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Gender differences in science: the case of scientific productivity in Nano Science & Technology during 2005–2007

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Abstract Although, women's contribution to science is crucial to social development, gender difference has been for a long time affecting the quantity and quality of scholarly activity. In spite of some improvements, women are still suffering from gender gap and biases in science world. Using a scientometric method with a comparative approach, the present communication aims to study women performance in Nano Science & Technology in terms of their scientific productivity and impact and to contrast them to their male counterparts. The significance of the study relies on the importance of a balanced development of human society in general and in different scientific milieus in specific. According to the research results, although female Nano-researchers are scarce in number, they equally perform in terms of scientific productions and impacts. That may imply gender egalitarianism in the field.

Keywords Nano science · Nano technology · Gender · Scientific productivity · Impact

Introduction

Women's contribution to science is one of social development indicators throughout the world. However, gender difference has been for a long time affecting the quantity and quality of scholarly activity. According to more recent research results, women's scientific and social activity shows improvements (see e.g. Abramo et al. 2009; Breimer et al. 2010; Arensbergen et al. 2011; Mendlowicz et al. 2011; Kretschmer et al. 2012b; Vela et al. 2012), though not completely remedied. Women's scholarly activity is generally characterized by three undesirable aspects: (1) low involvement in science in general and in engineering, technology, and mathematics in specific, (2) "Leaky Pipeline" phenomenon i.e. the decline

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of the number of female researchers as their academic ranks improve, and (3) the productivity puzzle i.e. the gap between female and male researchers in terms of the quantity of their scholarly production (Arruda et al. 2009).

These deficiencies are not necessarily intrinsic to female performance, but may be considered as the side-effects of women's roles in society and family, exacerbated by social biases. For instance, gender and its related factors—e.g. age, marriage and maternity— are among those affecting researchers' scientific productivity Abramo et al. (2008a), though not always in an expected way. For instance, women generally publish less than their male counterparts, with mother researchers being expectedly even less productive during pregnancy and child-rearing periods. However, they ironically have equal or more articles than their single/non-mother female peers (Fox 2005). The females' parental roles, though vital to human life and survival in their natures, are unfortunately underestimated and used against women, resulting in wide-spread sexual biases throughout the world (e.g. Ginther 2003; Villaroya et al. 2008; Zinovyeva and Bagues 2010), though sometimes believed to be occasional, aberrant or not in force anymore (e.g. Ceci and Williams 2011; Mutz et al. 2012). Women's scholarly productivity strongly depends on their situation in social organization of science (Arruda et al. 2009; Cronin and Roger 1999; Prpic 2002). Consequently, gender plays a determining role in individuals' presence in scientific realms.

Statement of the problem

Scientific production is a critical aspect of academic achievement seriously influencing executive evaluations and decisions on budgeting, promotion and payment levels (Borrego et al. 2008). Several studies revealed a gap between female and male researchers in terms of their scholarly activities especially as regards scientific production (see e.g. Martinez et al. 2007; Sax et al. 2002; Stack 2004; Symonds et al. 2006). Women averagely produce fewer research articles and less often obtain high scientific and academic positions compared to their male counterparts. The fact is especially notable in science and technology related areas e.g. basic sciences, engineering, technology and mathematics which women faintly participate in. However, research results are different and even contradictory regarding the impact of female and male researchers (Leta and Lewison 2003; Borrego et al. 2008; Long 1992; Symonds et al. 2006; Håkanson 2005; Mauleón and Bordons 2006).

Women's scientific contribution to Nano Science & Technology (Nano S&T) being unstudied so far, it is unclear how female Nano-specialists achieve in their scientific competition. On the one hand, given the field's scientific and technological nature (e.g. Meyer and Persson 1998; Meyer 2001; Kuusi and Meyer 2002) and the persistence of the gender gap in technological and scientific fields, females are not expected to widely embrace the field. However, as a relatively newly emerging field, it might experience gender egalitarianism, particularly given the recent enhancement in women's scholarly activity patterns.

