studies obtain data from the original journals, in which the full name of the authors is more frequently included. This was the approach followed in the feasibility study conducted by BIOSOFT (BIOSOFT, 2001), but it was observed that the full name of the authors was missing in 2/3 of the studied journals, so the validity of this approach is also low. Thirdly, data can be collected from questionnaires and interviews (KYVIK & TEIGEN, 1996; JACOBS, 2001; PRPIC, 2002), but the reliability of the results will depend on the response rate. Finally, searching for publications from a specific population of scientists (scientists from a specific centre, specialty or region) whose full name and sex are previously obtained from their institution, scientific societies or directories is an interesting option (LEMOINE 1992; LONG, 1992; GOEL, 2002; BORDONS et al., 2003).

The latter approach is the one here followed. The objective of this study is to make a comparative analysis of the scientific performance of male and female scientists in the area of Materials Science at the Spanish Council for Scientific Research (CSIC) during the years 1996–2000. Starting from the list of scientists working at CSIC in the Materials Science area, a specific search strategy was built to collect scientific publications with the greatest level of precision and reliability. This study forms part of

a research line devoted to obtaining bibliometric indicators by gender applied to the Spanish CSIC. In a previous paper the areas of Natural Resources and Chemistry were studied through productivity and impact measures (BORDONS et al., 2003). In the present study, new indicators are introduced related to publication practices of scientists, such as their national/international orientation, signing order of authors in publications and different measures of collaboration.

The main questions here addressed are the following:

- Are there any differences in productivity and impact by gender?
- Is there any relationship between signing position in the publications and gender?
- Are women more nationally oriented than men?
- Are women as collaborative as men?
- Why are there so few women in the upper categories?

The structure of the article is the following. First, scientific productivity by gender is studied, irrespective of other possible variables. Second, professional category of scientists is introduced in the analysis, since it might play an important role in explaining differences in the behaviour of scientists. Thirdly, the age of scientists is taken into account.

Methodology

The study focuses on the scientific activity of 333 scientists, which were permanent scientists at CSIC in the area of Materials Science (MAT), in the year 2000. Although scientific activity is multidimensional, we will focus only on the research dimension, which is studied from a quantitative point of view.

Starting from the list of scientists working at CSIC in 2000, their scientific publications were downloaded from bibliographic databases and a bibliometric profile for each scientist was built.

Personal data of scientists

Personal data of scientists were obtained from CSIC organisation, which provided for every scientist the following information: full name, sex, professional category, years at CSIC, and date of birth. Permanent scientists at CSIC are distributed over three different professional categories: tenured scientist, research scientist and research professor.

Scientific publications

Scientific publications of scientists during 1996-2000 were obtained from the international database Science Citation Index (SCI) (CD-ROM edition) and the national database *Indice Español de Ciencia y Tecnología* (ICYT). SCI covers more than 3,700 high quality journals from all fields of science. ICYT includes the most important Spanish journals concerning science and technology.

Documents published by CSIC were downloaded from SCI and ICYT, and their institutions were normalised following a specific codification scheme developed at CINDOC (FERNÁNDEZ et al., 1993). The scientists names included in the MAT personnel file were matched with the authors names included in the bibliographic database to obtain the scientific production of scientists under study. Since authors names are not normalised in the bibliographic database, a specific search strategy was built including different variant names in the search (for example, publications of "A.García de Hoz" were searched under the following author names: "García A", "García-de-Hoz A", "De-Hoz AG", "Hoz, AGD"). Those publications retrieved through a "variant name" were marked and checked through automatic and manual procedures to verify if belonged to the studied author. Verification process included analysis of co-authors, subject field of the authors, addresses, web page data and expert advice. Initially, a total of 673 different author's names were obtained in SCI and 270 in ICYT. After normalization of names, the number of different authors was reduced in more than 55% in SCI and 34% in ICYT.

Individual bibliometric profile of authors

For every author, a bibliometric profile was built including the following indicators:

1. Productivity: number of international (SCI) and national documents (ICYT) per scientist. Full count, in which each document is fully assigned to each of the contributing authors, was applied.

2. International visibility: measured through the impact factor of publication journals in year 2000 (JCR 2001).
   - Average impact factor of publication journals.
   - Percentage of documents published in "top journals", defined as those included in the first quartile of the ranking of journals in descending order of impact factor within each discipline (% Doc Q1).

3. Publication practices
   - International orientation of scientists: measured through the percentage of SCI documents.

- Signing position of authors: for each author the percentage of his/her documents in which sign as first author, last author and single author is calculated.
- Collaboration practices: analysed through the coauthorship index (average number of authors per document), collaboration rate (percentage of documents with more than one address) and international collaboration rate (percentage of documents with at least one foreign address).

Inter-gender differences in the bibliometric profile of scientists were studied. Influence of professional category and age on research performance was also analysed.

