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Gender gaps in international research collaboration: a bibliometric approach

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Abstract

This paper addresses gender differences in international research collaboration measured through international co-authorship. The study is based on a dataset consisting of 5600 Norwegian researchers and their publication output during a 3-year period (44,000 publications). Two different indicators are calculated. First, the share of researchers that *have* been involved in international collaboration as measured by co-authorship, and second, the *share* of their publications with international co-authorship. The study shows that the field of research is by far the most important factor influencing the propensity to collaborate internationally. There are large differences from humanities on the one hand, where international collaboration in terms of co-authorship is less common, to the natural sciences on the other, where such collaboration is very frequent. On an overall level, we find distinct gender differences in international research collaboration in Norway in the favour of men. However, men and women are not equally distributed across fields and there are relatively more female researchers in fields where the international collaboration rates generally are lower. When the data are analysed by scientific field, academic position, and publication productivity of the researchers, the gender differences in the propensity to collaborate with colleagues in other countries are minor only, and not statistically significant. Concerning gender inequality in science, the main challenge seems to be the lower productivity level of female researchers, which obviously hinders their academic career development. Differences in international collaboration are unlikely to be an important factor in this respect, at least not in the Norwegian research context analysed in this study.

Keywords Gender inequality · Science policy · Research productivity · Bibliometrics · International research collaboration

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Introduction

Men and women have been shown in numerous studies to perform differently according to various indicators related to the process of scientific publishing. In particular, female researchers on average are less productive and publish fewer publications than male researchers. This has been demonstrated in numerous studies (for example, Kyvik and Teigen 1996; Piro et al. 2013; Larivière et al. 2013; Mayer and Rathmann 2018). The pattern seems to be universal across fields and nations, although the differences vary. As an example, Rørstad and Aksnes (2015) showed that after adjusting for position and age, female researchers in Norway on average publish 10–20% less than men. The question of whether women are less cited than men has also been analysed in several studies. Here, the results are less clear, and the findings vary. As an example, a previous Norwegian study found only small gender differences (Aksnes et al. 2011), while a global analysis based on articles with first and last authors showed lower citation rates for female authors (Larivière et al. 2013). Lagging behind in terms of scientific production and impact represent a major problem because these two factors are decisive, for example, for academic promotion and in the evaluation of research proposals by funding agencies (European Commission 2015).

In this study, another dimension is analysed, namely gender differences in international collaboration. Studies of scientific collaboration are commonly based on co-authorship data. Here, a publication is considered to be co-authored if it has more than one author and internationally co-authored if it has authors affiliated with institutions located in different countries. International co-authorship is then applied as a proxy or indicator of international collaboration. Compared with other methodologies, bibliometric data can provide unique and systematic insight into the extent and structure of scientific collaboration. One advantage is that large datasets can be easily analysed, for example, entire countries, and the results will be empirically robust. Moreover, the indicator captures both formal and informal types of collaboration. At the same time there are also limitations attached to using such data as a measure of collaboration (Katz and Martin 1997). The biggest issue is that research collaboration does not always result in joint co-authored publications. Another problem relates to the limited coverage of the bibliographic databases typically applied in such studies (e.g. Web of Science (WoS) or Scopus), where books, books chapters, and articles in national journals are not indexed by the databases to the same extent as articles in international journals (Aksnes and Sivertsen 2019). This problem affects the humanities and the social sciences in particular.

In general there has been a large increase in the extent of international collaboration in recent decades, and this is documented in a number of previous studies (e.g. Leydesdorff and Wagner 2008; Adams 2012; Wagner et al. 2017). In many countries, the majority of scientific publications are now internationally co-authored. Another important issue is that there are large differences in the collaboration rates across countries, as was shown in a paper by Luukkonen et al. (1992) and in numerous later studies (e.g. National Science Board 2018). Generally, countries with smaller science systems tend to have higher proportions of internationally co-authored articles than larger nations, although size only explains a minor part of the variances in co-authorship rate at the country level. Finally, previous research has shown that there are large differences in the collaboration rates at the level of fields and disciplines (Aksnes et al. 2008; National Science Board 2018). For example, the proportion of publications involving international co-authorship is much higher in the natural sciences than in the social sciences and humanities. There seems to be an almost universal hierarchy among the disciplines with regard to international collaboration. These differences in turn relate to the nature of the study objects and the role of teamwork in the research process and co-authorship practices. In the humanities, the majority of the publications have only one author, and therefore this field will by default have low collaboration rates (Aksnes et al. 2008).

Gender differences in collaboration have become ever more important to study due to the steady global increase in research collaboration in groups and networks (Leydesdorff and Wagner 2008) and in interdisciplinary research (Lee and Bozeman 2005). Based on a review of former networking studies, Fell and Köning (2016) examined reasons for why gender differences in collaboration might be expected and factors that particularly affect female researchers. Women have generally been found to be more agreeable than men, and this personality trait might lead to more networking. Moreover, women outperform men in tests of emotional intelligence, and this ability might be beneficial for collaborating. On the other hand, there are also issues that pull in the other direction, for example, that women traditionally have more responsibility for child care (which is time-consuming and would limit their time for activities such as building networks). Also, there are findings suggesting that women receive less optimal mentoring than men, which means that their socialisation into the scientific communities is not as good as for men (Fell and Köning 2016).

Several studies have been carried out over the years to investigate whether there are gender differences in collaboration. These studies address collaboration more generally or international collaboration (collaboration with colleagues in other countries) more specifically. Concerning the first issue, empirical evidence has been provided that women generally are less engaged in collaborative projects than men and that they publish more single-authored works (Boschini and Sjögren 2007; Fox 2001; Jadidi et al. 2018; Nielsen 2016; Zettler et al. 2017). Women have also been shown to be less inclined to participate in long-standing research collaborations, which are associated with high scientific impact (Jadidi et al. 2018; Zheng et al. 2016). Nevertheless, there are also studies reporting deviating findings. Fell and Köning (2016) in a study of industrial-organisational psychologists found that female researchers were more engaged in scientific collaborations than men. Similarly, Abramo et al. (2013) showed that female researchers in Italy had higher overall collaboration rates than men.

When it comes to international research collaboration, the knowledge on gender differences seems inconclusive (Poole and Bornholt 1998; Larivière et al. 2011; Vabø 2012). Some studies have reported that women on average have lower rates of international collaboration then men. For example, Frehill and Zippel (2010) found that among holders of doctoral degrees in the US, men were more often than women engaged in international collaboration. Similarly, a bibliometric analysis by Elsevier (2017) showed that women are less likely than men to collaborate internationally. The *She Figures* report by the European Commission (2015), however, reported only marginal differences, where the propensity of women to publish articles with international co-authors was almost equal to men. This issue is important to analyse further because international research collaboration has been shown to be advantageous to researchers' productivity and scientific impact (e.g. Abramo et al. 2009, 2011; Adams 2012; Fox 2018; Kyvik and Reymert 2017; Larivière et al. 2013).