Analyzing the scientific productions in Nano S&T journals indexed by the Web of Science during 2005–2007, the present study aims to look into the scholarly activity of female researchers in the field and compare it to that of male researchers. It tries to clarify whether women and men equally contribute to the field, whether women's scientific productivity is improving, and how influential are their publications in comparison with men.

Literature review

Scientific productivity in Nano S&T

Being a newly emerging and developing discipline, Nano S&T has not been largely studied in terms of scholarly productivity patterns. Among the scarce studies, one may mentioned the pioneering research carried out by Braun et al. (1997). Studying the literature containing the nano-prefix in their titles, they confirmed an exponential growth rate of Nano-scale research promising its prosperous future. Based on their methodology, Meyer and colleagues carried out further studies investigating the interdisciplinary patterns, patenting activities, and research collaboration in the field (Meyer and Persson 1998; Meyer 2001; Hullmann and Meyer 2003).

Further in 2001, Braun et al. identified 16 nano-titled journals dedicated entirely to the field to study the characteristics of the journals' gatekeepers, i.e. their editorial members. In addition to the structure of the gatekeeper group and their nationalities, they studied their genders and found out gender discrimination favoring males. As far as we searched, that is the one and only research taking into consideration the gender inequality in Nano scholarly community.

Schummer (2004), too, investigated the multidisciplinary, interdisciplinarity, and patterns of research collaboration in the field. Studying the relationship between scholarly publication and patenting activity in Nano field, Meyer (2006a, b) found out that in spite of the fact that patenting scientists appear to outperform their solely publishing, non-inventing peers in terms of publication counts and citation frequency, they may not occupy top positions within the top performance class. Recently, Didegah and Thelwall (2013) studied the main determinants of research citation impact in the field.

Given the lack of empirical evidence on the gender performance in Nano S&T, it would be helpful to have a look at women's status in science.

Women in science

Research findings indicate that gender affects various aspects of individuals' scientific lives such as education level, specialty, employment, promotion, scientific production, citations, research grants, etc. Therefore, one can see that gender shapes women's scientific lives in general and their scientific production in particular. Let have a closer look to these dimensions.

The impact of gender on women's scientific lives

Some women studies provide us with useful information about their scientific activity status-quo, as well as reasons of their low or lessening contribution to science. For instance, Martinez et al. (2007) found that in the United States, women largely gave up research and academic studies in the time span between postdoctoral studies and employment as faculty. The problem partially goes back to their reluctance to continue their activities. Family engagements, especially having children and having to spend time with them and other members of the household were of main hindering factors in this regard.

Aside from factors related to women's roles in the family, there exist some social biases against women affecting their scientific performance. Ginther (2003) discovered a constant anti-feminine discrepancy in payment levels among female and male academic staffs. Zinovyeva and Bagues (2010) identified not only men-against-women, but women-against-women discriminations. They confirmed that the presence of female evaluators at promotion committees for choosing applicants qualified for associate/professor positions was likely to reduce female applicants' chances, while increasing the possibility of males' success.

Some studies confirm relationships between gender on the one hand and academic activity levels and employment on the other one. Villaroya et al. (2008) investigated gender equality during different stages of doctoral theses fulfillment. Their results indicated that women and men succeeding to earn a Ph.D. degree are equal in number. Nevertheless, there exists an obvious gender inequality favoring men among theses supervisors and examining committee members. Studying the effect of gender on employment, Andersen (2001) revealed an unbalanced gender distribution among researchers in Denmark. Bornmann and Endres (2006) confirmed the effect of gender and social factors on finding suitable jobs after completion of doctoral studies, with gender being a strong and determining factor. Ginther and Kahn (2006) found out that women succeed less often in getting tenure or promote to professor. They revealed that family conditions affect males and females' scientific prospects in different ways. While pregnancy and childbirth prevent women from promoting to higher ranks e.g. postdoctoral studies, being married and having children help men in their scientific progress (see also Kyvik and Teigen 1996). Danell and Hjerm (2012) found out that in spite of policies aiming to increase the proportion of Swedish female professors, they are still disproportionate to males in achieving a Professorship, and their situation is not improving over time.

