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Gender disparity in Polish science by year (1975–2014) and by discipline

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ABSTRACT

The production and impact of male and female authors in Poland over the period 1975–2014 have been studied. The method is based on a special property of Polish last names, namely several popular last names have separate masculine (-ski, -cki) and feminine (-ska, -cka) forms. In this respect Polish is different from most other languages, in which the last name has only one form independent of the gender. A set of 56 634 unique publications of authors bearing one of 26 most popular -ski or -cki names was analyzed. The male dominance was observed over the entire studied period, yet it became systematically less significant over the period 1995–2014, especially in terms of production.

1. Introduction

The universities in Poland were purely male domain till the late 19th century. Female students were not admitted to Jagiellonian University in Cracow until 1894, and to Warsaw University until 1915. In this respect Poland is not much different from other European countries. For example Julie Daubie received an university diploma in 1861 as the first woman in France, but many prestigious European universities did not admit women even after WW I. The role played by women in science and education gradually increased, and in 1981 Maria Joanna Radomska was elected the first female rector of a Polish university. Yet even in the 21st century the universities in Poland, and in many other countries remain chiefly male domain.

The gender disparity in science and education has been widely discussed in popular press and in scientific journals. There is no generally accepted definition of gender disparity, and many different aspects have been recalled including graduation rates at various levels, success in applications for professorial positions and for grants, and the number of publications and citations (Ceci, Ginther, Kahn, & Williams, 2014). Those rates are rapidly changing, so the empirical results become soon outdated, and findings representing current state (year 2015) should be clearly distinguished from historical findings (e.g., year 2000). The level of gender bias is specific to certain country and even to certain university or department, thus the results obtained with a small sample can hardly be generalized. On the other hand it is rather difficult to process large sets of gender-related data unless the gender information is explicitly reported in the database. Survey of Earned Doctorates (2012) reports fractions of female doctors promoted in particular years in the USA in several fields. In 1983 more male than female doctors were promoted in 6 broad fields, and the only field with about 50:50 proportion was education. On average one female doctor was promoted per two male doctors at that time. By 2013 the number of female doctors promoted by year doubled while the number of male doctors increased by 40%. Nowadays the numbers of male and female doctors promoted per year are almost equal, and more female than male doctors are promoted per year in life sciences, social sciences and in

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education. The proportion is nearly 50:50 in humanities, and only physical and engineering sciences are still dominated by men.

In general gender-specific information on journal articles is not explicitly available, because the names of authors of scientific publications often do not reveal their gender. The last names are seldom gender-specific, and the first names (which are often but not always gender-specific) are usually replaced by their initials in the databases of scientific publications. Even when the first name is not abbreviated, the gender is not always obvious, e.g., Janis is a feminine name in English-speaking countries, but in Lithuania Janis is a masculine name (=John). Therefore full advantage of publication databases, which offer a possibility of automatic processing of thousands of records can hardly be taken in gender-related studies, and such studies need a lot of tedious manual work.

Multiauthorship of scientific papers is another problem in gender-related studies. While doctorates, and professorial positions are individual achievements (which can be attributed to certain male or female scientist, and not to anyone else), the scientific papers have often more than one author. Even when the gender of each co-author is known, the assignment of the credit to male and/or to female scientist(s) is not obvious in multiauthored papers, and two opposite approaches have been used. Assignment of full credit for a paper to co-author X irrespective of the number (and gender) of co-authors, as by Slyder et al. (2011), Borrego, Barrios, Villarroya, and Olle (2010), Aksens, Rorstad, Piro, and Sivertsen (2011), Duch et al. (2012), and Hopkins, Jawitz, McCarty, Goldman, and Basu (2013) is technically easier and more popular. In contrast fractional assignment of credit has been used. For example Lariviere, Ni, Gingras, Cronin, and Sugimoto (2013), and Paul-Hus et al. (2015) assigned only $1/x$ count of authorship of a paper to each of its x co-authors. Both approaches have their pros and cons, which have been discussed in detail by Kosmulski (2012a). This should also be emphasized that equal ($1/x$) assignment of authorship to each co-author is not the only and not necessarily the best method of fractional counting of the authorship. Different bibliometric indicators are highly correlated. Complicated indicators (e.g. involving fractional authorship counting) often lead to practically the same results as their simpler counterparts (full credit assigned to each co-author). For example the success of the h-index is due its simplicity. None of the "corrected" h-type indices (e.g. involving fractional authorship counting) enjoyed similar popularity as the original h-index in spite of obvious disadvantages of the later.