The software used for the statistical analysis of data was SPSS, version 12. Differences between means were explored through tests for non parametric variables (Kruskal-Wallis, Mann-Whitney and Wilcoxon tests).

Results

A total of 333 scientists were working in Materials Science centres of CSIC in year 2000. It included 106 women (32%), this share being very close to the average percentage of female scientists in the whole CSIC (33%). The distribution of scientists by professional category and gender for MAT and for the whole CSIC is shown in Figure 1.

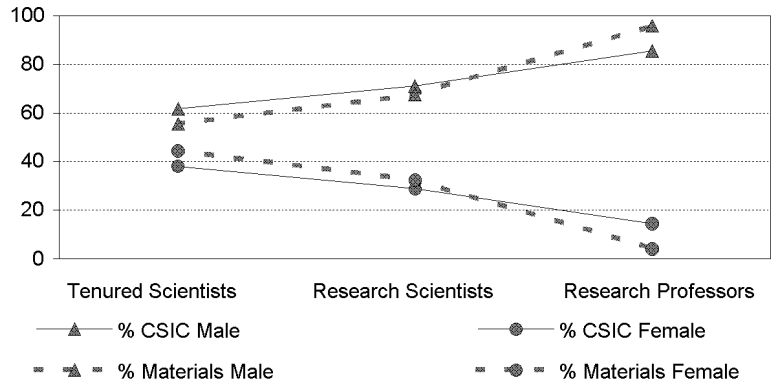

Figure 1. Percentage of men and women within each professional category

The percentage of women decreases as we go up in the professional category, that is, 44% of MAT scientists are women in the lower category (tenured scientist), while only 32% and 4% appear in the middle and upper categories (research scientist and research

professor, respectively). The final diagram, the so-called "scissors diagram", has already been described in many scientific institutions and countries, and it is a clear sign of the under-representation of women in the top positions in science. It should be noted that there are only three women in the research professor category, so it limits the significant of some of the results.

Women are in average younger than men (47 vs. 51 years old) ($p<0.001$). The distribution of scientists by age and sex is shown in Figure 2. More than 45% of females were 40-49 years old, vs. 33% of men. On the other hand, only 4% of women were older than 59 years vs. 24% of men.

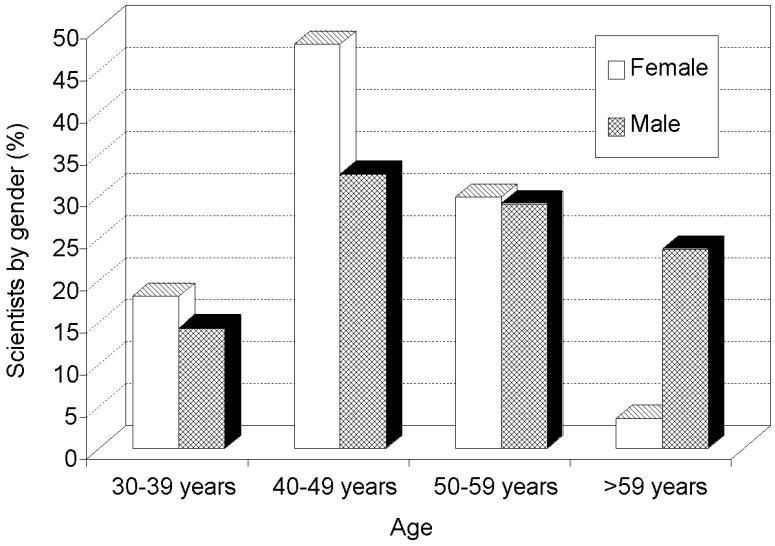

Figure 2. Distribution of scientists by gender and age

The average age of scientist increases with professional category: 46 years for tenured scientists, 52 years for research scientists and 57 for research professors. Within each professional category, inter-gender differences in age are not found.

The distribution of scientists by gender, age and professional category is shown in Figure 3. In the 30–39 age brackets all scientists are in the lower category, independent of their sex. But as we go up in the age brackets, the percentage of men in upper categories increases more than that of women. At the ages of 40–49, 75% of women are in the lower categories, while the corresponding percentage for men is 56%. At the ages of 50–59, most of women are still in the lowest category (58% vs. 23% of men), while

most of men are in the upper category (55% vs. 6% of women). Why are there so few women in the upper categories? Are they less productive than men? That is the question we would have tried to answer in this paper.