The impact of gender on women's scientific productivity

Factors affecting women's scientific productivity

Studying a sample of researchers from four universities in Norway, Kyvik and Teigen (1996) revealed that women with little children and those lacking cooperation with other researchers had less scientific productions than their male and female colleagues. Unlike men, there is a negative relationship between women's scientific production and household conditions. In contrast, Wennerås and Wold (2000) showed that family and children were not determining factors in women's poor scientific production or low quality works. On the contrary, mother researchers had more scientific productions than childless ones. They believed that women's poor scientific activity and slow progress was rooted in fact in the unbalanced distribution of budgets among women and men.

Fox (2005) studied the relationship between marriage, and maternity on the one hand and women's scientific activity on the other one. The results showed that the relationship between marriage and scientific production varied among women depending on their marriage type and husband profession. Remarried women, especially those married their peer scholars, professors or researchers were scientifically more productive than those being married for the first time. Investigating family structures revealed that women having infants or pre-school children were more productive than those without children or with children at school ages. Leahey (2006) concluded that in sociology and linguistics, women accomplish lower specialty levels and consequently less scientific production.

The impact of gender on women's scientific productivity

As early instances, Cole and Zuckerman (1984) and Long (1992) affirmed females' low scientific productivity and underrepresentation among prolific authors, although they achieved a higher impact according to the latter. According to Sax et al. (2002) there still exists a gender gap in terms of scientific production especially at higher academic levels, in spite of the increase in women's publications in the last decades. Stack (2002) observed no gender gap in the field of criminal justice, whether in papers or impacts. However, he declared that even after child-rearing period, women publish fewer articles in the sciences and engineering (Stack 2004). Håkanson (2005) showed that despite their growing number and share in three core journals of Library and Information Sciences, female authors received fewer citations, implying some gender bias in citation behavior in the field.

Mauleón and Bordons (2006) findings indicated that women did not significantly differ from men in material sciences in terms of their scientific productivity or impacts—whether in terms of the average impact factors of the selected journals or the percentage of publications in highly prestigious journals. Nevertheless, in the research scientists group, women were more inclined to publish in high-impact journals. Galivan and Benbunan-Fich (2006) discovered that women constituted a meager portion of prolific authors in Information Systems journals. On the contrary, according to Borrego et al. (2008) female researchers' share of publication in prestigious journals was approximately equal to men's in Spanish universities. Based on their results, there were no significant differences between the two genders in prolific and non-prolific authors; however, in average researchers group, women's share was lower than men's. Moreover, citation patterns showed no significant gender difference as regards the number of citations or self-citations. Mozaffarian and Jamali (2008) investigated gender differences among Iranian researchers in writing articles and concluded that women's scientific production was much lower than their male counterparts'.

Guerrero-Bote et al. (2009) showed that women are disproportionately lower in number as first or last authors. Larivière et al. (2011) discovered that women professors in Canada received fewer research budgets after the age of 38 and had less scientific productivity and recognition compared to their male peers. In a large-scale study of Norwegian researchers in all areas of knowledge, Aksnes et al. (2011) found out that female researchers are slightly less cited than their male peers. They attributed the gender differences in citation rates to differences in productivity.

Mendlowicz et al. (2011) reported that women's total share of publications in the Brazilian psychiatric journals have been increasing during 2001–2008. Moreover, women were increasingly likely to be first author, signifying the start of a movement towards elimination of the gender gap. Studying high-quality Spanish journals in all fields of science regarding the presence of females in their authorship, editorial board membership and editorship, Mauleón et al. (2012) revealed a gender gap favoring men in all these categories, though the gap was found to be diminishing over the years in most areas, especially in authorship and very slightly in editorial board membership. Breimer and Leksell (2011) confirmed overrepresentation of males among highly productive researchers. Pudovkin et al. (2012), too, concluded that male scientists were more prolific and cited more often than females. However, in a follow-up study looking for the reasons of this divergence, Kretschmer et al. (2012b) showed that apart from a small group of star scientists, female researchers had citation superiority. They found their results to be in accordance with Abramo et al. (2009) confirming a marginal citation gap between the two genders, except for star scientists.

