Chapter 13

SCIENTIFIC AND TECHNOLOGICAL PERFORMANCE BY GENDER

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Abstract: The availability of sex-disaggregated data in the fields of research, technology and development is extremely important for supporting the growing political commitment to promote and monitor women participation in the different fields of S&T. During the late 1990s the European Commission identified as a priority the availability of this data. Even if scientific publications and patents are widely accepted indicators of scientific and technological performances, until now it has been impossible to measure bibliometric and patent output by gender in a large set of data. Starting from a feasibility study carried out for the European Commission on the whole set of patents published in 1998 by the European Patent Office and on 30,000 authors of items published in 1995 on scientific journals of international relevance, the paper demonstrates that it is possible to obtain robust gender indicators on S&T output.

1. INTRODUCTION

Many metaphors are generally used in gender studies on science and technology (S&T): *leaky pipeline, crystal glass ceiling, scissors effect, impossible pursuit, overtaking model* (Palomba, 2000). These metaphors give both the idea of an inefficient use of human resources and of invisible constraints which bias scientific performance. They refer to the difficulties of women in reaching career levels comparable to those of their male colleagues, merits and education levels being equal. This waste of resources takes place in different ways and at different times of women's involvement in science.

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At the beginning young female students are not encouraged to undertake full time research professions and therefore "they are lost to the scientific world" (Palomba, 2000) like a *leaky pipeline* which continues through their entire career. Invisible obstacles, described as *a crystal glass ceiling*, prevent women from career progression. The *scissors effect*, which represents the most stable, statistically measurable phenomenon, indicates the progressive split between male and female careers. The two metaphors *impossible pursuit* and *overtaking model* refer to female presence in the different scientific fields: women cannot overcome the initial disadvantage of being under-represented in *hard sciences*, so that their pursuit is impossible. In sectors in which women are highly represented at the beginning of their career, they become a minority whilst proceeding to the top positions; one possible explanation is that in these sectors it is more difficult to find attractive professional positions outside academies and research institutions.

The growing importance of the issue of gender presence in science and technology led to defining indicators which could explain inequalities and differences between groups in terms of vertical and horizontal segregation (Siltanen et al. 1995). The former indicates the share of women in research activities and/or in specific disciplinary fields, and it has the implicit assumption that a more balanced distribution of women may be a good result in terms of gender equalities. The vertical differences, although strictly related to the horizontal differences, investigate the distribution of women throughout the scientific career ladders. Close to the issue of vertical segregation the reward and recognition system of European Universities and scientific institutions has been analysed (Harding et McGregor, 1996; Osborn, 2000).

The statistical description of the participation of women in S&T sectors is developing step by step. Until now the efforts for collecting gender data in Europe has not already produced harmonised and comparable sex-desegregated data for R&D and for S&T human resources. Problems of homogeneity and completeness of data still have not been solved. As a matter of fact, 'general purpose' data sets, which include demographic data and labour force surveys, may only be used for basic analysis, whilst dedicated surveys tend to lack coverage and representativeness.

There is a need for promoting gendering and statistical collection at national and European level (the top–down approach), as repeatedly recommended by the European Commission (European Commission, 2003) which considers the collection of data on scientific publications distributed by gender as a long term important task to achieve. In the meantime the collection of existing data at national level (the bottom–up approach) may show particular/local contexts and produce an insight into the development of new gender indicators.

This paper summarises a project (Naldi and Vannini Parenti, 2002) carried out for the European Commission – DG Research, aimed at assessing the feasibility of producing patent and bibliometric indicators by the gender of the inventor/author. It would appear to be the first study of its kind, and the results provide some pioneering measures of sex desegregated S&T output and productivity.

2. ANALYSES OF SCIENTIFIC PERFORMANCE AND POLICY FOR GENDER MAINSTREAMING

The wastage of women's skills and knowledge weigh heavily in the science system. First gender studies on science have posed the question of male and female scientific productivity in the US; they showed that female scientists produce a lower number of publications, and are less cited (Cole and Cole, 1973). Some studies in Europe followed a comparable approach and reached the same conclusions (Bochow and Joas, 1987). These results have been explained only in terms of family roles and workloads, but these variables have been considered overestimated by further studies (Zuckerman, 1992). All studies cited from the European Report on Science and Technology Indicators of 2003 show, on the contrary, a relationship between familiar factors and women's careers, even if each one uses different methodologies.