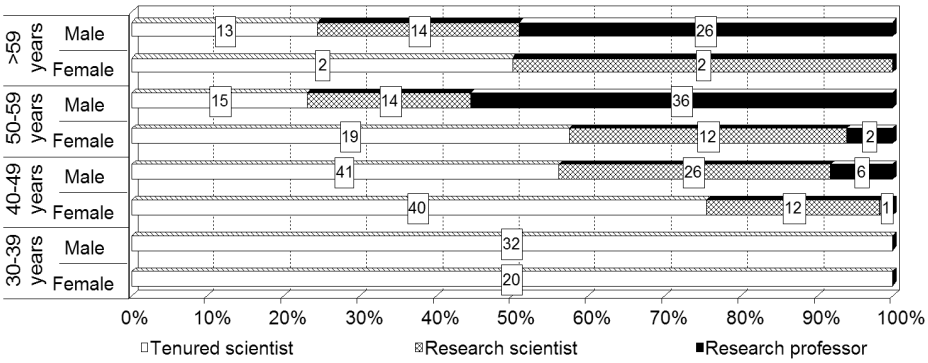

Figure 3. Distribution of scientists by gender, age and professional category

Scientific productivity

The scientific production of the 333 scientists accounted for 4,383 documents in SCI journals and 519 in ICYT. A total of 310 scientists (93% of them) published at least 1 document in the period, and none of the genders predominated among the no-publishing scientists. On average, scientists published 88% of their documents in SCI journals and 12% in ICYT ones.

It should be noted that 50% of scientists published in both national and international journals, while 40% only published in international journals and 3% only in national ones. It is interesting to note that the percentage of women with only international publications was higher than that of men (50% vs. 35%) (Figure 4).

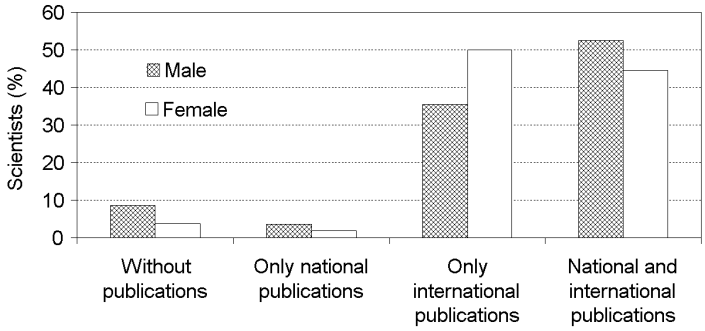

Figure 4. Distribution of scientists by type of publications

Analysis by gender

On average, each scientist published 20 documents in SCI journals and 2 documents in ICYT ones during the five years under study. Men and women had a similar number of ICYT documents, but men showed a higher number of SCI documents (Table 1). In relation to the impact of the publication journals, no significant differences were found according to the sex of the scientists. Moreover, both men and women published around 63% of their documents in top journals, that is, in journals located in the first quartile of their discipline. In any case, since publication habits may change according to the status or to the age of scientists, the influence of these variables is analysed in the next sections.

Table 1. Scientific productivity and impact by gender

	Female (N=106)	Male (N=204)	Total (N=310)	SIG
No. SCI documents	15.67±12.29 (0-66)	22.88±20.02 (0-114)	20.42±18.07 (0-114)	0.001
No. ICYT documents	2.11±3.22 (0-15)	2.70±3.93 (0-20)	2.50±3.71 (0-20)	NS
No. Total documents	17.78±12.88 (2-68)	25.58±20.17 (1-115)	22.91±18.37 (1-115)	0.001
Average IF	1.857±0.818 (0.646-4.597)	1.841±0.888 (0.099-4.619)	1.847±0.863 (0.099-4.619)	NS
% Doc.Q1	63.04±22.60 (0-100)	62.68±24.52 (0-100)	62.80±23.84 (0-100)	NS

Data are expressed as average ± standard deviation, (min-max).

Men signed as last author more frequently than women: on average each male scientist had 28% of its production signed as last author, while the corresponding value for female scientists was 20% ($p<0.05$) (Table 2). However, it should be noted the high inter-individual variability as shown by the high values of standard deviation. Finally, male scientists also had more single-authored publications than female ones (2% vs. 0.4% of men and women production respectively) ($p<0.01$).

Table 2. Signing position of authors in SCI documents

	Female (N=104)	Male (N=196)	Total (N=300)	SIG
% First author	25.31±25.12 (0-100)	20.00±21.08 (0-100)	21.84±22.66 (0-100)	NS
% Last author	21.86±23.92 (0-91.67)	27.99±25.59 (0-100)	25.86±25.1 (0-100)	0.05
% Single author	0.41±2.55 (0-22.22)	1.90±10.35 (0-100)	1.38±8.52 (0-100)	0.01

In relation to collaboration habits, no differences between sexes were found. On average, the production of a scientist included 5 authors per document; collaboration was present in 62% of the documents of each author and there were international partners in 36% of his/her documents in collaboration. A high inter-individual variability was observed (Table 3).

Table 3. Scientific collaboration in SCI documents

	Female (N=104)	Male (N=196)	Total (N=300)	SIG
No authors/doc.	4.71±1.22 (2-8.14)	4.77±1.34 (1-8.38)	4.75±1.30 (1-8.38)	NS
% Doc. in collaboration	60.03±27.66 (0-100)	63.82±27.98 (0-100)	62.50±27.88 (0-100)	NS
% Internat collab.doc.	35.87±27.84 (0-100)	35.65±24.58 (0-100)	35.73±25.71 (0-100)	NS

Analysis by gender and professional category

SCI productivity increased with professional category for both men and women (Table 4), while no differences in impact factor of publication journals by category were observed within each sex (Table 5).

