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The scientific career through a gender lens: a contrastive analysis of the EU and Russia

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ABSTRACT: This study deals with the assessment of gender diversity among researchers and women's outcomes in STEM-related fields in academia. To understand how gender impacts the researcher journey in STEM (science, technology, engineering and mathematics), a comprehensive review of statistical data published on the gender composition of scientific workforce in STEM areas has been performed. Based on the review, a multifaceted picture of the main activities that researchers undertake has been created, including publishing research outcomes, receiving recognition from the scientific community, registering patents and participating in STEM-related events. The results suggest gender segregation persisted in academia in STEM areas both in Russia and the EU during the period 2019-2020. Gaining the insights into trends in gender-based involvement in research might help further reduce the gender gap in the global scientific workforce, and contribute to more collaboration of male and female scientists across disciplines and countries.

Keywords: Academia, gender gap, STEM, publications, female scientific career, research footprint, citations, patents, research performance

INTRODUCTION

Recent years have witnessed enormous strides for women' s participation in academia due to the implementation of gender-sensitive state policies, the subsequent uptake and advocacy, as well as the greater penetration of advanced technologies. At first glance, the existing pool of researchers might seem to be gender balanced in most countries, if no differentiation is made by the field of study.

Being recognised globally as a driving force for countries' economic development, STEM (science, technology, engineering and mathematics) areas in research still lack gender diversity resulting in the loss of women's scientific, creative and innovative potential. Although persistent underrepresentation of women in STEM research is a well-known phenomenon in society, there is no comprehensive overview of female careers in STEM academia despite pervasive, yet fragmented, data on gender differences documented across some countries within STEM disciplines.

The focus of the research reported in this article was to examine the gender effect in academia in the areas of STEM viz. total female authors, their productivity, research performance and impact of academic careers in the Russian Federation, and to compare the results with the relevant data for selected European Union countries. The EU being the world leader in integrating the gender dimension in STEM academia was expected to demonstrate the progress made towards gender equality, and thus providing a potential model for other countries.

The research questions for this study included: if there is a difference in the number of citations attracted by articles, as well as of STEM-related awards and patent applications authored by male and female researchers, and whether these metrics vary by gender, discipline and across countries. One more aspect under consideration was the gender composition of academics in technical universities in Russia and Europe.

The objective of this research was to analyse whether men and women differ in their STEM-related research impacts. Analysis of gender-related differences in STEM research areas may contribute to a better understanding of gender peculiarities in the extent to which female scientists promote their research accomplishments relative to men, and also to facilitating women's greater involvement in science leading to the full contribution of all stakeholders within the global scientific endeavour.

BACKGROUND

With the advent of the digital era, the world has witnessed multiple changes in all spheres, including STEM. Technological advances and social traditions mix up resulting in new challenges, habits and norms. The most drastic changes are seen in the way people think, i.e. their thinking patterns and the speed of communicating and accessing information [1], and gender-related issues. However, the latter is progressing slowly due to the calcified traditions and habits. The current challenges can be dealt with by a combined approach [2][3].

According to UNESCO data, only around 30% of all female students opt for STEM-related fields in higher education [4]. Overall, female students' enrolment is particularly low in ICT (3%), natural science, mathematics and statistics (5%) and in engineering, manufacturing and construction (8%). In 2019, 28.8% of researchers globally were women [4][5]. According to United Nations reports, women are typically given smaller research grants than their male colleagues and, while they represent 33.3% of all researchers, only 12% of the members of national science academies are women. Despite a shortage of skills in most of the technological fields driving the Fourth Industrial Revolution, women still account for only 28% of engineering graduates and for 40% of graduates in computer science and informatics. Female researchers tend to have shorter, less well-paid careers. Their work is underrepresented in high-profile journals and they are often passed over for promotion [6][7].

Numerous studies confirm that gender disparities present from primary through tertiary education to employment in STEM sectors [8-10]. Gender stereotypes and long-standing prejudice historically caused girls and women to steer away from STEM specific fields [11]. In this study, female scientists' total productivity and mainstreaming have been addressed, as well as their research outcomes across STEM as the global average. The conducted analysis shifts the lens from issues of women's disparities in STEM-related sectors in academia in a single country to the total values at the EU level in comparison with the Russian Federation. In that way, women's research impact is better demonstrated as terminology describing the number of citations, occupation categories and other indicators may differ from country to country causing potential errors. Even when the same definitions of terms are used in some countries, the social significance of the selected categories can be different.