In the 1990s studies at EU level and inside the Member States showed the complexity of the phenomenon that cannot be easily explained without taking into account different perspectives and variables related to the context of S&T. Many factors may influence scientific productivity: the structure and organisation of scientific communities, the selection criteria of accessing postgraduate education and professions, the evaluation procedures of applications and grants of research funding as well as the participation to commissions and evaluation committees.

Analyses carried out in both Europe and in the US showed a close relationship between the scientific production and career levels (Long, 1992; Kaplan et al., 1996). Other studies stressed, in particular, the quality of publications (Campanelli et al., 1999) and citation patterns (Sonnert and Holten, 1996). Two studies (Long, 2001; Di Cesare, Luzi, Valente, 2003) have analysed the relationship between careers and publications. Long demonstrated that the male full professors of universities publish 30% more than their female colleagues. The second analysis related to male and female researchers of the Italian National Research Council extracted from the Social *Science Citation Index* for 1999–2001, demonstrated the increased attitude of male and female researchers to publish when belonging to a high grade hierarchy.

The lack of longitudinal studies represents a limit to interpretation: Xie and Shauman (1998) showed a decrease in difference of scientific production considering national inquires in the period of time 1969 to 1993.

The difference of scientific production depends partially from the overestimation of males in extremely productive groups and the lack of consideration of the part-time jobs of female researchers. (European Commission, 2003B)

At the end of the 1990s the European Commission promoted both specific and long term actions; the first type of action was to commission a report on women and science in the EU to an *ad hoc* group, the European Technology Assessment Network (ETAN) group. The report, published in 2000, in dealing with gender inequality in science, highlighted the phenomenon of the 'leaky pipeline'. From the ETAN report forth, this phenomenon has been further confirmed without distinction of countries and disciplines; even countries with advanced equality legislation are experiencing the situation and consequences of the *leaky pipeline*. This phenomenon represents one of the cases in which, besides quantitative studies and integrated data, qualitative analyses become crucial for a better understanding of the causes of this discrimination and waste of resource as well as for the identification of positive actions. The ETAN group also recommended that Women and Science Units would be present in all State Members, and this recommendation has been adopted by many Member States.

As a long term policy the Commission set out an action plan to promote gender equality in science and appointed a group of experts (known as the Helsinki Group) which meet on a regular basis. The group guarantees exchanges of experiences on measures and policies introduced in different countries and provides sex desegregated statistics, thus allowing continuous monitoring and promotion of the participation of women in S&T. One of the most important achievements of the group has been the delivering of national reports, based on a common structure, in which the collection of information on policy measures are as relevant as statistical data on women in science.

The focus on national policies was one of the commitments for the Member States identified by the Research Council as a priority, together with information exchange about human resources in S&T and common procedures of collecting data. Data collected by the Helsinki Group show that the organisation of the scientific system is quite similar among member states, being most of the responsibility centred in Ministries often devoted also to education and cultural issues. Member states also have weak points in common: under representation of women and lack of gender balance, on the top career ladders and decision levels.

Differences arise with reference to policy context and to the different measures to promote gender equality: the presence of a Ministry for Women or of a Women and Science Unit inside the Science Ministry; the provision of targets and quotas for a gender balance on university/research institute committees; the development of gender equality indicators; the production by Universities and Research Institutes of equality plans. Besides positive actions like supporting networks of women in science and establishing targets, quotas, research funds and prices for women, some countries have recently been considering gender mainstreaming, which is the systematic integration of gender equality into all policies and programmes and is embedded into EU policy.

Gender mainstreaming measures focus on 'legislation' and 'gender studies'. The latter is a strategic issue to increase the knowledge for better comprehension and interpretation of the phenomenon, as institutional practices seem to produce, albeit unintentionally, discriminatory effects that cannot be changed by new legislation alone. 'Gender proofing pedagogy of science education', relates to gender differences in the methods and content of teaching and involves the question of values of science. 'Work/life balance measures' which includes part-time as well as time flexibility, are examples of tools which may benefit men as well as women. Another mainstreaming tool is 'modernising human resource management', that includes transparency in appointment, promotion and recruitment procedures, as well as the reinterpretation of the concepts of merit and excellence. This is a very challenging task, considering that in the 1980s Merton had already pointed out that 'reward' and 'excellence' have instrumental and honorific, thus not objective, meaning, which makes evaluation activity very difficult.