Gender-related studies of publications and citations are often carried out with relatively small datasets. For example Ceci et al. (2014) excluded "studies with fewer than 75 subjects" in their summary of gender differences in the number of citations per publication. This statement suggests, that studies with fewer than 75 subjects have been published. Slyder et al. (2011) studied 213 individuals (44 women and 169 men), faculty members of 10 American universities, representing forestry and geography. The number of papers or of citations of these individuals are not reported. Only the number of citations of the most-cited first-authored paper was taken into account. In this respect female researchers received on average better scores (55.41 citations per paper) than their male colleagues (52.22), yet the sample consisted only of 213 papers (last-authored and less-cited papers were ignored), and the number of citations of the most-cited first-authored paper is rather controversial as the indicator of the scientific output, especially in the USA where the supervisor (professor) usually puts his(her) name in the end of authors' list in multi-authored papers. In 2008, Borrego et al. (2010) studied 731 individuals (305 women and 426 men), doctors promoted over the period 1990–2002 from universities in Spain, representing different disciplines, except humanities. The studied group is only a small fraction of all doctors promoted in Spain outside humanities over the above period, and the criteria of selection of the individuals to be studied were not explained. The number of papers or of citations of these individuals are not reported. The comparison of male and female researchers is chiefly based on the fractions of individuals who have published at least one paper (as opposed to those who have published zero papers) and of individuals who received at least one citation (as opposed to those who received zero citations). Female scientists were more successful in both productivity and in impact (self-citations included or excluded). Yet the criterion used by Borrego et al. (2010) was rather unusual. Namely an author of one paper received the same credit as an author of 10 papers, and a scientist with 1 citation received the same credit as a scientist with 10 citations.

Aksens et al. (2011) studied 8467 Norwegian scientists (2932 women and 5535 men), who have published at least one ISI-indexed article between 2005 and 2008. A set of 17 239 unique articles was considered, but many articles were multi-authored, so the entire number of articles considered was 37 698 (5535 authored by women and 28 237 authored by men), and they received 304 913 citations (78 571 by women and 226 342 by men). Men were on average more productive (5.1 papers per person vs. 3.2 in women), and the detailed analysis by discipline showed that male researchers were more productive than their female colleagues in 13 disciplines, and the only exception was humanities where male and female researchers were equally productive. The male researchers were more productive in all age groups and in all academic-position groups, and the difference was least significant in PhD students and in the age group <30. Apparently Aksens et al. (2011) had access to *Norwegian Research Personnel Register*, but they do not report who and how can access that database. Very likely the database is only available to certain privileged users, so their findings cannot be verified by other researchers.

In 2010 Duch et al. (2012) studied 4292 faculty members of top research institutions in the USA (890 women and 3402 men) representing 7 disciplines. The entire number of articles considered was 437 787 (52 219 authored by women and 385 568 authored by men), and the impact of those articles was not reported. Male scientists were on average more productive in overall comparison (113 vs. 59 papers per author) and in each of 7 disciplines.

Hopkins et al. (2013) surveyed 1065 scientists from different countries, including 494 USA residents. The surveyed scientists were randomly selected among representatives of 4 disciplines, who published at least one article each in selected sets of WoS®-indexed journals (relevant to certain disciplines) in 2005, and at least one other article between 2001 and 2004.

The response rate was 19.6%, that is, the number of solicitations was over 5 thousand, and 20.7% of the respondents were women. In each of 4 disciplines the mean h-index of women was substantially lower (56 to 78% of that of men).

Lewison (2001) analyzed all 2779 papers (articles, notes and reviews) published between 1980 and 2000 by authors from Iceland, covered in the *Science Citation Index* (CD-ROM version) and representing 9 major fields. Fractional counting of authorships was used. Men were more productive in all considered major fields and the contribution of female authorship ranged from 0% in mathematics to 24% in biomedicine. About 45% of the authorships remained undetermined (not attributed to male of female authors) and the above fractions relate only to the authors whose gender could be identified.

West, Jacquet, King, Correll, and Bergstron (2013) used JSTOR network dataset, which covers very different publications than WoS® to study 2.8 million authorships with identified gender associated with 1.5 million publications. The gender composition of authorship were analyzed by field, by decade (1900s–2000s), and by the rank in the authors' list (1st author, 2nd author, etc.). The contribution of female authors over the period 1990–2011 was field-dependent and ranged from 11% in mathematics to over 40% in sociology, in demography and in education. The overall contribution of female authors increased from 11% in the 1960s to almost 30% in the 2000s, and the trends in single authorships and in 1st authorships (of multiauthored papers) were similar.