METHODOLOGY

Research footprints, including citations, grant awards, patent applications, collaboration between scientists, as well as academia and industry are equally vital for scientific career advancement. In this study, to analyse the gender differences in the total productivity and the impact of female academic careers across STEM-related fields, different dimensions of diversity have been separated; for example, types of researchers, research participation, gender diversity within STEM, research footprint and their results.

The scientific impact of publications by male and female researchers was compared using the field-weighted citation impact (FWCI) metric, which refers to the ratio of the citations actually received to the total of citations expected based on the average in the subject. The citation count is normalised to account for the subject area, publication type and year because these variables greatly impact the accrual of citations by a publication. FWCI indicates how the number of citations received by an entity's publications compares with the average number of citations received by all other similar publications in the global data. An extensive analysis was conducted of statistical information from the EU and Russia, reports on numerous initiatives and activities conducted globally by UNESCO, UN and locally by universities, as well as articles on gender-based scientific career assessment. A survey was also carried out as part of the present research revealing personal perceptions of educational and professional opportunities provided by universities for women. The results suggest considerable progress which is of utmost importance for sustainable development.

DISCUSSION

Human Resources in the Research Profession

The share of female scientists and engineers employed in the STEM sector varied significantly between selected EU member states in 2019, ranging from 55% in Lithuania to 26% in the Netherlands.

Table 1: Participation of female researchers in selected EU countries and Russia (UNESCO Institute for Statistics, 2019).

Country	Female researchers (%)
Netherlands	25.8
Czech Republic	26.8
Luxembourg	28.0
Russia	39.6
Serbia	50.0
North Macedonia	52.3
Lithuania	55.0

In absolute terms, there were more than 6.3 million female scientists and engineers in the EU, accounting for 41.3% of the total employment in science and engineering. Among European countries Russia was in a mid-position.

Women Researchers in Top-level Positions in the Fields of Science and Engineering

Looking at the percentage of female scientific workforce in STEM reveals that although women outnumber men at the first two levels of tertiary education, they are less likely to have a PhD degree often required to embark on an academic career [12]. Women are underrepresented as researchers - especially in STEM areas. Statistics indicate that women's participation in STEM-related fields was more concentrated in low-ranked positions, such as junior research fellows and lecturers, although the number of women scientists and engineers in Russia reached 40% due to the tradition of gender equality in science, laid down in the Soviet Union. Women are still a minority as they comprise only 6% of university professors, and about 2% of academicians in the Russian Academy of Sciences being the country's main research organisation. For comparison in 2020, European universities had 29% female researchers, but just 18% full professors.

Table 2: Participation percentage of women among academic staff in STEM in Russia and the EU in 2019 [13][14].

Academic staff	Proportion of women in academia (%)	
	Russia	EU-28
Female researchers	39.6	29
Full professors	6	18
PhD	45	47.9

The situation is similar when analysing the proportion of women in decision-making establishments. The proportion of women in top research positions was highest (> 25%) in Romania (31.7%), followed by Latvia (29.1%), Turkey (27.8%) and Croatia (26.2%). The lowest (< 10%) figures for women in top-level academic positions were reported in Malta (2.3%), Luxembourg (9.3%), Cyprus (9.5%) and Ireland (9.6%) [15].

In Russia, women lagged behind men in the share of administrators in science and education in the total labour force. In 2020, this stood at 12.8% among heads of institutes of the Federal Agency for Scientific Organisations, and 16.3% among rectors of universities of the Ministry of Education and Science. Thirteen point three percent of women reached top-level positions at universities of the Ministry of Healthcare [16].

In the EU, women headed only 13% of universities and higher education institutions (HEIs). On average in the EU, only 22% of board members were women. The figure topped 40% only in Sweden (49%), Norway (45%) and Finland (44%). The participation of women on boards was lowest (< 10%) in Luxembourg (4%) and Poland (7%). The UK (25%), France (27%) showed figures slightly above the EU average, whereas Germany (20%) and the Netherlands (20%) had ratios slightly below the EU average [17].

As can be seen, the situation in Europe is heterogeneous. Scandinavian countries are locomotives and show a situation close to gender parity. However, it is not implied that gender parity has to be reached by all means. Equal opportunities are in focus of the research. An iconic example of equal opportunities comes from Finland, where Sanna Marin became the world's youngest prime minister aged just 34. While 119 countries have never had a woman leader, all five leaders in her coalition government are women. This is the opposite side of gender disparity and the outcome will be interesting to witness. As far as the female-to-male ratio of academic staff is concerned, the analysis of gender composition in European and Russian universities has revealed a trend - on any level Russia takes a mid-position.