3. FIRST NAMES AS A TOOL FOR GENDER CLASSIFICATION

Patent and bibliographic databases do not contain coding on gender of inventors and authors. To overcome the problem a feasibility study has been performed to verify the effectiveness of genderise data on patents and scientific publications by using the first names of authors and inventors.

For this purpose a comprehensive 'First Name Data Base' (FNDB) was created and applied to a significant sample of patents and scientific publications. The current release of FNDB covers 6 European languages: English, French, German, Italian, Spanish, and Swedish and contains 8,291 different names selected from more than 32,000 names collected from different sources such as dictionaries, calendars, books and internet sites, files from Record Offices, and phone books. In FNDB, 3,634 names are classified as female, 4,115 as male, and 452 are commonly used for both genders or are language dependent.

The setting up of a high quality database had two objectives: (1) to perform gender analyses on any list of first names, and (2) to allow expansion to other languages. Each name is classified by gender, following a classification which is language/country dependent, to solve cases in which the same name belongs to different genders in different languages. This is the case for example of 'Andrea' which is male in Italian and female in Spanish and German. The adopted strategy improves data quality and reliability and is described in details in the Final Report of the project (Naldi and Vannini Parenti, 2002) together with the techniques developed to manage diacritics, double names, exceptions, etc.

The degree of coverage of FNDB has been tested on more than 100,000 names of inventors and on about 30,000 names of authors of scientific papers. The results are summarised in Table 13.1.

Table 13.1. DB coverage by country/language

	Inventors					*Authors*				
Country	Total	Not found	%	Both	%	Total	Not found	%	Both	%
DE	55,195	842	1.5	89	0.2	6,865	257	3.7	51	0.7
ES	1,383	44	3.2	12	0.9	2,766	166	6.0	62	2.2
FR	16,973	239	1.4	524	3.1	6,030	191	3.2	228	3.8
GB	15,979	420	2.6	197	1.2	7,468	487	6.5	237	3.2
IT	6,745	106	1.6	12	0.2	5,202	104	2.0	18	0.3
SE	6,718	296	4.4	56	0.8	1,528	114	7.5	25	1.6
Total	102,993	1947	1.9	890	0.9	29,859	1,319	4.4	621	2.1

The adopted methodology is successful in more than 90% of cases: 97.2% of the inventors and 93.5% of authors were identified by FNDB. The unidentified inventors and authors remained unclassified because their names were not included in the database (1.9% and 4.4%) or are currently used for both genders (0.9% and 2.1%). Coverage of patents is strongly influenced by German inventors who represent more than 50% of the total number of the names. The sample of authors of scientific publications is better distributed amongst the 6 Countries but contains a larger number of 'foreign' people (mainly from Arabic and Far Eastern countries) who are working in the 6 countries and whose names are not included in FNDB.

A further demonstration of the feasibility of the methodology comes from the analysis of the distribution of missing names by number of occurrences: 73% inventors and 90% authors of the missing names appear only once in the database. These names can be considered as spelling errors and rare, or foreign, names.

4. GENDER ANALYSIS ON R&D OUTPUT

This study has been performed on two sets of data:

- Patents published in the year 1998 by the *European Patent Office* (EPO) and produced by inventors whose working address is in France, Germany, Italy, Spain, Sweden, and the UK.
- Scientific papers published in the year 1995 in 157 scientific journals of international relevance by authors of the same 6 EU countries.

4.1 Notes on the Adopted Methodology

The EPO database already includes the first names of the inventors. For this reason it has been possible to process the whole set of 47,820 patents and 102,993 inventors published for the year 1998 from the 6 countries.

Patents are classified according to the International Patent Classification (IPC) Schema. Up to 4 IPC codes are assigned to each patent. Correspondence tables have been applied to assign patents to Industry Sectors (Verspagen, Moergastel, Slabbers, 1994) and Field of Technology. The same patent can be assigned to more than one Industry Sector / Field of Technology.

Differently from the patents databases, bibliographic databases do not contain the first names of the authors but only their initials. For this reason it was necessary to collect the names manually from the original paper, where, however, the first name is available in less than 50% of cases. The sampling procedure was based on an '*a priori*' selection of the journals. Journals were selected on the basis of the high availability of authors' first names, high frequency of items written by authors of one of the 6 countries, high scientific relevance, and balance of the geographical and disciplinary coverage. Since it was impossible to predict in advance the number of first names actually available in the chosen journals, the sample was built in a dynamic way, carrying out adjustments in real time during data collection, with the goal of collecting a significant number of authors for each country and discipline. Extra data have been collected for Medicine, Chemistry and Physics in order to check the sampling methodology and suggest possible future extension of the analysis. A sample of 9,344 publications and 36,239 authors was obtained after processing more than 100,000 items published in the selected journals.