Within each professional category, no significant differences in the number of SCI documents of men and women were found. Correspondingly, the lower SCI productivity of women we found in the previous section could be partly due to the lower presence of women in the highest and most productive categories.

Concerning ICYT documents, male research scientists showed a higher number of documents than their female colleagues. Moreover, the orientation towards SCI documents was higher for women than for men in the research scientist category: on average each female research scientist published 94% of her production in SCI, while men published 83% of their documents in SCI-covered journals (Table 4).

In relation to the impact of the journals used for publication, female research scientists showed a trend to publish in higher impact factor journals than men in the same category (Table 5). No differences by gender were found in the other two categories. There were not significant differences in the percentage than men and women published in top journals in any of the categories.

Table 4. Scientific productivity by professional category and gender

Professional category	Female	Male	Total	SIG*
No. SCI dcuments				
Tenured scientist	13.14±7.74 (0-34)	14.64±10.39 (0-44)	13.93±9.23 (0-44)	NS
Research scientist	21.52±18.55 (3-66)	23.57±17.61 (0-85)	22.89±17.83 (0-85)	NS
Research professor	32.67±19.66 (18-55)	32.94±25.84 (0-114)	32.93±25.49 (0-114)	NS
No. ICYT documents				
Tenured scientist	2.28±3.38 (0-15)	1.92±3.23 (0-18)	2.09±3.30 (0-18)	NS
Research scientist	1.12±2.17 (0-8)	3.24±3.91 (0-20)	2.54±3.56 (0-20)	0.001
Research professor	6.00±3.61 (3-10)	3.28±4.61 (0-19)	3.40±4.59 (0-19)	NS
% SCI documents				
Tenured scientist	85.45±21.09 (0-100)	83.60±25.78 (0-100)	84.48±23.61 (0-100)	NS
Research scientist	94.30±11.65 (61.90-100)	83.27±20.59 (0-100)	86.90±18.80 (0-100)	0.01
Research professor	80.81±15.42 (64.29-94.83)	84.30±26.84 (0-100)	84.15-26.39 (0-100)	NS

*Significance level in the comparison of men and women.

Table 5. International visibility by professional category and gender

Professional category	Female	Male	Total	SIG
Impact factor				
Tenured scientist	1.78±0.80 (0.70-4.60) N=76	1.91±1.01 (0.10-4.62) N=83	1.85±0.91 (0.10-4.62) N=159	NS
Research scientist	2.13±0.87 (0.65-3.53) N=25	1.68±0.82 (0.61-3.88) N=50	1.83±0.86 (0.61-3.88) N=75	0.05
Research professor	1.52±0.56 (0.90-1.99) N=3	1.88±0.76 (0.66-3.81) N=63	1.86±0.75 (0.66-3.81) N=66	NS
% Doc.Q1				
Tenured scientist	63.88±23.69 (0-100) N=76	61.66±26.54 (0-100) N=83	62.72±25.17 (0-100) N=159	NS
Research scientist	59.61±20.10 (16.67-88.89) N=25	61.55±24.36 (0-100) N=50	60.90±22.91 (0-100) N=75	NS
Research professor	70.20±12.19 (59.26-83.33) N=3	64.92±21.98 (17.65-100) N=63	65.16±21.60 (17.65-100) N=66	NS

Publication habits were more evident in the international publications than in the national ones, so only the former are shown in the Table 6. As we go up in the professional category the trend to sign as first author decreases and the trend to sign as last author increases. This holds for both sexes. However, female research scientists signed less often than their male counterparts as first author ($p<0.05$) or single-author ($p<0.05$). On the other hand, female tenured scientists also showed a lower percentage of single-authored documents than men.

Concerning collaboration, detailed results are not shown since inter-gender differences were not found through the different indicators used.

Table 6. Signing habits by professional category and gender (SCI publications)