Women's different approach to various scientific fields

Leta and Lewison (2003) declared high participation of women to Immunology, Oceanography and Astronomy. They were equal to males regarding the number of articles published in international journals and citations received. However, women were less likely to win scholarships. They presumed some gender discriminations in refereeing processes in Brazil. Symonds et al. (2006) investigated biographies and works of a group of ecologists and evolutionary biologists at Australian and British universities. They revealed that women were obviously distant from men in terms of their total publications. Moreover, they were highly frequent in the less-prolific author category, but absolutely absent from the most-prolific ones. However, women's impact was higher than men's, signifying that seemingly the former were more concerned with the quality, while the latter with the quantity of their scientific outputs.

Bordons et al. (2003) investigated the scientific productivity of researchers in Natural Resources and Chemistry in Spain based on their gender and professional ranks. They found no significant differences between women and men in their scientific productions or impacts; however, the most productive researchers were mainly consisted of men. They were found to be more interested in Chemistry than Natural Resources, due to the initiation of feminization process at the lowest professional categories in the field.

The study carried out by Mauleón and Bordons (2010) reveals a low female involvement in technology although their involvement increases at a higher rate than that of men. Lewison and Markusova (2011) showed that women participated more to Biological Sciences than to Engineering, Mathematics and Physics. They were less cited in all the investigated areas and years. Slyder et al. (2011) observed no gender discriminations in citation process in the fields of Geography and Forestry. They believed that this is due to male and female scientific cooperation in these fields. According to Arensbergen et al. (2011), in the new generation of Social Scientists, not only the gender gap was gradually fading away, but also young female researchers were even outperforming their male peers. Vela et al. (2012) discovered that although women seemed to be considerably less frequent as editorial board members in the field of Software Engineering, they turned out to be equal to men after being normalized based on female author population in the field. Kretschmer et al. (2012a) discovered overrepresentation of females as first authors in gender-related journals confirming subject dependence of the phenomenon.

Overall, the review of the literature on women's scientific activity and production indicate that gender inequality affects women's scientific contribution even in developed countries. The factors affecting women's scientific contribution can be categorized into three groups: social, psychological and family-related factors. Among the social factors, one may notice anti-feminine biases in selection processes for employment or promotion and unequal distribution of research grants and incomes. The psychological factors include women's lack of enthusiasm to join scientific and technological fields and to continue their academic education to higher ranks. The psychological traits seem to be in turn exacerbated—if not completely caused—by the social discriminations and females' dual roles in home and society. Women's scientific lives, unlike men's, are negatively affected by the familial factors, e.g. marriage, age and the number of children and their ages, especially regarding their scientific progress and productivity. The most important point derived from the literature is that despite the continued existence of the gender differences and inequalities in scientific productivity, academic promotion, research grants and payment, women's scientific activity has been clearly improving during recent years, so that according to more recent studies gender inequality is gradually vanishing in some cases though not completely eradicated.

Research significance

After a long history of campaigns against suppressions and deprivations, women largely get involved in a variety of social, cultural and scientific activities. However, their contribution to science and research has not yet reached a satisfactory level, in spite of the recent considerable increase in the amount of female faculties and researchers and their scientific articles. It seems therefore that their position in the science realm is still fragile and far from being stabilized.