Each publication was classified according to the disciplinary sector(s) of the journal in which it was published. The *Science Citation Index* (SCI) '95 classification of the journals, based on 183 disciplines, was used. SCI disciplines have been grouped into 9 disciplinary sectors: Biology (Biol), Biomedical Research (Biomed), Chemistry (Chem), Clinical Medicine (Med), Earth and Space (Earth), Engineering (Eng), Mathematics (Math), Physics (Phys), Multidisciplinary Sciences (Mult). Some disciplines may be associated with more than one sector. Journals may be associated with more than one discipline and may belong to more than one sector.

Three indicators were introduced in order to evaluate patents and publications produced by co-operation among inventors/authors of different countries and gender:

- *Participation* counts the number of patents/publications with at least one author of a given gender/country;
- *Contribution* measures the involvement of each gender/country in the production of a patent/publication, assuming that each person contributed the same amount. *Contribution* is also called *'patents/publication-equivalent'* since it sums up the single shares of each item attributed to a given gender/country. In general, for a patent/publication with *n* authors the contribution of each gender/country is equal to the number of authors of the respective gender/country divided by *n*. The sum of the *contributions* of all the genders/countries involved in a patent/publication is always equal to 1;
- *Presence*: Total count of the authors of a given gender/country in each patent/publication.

4.2 Distribution by Gender

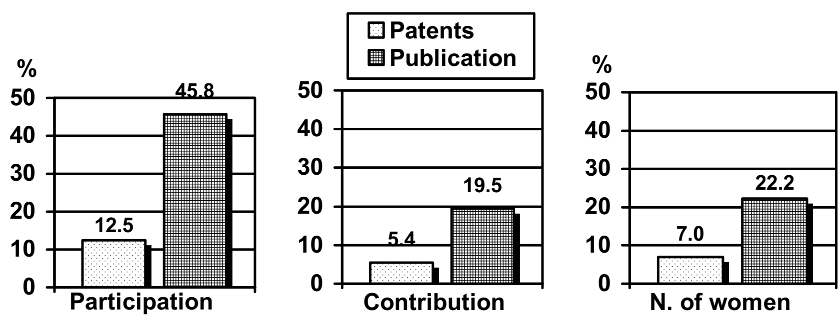


Figure 13.1. Participation, contribution and presence of women in patents and publications

Figure 13.1 shows the participation, contribution, and presence of women respect to the total number of inventors/authors.

The patents with at least one female inventor are 12.5% whilst 97.3% of the patents have at least one male inventor. As a consequence 87.5% of the patents has been entirely produced by men and 2.7% entirely by women. On the other hand female inventors are 7% of the total number and contribute to the overall production of patents with 5% of equivalent patents. It is important to note that since one half of the patents are produced in Germany, the low percentage of German female inventors influences significantly the global statistics.

The publications with at least one female author are 45.8% whilst the items with at least one male author are 94.7%. As a consequence 54.2% of the items have been entirely produced by men and 5.3% entirely by women. On the other hand female authors constitute 22% of the total and contribute 20% of equivalent publications to the overall scientific production.

4.3 Distribution by Country

Figure 13.2 shows the contribution of women to patents and publications in the 6 countries. In analysing the statistics on patents, the geographical bias has to be taken in consideration: German inventors are almost one half (48%) of the total and are involved in 44% of the patents. French and British inventors represent both 15% of the total, Italy and Sweden about 6%, Spain only 1.2%.