Professional category	Female	Male	Total	SIG
% Documents as first author				
Tenured scientist	30.18±25.94 (0-100) N=76	27.31±23.10 (0-100) N=83	28.68±24.46 (0-100) N=159	NS
Research scientist	12.49±17.84 (0-72.22) N=25	20.68±21.05 (0-88.89) N=50	17.95±20.29 (0-88.89) N=75	0.05
Research professor	8.59±8.34 (0-16.67) N=3	9.83±12.81 (0-60) N=63	9.78±12.59 (0-60) N=66	NS
% Documents as last author				
Tenured scientist	16.53±19.74 (0-82.35) N=76	16.41±20.93 (0-100) N=83	16.47±20.31 (0-100) N=159	NS
Research scientist	36.21±29.08 (0-91.67) N=25	27.49±23.46 (0-77.78) N=50	30.40±25.61 (0-91.67) N=75	NS
Research professor	37.16±26.45 (11.11-64.00) N=3	43.63±24.85 (0-100) N=63	43.34±24.74 (0-100) N=66	NS
% Single author				
Tenured scientist	0.46±2.91 (0-22.22) N=76	3.18±15.48 (0-100) N=83	1.88±11.42 (0-100) N=159	0.01
Research scientist	0.08±0.41 (0-2.04) N=25	1.65±4.05 (0-17.65) N=50	1.13±3.39 (0-17.65) N=75	0.05
Research professor	1.85±3.21 (0-5.56) N=3	0.41±1.48 (0-7.41) N=63	0.47±1.58 (0-7.41) N=66	NS

The number of years working at CSIC was used as a proxy of the length of the scientific career of scientists at the institution: on average 14 years for women and 17 years for men ($p<0.01$). Within each professional category, inter-gender differences

were found only for tenured scientists: women had remained in that category longer than their male colleagues (12 vs. 10 years)($p<0.01$), that is, it seems it takes women longer to promote to the middle professional category.

Analysis by gender and age

Scientists were grouped in four age classes to analyse the influence of age on research performance. Descriptive statistics on scientific production by gender and age are shown in Annex I, the main results being shown graphically (Figures 5–10). Data corresponding to women in the last age bracket (>59 years) should be read with caution due to its small size (3 women).

It is interesting to show that SCI productivity of men reaches a peak at the 40–49 years of age; while later on there is a decreasing trend. For women, there are not significant differences in the productivity according to their age. As a consequence, productivity of men is higher than that of women at the ages of 40–49 ($p<0.01$) and 50-59 ($p<0.05$) (Figure 5).

A decreasing trend over age classes in the average impact factor of publication journals is observed for all scientists ($p<0.01$) and for men ($p<0.01$), but not for women. Moreover, women older than 60 years showed a higher average impact factor than men of the same age ($p<0.05$) (Figure 6).

For both sexes the trend to sign publications as first author decreases with age (Figure 7), while increases the trend to sign as last author (Figure 8). No significant differences by gender in the percentage of documents as first or last author are found.