Fox (2005) suggests two motives for comparative studies of women and men researchers' scientific productivities: given the gender inequality in academic positions, promotions and payments, we would not be able to evaluate or improve the current situation without investigating the differences and their underlying factors. Scientific productivity being a vital social process in disseminating research findings, this could marginalize the already fragile positions of women and end up hampering long-term development of science (Danell and Hjerm 2012). Leahey (2006), too, believes that studying women's contribution to science is important to discover not only the gender gap in scientific activities, but also its resulting gender imbalance.

Generally speaking, in order to avoid any possible retrogressive consequences for females as one of the two human pillars, it is essential to institutionalize women's role in science and this requires a wide range of comparative studies on women's and men's scholarly performances and status in science community. Particularly, the gender evaluation of scientific productions would shed light on their scientific and technological (in) abilities in progressing knowledge and thereby help develop strategic plans to empower them and sustain their progress.

Research aims and objectives

The present communication mainly aims to discover women's scientific performance patterns compared to men in Nano S&T. To do so, it attempts to test the following hypotheses derived from the literature on the scientific performance of women:

1. Female researchers are significantly less frequent than males in Nano S&T.
2. Male researchers publish significantly more scientific productions than females.
3. Male researchers achieve significantly higher impacts than females.

Research methodology

The research method

The present study applies a scientometric method with a comparative approach to study women's scientific productivity in the field of Nano S&T during 2005–2007.

Table 1 The frequency of nano scientists in terms of their scientific productions

Groups	Researchers		Papers	
	No.	Percent	No.	Percent
3 or more papers	1,151	8.53	4,942	25.77
2 papers	1,893	14.03	3,786	19.74
1 paper	10,447	77.44	10,447	54.48
Total	13,491	100	19,175	100

The identification of nano scientists

Eighteen Nano S&T journals were identified using the subject category in the Journal Citation Report (JCR). The journal papers were identified using a disjunctive search with "SO" field tag. After downloading the bibliographic data, we extracted the authors' information and then tried to identify their genders by searching Google. In order to increase the precision of the identification, we used as search strategy, a conjunction of each author's name with a part of her article title, email or affiliation.[1] Moreover, we prepared and sent via email a simple questionnaire inquiring the researchers' gender, in case of hesitation.

In order to remove casual contributors, we tried to limit the research to those authors sustainably and frequently contributing to the journals based on three criteria: (1) being the first author; (2) having more than 2 articles (higher than the average); and (3) publishing at least 1 article per year. Primary verification of the data showed that 13,491 first authors had 19,175 (averaging 1.42) contributions. We, then, verified their sustainability in publication and the amount of their papers. As shown in Table 1, out of the 13,491 first authors, 10,447 (accounting for 77.44 %) published just one and 1,893 authors (accounting for 14.03 %) just 2 articles. The smallest number of the researchers, i.e. 1,151 people (8.53 %) produced higher than the average number, ranging from 3 to 23 articles. All these 1,151 researchers were found to have at least one paper in each year. Consequently, the research population consists of these 1,151 authors being the most productive, sustainable, first authors in Nano S&T.

Data analysis tools and methods

Excel was used to parsing and preparing the data downloaded. The data were then analyzed by SPSS using descriptive statistics (including frequency, percentage and mean) and inferential statistics (including Chi square and *T* test).

Research findings

Descriptive findings

General characteristics of the research population are illustrated in Table 2. As shown, a high majority of the nano scientists are male (923 out of 1,151 researchers accounting for

[1] The data were extracted from "AU", "Title", "Email", "RP" or "C1" fields, respectively.

Table 2 Descriptive findings

Gender	Researchers		Papers				
	No.	Percent	No.	Percent	Min	Max	Mean
Females	148	12.9	592	11.98	3	14	4
Males	923	80.1	4,045	81.85	3	23	4.38
NA	80	6.9	305	6.17	3	9	3.86
Total	1,151	100	4,942	100	3	23	4.29

Table 3 Nano scientists categorized based on their scientific productions

Groups	Males		Females	
	Frequency	Percent	Frequency	Percent
3–6 papers	814	88.19	138	93.24
7–10 papers	84	9.10	6	4.05
11–14 papers	16	1.73	4	2.70
15–18 papers	5	0.54	0	0.00
19–22 papers	3	0.33	0	0.00
23 papers	1	0.11	0	0.00
Total	923	100.00	148	100.00

80.1 %). The total amount of males' publications is also considerably more than females' (81.85 vs. 11.98 % of the total papers). Nonetheless, their mean scientific production is slightly higher (4.38 articles vs. 4 articles). A look at the maximum number of articles reveals that the scientific production of the most prolific women (14 articles) has been much less than their male peers (23 articles).