Filling the knowledge gaps on gender gaps

In this study, we draw upon the methodological approach of three previous studies—presented below—but using a Norwegian dataset and including additional variables that were lacking in these studies. In this way, we are able to provide a better understanding of gender differences in international research collaboration.

Larivière et al. (2013) used WoS data from the period 2008–2012 to study differences in international co-authorship on 5.5 million papers with more than 27 million authorships. The dataset included information on the gender of the authors. Women were shown to be less frequently listed as first authors (roughly 2/3 of the papers had male first-authors) and less inclined to participate in international collaborations. In sum, these factors contributed to lower citation rates among women. Needless to say, such a large-scale study did not include individual data for the authors, such as academic position. The authors state (p. 213) that "it is likely that many of the trends we observed can be explained by the under-representation of women among the elders of science. After all, seniority, authorship position, collaboration and citation are all highly interlinked variables."

A second study is Abramo et al. (2013) analysis of international co-authorship among Italian professors based on WoS publications from 2006 to 2010. In this study, academic discipline and institutional affiliation were taken into account, documenting gender differences in international collaboration across scientific fields (all hard sciences and economics). Interestingly, female researchers were shown to have a greater capacity to collaborate in all other collaboration forms that were analysed except for the international dimension. The study only included researchers in tenured academic positions.

A third relevant study is Uhly et al. (2017) investigation of gender differences in international research collaborations in academia. This study, unlike the former two, included individual data on age (as well as academic discipline), but not on academic position. This study applied a different methodological approach and was based on answers from a survey (ten countries analysed with 13,000 respondents in total), where the informants answered yes or no to the question "Do you collaborate with international colleagues?" This makes the results difficult to compare with the two former studies. As the authors state, the measurement of international collaborations is highly dependent on the survey respondents' interpretations of the question, as contrasted by use of publication data where such bias does not exist (Melin and Persson 1996). At the same time, most studies on gender differences in research collaboration have been conducted based on surveys (Abramo et al. 2013).

The main result of Uhly et al. (2017) study is that women engage less in international collaboration than men and that the degree of female international collaboration is dependent on a complex set of individual factors (such as partner employment status and having children). The results led the authors to conclude that "glass fences" are apparent in "in the access to international research collaboration, as women are significantly less likely than men to participate in this elite activity" (p. 761).

In our present study, we aim at filling the knowledge gap in the understanding of gender differences in international research collaboration by comparing international paper co-authorship among men and women at Norwegian universities. This study has several important dimensions.

First, we use a database that, in contrast to WoS, has complete coverage of all peer-reviewed scientific and scholarly publication output, including books, edited volumes, and conference series. This means that we are able to provide a better coverage of the social sciences and humanities in particular.

Second, we analyse the issue at the level of fields and disciplines. The importance of comparing by fields has been documented by, for example, Kyvik and Reymert (2017) and Abramo et al. (2013), with the latter study arguing that gender differences in international cooperation "could be due to certain factors that characterize each discipline, beginning from the percentage of women in the total research staff" (p. 819).

Third, we take the *academic position* of the researchers into account, which is important because two previous Norwegian studies have found that older academic staff are less inclined than their younger colleagues to participate in international research networks (Kyvik and Reymert 2017; Kyvik and Olsen 2008).

In sum, these factors enable us to first test whether there are gender differences in international collaboration and second whether the differences vary by academic position (which is strongly correlated with age) and research field. In addition to this, we add a third main explanatory variable—scientific productivity—because we believe that international collaboration might be more manifest among established researchers with high scientific productivity. Such a decomposed analysis based on these factors might add important knowledge to the understanding of gender differences because while there might be gender differences at the overall level, or by *one* factor alone, it is not unlikely that the gender differences show covariation with other factors. Here, we try to isolate such factors in a multivariate analysis.

Data and methods

This study is based on the bibliographic Cristin database (the Norwegian Science Index) that has been developed as part of a current research information system for all public research institutions in Norway. The database has complete coverage of all peer-reviewed scientific and scholarly publication output, including books, edited volumes, and conference series (see Piro et al. 2013 for further details). The system ensures complete, verifiable, and structured data for bibliometric analysis. Of particular importance for the study of scientific collaboration is that all authors and addresses are indexed, including country as a controlled term. In this study, we have analysed publications from the three-year period 2015–2017.

A publication is considered to be internationally co-authored if it has authors affiliated with institutions located in different countries (in our case Norway and one or more other countries). This is the common principle applied in bibliometric studies of scientific collaboration based on co-authorship data (Katz and Martin 1997). A special case is authors having both a domestic and international affiliation. In this study, publications are counted as internationally co-authored if they have at least one foreign institution on the address list, regardless of whether the analysed set of authors or other co-authors are affiliated with this/these institution(s). Thus, we have not excluded cases where the authors have both a domestic and international affiliation. We think this is reasonable because publications authored by the latter type of researchers have an institutional international collaborative dimension. The alternative would be not to consider these publications as internationally co-authored. In order to assess to what extent this alternative would yield different results, we carried out a test and found that the issue is of marginal importance and is not likely to have an influence on the main findings of the study.[1]

[1] In total, 381 researchers (6.8% of the total) have one or more publications with a dual domestic and international affiliation. The number of such publications is 1378 (3.2% of the total). The reason why the proportion of publications is lower than that for researchers is probably that this issue sometimes only occurs in phases of career transitions where researchers move from one institution to another and where both institutions might be relevant to list as addresses. However, the large majority of the 1378 publications have other co-authors affiliated with the foreign institutions as well and would therefore count as internationally

As a source of information on the individual characteristics of the persons (gender, age, position, and institution), the data in the bibliographic database were coupled with another database, the Norwegian Research Personnel Register. This database contains individual data for all researchers in the Higher Education Sector and Institute Sector in Norway.

The data material consists of 5554 researchers from the four largest universities in Norway (University of Oslo, University of Bergen, The Arctic University of Norway, and The Norwegian University of Science and Technology). The study is limited to professors, associate professors, postdocs, and PhD students with at least one publication during the time period analysed. Their publication output during the period 2015–2017 in total accounts for 43,641 publications (Table 1). The researchers were assigned to research fields based on the field distribution of their publication output. In the Cristin database, all journals are classified into five broad areas (social sciences, humanities, natural sciences, technology, and medical and health sciences) and 85 subfields/disciplines, and a similar classification system is used for the book publications. Based on this system, the researchers were assigned to the broad areas and sub-areas/disciplines in which they had the highest number of publications. In cases where they had an equal number of publications in two or more categories, they were randomly distributed to one of these categories. It should be noted that some journals have a multi-disciplinary profile and address issues covering several disciplines (e.g. *Plos One* and *Science*). These journals are classified in general categories (e.g. multidisciplinary natural sciences and technology). A small minority of the researchers had the highest number of publications in these general categories and were therefore not assigned to specific disciplines.