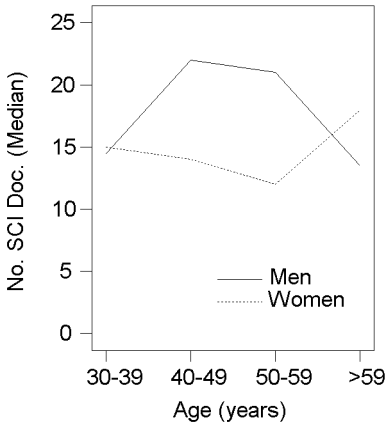

Figure 5. Average number of SCI documents by gender and age

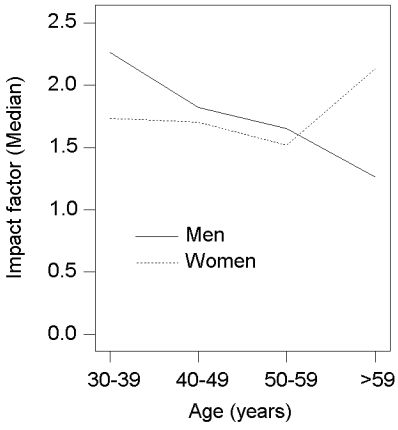

Figure 6. Average Impact Factor by gender and age

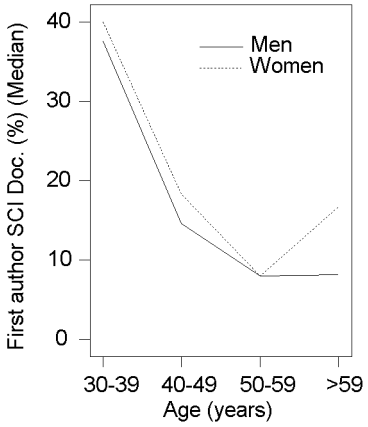

Figure 7. % SCI documents as first author

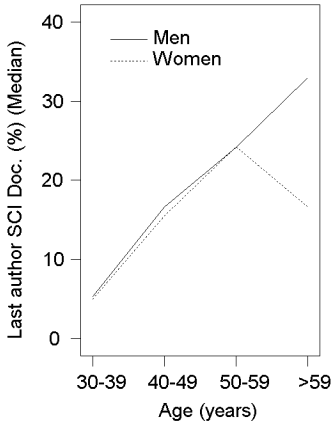

Figure 8. % SCI documents as last author

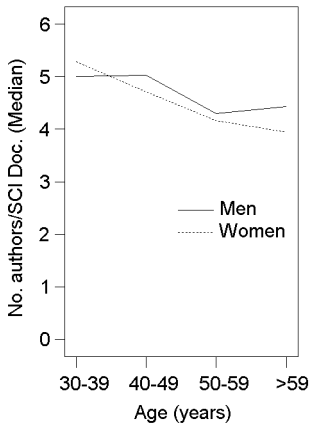

Figure 9. No. authors/SCI document

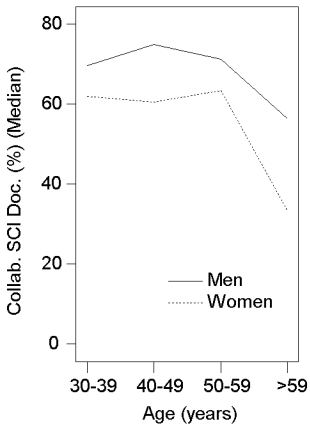

Figure 10. % Collaboration in SCI documents

In relation to the percentage of documents signed as single author, men showed the highest trend to publish alone at the ages of 50–59, while for women there were not significant differences in the percentage of single-authored publications according to age. When comparing both sexes, only at the ages of 40–49 years there were differences between men and women: women sign as single author significantly less than men of the same age (0.7 vs.1.4 documents/author, $p<0.01$).(See Annex I).

Finally, in relation to the collaboration practices, there was a trend towards less number of authors per document ($p<0.05$) and less percentage of documents in collaboration (no significant) for the oldest scientists (Figures 9 and 10). However, only in the group of 40–49 years there were differences by gender, women showing a slightly less percentage of documents with more than one address than men (69% vs. 61% of their documents).

Discussion and conclusions

The study of inter-gender differences in scientific activity is at present recommended to gain in-depth knowledge about the situation of women in science. Bibliometric indicators can contribute to this goal by means of the analysis of scientific output from a quantitative point of view. Our study indicate that obtaining bibliometric indicators by gender is not easy, since the sex of the authors is not included in bibliographic databases and different sources of data have to be combined.

The distribution of women by professional categories in the area of Materials Science in the Spanish CSIC follows the "scissors diagram" described in other institutions and countries: the percentage of women clearly decrease as we go up in the professional category. As compared with the whole CSIC, it can be mentioned that the area of Materials Science shows a slight higher percentage of women in the two intermediate categories, but the situation is especially dramatic in the upper category (30% of men are in the top position vs. 3% of women).

Why are there so few women in the upper categories?

Is the low presence of women in the upper categories due to their later entrance in science? Are they less promoted because of their worse performance? Are there any sign of discrimination in the promotion system? These and other explanations have been pointed out in the literature and we have tried to check some of them in the Materials Science area of the Spanish CSIC. The influences of other factors such as the higher family commitments of women, who are frequently in charge of childcare and household management, have been analysed in other studies by means of questionnaires and interviews but its study is far beyond the objective of the present paper.

1. Later entrance of women in science.

Our data support this argument, since women are in average younger than men (47 vs. 51 years old). The largest difference appears in the last age bracket: only 4% of women are older than 59 years vs. 24% of men. From this point of view, it could be argued that is just question of time for women to reach the upper category. If that were the case, we would expect to find a similar distribution by categories of men and women of a similar age. However, the distribution of scientists by category within each

age bracket clearly shows a very unequal distribution for men and women. Most of women of 50-59 years old belong to the lowest category (58% vs. 23% of men), while most of men are in the upper category at the same age (55% vs. 6% of women). In summary, the later entrance of women in science may contribute to their lower presence in the upper categories, but it can not be argued as the only explanatory reason.

2. Are there any sign of discrimination in the promotion system?

As possible signs of unequal promotion of men and women, inter-gender differences within each category in productivity, impact, age and average number of years at CSIC were explored. The lack of significant differences in each of these variables would support the rejection of the existence of inequalities in the promotion system –as far as can be analysed through the variables studied.

Productivity increases with professional rank for both men and women, supporting this finding the importance of productivity for promotion. Two different factors interact. Firstly, the most productive scientists are more likely to arrive to the upper category. Secondly, there is a cumulative advantage effect that makes it easier for professors to maintain a high productivity. Limiting comparisons within each category, no significant inter-gender differences in productivity were found. This had been also verified for CSIC scientists in the areas of Natural Resources and Chemistry in a previous study (BORDONS et al., 2003). This seems to indicate that a similar productivity is requested for both sexes in the promotion system.

In relation to impact, it is not clearly related with professional rank. As category increases, also increases productivity, but not the average impact factor (also found by MAIRESSE & TURNER, 2002). Promotion is apparently more related to productivity than to impact. It seems that the higher productivity of scientists in the upper category is achieved publishing in journals spread through a wide array of impact factor values. Maybe publication strategy of scientists in the upper category is not so impact factor oriented, since promotion is not an objective anymore.