Eighty researchers remained unidentified as regards their genders and were not eligible for further analysis. By omitting them, the total number of the researchers amounted to 1,071 consisting of 148 women and 923 men (Table 2).

Table 3 categorizes women and men in terms of the amount of their scientific productions in Nano S&T. As seen, none of the female Nano scientists produced more than 14 articles. Although male authors are relatively more frequent in more prolific categories, they are scarce in number, so that only 9 men (accounting for 0.98 % of their total number) published more than 14 articles. The greatest portions of males and females (accounting for 88.19 and 93.24 %, respectively) categorized as less productive authors published 3–6 papers.

The comparison of male and female researchers' frequencies

In order to compare the number of male and female scientists in nano discipline, a Chi square test was performed. As shown in Table 4, there is a significant difference between women and men researchers favoring the latter in terms of their frequencies ($\chi^2 = 558.037$, $P <= 0.0001$).

The comparison of male and female researchers' scientific productivity

We compared women and men researchers in terms of their mean number of papers using *T* test (Table 5). The test yielded a *t*-value of 1.91 rejecting any significant difference

Table 4 Chi square result for comparing males and females' frequencies

Gender	Observed	Expected
Female	148	534
Male	923	534
Total	1,071	
$X^2 = 558.03$; df $= 1$; $P = 0.0001$		

Table 5 *T*-test result for comparing males and females' productivity means

Gender	No.	Mean	Std. Dev.	*t*	*P*
Female	148	4	1.71	1.91	0.05
Male	923	4.38	2.31		

Table 6 *T*-test result for comparing males and females' productivity among all nano researchers

Gender	No.	Mean	Std. Dev.	*t*	*P*
Female	241	1.51	1.34	1.53	0.12
Male	1,700	1.40	1.01		

between the amount of scientific productions of women and men researchers ($t = 1.91$; $P = 0.05$). As a result, the two genders are revealed to scientifically perform at the same level.

As mentioned before, the present study rather concentrates on more prolific authors (publishing 3 or more articles). This gives rise to the question whether the equality of women and men is a pattern particular to the more prolific women or is intrinsic to the whole Nano community (encompassing even the less productive ones). To answer the question, the large Nano scientists' population (including researchers with less than 3 articles) was examined using *T* test. According to the results shown in Table 6, the women's mean scientific production (1.51 vs. 1.40) is apparently greater than men's, though not statistically different (*t*-value $= 1.53$, $P = 0.12$). Accordingly, the similarity between women and men in terms of their scientific productivity is not just characteristic to the sample selected but to the whole Nano community.

The comparison of male and female researchers' impact

In order to evaluate women and men Nano-researchers in terms of their impacts, a *T* test was carried out comparing the authors' citations per paper. As shown in Table 7, the *T*-value yielded equals 1.27 indicating no significant differences between the mean impacts of women and men researchers ($P = 0.20$).