Female researchers constitute 42% of the study population, while they only account for 32% of the publications. The female share of the researchers varies greatly by field, and it is highest in the medical and health sciences (53%), social sciences (50%), and humanities (46%) and considerably lower in the natural sciences (31%) and technology (22%). The female shares of the publication output, however, do not coincide with the distribution of researchers. Women publish less than men in all fields. In technology, the difference is smallest—22% of the researchers are women and they account for 19% of the output, i.e. a publication output 3 percentage points lower than expected based on the distribution of researchers. This female under-representation of the publications is moderate in the social sciences (4 percentage points difference) and humanities (4 percentage points difference) and high in the natural sciences (9 percentage points difference) and medical and health sciences (12 percentage points difference).

Scientific productivity is very skewed at the level of individuals. A large part of the researchers have very few publications, while a minority are highly prolific. This issue is essential to take into account when studying gender differences in international collaboration. Without a stratification of the study population into different productivity intervals, important nuances are lost. We have classified the individuals into three groups based on their publication output—one consisting of researchers with low productivity, one consisting of prolific researchers, and one consisting of researchers with intermediate productivity above or below the average (7.9) and median (4). The first group consists of researchers with 1 or 2 scientific or scholarly publications during the three-year period (32% of the study population), the second group is the researchers with 3–9 publications during

Footnote 1 (continued)

co-authored anyway. In fact, only 161 publications have no other co-authors from foreign institutions. These publications account for only 0.36% of the total publication set.

Table 1 Distribution of researchers and publications by research fields and gender

Fields	Number of researchers					Number of publications				
	Men		Women		Total	Men		Women		Total
	No.	Prop. (%)	No.	Prop. (%)	No.	No.	Prop. (%)	No.	Prop. (%)	No.
Humanities	420	54	363	46	783	2009	58	1445	42	3454
Social sciences	513	50	522	50	1035	2709	53	2357	47	5066
Natural sciences	902	69	408	31	1310	10,815	78	3016	22	13,831
Technology	662	78	183	22	845	6545	81	1572	19	8117
Medical and health sci.	747	47	834	53	1581	7719	59	5454	41	13,173
Total	3244	58	2310	42	5554	29,797	68	13,844	32	43,641

the period (46% of the population), and the third group consists of the highly productive researchers with 10+ publications (22% of the population). However, at the level of gender, these proportions differ significantly. For example, 38% of the female population have 1–2 publications compared with 27% for men. On the other hand, men are a higher proportion than women in the group consisting of prolific researchers. These findings hold across all fields analysed (Table 2). Although the specific criteria used for the classification might appear somewhat arbitrary, it nevertheless allows us to add further insight into how international collaboration relates to productivity. However, as an alternative we have calculated a field-normalised productivity indicator where the number of publications from each researcher has been compared with the average for their subfield (85 categories).

In the analyses, we also include the academic position of the researchers. Thus, the analyses are carried out by field of research, academic position, and scientific production. A complete overview of the distribution of researchers across these variables can be found in Appendix Table 12.

The unit for the analysis is the individual researcher. For each person, we calculate whether they have published at least one publication involving international co-authorship (i.e. having co-authors affiliated with institutions in other countries) during the study period. Second, we calculate the proportion of each individual's publication output involving international co-authorship. Based on these measures, we calculate averages for the different categories the individuals are affiliated with in our cross-sectional analysis (see below). In other words, all individuals count equally as one unit in the analysis regardless of how many publications they have published. This way we avoid the analysis being biased towards highly productive researchers.

We believe both measures are important to consider. The first is a measure of whether the individuals have collaborated internationally, while the second is a measure of the degree of international collaboration. Based on the first dichotomous measure, we are able to analyse the shares of men and women that are involved in international collaboration, but this measure lacks information about the degrees of internationalisation among the individuals. As an example, in two groups we might find that 54% of the men have collaborated with colleagues in other countries, while 57% of the women have such collaboration. If, on the other hand, the measure is the proportion of internationally co-authored publications, we might find that in the female group the individuals on average have 35% of their publications with international co-authors, while the average for men is 39%. We now have two results that pull in different directions, and the two factors provide complementary information on gender differences in international collaboration. What is needed is a measure that takes both factors simultaneously into account. We therefore suggest a simple indicator combining both the *presence* and *scope* of international collaboration among men and women, which we call the Gender Difference Collaboration Index (GDCI), which is calculated as:

$$\mathrm{GDCI} = \left(\frac{m\mathrm{int}}{m} * \frac{\sum_{n=1}^{m} \left(\frac{\mathrm{pub\ int}_n}{\mathrm{pub\ tot}_n} \right)}{m} \right) - \left(\frac{w\ \mathrm{int}}{w} * \frac{\sum_{n=1}^{w} \left(\frac{\mathrm{pub\ int}_n}{\mathrm{pub\ tot}_n} \right)}{w} \right)$$

where *m/w* is the total number of men/women in the study sample, *m* int/*w* int is the number of men/women with international collaboration, pub tot is the total number of publications, and pub int is the number of publications with international collaboration. The GDCI varies between −1 (complete gender difference in favour of women) to 1 (complete gender difference in favour of men).

Table 2 Distribution of researchers by gender, field, and publication productivity

Fields	1–2 publications		3–9 publications		10 + publications		Total	
	Men (%)	Women (%)	Men (%)	Women (%)	Men (%)	Women (%)	Men (%)	Women (%)
Humanities	35	44	54	48	11	9	13	16
Social sciences	33	41	54	47	13	11	16	23
Natural sciences	27	40	43	44	30	16	28	18
Technology	23	27	45	46	32	27	20	8
Medical and health sci.	22	35	42	46	36	19	23	36
Total	27	38	46	46	27	16	100	100

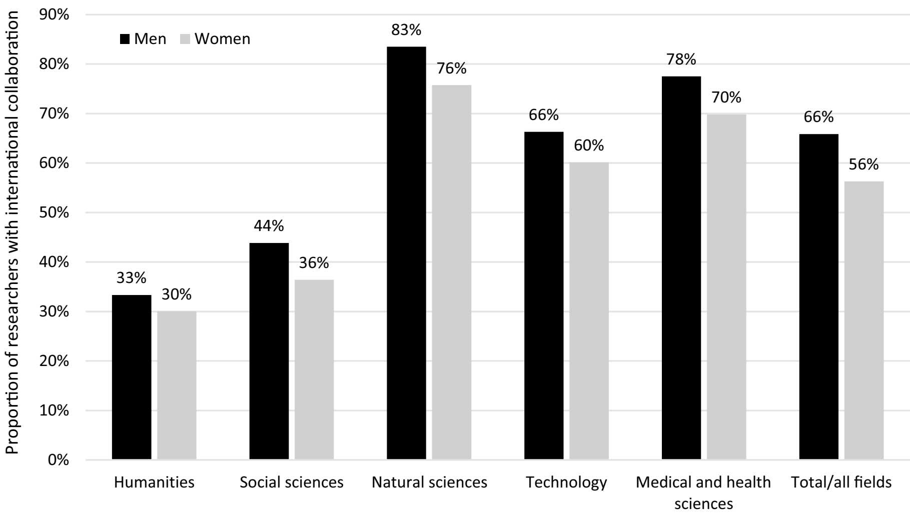

Fig. 1 Proportion of researchers involved in international collaboration by field and gender

In addition to GDCI values, we report size-adjusted GDCIs, i.e. GDCIs multiplied by the number of individuals (GDCI * Group *n*). Size-adjusted GDCIs are reported as percentages of the sum of total GDCIs (% of $\sum$GDCI * Group *N*). The rationale for adjusting the GDCIs by sample size (*n*) is that GDCI is only a measure of the size and direction of gender inequality and does not include information on the relative or weighted importance of the difference to the overall gender inequality. For example, we might find that men in one particular group are much more internationally collaborative than women. However, this group might consist of few individuals. Hence, even a large gender difference in international cooperation will make only a small contribution to the overall gender differences. In other groups we might find minor gender differences, but if the sample size is very large this might still have a large influence on the overall gender inequalities.