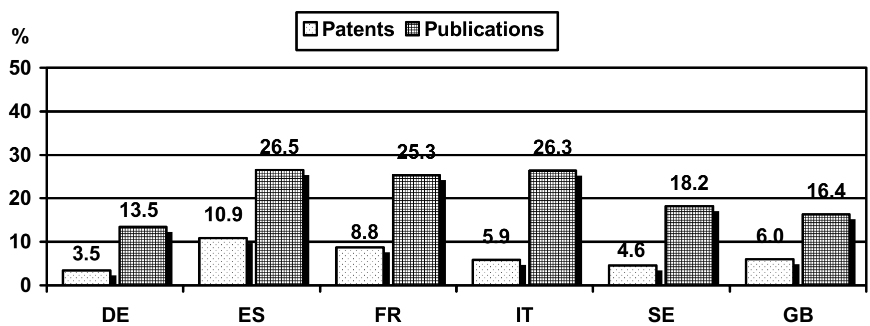


Figure 13.2. Female contribution by country to patents and publications

The country with a higher female contribution to patents is Spain followed by France. Scientific publications show two patterns of countries

— Italy, Spain and France with a relatively high female contribution and Germany, Britain and Sweden with significantly lower contribution.

The relevance of the differences in gender distribution amongst countries can be pointed out by observing that the percentage of German females is nearly half of those of Spain, Italy and France and that, for example, the total number (both men and women) of *publication-equivalents* produced by UK is more than twice that of Italy (2,387 compared with 1,121) but the total number of British female authors (1,260) is lower than the number of Italian female authors (1,426).

The statistics on participation confirm the trends of contribution shown in Figure 13.2. Spain and France have the highest percentage of patents with at least one female inventor (19.4% and 16.8% respectively) and Germany has the lowest percentage of female inventors (4.6% vs 15.8% of Spain). The percentages of publication with at least one female author in Italy, Spain and France (respectively 58.3%, 56.3% and 53.6%) is remarkably higher than that of Sweden (38.0%), United Kingdom (31.8%) and Germany (32.3%).

It can be noted that Sweden, which has a long tradition and practice in supporting gender policy, is just above the United Kingdom.

These results look less surprising if we compare our data with those provided by the WIS database of the European Community (European Commission, 2003B) (Figure 13.3): the percentage of female authors looks related to the share of global female labour force in the public sector (government and higher education sector) in the six countries considered. Public female researchers in Spain have the highest share, followed by Italy. France and Sweden are at the same level, whilst the United Kingdom and Germany are in the last position.

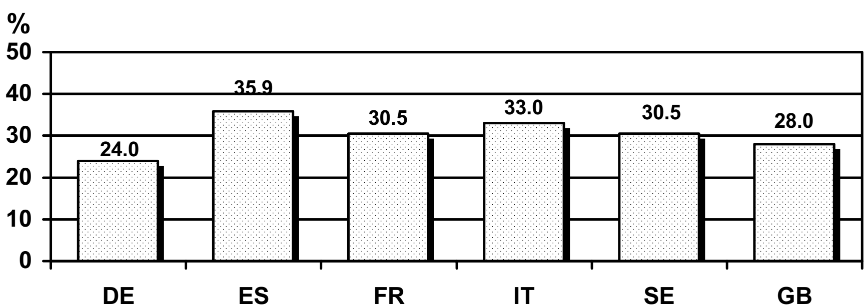


Figure 13.3. Share of women researchers in the two public sectors (GOV, HES).
Source: elaboration from WIS database, DG Research

Even if the data of Figure 13.3 refer to the year 1999 and only focus on researchers of the public sector, they may give interesting clues for interpretation and further analyses. We have to consider, for instance, that countries such as Sweden, the United Kingdom, and Germany have a high percentage of researchers working in the private sector; anyway this should not significantly influence the number of publications, because the private sector tends not to publish as much as the public sector.

4.4 Distribution of Patents by Industry Sectors

The following figure (13.4) shows the number of equivalent patents produced in each sector by female inventors, expressed as percentage of the total number of patents in the sector.

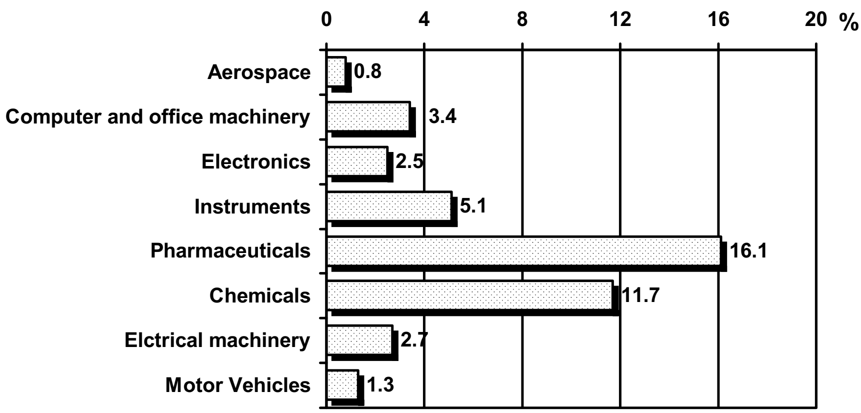
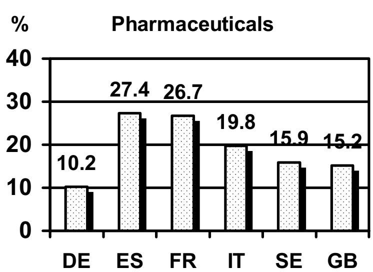