Lariviere et al. (2013) studied 5483 841 articles published over the period 2008–2012, from the WoS® database, with 27 329 915 authorships. The global fractional authorship of female authors was 30%, but in a few countries (Latvia, Ukraine) female authors dominated. Country-specific methods were used to identify the gender of the authors (based upon the first and the last names), and substantial fraction of authors could not be assigned to specific gender.

The above examples show that although gender-related studies of publications and citations are relatively abundant, many published analyses are problematic due to small size of sample, non-standard parameters used to assess the scientific output, unclear criteria of selection of the sample studied, possible bias, and substantial fraction of authors with unidentified or uncertainly identified gender.

This present study utilizes a special property of Polish last names to identify large numbers of publications of male and of female authors. The number of publications was used as a measure of production and the number of citations was used as a measure of impact. These two parameters are by far the most common bibliometric indicators. Normalization of the citation count to scientific discipline has been widely discussed in the literature, and various methods to execute such a normalization lead to different, sometimes controversial results (Kosmulski, 2012b). In the present study only absolute citation counts are reported.

2. Methods

The WoS® core collection was accessed on March 3, 2015. The results were stored, and they were processed afterwards. The study is focused on publications of two sets of authors: set 1: Kowalska or Wisniewska or Dabrowska or Lewandowska or Kaminska or Zielinska or Szymanska or Kozłowska or Jankowska or Wojciechowska or Kwiatkowska or Piotrowska or Grabowska or Nowakowska or Pawlowska or Michalska or Nowicka or Jablonska or Majewska or Olszewska or Jaworska or Malinowska or Witkowska or Gorska or Rutkowska or Ostrowska, and set 2: Kowalski or Wisniewski or Dabrowski or Lewandowski or Kaminski or Zielinski or Szymanski or Kozłowski or Jankowski or Wojciechowski or Kwiatkowski or Piotrowski or Grabowski or Nowakowski or Pawlowski or Michalski or Nowicki or Jablonski or Majewski or Olszewski or Jaworski or Malinowski or Witkowski or Gorski or Rutkowski or Ostrowski, with Polish affiliation, published in particular years over the period 1975–2014. The rationale for such a search is as follows. The above names represent simplified spellings (Polish diacritics omitted, e.g., Wisniewska is actually Wiśniewska) used in WoS® collection for 26 most popular Polish last names, which have separate masculine and feminine forms. These names cover between 0.1 and 0.5% of the entire Poland's population each, and 6.5% of Poland's population together (Polish Ministry of the Interior, 2015). A database "Nauka Polska" (publically available) was used to estimate the frequency of the names from set 1 or set 2 in the scientific community of Poland. This database covers 182 364 Ph.D. degree holders (and a few persons without scientific degrees) who either received their scientific degrees in Poland or are (have been) employed by Polish scientific institutions (also retired and deceased). The names from set 1 and set 2 constitute 4% of the scientists covered by "Nauka Polska" database, which is a substantially lower fraction than the aforementioned fraction in the entire population, but similar to the fractions in the entire population found in less recent sources. The same database can be used to estimate the fractions of female scientists in Poland overall (39%), among professor degree holders (20%), in physical sciences (35%) and in humanities (43%). The above numbers do not refer to any specific time point, because the database covers persons who received their Ph.D. degree at different times. Many of those persons have never worked in a scientific institution. The fractions of female researchers based upon "Nauka Polska" database roughly match the fractions of female researchers in Poland in the OECD database (publically available), which reports numbers of R&D personnel in Poland in particular years between 2003 and 2012. The results based upon "Nauka Polska" database are not fully reliable. A recent study of doctorate recipients from one Polish university indicated that information about many doctorate recipients was incomplete, incorrect or missing in "Nauka Polska" database.