Below, we present analyses using the different indicators described above. First, the two basic indicators are presented separately, i.e. the proportions of individuals who have collaborated internationally and the degree of international collaboration, and then GDCI-indicators are presented in multivariate analyses.

Results

Overall, 56% of the female researchers are involved in international collaboration as measured by co-authorship. The corresponding figure for men is 66%. Thus, our study shows that overall male researchers are more often involved in international collaboration than their female colleagues. However, as expected there are large differences across fields (Fig. 1). International collaboration is much more frequent in the natural sciences, medical and health sciences, and technology compared with humanities and social sciences, and this holds for both genders. In the humanities, fewer than one-third of the researchers have publications involving international collaboration. There are gender differences in all fields. The gap is largest in the social sciences where the

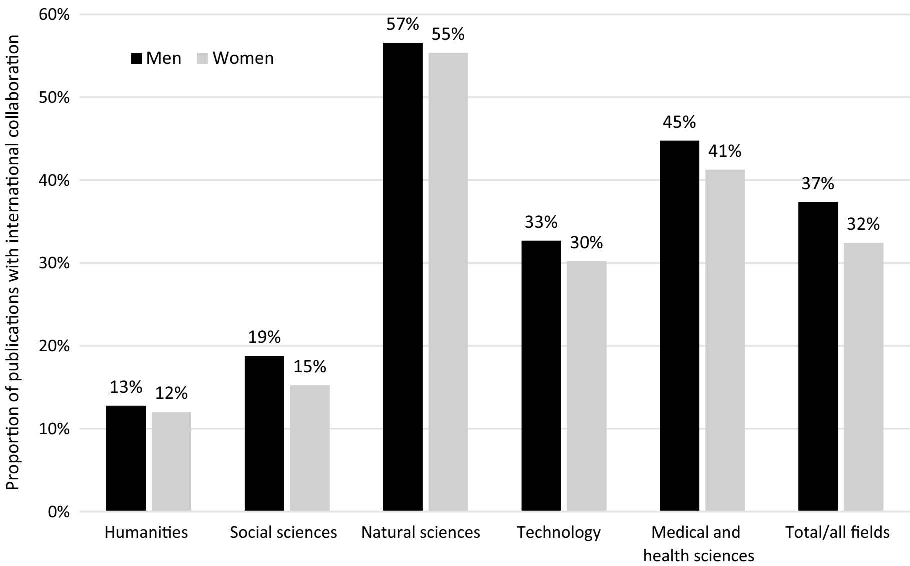

Fig. 2 Average proportion of international co-authorship per individual by field and gender

proportion for men is 44% and for women is 36% for women. The gap is smallest in the humanities (the difference is 3 percentage point).

Interestingly, in all domains the gaps are smaller than 10 percentage points, which is the difference for the total/all fields. This is due to the fact that male and female researchers are unevenly distributed across fields (see Table 2), and there are relatively more women in fields where the collaboration rates are lower. Correspondingly, in the natural sciences, which have the highest collaboration rates, there are relatively more men than women, and 28% of male researchers are in this category compared with 18% of female researchers.

Figure 2 shows the corresponding figures using the proportions of publications involving international collaboration as the indicator. Overall, male researchers have 37% of their publications in collaboration with researchers in other countries, while the corresponding figure for female researchers is 32%. Gender differences are observed across all fields, but now the differences are reduced. The most evident reduction in gender gaps is observed in natural sciences, where a 7-percentage point higher share of men are involved in international collaboration (Fig. 1), while the share of the publications that involve international collaboration is just 2 percentage points higher for men (Fig. 2). The reduction can be explained by differences in the underlying collaboration patterns. Among the researchers who have collaborated internationally (i.e. have published at least one internationally co-authored paper), women on average have higher collaboration rates than men.

The analysed dataset also includes data at the level of disciplines. An overview of both measures for the largest disciplines can be found in Appendix Table 13. This table shows that there are notable variations in the proportions of international collaboration also *within* the various fields. For example, in the humanities these proportions are much higher in archaeology and conservation than in literature. In medical and health sciences, international collaboration is much less frequent in nursing than in most of the other disciplines. In the social sciences, anthropology and law have the lowest proportions and geography

Table 3 Average number of authors per publication for researchers involved and not involved in international collaboration by gender

	Average number of authors per publication			*n* (number of researchers)		
	Men	Women	Total	Men	Women	Total
Researchers not involved international collaboration	2.6	2.9	2.7	1108	1010	2118
Researchers involved international collaboration	7.3	7.2	7.2	2136	1300	3436

Table 4 Average number of authors per publication by intensity of international collaboration and by gender

Proportion of internationally co-authored publications (%)	Average number of authors per publication			*n* (number of researchers)		
	Men	Women	Total	Men	Women	Total
0–10	2.6	2.9	2.7	1154	1029	2183
10–20	3.7	3.6	3.6	172	102	274
20–30	3.9	3.9	3.9	244	159	403
30–40	4.5	4.7	4.6	246	144	390
40–50	5.6	6.7	6.0	164	89	253
50–60	5.6	6.5	6.0	310	213	523
60–70	6.7	8.3	7.2	235	122	357
70–80	7.4	7.7	7.5	141	74	215
80–90	10.3	10.5	10.3	130	70	200
90–100	13.5	10.8	12.4	448	308	756

and economics have the highest. These variations can be explained by the differences in publication modes discussed in the introduction.

International collaboration is only one kind of collaboration. Collaboration more generally involves co-operation among two or more researchers, regardless of whether they are located at the same institution, at external national institutions, or at institutions in other countries. One might assume that the international collaboration dimension partly is influenced by the other dimensions. If male researchers tend to have more co-authors generally than female researchers have, then they might have access to a larger collaborative network and would thus have an increased likelihood of also having more international co-authors. In order to assess this question, we have analysed the average number of authors per publication for each individual (Tables 3 and 4). As expected, researchers involved in international collaboration (i.e. those who have published at least one internationally co-authored paper), tend to have a much higher number of co-authors per publication on average (7.2 authors, including the researcher in question) than those who have not collaborated internationally (2.7 authors, including the researcher) (Table 3). Interestingly, there are hardly any gender differences. For researchers who have not collaborated internationally, women have marginally higher numbers of co-authors on average than men, while the opposite is the case for researchers with international collaboration. Similarly, the issue was analysed according to the intensity of the international collaboration (Table 4). The analysis shows that there is a strong correlation between this intensity and number of co-authors. For example, researchers who have 0–10% of their publications in collaboration with colleagues in other countries have 2.7 authors per publication on average, while the corresponding figure for those with an international collaboration rate of 90–100% is 12.4 authors. This correlation holds for both genders, and overall there are small gender differences and no systematic patterns. In some categories, women have slightly higher numbers of authors than men, while the pattern is the opposite in other categories. In conclusion, this analysis does not support the assumption that men and women are different when it comes to co-authorship practices more generally.