For those scientists who arrive at the middle or upper category, there are no inter-gender differences in the length of their scientific career at CSIC. But the average length of the scientific career of women as tenured scientists seems to be larger than that of men. Maybe it is due to the above average presence of women in the collective of scientists who remain in the lowest category after more than 15 years working at the institution, many of whom have probably renounced to promotion.

3. Are women less productive than men? Do they publish in less quality journals?

Leaving other factors aside, male scientists show in our study greater productivity than female scientists, as reported in other CSIC areas (BORDONS et al., 2003) and in other studies (GUPTA, 1999; PALOMBA, 2001; JACOBS, 2001; PRPIC, 2002). However, we know that productivity can be influenced by different factors such as age or professional category (ABBOT, 2000; Cole & ZUCKERMAN, 1984), which should be taken into account.

In our study, productivity tends to increase with professional rank for both men and women. Keeping this in mind, the lower productivity of women as a group can be partly due to the fact that they are working at lower professional ranks compared to men.

In relation to age, we have not found differences in the productivity of women by age classes, while productivity of men increases with age and attains its highest values at the ages of 40–49 and 50–59. As a result, women are less productive than men at these age classes.

Previous studies have shown different results in the relationship between age and productivity. Some authors have reported that publishing activity first increase, reaches a peak around mid-career and then decline (MAIRESSE & TURNER, 2002), while others have described a descending trend in productivity over the years (Palomba, 2001). Differences in the signing habits of authors and in the organisational structure of research according to disciplines and countries might partly explain these differences. As scientists advance in their professional career they get involved in new responsibilities and the time they spent in research probably decreases in favour of managerial tasks, but their productivity may remain or even increases if they form part of a successful group. The fact that women do not increase their productivity over time in our study could indicate a less cumulative advantage effect for them: maybe they are less often leaders or do not belong as frequently as men to the networks in their discipline. Since promotion is highly dependent on international publications, the lower productivity of women in their middle ages can be a contributing factor to their lower promotion.

In relation to the quality of the publications, a few studies have shown that women publish documents of higher quality than men, as measured through the number of citations received (LONG, 1992). In our study, women in the research scientist category publish on average in higher impact factor journals than men in the same rank. Considering the average impact factor of the production of men and women, the former had the maximum values, but also the lowest ones. It appears that women tend to be more selective and stable in their publication strategy. A decreasing trend in the average impact factor of men publications over age brackets is observed, while for women there are not significant differences in the impact factor according to age.

4. Differences in working styles.

Differences in working styles between men and women have been described elsewhere (ETZKOWITZ, 2000) and may lead to differences in productivity (XIE, 1998; GARFIELD, 1992–1993). Our paper analyses signing and collaboration practices and the degree of international orientation of scientists according to their trend to publish in international or national journals.

In the area of Materials Science we have detected *signing habits* related to professional category. The lower the professional category the higher trend to sign as first author, while the trend to sign as last author increases with category. This holds for

both, men and women. In many disciplines it is common that a junior scientist, who performs most of the experiments and technical part of the research, signs in first position, while a senior scientist, who is in charge of the group signs in the last place (RENNIE, 1997). Concerning single-authorship, it was not related with professional category, although we had expected to find more single-authored documents in the upper categories since the most characteristic type of document with just one author is the review, which is frequently done by request to prestigious authors.

The main inter-gender differences concerning authorship were those related with single-authorship: women sign alone less often than men in the tenured and research scientist categories. It could indicate that women are less likely than men to work alone in these categories. However, single-authored documents are uncommon among scientists; they are occasional papers which demonstrate the individual scientific capacity. In the context of highly productive authors the presence of single-authored documents is probably more related to scientific prestige than to collaboration habits.

As a matter of fact, very few differences in the *collaboration practices* of men and women were found. On the one hand, women showed a slightly lower trend than men to publish documents in collaboration at the 40–49 age class. In relation to the international collaboration, although some studies have described low international collaboration for women (GOEL, 2002), which could lead them to be less integrated in the international scientific networks, our results do not confirm this behaviour for the CSIC scientists in the area of Material Science.

Moreover, although previous studies have suggested that women publish more often than men in national journals (LEMOINE, 1992), this is not the case for Spanish female scientists in Materials Science. Even the contrary is true: a) the percentage of women that only publish in international journals is higher than that of men (50% vs. 35%); b) women in the research scientist category shows a higher international orientation than men, as measured through the percentage of international documents (94% vs. 85% for men). Curiously, the international orientation of men decreases with age (but not with professional category). Probably, men in the last age bracket are not so-impact factor oriented and get more involved in national topics and journals.

Concluding remarks

We consider that bibliometric indicators by gender can provide an interesting overview of the situation of women in science. However, obtaining them is difficult and time-consuming. Including the full name and sex of the authors in the bibliographic databases would be advisable to facilitate future studies. The present trend towards the development of institutional databases containing the scientific production of their scientists is other interesting option to make inter-gender studies possible.