Authors of Research Publications

Researchers foster scientific developments by publications. To provide greater insight into who participates in research as an author, the gender composition of authors has been analysed in Russia and the EU. As a whole in all countries studied, the ratio of women to men among all authors is closer to parity than ever before. In addition to the general global trends, the significant variations by country have been observed; the proportion of female scientists can be as low as 28% in Germany and reaches parity with 50% in Russia. Yet, these aggregate numbers hide considerable subject area differences in Russia, as the fraction of women is as low as 15% in mathematics, and reaches 28% in science.

Table 3: The proportion of women among authors in STEM in the Russia and the EU in 2019 [15][17].

Subject area	Russia %	EU %
Science	28	49
Technology engineering	20	25
Mathematics	15	26

Consequently, in Russia, gender disparities still linger in publication activity in STEM areas. Women now comprise a lesser share of authors who publish their works in scientific journals (21%). At the EU level, the ratio of women to

men is the lowest in technology and engineering and slightly higher in mathematics. Science stands apart with almost equal number of women and men among authors.

Research Footprint: Citation Impact

To provide insight into the scholarly impact of publications, a field-weighted citation impact (FWCI) has been analysed in Russia and the EU. Among the countries studied, the average FWCI for men compared to women was close to equivalent in the EU-28, when assessing all authors (first, last author's positions and correspondent authors), regardless of the author's position,. In general, scientific publications authored by women were systematically less central than articles written by men in the countries under consideration.

Table 4: Average field-weighted citations impact (FWCI) of women and men being active authors in Russia and the EU in 2019 [14][16].

Countries	Russia	EU-28
Average of relative citations	0.42 male/0.3 female	1.118 male/1.096 female

The difference between the average FWCI among men and women was higher in the EU than in Russia when assessing STEM areas.

Research Footprint: Patent Applications, Research Grants Awarded

While further examining the scientific contributions of women in Russia and the EU, the gender of individual applicants of STEM patent documentation has been analysed in view of gender-related inventiveness. According to the data by the UK's Intellectual Property Office (IPO), the proportion of female inventors doubled over the past 20 years, from 6.8% in 1998 to 12.7% in 2019 [18]. During the same period, the proportion of applications with at least one woman listed among the authors increased from 12% to 21%. Nevertheless, mirroring the challenges faced in citations regarding the gender identification of authors, women inventors and assignees appearing on European Patent Office (EPO) documentation were contributors on fewer patent applications than men on average in Russia and the EU. Women inventors accounted for just 13% of patent applications globally [19].

The gender disparity among inventors becomes even more apparent when one considers that most women innovate and invent individually (6%), compared to 69% of all patent applications coming from either individual man scientists or male research groups. There are practically no groups that would unite only women inventors - they account for only 0.3% of applications. This means that for every seven male inventors, there is one woman in the EU. Much greater and more persistent gender differences in the Russian patent holders have been identified, which have profound implications for the impact of women's work. Among inventors, men tend to apply for more patents than women in Russia.

Within the analysed countries, the ratio of women to men among grants awardees has mirrored the ratio observed for patent applicants. On average, men tended to receive more grants in STEM than women in the reviewed countries. In Russia, the average number of awards won by men was 1.1-1.2 times greater than in the EU-28.

Table 5: Ratio of the average number of patent applications and research grants won by women to men [16][19].

Scientific impact	Russia		EU-28	
	Men	Women	Men	Women
Patent applications	3.53	2.80	7.06	5.68
Research grants	1.34	1.17	1,119	1,069

Nobel Prizes

There is overwhelming evidence men still dominate the most prestigious awards in STEM since the delineation of these areas in the 18th Century**.**

Table 6: Distribution of Nobel Prizes in the period from 1901 to 2019 [20].

Nobel prizes winners		
Area	Female (%)	Number of the awarded
Physics	1.8	219
Economic sciences	2.2	89
Chemistry	3.7	188
Physiology/medicine	5.4	224
Literature	13.6	118
Peace	16.5	109

All the 2019 Nobel Prizes in science were awarded to men. Since Marie Curie won the Nobel Prize in Physics in 1903, Professor Maryam Mirzakhani from Iran was the first women honoured with the prestigious Fields Medal for her outstanding contributions to the complex geometry and dynamical systems in 2014. The rarity of female Nobel laureates is indicative of women's exclusion from the science teams in STEM and suggests that those women who persist in these scientific areas face explicit and implicit barriers to advancement.