The analysis so far has shown that gender differences in international collaboration are observed for the two different measures, albeit to various extents. These crude figures might, however, be contingent upon the gender composition by academic position and publication output. In order to assess this question, in Tables 5 and 6 we present the results split by field, gender, academic position, and publication volume simultaneously. Here figures are shown only for categories with more than 20 researchers. In Table 5 we report the percentage of men/women who *have* collaborated internationally (yes or no), while in Table 6 we report the average shares of publications with international co-authors.

Comparing academic fields, researchers in the humanities (32%) and social sciences (40%) have the lowest shares of international co-publications, while those in technology (65%), medical and health sciences (73%), and natural sciences (81%) are far more international (Table 5, right column). The same rank order is also found when comparing shares of publications that involve international co-authorship (Table 6). Here, the lowest share is found in the humanities (12%) and the highest in natural sciences (56%).

In both tables, there is a clear association between the publication volume and international collaboration. At the overall level, 37% of men with 1–2 publications have collaborated internationally, while the corresponding figure for women is 33% (Table 5). For the group with 3–9 publications, the figures are 66% and 63%, respectively, and for the group with 10+ publications the figures are 95% and 93%, respectively. Thus, a higher publication volume increases the probability for international collaboration. This is not surprising because this indicator requires only one publication with international co-authorship. For the other indicator there is a similar but weaker association (Table 6). Across the three productivity groups, the proportions increase from 31 to 50% for men and from 27 to 45% for women.

In most fields and productivity groups, shares of international collaboration are highest among men. There are (at the overall level, i.e. by fields not taking academic position into account) only three categories where women rank higher than men on *both* measures (Tables 5 and 6), namely researchers with 1–2 publications in the medical and health sciences, researchers with 3–9 publications in technology, and researchers with 10+ publications in the social sciences. There are also a few categories where the two indicators show deviating patterns and one gender has the highest proportion on one indicator and the lowest on the other.

The findings above have important implications for the interpretation of the aggregated figures presented in Figs. 1 and 2. As shown in Table 2, a larger part of the female researchers are found in the category of researchers with low productivity (1–2 publications) compared with men (overall 38% and 27%, receptively). At the same time, this group has the lowest proportions of international collaboration. Thus, some of the inequalities at aggregated levels can be explained by the different representations of genders across productivity groups. As an example, in the natural sciences overall, 76% of the female researchers have

Table 5 Proportion of researchers involved in international collaboration by field, academic position, publication productivity, and gender*

Fields	1–2 publications		3–9 publications		10+ publications		Total (%)
Positions	Men (%)	Women (%)	Men (%)	Women (%)	Men (%)	Women (%)	
Humanities	12	11	38	39	77	74	32
Professors	13	17	38	35	73	74	38
Associate professors	9	16	46	45			32
Postdocs							27
PhD students	8	6					15
Social sciences	20	13	50	45	78	85	40
Professors	25	21	55	49	85	87	53
Associate professors	19	10	46	43		87	35
Postdocs				54			45
PhD students	14	13	40	29			19
Natural sciences	60	59	87	83	100	98	81
Professors	75		91	90	100	97	93
Associate professors	55		87	84	98		81
Postdocs	65	70	88	91			83
PhD students	55	56	79	70			65
Technology	38	27	60	62	95	90	65
Professors			73		97	91	85
Associate professors	21		60		93		64
Postdocs			69				71
PhD students	43	29	51	49			47
Medical and health sci.	43	46	79	76	98	98	73
Professors	30		83	80	97	96	88
Associate professors	30	45	78	75	100	100	74
Postdocs		64	78	82			79
PhD students	45	41	70	71			54
Total	37	33	66	63	95	93	62

*Figures are only shown for categories with more than 20 researchers

collaborated with researchers in other countries compared with 83% for male researchers (Fig. 1). In other words, there is a difference of 7 percentage points. However, when the issue is analysed at the level of productivity groups, men in the natural sciences overall have 1, 4, and 2 percentage points higher proportions than women in the three productivity groups (1–2, 3–9, and 10+ publications, respectively) (Table 5). This means that in all groups the difference is significantly smaller than the difference at the overall level.

When also taking academic position into account, the pattern becomes less clear. In Table 5, men have higher collaboration proportions than women in 20 of 31 categories based on combinations of fields, academic positions, and productivity intervals, while the opposite is the case in 10 categories. In Table 6, there are 15 categories where men rank above women, 14 categories where women rank above men, and 2 categories with no difference. There are also a few cases where the two indicators provide contradictory results (i.e. categories where one gender has the highest proportion on one indicator and

Table 6 Average proportion of international co-authorship per individual by field, academic position, publication production, and gender*

Fields	1–2 publications		3–9 publications		10 + publications		Total (%)
Positions	Men (%)	Women (%)	Men (%)	Women (%)	Men (%)	Women (%)	
Humanities	8	8	13	13	24	26	12
Professors	9	13	12	13	23	22	14
Associate professors	6	10	17	15			13
Postdocs							11
PhD students	8	5					9
Social sciences	15	10	20	17	25	27	17
Professors	18	16	20	18	29	32	21
Associate professors	16	8	21	16		25	16
Postdocs				18			16
PhD students	9	10	16	14			11
Natural sciences	51	49	53	57	66	67	56
Professors	64		53	55	67	69	60
Associate professors	43		53	54	57		51
Postdocs	58	62	56	65			61
PhD students	48	48	51	54			51
Technology	34	22	27	29	40	40	32
Professors			33		41	43	38
Associate professors	18		26		32		27
Postdocs			38				41
PhD students	39	25	21	24			27
Medical and health sci.	37	38	42	40	53	49	43
Professors	20		43	43	52	49	47
Associate professors	26	37	35	34	53	50	38
Postdocs		53	48	45			50
PhD students	40	35	44	42			39
Total	31	27	34	32	50	45	35

*Figures are only shown for categories with more than 20 researchers

the lowest on the other). In addition, the number of observations in each category varies significantly (Appendix Table 12). Accordingly, it might be difficult to interpret and draw conclusion based on these findings.