Many other Polish names, which are equally popular as the names included in set 1 and set 2, have only one form, common for men and women, but with the above names, the suffix -ski or -cki unequivocally indicates a man, and the suffix -ska or -cka unequivocally indicates a woman, at least in Poland. In this respect, the present method is different from the methods used by Paul-Hus et al. (2015) and by Lewison (2001), who assigned all names with certain suffix to certain gender. Such an approach is not applicable to Polish science. Namely there are numerous relatively popular Polish names, e.g., Gąska, Trzaska (>0.01% of the entire population each), and Dacka, which have one form, common for men and women in spite of their suffix -ska or -cka. In other words, an assumption that a suffix -ska or -cka unequivocally indicates a woman would be incorrect. In this present method a smaller dataset with higher degree of certainty in gender assignment is preferred over a larger dataset, in which the certainty of gender assignment is lower. Gender-specific surnames are not unique for Poland, and they also occur in neighboring countries, e.g., in Russia 89% of papers had at least one author whose gender could be recognized by means an a simple suffix-based principle (Paul-Hus et al., 2015), but in the Western countries the last names have only one form, common for men and women, and the fact that husband and wife have different last names often leads to a confusion (the author of the present article and his wife have experienced such situations themselves). Many Polish families who emigrated to Western countries decided to use only masculine form of the last names also for women. There may be a Mrs. Kowalski in the USA, but never in Poland. There are many dozens of scientists bearing each of the above 26 names. The proportion of women to man bearing each of the above 26 names is similar as in the entire Poland's population (107 women per 100 men). However substantial excess of women occurs only in the age group 60+, and in the professionally active age group, the proportion is close to 50:50. The sample used in this study is large enough to be representative to the entire scientific community in Poland. Only papers with Polish affiliation were taken into account to avoid assignment of women with masculine form of last name to men. In this present study, papers with at least one author from set 1 are considered as papers of female authors, and papers with at least one author from set 2 are considered as papers of male authors. With such a definition, male co-authors are allowed in papers of female authors and vice versa. Although the assignment of full credit for every co-author for a multiauthored paper may seem unfair, fractional counting of authorship is seldom used in practice. About 5% of unique papers (e.g., co-authored by Kowalski and Ostrowska) were counted twice: as a paper of male author and as a paper of female author. On the other hand, a paper with multiple co-authors from set 1 or with multiple co-authors from set 2 is counted only once. Double surnames (double-barrelled names) like Kowalska–Ostrowska are relatively popular in Poland, especially in women. In WoS® searches, the papers of author Kowalska–Ostrowska are counted in queries "AU = Kowalska" but not in queries "AU = Ostrowska". In other words the above sets of last names include also double-barrelled names with one of the names from the list coming first. On top of the searches for set 1 and set 2, separate searches for particular names from both sets have been carried out. Since the numbers of papers per year per name were small (often less than 10) the results were grouped into four 10-years-long periods (1975–1984, 1985–1994, 1995–2004 and 2005–2014) to avoid random scatter. No attempts were made to indentify the output of particular scientists (numerous homonyms) or even to estimate the numbers of unique scientists in set 1 or set 2. The study is based on the assumption that the results obtained for set 1 and set 2 are representative to the entire scientific community of Poland.

The assignment of scientific papers to certain disciplines is not easy, and WoS® is not necessarily the best tool to study such effects. The subject categories in WoS® follow the names of the journals rather than the topics of the papers. Many high-impact papers in different disciplines are published in interdisciplinary journals like *Nature*, which are not assigned to any specific discipline. Nevertheless a discipline-specific search of the papers of the author sets 1 and 2 with Polish affiliation has been carried out. Sub-sets belonging to research areas: physics, chemistry, engineering and biochemistry (more precisely: Biochemistry & Molecular Biology) were studied in detail. They are four of five most popular research areas in papers with Polish affiliation. They are also four of five most popular research areas in papers by Polish male authors and by Polish female authors, although the order of the most popular research areas in male authors on the one hand and in female authors of the other are different. The subject category materials science is actually the #4 most frequent research area in papers with Polish affiliation, but there is a substantial overlap between materials science and other popular categories. Actually only 30% of papers assigned to materials science were not assigned to physics or to chemistry or to engineering. Consequently the gender-related distribution of production and impact in materials science is very similar to that in physics and in engineering. Even in the above most popular research areas, one-digit numbers of publications and of citations per set of authors per research area per year were commonplace, especially before 1990, and in less popular research areas (outside the top five), these one-digit numbers were often zeros. Thus the year-by-year graphs were presented only for the most-common research areas.

3. Results and discussion

Polish scientists bearing one of the names from set 1 and from set 2 have published 21 711 and 39 149 papers with Polish affiliation, respectively. Among those papers 21 043 papers of female authors and 38 452 papers of male authors were published between 1975 and 2014. The authors from set 1 and set 2 published together 56 634 unique publications between 1975 and 2014, and this makes 11.4% of the total scientific output of Poland over that period. Many papers of authors from set 1 and set 2 have co-authors from Poland and from other countries, who belong neither to set 1 nor to set 2. Small number of papers with Polish affiliation before 1975 is due to the fact that WoS® database seldom reports affiliation in very old papers. The papers by female and male authors published between 1975 and 2014 received 168 418 and 368 119 citations, respectively, and this results in 8 and 9.6 citations per paper, respectively. Thus in 40-years perspective the male authors were on average more productive, had higher total impact, and higher impact per one published paper. This result is in line with male domination indicated in the large-scale studies by Aksens et al. (2011), Duch et al. (2012), Hopkins et al. (2013), and Lariviere et al. (2013). Yet the gender-related phenomena are very dynamic, and this is why they were studied year-by-year.