Table 7 *T*-test result for comparing males and females' impacts

Gender	No.	Mean	Std. Dev.	*t*	*P*
Female	148	3.32	5.09	1.27	0.2
Male	923	4.09	7.09		

Discussion

Hypothesis 1: female researchers are significantly less frequent than men in Nano S&T

Results of the Chi square test comparing the two genders' frequencies revealed that men researchers are significantly higher than women in number (Table 4). Therefore, the alternative hypothesis of inequality of the two genders frequencies is confirmed. Consequently, males are revealed to be overrepresented in Nano studies than females. This finding is in line with previous research results regarding the faint participation of women in the scientific fields especially Technology (Mauleón and Bordons 2010), Engineering Sciences (see e.g. Hobbs et al., NA; Boschini 2000; Glover 2002; Kulis et al. 2002; McMollen et al. 2010) and math-intensive fields (Ceci and Williams 2010a, b). It is also in accordance with Kretschmer et al. (2012a) in that they confirmed subject-dependence of the phenomenon, though they revealed a female dominance as chief authors in the studied field. Therefore, as expected, the discipline of Nano S&T seems to be male-dominated like many other scientific disciplines. The result is also in accordance with Braun et al. (2007) confirming the existence of gender discrimination among editorial board members of Nano journals.

Women are seen to increasingly enter and be more successful in life sciences, social sciences, psychology, and veterinary sciences (Ceci and Williams 2011), while being less pronounced in math-intensive fields (Ceci and Williams 2010a, b). These facts may imply rather some gendered preferences than their lack of talents and aptitudes in these fields. As Ceci and Williams (2011) put it "women choose at a young age not to pursue math-intensive careers… Females make this choice despite earning higher math and science grades than males throughout schooling". Their plans for their careers and futures seem to diverge from males' earlier than or during adolescence and before widely confronting the inequities. However, the role of social biases and discriminations could not be totally denied. Since, the social anti-feminine paradigms are still acting, at least, deep in our unconscious even where they seem to be uprooted. It is thus not unlikely that they push them to quit the preferably male-dominated milieus in search of more peaceful, less-competitive and more feminine ones leaving them more time to get ready for their familial roles. Therefore the big unanswered question is the extent to which females are driven by different factors namely gender preferences, gender expectations, family observations, social biases, and natural talents and aptitudes.

Hypothesis 2: male researchers publish significantly more scientific productions than females

The result of the *T* test comparing the scientific productions of women and men researchers exhibited no significant differences between the two genders in terms of their mean scientific production (Table 5). Therefore, the null hypothesis expressing the equality of the two genders' papers is confirmed and the alternative hypothesis suggesting a significant difference between the mean scientific production of women and men researchers is rejected. This is in line with Stack (2002) and Mauleon and Bordons (2006) and contradicts the findings of the previous researches confirming women's meager scientific production compared to their male peers Abramo et al. (2008a, b; Larivière et al. 2011; Prpic 2002; Mozaffarian and Jamali 2008).

The insignificant difference in productivity could occur for two reasons: First, the study being limited to more prolific authors, this could result in the equality. In other words, that is just the elite part of the female community—but not all of them— that succeeded to increase their scientific production level and got reached their male counterparts'.

Nevertheless, that was found to be unlikely, as the *T* test carried out among the whole community members—whether prolific authors (with more than 3 articles) or non-prolific ones (with 1 or 2 articles)—yielded a similar result confirming the insignificance of the difference between women's mean scientific production (1.51 papers) and men's (1.40 papers) (Table 6). Therefore, this can be admitted as a general characteristic of the whole Nano scientific community and not just its leaders.

Instead, a second reason could sound more plausible: the level of scientific production in Nano S&T is fundamentally lower than other scientific disciplines examined by previous studies. Thus, Nano-scientists are commonly experiencing a relative shortage in their scientific production, no matter what gender. To check the possibility of the reason, we reviewed the previous researches comparing the mean scientific production of women and men researchers in several scientific fields. The results showed that the level of men's activity in other disciplines was generally higher than their peers of the same sex in Nano S&T. As instance, in Material Sciences, Social Sciences, Chemistry, Natural Sciences and Medicine, men's mean scientific papers were found to equal 25.58, 13.4, 20.79, 10.10 and 17.8, respectively; whereas the statistics for women in the aforesaid disciplines were 17.78, 9.6, 15.84, 8.37 and 9.7 articles, respectively (Prpic 2002; Bordons et al. 2003; Mauleon and Bordons 2006). A rough comparison of these numbers with those yielded for Nano S&T reveals a radical difference in the level of scientific productions. So, the insignificance of the gender difference cannot be necessarily attributed to women's improved scientific activity but rather to a relatively low level of men and women's productivity.