In order to analyse these findings further, a bivariate correlation analysis was carried out of the dependent and independent variables. Spearman's rank-correlation coefficients (rho) were calculated because the data were not normally distributed (Table 7). As can be seen, there is a very weak correlation between gender and the two core indicators—engaging in international collaboration (yes/no) (Spearman's rho = 0.10, significant at the 0.01 level) and the proportion of publications with international co-authorship (Spearman's rho = 0.08, significant at the 0.01 level). In contrast, the two other variables of productivity interval and field show a stronger correlation with the indicators of international collaboration. Here the Spearman's rho ranges from 0.27 to 0.44. Thus, these results indicate that international collaboration is more strongly associated with publication productivity and

Table 7 Bivariate analysis. Spearman's rho for the correlation of dependent and independent variables

	Total number of publications	Normalised number of publications	International collaboration (yes/no)	Number of publications with international co-authorship	Proportion of publications with international co-authorship	Average number of authors per publication
Gender						
Corr. coeff.	0.16**	0.12**	0.10**	0.14**	0.08**	0.010
Sig.	0.000	0.000	0.000	0.000	0.000	0.633
Position						
Corr. coeff.	0.48**	0.54**	0.19**	0.30**	0.07**	− 0.10**
Sig.	0.000	0.000	0.000	0.000	0.000	0.000
Field						
Corr. coeff.	0.12**	− 0.08**	0.37**	0.39**	0.44**	0.64**
Sig.	0.000	0.000	0.000	0.000	0.000	0.000
Productivity interval						
Corr. coeff.	0.93**	0.85**	0.44**	0.64**	0.27**	0.22**
Sig.	0.000	0.000	0.000	0.000	0.000	0.000

The fields have been ranked according to increasing proportion of international co-authorship: 1. Humanities. 2. Social sciences. 3. Technology. 4. Medical and health sciences. 5. Natural sciences. Positions have been ranked as follows: 1. PhD students. 2. Post docs. 3. Associate professors. 4. Professors

**Correlation is significant at the 0.01 level (2-tailed) field rather than gender. There is no correlation between gender and average number of authors per publication (Spearman's rho = 0.01). As expected there is a very strong correlation between productivity and the normalised number of publications.

As a next step, a regression analysis for each field was carried out. When we take academic position, productivity intervals, and average number of authors per publication into account and conduct regression analysis on each major field, we are able to determine whether men collaborate more internationally than their female colleagues do. Table 8 summarises the regression results of the indicator of researchers involved in international collaboration (i.e. if a researcher has or has not collaborated internationally, see Table 5). The table includes the numbers of observations, the adjusted regression coefficients, and the standardised coefficients for each of the variables—gender (men = 1, women = 0), position (professors, associated professors, and postdocs relative to PhD students), productivity intervals (relative to the less productive group of researchers), and average number of authors per publication. Because the dependent output variable is binominal (1 or 0 if the researcher has collaborated internationally or not), logistic regression analyses were conducted. Due to the large differences in the propensity to collaborate internationally across fields, we have not carried out this analysis on the overall level (all fields).

The analysis shows that the selected variables—gender, academic position, productivity, and average number of authors per publication—in total explain 25–35% of the variance. The figure is lowest for the social sciences (0.25) and highest for the natural sciences (0.35). International collaboration can therefore partly be explained by these variables.

The regression summary reveals that productivity is the most important variable in terms of international collaboration, while gender is the least important variable. For all fields, researchers who have published 3–9 articles collaborate more internationally than the less productive researchers, and the highly productive researchers have even higher figures. These results correspond with the findings in Table 5. As for academic position, the results are not completely consistent across fields. However, we find that the international collaboration rates of professors are statistically significant and higher than for PhD students in all fields except the humanities. Interestingly, the results show that gender is a statistically significant variable only in the natural sciences.

A similar regression analysis was also carried out for the indicator measuring the degree of collaboration, i.e. the share of publications with international co-authorship (see Table 6). Because the dependent variable in this case is continuous and not categorical, we used linear regression. Moreover, the variable was not normally distributed and thus was log-transformed. As a result of the log-transformation, the researchers without international collaboration (values of 0) were left out of the analysis. Thus, this analysis has important limitations but nevertheless provides interesting complementary results. The regression results are presented in Table 9 below. This analysis concerning gender shows results in line with those presented above. For none of the fields was gender a statistically significant variable.

In Table 10 we present GDCI values in all categories so that we can identify one unified expression of the gender inequality. In addition to GDCI values, we report size-adjusted GDCIs (summed to 100, where GDCIs are adjusted for sample size). This enables us to identify in which categories the origins of the gender equality can be found and the relative contribution of each category to the total inequality.

The first observation in Table 10 is that it is in the group of less productive researchers (1–2 publications) that we find the greatest source of gender inequality. In the two publication output groups that we consider the most important ones, the gender inequality is much higher among the most productive researchers (36% of the total size-adjusted

Table 8 Logistic regression analysis, researchers involved in international collaboration (yes or no), and selected variables by fields

	Humanities	Social sciences	Natural sciences	Technology	Medical and health sci.
Number of observations	783	1035	1310	845	1581
Pseudo-R^2	*0.32*	*0.25*	*0.35*	*0.31*	*0.31*
Gender (men)	0.13 (0.20)	0.08 (0.16)	0.46* (0.19)	0.39 (0.22)	0.07 (0.15)
Professors	0.73 (0.42)	1.14** (0.27)	1.25** (0.26)	1.04** (0.26)	0.66** (0.21)
Associate professors	0.89* (0.42)	0.56* (0.27)	0.87** (0.25)	0.47 (0.25)	0.75** (0.19)
Postdocs	0.61 (0.53)	0.98** (0.37)	0.61* (0.24)	0.65* (0.29)	0.61** (0.22)
Medium production (3–9 publications)	1.81** (0.27)	1.55** (0.19)	1.23** (0.18)	1.03** (0.21)	1.33** (0.16)
High production (10+ publications)	3.22** (0.39)	2.96** (0.29)	3.83** (0.73)	2.98** (0.33)	3.48** (0.36)
Average number of authors per publication	1.54** (0.16)	0.78** (0.08)	0.54** (0.05)	0.69** (0.08)	0.34** (0.03)

Unstandardised regression coefficients, standard errors in brackets. Statistically significant relationships shown with *signs (95% confidence interval) and **signs (99% confidence interval)

Table 9 Linear regression analysis, average proportion of international co-authorship, and selected variables by fields

	Humanities	Social sciences	Natural sciences	Technology	Medical and health sci.
Number of observations	249	415	1062	549	1161
R^2	*0.25*	*0.28*	*0.13*	*0.25*	*0.20*
Gender (men)	0.06 (0.07)	0.01 (0.06)	−0.06 (0.03)	−0.02 (0.07)	0.04 (0.03)
Professors	−0.01 (0.15)	0.09 (0.12)	−0.07 (0.05)	0.11 (0.08)	−0.11* (0.05)
Associate professors	0.02 (0.15)	0.13 (0.12)	−0.18** (0.05)	0.10 (0.09)	−0.19** (0.05)
Postdocs	0.00 (0.20)	0.02 (0.15)	−0.01 (0.05)	0.26** (0.09)	−0.02 (0.05)
Medium production (3–9 publications)	−0.75** (0.11)	−0.73** (0.09)	−0.34** (0.04)	0.75** (0.09)	−0.51** (0.05)
High production (10+ publications)	−0.93** (0.13)	0.98** (0.10)	−0.31** (0.05)	−0.87** (0.10)	−0.53** (0.06)
Average number of authors per publication	0.08** (0.20)	0.09** (0.02)	0.01** (0.00)	0.10** (0.02)	0.01** (0.00)