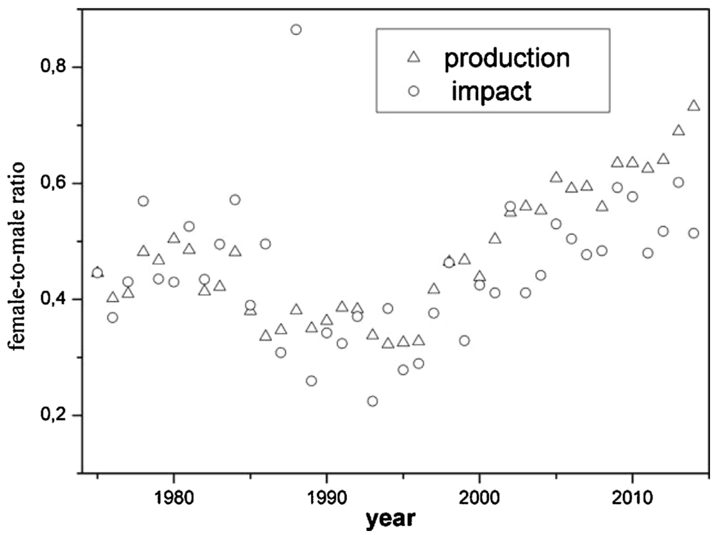

Fig. 1. Production and impact of female authors plotted as fraction of production and impact of male authors.

For each particular year the number of papers published and the number of citations received by male scientists (set 2) was greater than the output of their female counterparts (set 1). The ratio of the numbers of papers by authors from set 1 and from set 2 each year and of the numbers of citations thereof are plotted in Fig. 1. All 80 ratios are <1. This result is relevant to achievements of scientists working in physical and biomedical sciences which are represented by many journals in WoS® collection, and which produce large numbers of citations per paper. The results shown in Fig. 1 are rather irrelevant to the contribution of humanities, due to different publication and citation culture (most work published in non-WoS®-indexed journals).

The data points in Fig. 1 show trends with time. Both production (correlation coefficient of 0.95) and impact (correlation coefficient of 0.8) of female authors expressed as the fractions of production and impact of their male counterparts almost linearly increased over the period 1995–2014. This tendency can be interpreted as gradual gender-equalization in science. The trends are less clear when the entire period 1975–2014 is taken into account, and the corresponding correlation coefficients are 0.69 (production) and 0.19 (impact). The later was strongly influenced by one outstanding data point. High impact of papers of female authors published in 1988 is due to only one paper by Stefania Jabłońska (with co-authors), which received 2229 citations, that is, twice as much as all other papers of female authors published in that year together. The minimum in the contribution of female authors both to production and to impact around 1990 (Fig. 1) is the result of deep economic and political crisis in Poland in the 1980s.

The results presented in Fig. 1 suggest a substantially stronger male domination in Polish science than the result of Lariviere et al. (2013). The female-to-male ratio in production reported by Lariviere et al. (2013) over the period 2008–2012 for Poland was 0.754 (higher than in any other country from the top-30 in production) while the present results suggest 0.62 for the same period. The difference is due to different methods used in the both studies (discussed in more detail in the introduction).

Fig. 2 shows the production of female and male authors on log-scale to emphasize the variations in the 1980s and in early 1990s. A minimum in the scientific activity of both male and female authors falls in 1982. Such a minimum was also observed in the overall production of Polish science (not limited to set 1 and set 2). Yet the male authors sooner recovered, and reached their production from 1978 (before the crisis) already in 1986, while the production of female authors stayed below the level from 1978 until 1994. Apparently the competition for limited resources (e.g., due to low value of local currency), and mass emigration of scientists slowed down the process of gender equalization over the period 1980–1994.

The male dominance showed up to 2002 (cf. Fig. 1) was equally significant in terms of production on the one hand and of impact on the other. Indeed the number of citations per paper in papers published between 1975 and 2002 was greater in female authors (12 single years) and in male authors (16 single years) at random times. In this respect the present results are similar to those by Aksens et al. (2011) who report (in their Table 1) the male dominance in the number of papers and in the number of citations, but not in the number of citations per paper. However, in papers published from 2003 on, male authors had systematically greater number of citations per paper than female authors. The disparity between impact and production over the recent decade may have different reasons. For example the impact of just one outstanding scientist can be on the same order of magnitude as the total impact of set 1. Thus the presence of one outstanding scientist in the sample may substantially affect the results of analysis.