Figure 13.4. Female contribution to patents by Industry sectors



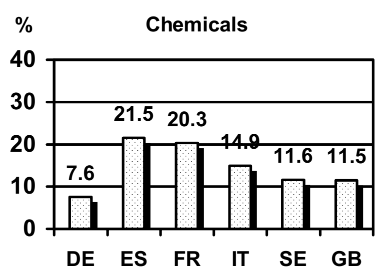


Figure 13.5. Female contribution by country to patents in Pharmaceuticals and Chemicals

Distribution by country of the two sectors where the female contribution exceeds 10% is reported in the following Figures 13.5 and 13.6.

As a general consideration Germany confirms its position of leadership in all the sectors for the general ranking, maintaining the first place both for number of patents and for total inventors. On the other hand, Germany has the lowest percentage of women in almost all the sectors whilst France and Spain have a strong presence of women in most fields.

4.5 Distribution of Scientific Publications by Discipline

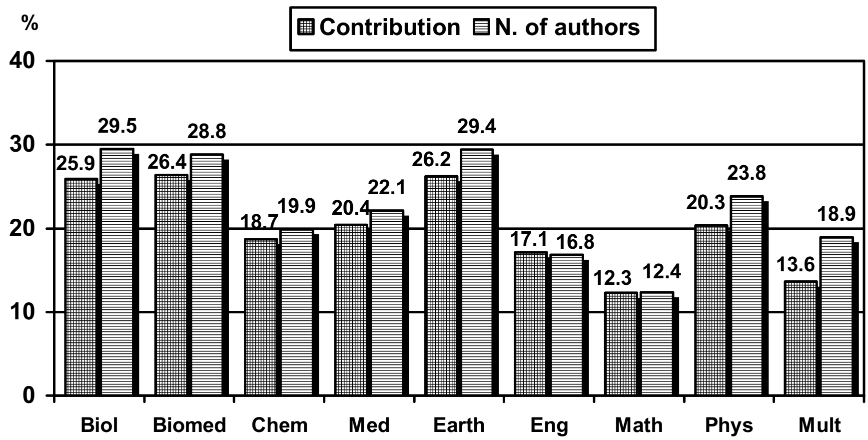


Figure 13.6. Female contribution to scientific publications by discipline

Whilst the percentage of female authors is significantly above the average in Biology, Biomedicine, and Earth and Space Sciences, it is below the average in Engineering, in the Multidisciplinary sector and in Mathematics (χ^2 = 335,991, df = 8, p < 0.001).

Some peculiarities which arose from the statistics can be pointed out and deserve further analysis:

– The *participation* of women in Mathematics is remarkably low. This is only partially justified by a general (*i.e.* independent of gender) low level of co-authoring in this discipline.
– Engineering is the only discipline in which the *contribution* of women is greater than the percentage of the *number of authors*.
– Clinical Medicine is the discipline where the difference between the two groups of countries is less evident although still significant.
– Italian female authors in Biomedicine participate in about 80% of the publications with more than 40% of article equivalents.

- The generally small presence of women in Mathematics is particularly low (well below 10%) in Germany, Britain, and Sweden.
- There is a very high percentage of Swedish women in Earth and Space Sciences. This data should be further analysed with a larger data sample.

4.6 Other Bibliometric Indicators

4.6.1 Gender by type of publication

The cross-tabulation between gender and type of publication shows that the percentage of female authors in the types of publication traditionally used to communicate scientific results: articles (22.7%); letters (21.9%); and notes (21.4%); is significantly higher ($\chi^2 = 63{,}052$, df = 5, $p < 0.001$) than in publications relating to editorial activity: editorials (10.6%) and reviews (14.8%). This can be explained either by a lower level of interest of females in the editorial activity of the journals (editorial, notes, etc.) or by some kind of discrimination in the editorial management.