Unstandardised regression coefficients, standard errors in brackets. Statistically significant relationships shown with *signs (95% confidence interval) and **signs (99% confidence interval)

Table 10 Gender Difference Collaboration Index (GDCI) by field and publication productivity

Fields	1–2 publications			3–9 publications			10+ publications		
	GDCI	N (M/W)	Size adj. GDCI (%)	GDCI	N (M/W)	Size adj. GDCI (%)	GDCU	N (M/W)	Size adj. GDCI (%)
Humanities	0.000	147/159	0.00	0.000	226/173	0.00	−0.006	47/31	−0.45
Social science	+0.015	169/216	+5.61	+0.024	276/247	+12.19	−0.034	68/59	−4.19
Natural science	+0.016	242/164	+6.31	−0.009	391/180	−4.99	0.000	269/64	0.00
Technology	+0.068	150/49	+13.14	−0.020	298/85	−7.44	+0.021	214/49	+5.36
Medical and health sci.	−0.019	164/292	−8.41	+0.022	317/382	+14.93	+0.041	266/160	+16.96
Total	+0.025	872/880	+40.62	+0.017	1508/1067	+23.36	+0.055	864/363	+36.02

GDCIs) compared to the middle group (3–9 publications, 23%). Second, gender differences are almost non-existent in the humanities where international collaboration is far less common compared to other fields. Among the most productive humanists (and social scientists, too), women are in fact more internationally collaborative than men, but the overall contribution to gender differences is just 0.45%. Third, in the natural sciences there are no gender differences among the most productive researchers. Although this field tends to be dominated by men, the publishing behaviour of female natural scientists does not deviate from men among the most prolific researchers. In the least productive group, male natural scientists are more collaborative, while women have a higher index in the mid-productivity group (3–9 publications). Fourth, in technology there are strong gender differences (in favour of men) among researchers with few publications. Fifth, and most notably, in medical and health sciences female researchers are more internationally collaborative among the least-productive researchers, but the two single most important contributors to gender differences are found here among the more productive researchers. Although GDCI values are higher in some other categories, these two categories contribute to the largest part of the gender inequality in favour of men (due to the high n). Despite the fact that women are equally or more internationally collaborative than men in several categories, the overall results show that men rank above women in all productivity categories.

In Table 11 we provide more detailed results where academic position is also added as an explanatory variable. This enables us to identify in which areas of research, for which type of positions, and at which productivity level gender differences are present. At first glance, it is clear that gender differences in international collaboration are very minor or not present in most categories. In the categories where women have higher GDCIs than men, the relative contribution to the total inequality tends to be small because the GDCIs in favour of women are often based on very small samples (often in combination with low GDCIs). If we arbitrarily choose a 5% size-adjusted GDCI as the threshold for significant gender inequality, there are only two categories (female postdocs in the natural sciences and associate professors in medical and health sciences with 1–2 publications) where women have a substantially higher size-adjusted international collaboration index than men. Among men, on the other hand, there are several such categories. The strongest contributions to men's higher degree of international collaboration is found for PhD students in technology and in the medical and health sciences with 1–2 publications and professors in the medical and health sciences with 10+ publications. Male PhD students contribute to 11.5% of the total size-adjusted GDCIs in technology and to 9.6% of the total size-adjusted GDCIs in the medical and health sciences.

Discussion

Our analyses have shown that the field of research is by far most important factor influencing the propensity to collaborate internationally. There are large differences from the humanities on the one hand, where international collaboration in terms of co-authorship is less common, to the natural sciences on the other, where such collaboration is very frequent. This study also demonstrates that publication productivity and academic rank are factors that are important to take into consideration when analysing scientific collaboration

Table 11 Gender Difference Collaboration Index (GDCI) across fields, academic position, and publication production

Fields	1–2 publications			3–9 publications			10+ publications		
Positions	GDCI	*N* (M/W)	Size adj. GDCI (%)	GDCI	*N* (M/W)	Size adj. GDCI (%)	GDCI	*N* (M/W)	Size adj. GDCI (%)
Humanities									
Professors	−0.008	(53/24)	−0.58	+0.003	(135/69)	+0.57	+0.009	(40/23)	+0.53
Associate professors	−0.010	(66/56)	−1.14	+0.012	(63/69)	+1.48			
Postdocs									
PhD students	+0.004	(24/65)	+0.33						
Social sciences									
Professors	+0.009	(57/28)	+0.72	+0.023	(172/95)	+5.75	−0.035	(46/30)	−2.49
Associate professors	+0.022	(59/89)	+3.05	+0.030	(69/98)	+4.69			
Postdocs									
PhD students	−0.001	(44/91)	−0.13	+0.025	(20/28)	+1.12			
Natural sciences									
Professors				−0.009	(164/42)	−1.74	−0.003	(192/36)	−0.64
Associate professors				+0.005	(61/38)	+0.46			
Postdocs	−0.056	(46/30)	−3.89	−0.101	(84/46)	−12.29			
PhD students	−0.008	(120/108)	−1.71	+0.027	(82/54)	+3.44			
Technology									
Professors							+0.008	(144/22)	+1.24
Associate professors									
Postdocs									
PhD students	+0.095	(95/34)	+11.47	−0.014	(138/43)	−2.37			
Medical and health sci.									
Professors				+0.009	(133/82)	+1.81	+0.039	(208/103)	+11.35
Associate professors	−0.088	(27/49)	−6.26	+0.015	(74/114)	+2.64	+0.032	(38/43)	+2.43
Postdocs				+0.011	(46/76)	+1.26			
PhD students	+0.036	(98/187)	+9.60	+0.013	(64/110)	+2.12			

at the levels of individuals, and this is also emphasised in studies by Bozeman and Gaughan (2011) and Zeng et al. (2016).

Our results show that there are distinct gender differences in international research collaboration in Norway at an overall level. However, women and men are not equally distributed across the variables analysed here. First, there are relatively more female researchers in fields where the international collaboration rates generally are lower, and this might explain why the gender differences at the field level are lower than the differences at the overall level. Second, women account for higher proportions of personnel with lower academic ranks and with lower publication productivity. In these groups, the propensities to collaborate internationally are lower for both genders. As a consequence, the gender differences are smaller when academic position and productivity are taken into account. The regression analysis shows that the gender differences are not statistically significant when these variables are taken into account, with the exception of the natural sciences for the indicator of researchers involved in international collaboration. In this way, our findings confirm the assumption by Larivière et al. (2013) concerning the importance of seniority as an explanation for the gender disparities that have been identified (as described in the introduction). It is a general principle in analyses like this one that one should compare "like with like", and our study has demonstrated that gender differences in scientific collaboration might be overestimated if factors such as productivity and academic rank are not taken into consideration.