Anyway, this result implies the existence of a relative shortage in scientific productivity in Nano S&T. The finding would seem more serious when one takes into account the elite community selected for the present research (i.e. prestigious Nano-journals and first authors who often consist of senior researchers and are expected to have a high level of scientific production). However, the finding may not necessarily be interpreted as a deficiency, as it probably originates from the characteristics intrinsic to the examined field, e.g. its:

1. Relative limited community (including specialists, journals and institutions) and ad hoc nature resulting in a relatively fewer outputs;
2. Interdisciplinarity and multidisciplinarity leading to scattering of the outputs in other subject categories, e.g. physics and chemistry journals (Eto 2003);
3. Technology-dependence orienting the scholarly endeavors towards non-journal outlets, specially patents (see e.g. Meyer 2006a, b), and also negatively affecting the publication process—e.g. in the case of corporate patenting (Czarnitzki and Wolfgang 2007);
4. Relative newness compared to established scientific fields.[2]

Whatever would be the reason, the field seems to experience some gender egalitarianism in scholarly publication apparently differing from other disciplines, as observed by Stack (2002) for criminal justice.

Hypothesis 3: male researchers achieve significantly higher impacts than females

The result of the *T* test comparing female and male scientists' impacts exhibits an insignificant gender difference (Table 7). Therefore, the alternative hypothesis of males outperforming females in their impacts is rejected.

[2] The oldest Nano-related publications and patents tracked by previous studies date back to 1986 (Braun et al. 1997) and to 1969 (Meyer 2001), respectively.

This result contributes to knowledge in that female Nano-authors keep pace with men in receiving recognition. The previous researches show different and sometimes contradictory results regarding the impact of women researchers. For instance, while some reported a gender equality (Leta and Lewison 2003; Borrego et al. 2008; Abramo et al. 2009) or a female superiority (Long 1992; Symonds et al. 2006) in citations or in the impact factor of the journals selected for publication (Mauleon and Bordons 2006), some declared a gender inequality in citation favoring men (Håkanson 2005; Lewison and Markusova 2011; Pudovkin et al. 2012), though slightly (Aksnes et al. 2011). Thus, one cannot simply derive a general pattern of the genders' impacts to interpret the finding on its basis.

The overall lower level of scientific productivity in Nano S&T in comparison to other fields, as well as its relative newness, might result in a low recognition. As Aksnes et al. (2011) put it, increasing output has a cumulative advantage effect on citation rates, causing the less-prolific researchers to be expectedly less recognized due their significantly fewer publications. This would have had even more negative effects on women as the more fragile part of the community. However, according to the result, they are not lagging behind men in their impacts. Nevertheless, we need to do further research to gather empirical evidence for making a definite judgment in this regard.

Conclusion

The results of this study show that scientific activity patterns of women and men in Nano S&T are nearly similar to other scientific disciplines, in that men are over-represented whether in the whole Nano community or in the prolific authors categories. Nevertheless, contrary to all expectations, they did not outperform women regarding their mean scientific production or impact. Though less frequent in number, the female Nano-scientists keep pace with men in their scientific productivity and recognition, signifying their capabilities and strengths in science competition.

Research limitations

The present study confronted with some limitations which we tried to minimize as possible. Many spelling variations in authors' names required smoothing the names out, a very difficult and time-consuming task due to the large number of the authors. Moreover, many authors did not return the questionnaires in time. We had to deeply search Google and then Google Image to find direct or indirect gender information such as photos or gender clues like third-person personal pronouns. The content of the retrieved records—up to three layers— were analyzed. In spite of all endeavors, some authors' genders remained unidentified due to either filtering or lack of gender information.

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