4.6.2 Distribution by first authors

This analysis was carried out on the 6,159 items of the sample with two or more authors and where the authors were not listed in alphabetical order. No significant differences were found between the gender distribution of first authors and the gender distribution of all the authors of this specific sample

4.6.3 Single authors

This analysis was carried out on the 1,570 items written by single authors. In the publications with only one author the female contribution is 10.8%, significantly ($\chi^2 = 113{,}983$, df = 1, $p < 0.001$) smaller than the whole data sample. Figure 13.7 shows the female contribution of single authors by country.

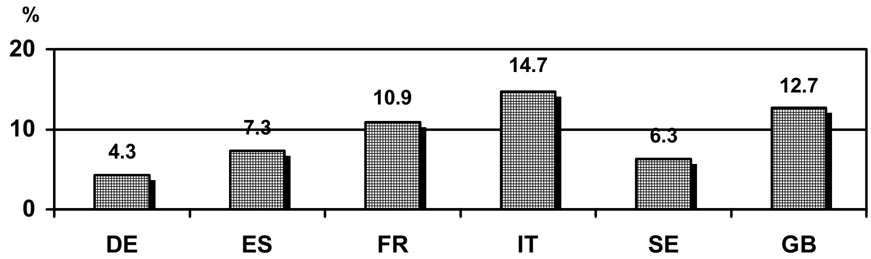


Figure 13.6. Percentage of women among first authors

4.6.4 Co-authoring

Figure 13.8 shows the contribution of women as a function of the number of co-authors. The contribution of women, and not only their participation, increases with the number of co-authors. That could indicate a better inclination of women to co-operate and to participate in large research groups.

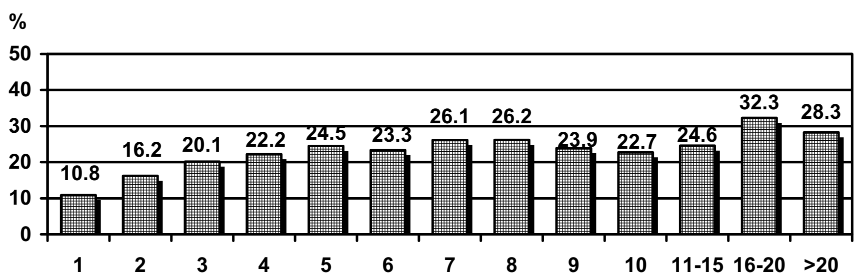


Figure 13.8. Female contribution by number of co-authors

5. CONCLUSIONS

In this paper we confirm the feasibility of the approach of using first names to produce robust gender indicators which can be applied to any data set containing first names. The statistical tables presented are highly reliable for the size of the sample analysed.

As a further step, in our opinion, the study should be extended to cover more countries and a larger period of time in order to include at least all EU countries and to evaluate the trends also in connection with the political actions promoted at national and international level.

More particularly, even if the mean contribution of female inventors to patents is still relatively low, there are some technologies in which the participation of women is highly significant. For these fields, an accurate analysis of temporal data would provide important indicators on the presence of women in the sector of industrial R&D, a situation which up to now has not been explored in detail.

As for the interpretation of the statistics on scientific productivity, it is worthwhile considering the different policies of publication and the chosen channels of dissemination in the different disciplines. Even if the international journals are favourite, in some cases (e.g. social sciences and humanities) the authors' preference goes to monograph publications, which are excluded from the citation indexes. Depending on the disciplinary sectors, some parameters, such as the number of authors per publication and the yearly mean scientific production, may vary, as well as the number of journals included in the principal citation indexes. For this reason an exhaustive investigation should take a broader set of sources into account and include social sciences, the arts and the humanities. Moreover, some scientific communities, such as physics, mathematics, computer science, start giving great importance to the diffusion of results trough Open Archives. With the increasing prestige and number of publications available on Open Archives gender analyses have also to take these new channels of diffusion into account. They can also turn out to be an important tool for collecting authors' first names more easily, facilitating the bibliometric analysis of publications.

In the future it would be useful to connect data on scientific productivity with other variables, such as the number and position of female and male scientists and researchers, which can provide a new perspective for analysing more deeply the question of gender in scientific performance. Moreover, it would be necessary to introduce objective measures on the way of working in the scientific world (Palomba, 2000) in addition of the reinforcement/improvement of qualitative and quantitative studies.

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