This study shows that the under-representation of women in the upper categories of the CSIC in the Materials Science area can not be explained only by their later entrance in science. Productivity increases with professional category for both men and women. Inter-gender differences in productivity within each professional category were not found, issue that might indicate that scientific requirements for promotion are independent of sex. However, a different "life-cycle" of productivity for men and women is found in the area. The lower productivity of women as a group can be due to their lower presence in the upper and most productive categories, but also to their lower productivity at specific age classes, whose reasons would require further analysis.

Women are aware of the difficulties in gaining positions in the scientific career ladder. Different data suggest that women are making a remarkable effort to increase their presence in science and to adjust to patterns of international scientific excellence: MAT women in the research scientist category publish in journals with higher impact factor and show a higher international orientation than men. The feminization of the area of MAT started in the lower professional category and it should evolve to the upper category in the future; factors that could hinder women research performance should be identified and overcome.

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This research was financed by the Spanish Ministerio de Trabajo y Asuntos Sociales (Research project I+D+I 87/02). Elba Mauleón has participated thanks to a FPU grant (AP2003-1361) from the Spanish Ministerio de Educación.

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Annex I
Scientific activity of scientists by gender and age (SCI publications)

Age	Female		Male		Total		SIG
	Med±SD (N)	Range	Med±SD (N)	Range	Med±SD (N)	Range	
No. SCI Documents							
30-39	15.32±6.10 (19)	7-27	17.33±9.71 (30)	1-39	16.55±8.48 (49)	1-39	NS
40-49	16.00±12.82 (52)	0-66	27.39±22.95 (69)	1-114	22.50±20.01 (121)	0-114	0.01
50-59	15.31±14.64 (32)	1-61	25.19±22.41 (63)	0-108	21.86±20.59 (95)	0-108	0.05
>59	16.00±9.16 (3)	6-24	15.98±13.08 (42)	0-51	15.98±12.78 (45)	0-51	NS
% SCI Documents							
30-39	89.94±14.73	51.61-100	92.96±12.99	46.67-100	91.79±13.62	46.67-100	NS
40-49	85.29±22.89	0-100	90.16±15.02	33.33-100	88.07±18.88	0-100	NS
50-59	88.59±16.30	50.00-100	79.33±31.76	0-100	82.45±27.79	0-100	NS
>59	95.24±8.25	85.71-100	73.26±27.63	0-100	74.73±27.30	0-100	NS
Average IF							
30-39	1.87±0.74	0.80-3.72	2.26±1.08	0.79-4.62	2.11±0.98	0.79-4.62	NS
40-49	1.85±0.80	0.71-4.28	1.92±0.78	0.73-4.05	1.89±0.79	0.71-4.28	NS
50-59	1.83±0.93	0.65-4.60	1.81±0.91	0.10-3.88	1.81±0.91	0.10-4.60	NS
>59	2.25±0.36	1.97-2.66	1.43±0.69	0.60-3.85	1.48±0.71	0.60-3.85	0.05
% Doc. Q1							
30-39	64.27±17.08	37.5-100	62.44±23.11	22.22-100	63.15±20.80	22.22-100	NS
40-49	63.47±23.46	13.33-100	64.83±20.71	0-100	64.26±21.82	0-100	NS
50-59	62.54±24.11	0-100	61.59±27.78	0-100	61.93±26.38	0-100	NS
>59	53.24±31.68	16.67-72.22	60.68±27.21	0-100	60.16±27.18	0-100	NS
% Doc. as first author							
30-39	45.40±24.35	8.33-84	35.98±21.16	0-75.00	39.64±22.68	0-84	NS
40-49	23.46±23.62	0-100	19.40±17.91	0-77.78	21.11±20.51	0-100	NS
50-59	15.85±20.78	0-100	16.98±22.63	0-100	16.57±21.87	0-100	NS
>59	29.63±37.82	0-72.22	13.37±18.37	0-80	14.51±19.98	0-80	NS
% Doc. as last author							
30-39	6.75±8.31	0-31.25	12.32±18.55	0-86.21	10.16±15.53	0-86.21	NS
40-49	23.62±22.60	0-75	24.60±21.87	0-100	24.19±22.09	0-100	NS
50-59	26.82±27.41	0-91.67	31.06±27.14	0-100	29.54±27.16	0-100	NS
>59	35.18±42.07	5.56-83.33	41.19±26.93	0-100	40.77±27.57	0-100	NS
% Single authored-documents							
30-39	0.00±0.00	0-0	0.49±1.63	0-7.69	0.30±1.29	0-7.69	NS
40-49	0.69±3.57	0-22.22	1.37±3.32	0-17.65	1.09±3.43	0-22.22	0.01
50-59	0.24±1.04	0-5.56	4.47±18.62	0-100	2.95±15.01	0-100	NS
>59	0.00±0.00	0-0	0.19±1.22	0-7.69	0.18±1.17	0-7.69	NS