The analyses at the level of field, academic position, and productivity provide a much less distinct picture. In fact, in several categories female researchers have higher rates of international collaboration than male researchers. Still, in the majority of categories where field, academic position, and productivity are analysed separately, shares of international collaboration are slightly higher for men than for women. We find the strongest gender difference in favour of men in the medical and health sciences. The differences are particularly pronounced at an early phase of the researchers' careers—i.e. researchers in recruitment positions and researchers with a relatively low number of publications—and the differences are less pronounced at later stages.

As noted in the introduction, previous research has not provided consistent findings concerning gender differences in international research collaboration. The *She Figures* report (European Commission 2015) concludes that for the EU-28 overall, the female to male ratio is only marginally smaller than 1. This means that the propensity of women to publish articles with international co-authors is almost equal to men. However, at the level of individual countries, there are some differences. For Norway there is no gender gap at all, and the ratio is 1. This might appear surprising considering the results of our study showing a gender gap at the overall level. However, the *She Figures* report is based on analyses of corresponding authors only. This is an important limitation that is acknowledged in the report (page 162): "This indicator […] carries the risk of focusing on those women who stand out from the average population of women scientists by virtue of their more established collaboration networks. Because of this potential selection bias, this indicator might provide a more positive picture than is truly the case in the whole population of researchers with regards to gender parity".

A bibliometric analysis carried out by Elsevier (2017) concluded that women are less likely than men to collaborate internationally. This finding held for all 12 countries analysed in the study, and the differences in the period 2011–2015 ranged from 10 percentage points (Chile) to 4 percentage points (Portugal and Japan). However, this analysis was carried out at an overall level and the facts that the collaboration rates vary a lot across fields and that men and women are not equally distributed were not taken into consideration. As seen in our study, such factors might explain a significant part of the observed gender gaps.

Although our findings are based on a large dataset, they are limited to just one country. As explained in the introduction, there are large differences in the rate of international co-authorship across countries. As a small country, Norway has higher collaboration rates than many other countries, and thus analyses of other larger countries might reveal lower frequencies of such collaboration than the ones presented in this study. However, the issue concerning gender gaps might not be affected by such differences. In the *She Figures* report (European Commission 2015), only two countries (Cyprus and Iceland) had higher gender ratios of international collaboration than Norway. It is therefore likely that the gender gaps might be somewhat smaller in Norway compared with several other countries. Further analyses would be required in order to address this question.

Conclusions

The main contributions of our study are twofold. Methodologically, by applying two different measures of international collaboration and combining them into a single index, we have been able to provide complementary pictures of this dimension. Empirically, we have presented new evidence on gender differences in international research collaboration by applying a database with complete coverage of the scientific and scholarly publication output.

International collaboration is a crucial part of today's science and represents an important difference in how science is carried out today compared with the recent past. Such collaboration might contribute positively to the career development of individual researchers, and therefore international collaboration is an important issue to address concerning gender inequality in science. Our study has shown that there are notable gender differences at the overall level. However, when field, academic rank, and productivity are taken into consideration there are only minor and non-statistically significant sex differences in the propensity to collaborate with colleagues in other countries. Concerning gender inequality in science, the main challenge seems to be the lower productivity level of female researchers, which obviously hinders their academic career development. Differences in international collaboration are unlikely to be an important factor in this respect, at least not in the Norwegian research context as analysed in this study.

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Appendix

See Tables 12 and 13.

Table 12 Distribution of researchers and publications by fields, scientific position, publication productivity and gender. Number of individuals

Fields	1–2 publications		3–9 publications		10 + publications		Total
Positions	Men	Women	Men	Women	Men	Women	
Humanities	147	159	226	173	47	31	783
Professors	53	24	135	69	40	23	344
Associate professors	66	56	63	69	4	7	265
Postdocs	4	14	16	19	2	1	56
PhD students	24	65	12	16	1		118
Social sciences	169	216	276	247	68	59	1035
Professors	57	28	172	95	46	30	428
Associate professors	59	89	69	98	15	23	353
Postdocs	9	8	15	26	7	6	71
PhD students	44	91	20	28			183
Natural sciences	242	164	391	180	269	64	1310
Professors	32	9	164	42	192	36	475
Associate professors	44	17	61	38	47	19	226
Postdocs	46	30	84	46	19	5	230
PhD students	120	108	82	54	11	4	379
Technology	150	49	298	85	214	49	845
Professors	14	2	73	6	144	22	261
Associate professors	28	7	45	18	42	16	156
Postdocs	13	6	42	18	18	7	104
PhD students	95	34	138	43	10	4	324
Medical and health sciences	164	292	317	382	266	160	1581
Professors	23	11	133	82	208	103	560
Associate professors	27	49	74	114	38	43	345
Postdocs	16	45	46	76	18	11	212
PhD students	98	187	64	110	2	3	464
Total	872	880	1508	1067	864	363	5554

Table 13 Proportion of researchers involved in international collaboration and average proportion of international co-authorship per individual by disciplines* and gender

Discipline	Proportion of researchers involved in international collaboration		Average proportion of international co-authorship per individual		*N* (men/women)
	Men (%)	Women (%)	Men (%)	Women (%)	
Humanities					
Archaeology and conservation	55	36	29	16	36/29
History	34	12	9	2	25/59
Linguistics	42	55	18	26	64/50
Literature	20	10	6	3	49/40
Media and communication	45	67	16	29	24/29
Philosophy and history of ideas	35	18	16	5	22/54
Theology and religion	37	25	11	4	28/38
Medical and health sciences					
Biomedicine	83	78	50	55	148/143
Cardiovascular and respiratory systems	89	83	48	47	40/37
Dentistry	69	70	38	39	44/35
Neurology	78	68	47	43	56/59
Nursing	42	58	10	29	45/12
Oncology	85	75	46	47	53/40
Pharmacology and toxicology	68	75	43	43	52/38
Psychiatry	91	62	58	39	29/22
Psychology	72	69	38	34	112/115
Public, environmental and occup hlth	79	62	44	33	121/94
Natural sciences					
Biology	88	79	57	58	140/224
Chemistry	76	67	43	47	46/119
Earth sciences	86	87	62	63	78/207
Informatics	75	53	39	27	30/72
Mathematics	81	67	53	45	33/124
Physics	88	89	71	73	37/129
Social sciences					
Anthropology	29	30	8	11	30/28
Business and finance	53	38	22	23	42/64
Economics	53	67	31	48	15/53
Education and educational research	38	32	17	11	158/93
Geography	67	44	28	20	34/33
Law	33	26	10	10	80/92
Political science	51	47	23	16	47/81
Sociology	48	30	12	10	27/29
Technology					
Civil engineering	67	81	34	44	16/39
Computer and information science, computer engineering	74	51	36	24	35/109
Electronics and cybernetics	62	72	28	29	18/107
Energy	66	68	30	30	19/76
Marine technology	49	40	20	21	15/63
Materials science and engineering	82	70	54	38	27/71

*Only disciplines with at least 50 individuals (in total) have been included in the table

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