The production of Polish scientists strongly depends on their interaction with scientists from other countries. On average 29% of all Polish papers and 28% of papers with authors from set 1 or set 2 had co-authors from countries other than Poland. The male authors (set 2) were more engaged in international cooperation (30% papers with foreign co-authors) than their

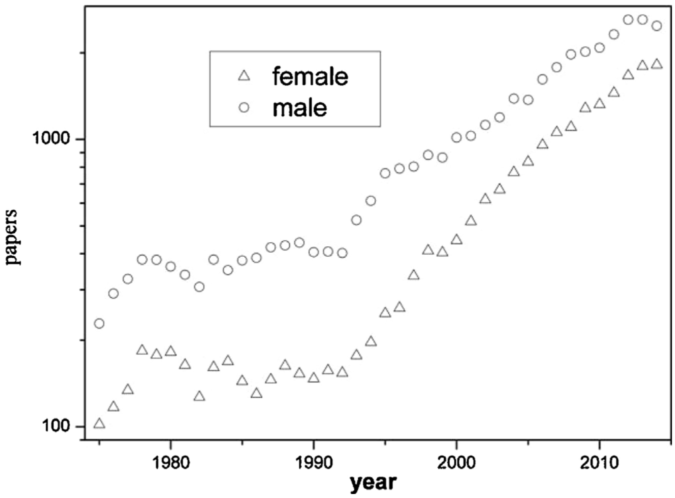

Fig. 2. Production of female and male authors as the function of publication year.

female counterparts (25%). Thus, male domination shown in Fig. 1 is to some degree due to greater ability of male scientists of establishing international cooperation. The level of international co-operation increased over the period 1975–1990 from less than 10% in the 1970s to 30% in early 1990s and since 1990 it oscillates in the range 28–35% without a clear trend. Thus the increase in the production and impact of Polish scientists after 1990 shown in Fig. 2 is not accompanied by increase in the fraction of papers with co-authors from other countries. The level of international cooperation depends on the discipline. Among the most popular research areas the fractions of papers with foreign co-authors are particularly high in astronomy (57%), and in physics (47%), and particularly low in veterinary (11%), in engineering (13%), and in computer science (16%), while for most other popular research areas the level of international cooperation is between 20 and 37%. Thus the results presented above for the entire set and below (for particular research areas) are moderately influenced by international co-operation, especially in terms of production, and they are chiefly due to papers which have only Polish affiliation (72% of the entire set).

Between 1975 and 2014 Polish authors published together 88 133 unique publications in physics, 82 419 in chemistry, 67 776 in engineering and 26 291 in biochemistry. Over the same period Polish scientists bearing one of the names from set 1 published 2772 papers in physics, 3764 papers in chemistry, 1479 papers in engineering and 1698 papers in biochemistry, and Polish scientists bearing one of the names from set 2 have published 8429 papers in physics, 5998 papers in chemistry, 5500 papers in engineering and 1653 papers in biochemistry. Thus the contribution of sets 1 and 2 to the Poland's publication output in physics, chemistry, engineering and biochemistry is about 11% in each research area, that is, the fractional contributions of sets 1 and 2 to particular disciplines are similar as their contribution to the total Poland's publication output (vide infra). The above results indicate a strong male domination in scientific production in engineering (1:0.27) and in physics (1:0.33), moderate male domination in chemistry (1:0.63), and equal contribution of male and female scientists to biochemistry (1:1.03). In terms of impact, the male domination was even more pronounced than in terms of production in physics (1:0.28) and in chemistry (1:0.54), but less pronounced in engineering (1:0.32) and the contributions of male and female scientists to biochemistry were equal (1:1). Thus the male domination in the overall production and impact discussed above was not equally distributed over different research areas. The year-by-year analysis of the production and impact of male and female authors in particular research areas is presented in Figs. 3–6. The ranges of the y-axis are different in Figs. 3–6 and they are adjusted to data (more precisely: to the maximum value of the female-to-male ratio in particular research areas). The data points in Figs. 3–5 show similar trends with time as the overall trends (Fig. 1). Both production (correlation coefficient of 0.83 to 0.95) and impact (correlation coefficient of 0.69 to 0.89) of female physicists, chemists and engineers expressed as the fractions of production and impact of their male counterparts almost linearly increased over the period 1995–2014. This tendency can be interpreted as gradual gender-equalization in physics, chemistry and engineering. The trends are less clear when the entire period 1975–2014 is taken into account. Also production (correlation coefficient of 0.38) and impact (correlation coefficient of 0.31) of female biochemists expressed as the fractions of production and impact of their male counterparts (Fig. 6) increased over the period 1995–2014, but the trend was less significant than in physics, chemistry or engineering. The poor time-correlation in the impact of biochemical papers was due to several outstanding data points. High impact of papers of female authors published in 1977, 1978, 1983, 1985, 1986, and 1994 is due to single papers published in given year by Renata Dąbrowska (with co-authors), which received more citations than all other papers of female authors published in the corresponding year together.