RESULTS

Best Practice to Counteract Gender Gap in STEM

The scientific community around the world is aware of the gender gap in STEM and has put forward a number of initiatives aimed at encouraging young women to get involved in STEM. One of the main reasons why special effort is necessary appears to be related to gender stereotypes; namely, masculine and feminine professions. There are promising reports about awareness-raising campaigns and affirmative actions, such as establishing national and international STEM camps (the Digital Girls programme), summer schools, as well as research programmes, ethics codes, International Day of Women and Girls in Science celebrations.

In order to better understand the efforts towards gender equality, existing initiatives to empower all women and girls in STEM at the national (Russian) and the EU levels have been reviewed within the present research. The initiatives cover ages 5-35 and are likely to form a pool of best practices. Three domains were considered: 1) secondary and high school extracurricular activities, 2) university summer schools and conferences, and 3) opportunities for career development as perceived by young female researchers.

1) An overview of European initiatives based on extracurricular activities, such as international camps is given below (Table 7). The purpose is to attract female students to STEM disciplines. The data show that while Russia organised only few courses for girls, Italian universities have held prominent camps oriented towards information and communication technologies every year since 2014. In 2020, the mode of in-person courses was modified to be held completely on-line as a consequence of social distancing requirements caused by the Covid-19 pandemic.

Table 7: European STEM camps for girls.

Name	Target age	Gender quota
Phygital (Italy)	5-15	60% female
Nuvola Rosa (Italy)	17-24	Female only
Nerd camps (Italy)	16-19	Female only
Robotic institute (Germany)	14-16	Female only
Technovation (global)	10-18	Female only
DigiVita summer camps (the Netherlands)	8-18	Female only

2) Below are just some events that contribute to the advancement of women scholars via grants, projects and other investments to show the diversity of the proposed initiatives. Among the existing practises, a particularly significant and innovative experience is represented by summer schools providing unique opportunities for women to be integrated in STEM-related fields.

Table 8: STEM summer schools/festivals/projects.

Summer school/festival	Gender distribution (%)	
	Female	Male
Summer School of Saint Petersburg Mining University (Russia)	41	59
Summer School for Female Leadership (Portugal)	27	0
Inspirefest (Ireland)	3000	Not
WISE campaign (UK)	> 1000	Not

The above data demonstrate that summer schools held over a significant period of time (3-4 entire weeks) with appropriate activities have become rather popular among women even at the Mining University in Russia.

3) A survey aimed at both assessing career opportunities for young female scientists (aged 25-35) provided by an institution of higher technical education, and feasibility of women's involvement in academia consisted of three groups of questions concerning science research work, teaching skills and academic career development (Table 9).

Saint Petersburg Mining University seems to be performing well in providing opportunities for enhancement of science research work (90% on average) for the female scientists. The second most appreciated opportunities concerned the improvement of their teaching skills (83%). The opportunities associated with obtaining information

on career development were assessed less positively. The indicators (%) were calculated as the share of those female respondents who ticked the response option *strongly agree*.

Table 9: Assessment of educational and professional opportunities for women scientists.

Opportunities given for the development of	Respondents (%)
Research work	90
Teaching skills	83
Academic career	58

The results suggest that Saint Petersburg Mining University provides a good base for research work, career development and the empowerment of women at the university level.

To sum up the conducted research, it is important to note that in reducing the existing gender gap, STEM camps, as well as summer schools have been effective tools to unite women and men in science, and achieve gender balance in STEM-related areas at the global level and within a country.

CONCLUSIONS

Knowledge-intensive economies are largely dependent on the excellence of individuals engaged in research. The relationships between female authors and research performance at both the European and Russian country levels indicate that the EU and Russia have not done enough to enlarge the women's talent pool, and there is still a long way to achieve gender equity in academia in STEM areas.

The research output of male and female scientists based on scientific activities was quantified and compared. The citation impact gives a substantial advantage to males in the countries under consideration. Male authors tend to cite men more than women in STEM areas. This is similar to the average number of patents with women applying for far fewer applications than men, though the percentage of patent applications including at least one woman among research teams is increasing. The comparatively low representation of women in decision-making establishments and at senior academic positions provide evidence of a gender imbalance in the research profession. This comprehensive picture of gender inequality in academia may help rephrase the conversation around the sustainability of women's research careers in STEM.

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