Figs. 3–6 indicate that the fractional contribution of female authors in particular disciplines is time-dependent thus the studies carried out for different time periods are not comparable. Nevertheless the present results roughly match

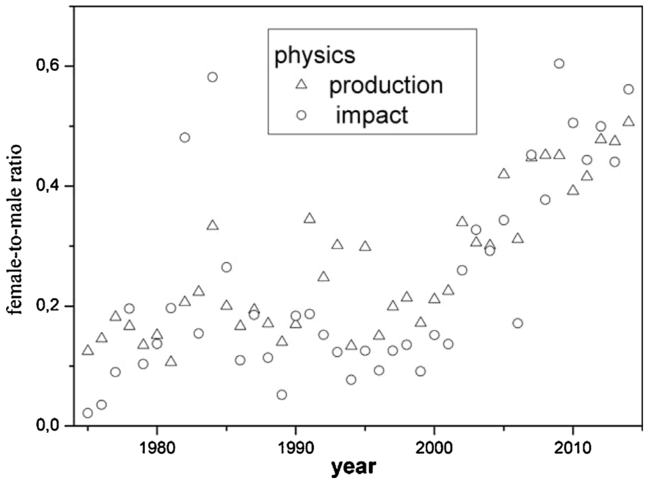

Fig. 3. Production and impact of female authors in physics plotted as fraction of production and impact of male authors.

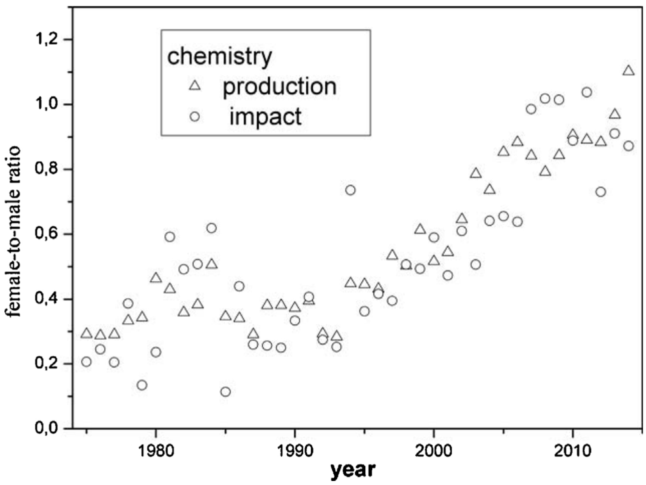

Fig. 4. Production and impact of female authors in chemistry plotted as fraction of production and impact of male authors.

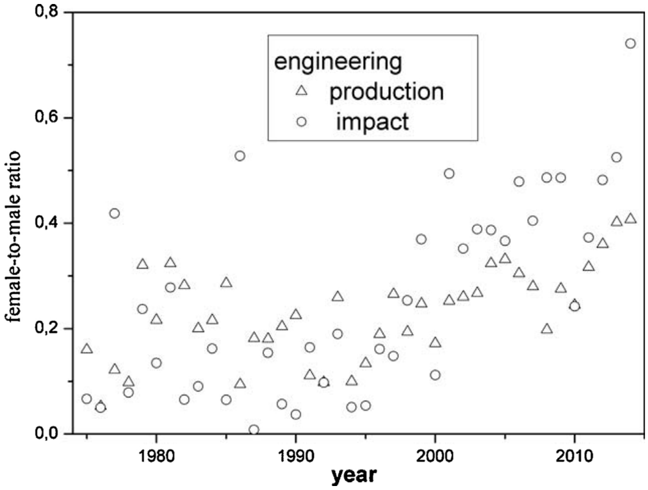

Fig. 5. Production and impact of female authors in engineering plotted as fraction of production and impact of male authors.

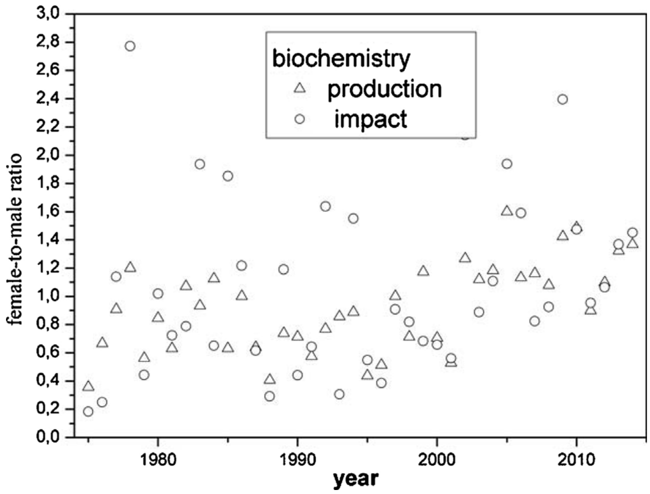

Fig. 6. Production and impact of female authors in biochemistry plotted as fraction of production and impact of male authors.

Table 1
Production and impact of female authors in psychology, cardiology, mathematics and zoology expressed as fraction of production and impact of male authors.

Period	1975–1994	1995–2014	1975–1994		1995–2014	
	Sample size (no. of papers)		Female-to-male authors' ratio of			
Area			Production	Impact	Production	Impact
Psychology	60	197	2.53	3.88	1.01	0.76
Cardiology	102	2651	0.46	0.27	0.4	0.38
Mathematics	333	1150	0.08	0.07	0.23	0.25
Zoology	107	302	0.51	0.42	0.36	0.42

the results from Survey of Earned Doctorates (2012), which suggests that the male domination decreases in the series engineering ≈ physics > chemistry > biochemistry. Apparently this series is universal (country-independent).

The production and impact in less popular research areas is presented in Table 1. A few research areas were selected with relatively many publications and with low mutual overlap.

Since the production in psychology, cardiology (more precisely Cardiovascular System & Cardiology), mathematics and zoology was low (for example 0.85 paper per year in male authors and 2.15 papers per year in female authors in psychology between 1975 and 1994), the period 1975–2014 was only divided into two 20-years periods (rather than analyzed year-by-year). Table 1 confirms very strong male dominance in mathematics (more significant than in engineering and in physics), which was also reported by Lewison (2001), and substantial male dominance in cardiology and in zoology (less significant than in engineering and in physics, but more significant than in chemistry). Like in the most popular research areas, signs of gender equalization are visible in mathematics, but not in cardiology or zoology. Interestingly enough apparent female domination in psychology was observed between 1975 and 1994, but not between 1995 and 2014. This result may be interpreted as "reversed equalization", that is, the originally observed female domination was balanced. However this result has limited significance because of the aforementioned small size of the sample. Moreover the WoS® system of research areas often does not reflect the actual topic of the publication, e.g., many papers in clinical psychiatry are assigned to psychology.

The scientific output of female and male authors was also compared name-by-name (Kowalska vs. Kowalski, etc.) in 10-year-long periods. The contributions of female authors was expressed as a fraction of output of their male counterparts over the same period. Among 104 numbers characterizing the production ratio (26 names × 4 ten-year-periods), numbers >1 indicating higher output of female authors were only obtained 6 times. Among 104 numbers characterizing the impact ratio, higher output of female authors was observed 14 times. Together 20 cases of female dominance were observed per 188 cases of male dominance. Out of 20 cases of female dominance, six refer to the last name Jabłońska/Jabłoński, and they are due to outstanding performance of one scientist, Stefania Jabłońska who is one of the most cited Polish female scientists of all times.

4. Conclusions

1. Male researchers in Poland have higher production and impact than their female counterparts. In specific disciplines the male domination can be more or less pronounced. Physics and engineering are strongly male-dominated while in biochemistry the production and impact of male and female scientists are nearly equal.

2. The contribution of female researchers to Poland's scientific output linearly increased over the period 1995–2014 both in terms of production and of impact.
3. The economic crisis of the 1980s depressed the scientific output of Poland, especially of female scientists.
4. Gender-related studies with small samples can be heavily affected by the presence of one outstanding scientist in the sample.

5. Further research

The present study can be expanded by addition of more popular "-ski" names to the sample. Yet each next name in the list is less popular than the top 26 names, and it brings (on average) fewer papers and fewer citations. Moreover the length of the queries in WoS® is limited.

The present method can be used to study gender-related trends in a few other countries, in which the surnames have feminine and masculine forms.

The present method can be used to study gender-related trends in publication activities related to particular cities, research institutions, journals, containing certain key words, etc.

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