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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 5,554 Norwegian researchers and their publication output during a three-year period (43,641 publications). Two different indicators are calculated. First, the share of researchers that *have* been involved in international collaboration measured by co-authorship, and second, the share of their publications with international co-authorship. We then develop an index which takes both these indicators into account: The Gender Difference Collaboration Index. The study shows that there are distinct gender differences in international research collaboration in Norway at an overall level. However, when the data is analyzed by scientific field, academic position and publication productivity of the researchers, the gender differences are less pronounced and in some cases, women have higher collaboration rates than men. The differences are largest for personnel in recruitment positions and for less productive researchers.

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 men. This has been demonstrated in numerous studies (for example, Kyvik & Teigen, 1996; Piro, Aksnes & Rørstad, 2013; Sugimoto et al., 2013). The pattern seems to be universal across fields and nations, although the differences vary. As an example, Rørstad & Aksnes (2015) showed that adjusted for position and age, female researchers in Norway on average publish 10 to 20 percent less than men. The question of whether women are less cited than men has also been analyzed in several studies. Here, the results are less clear, and 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, as these two factors are decisive for e.g. academic promotion and in the evaluation of research proposals among funding agencies (European Commission, 2015).

In this study, another dimension is analysed: gender differences in international collaboration. This issue has become ever more important to study, due to the steady increase worldwide in research collaboration in groups and networks, hence also growth in paper co-authorships (Leydesdorff & Wagner, 20008) and in interdisciplinary research (Lee & Bozeman, 2005). International research collaboration has been shown to be advantageous to researchers' productivity and scientific impact (e.g. Abramo, D'Angelo & Di Costa, 2009; Abramo, D'Angelo & Solazzi 2011; Adams 2012; Kyvik & Reymert, 2017; Larivière et al., 2013.

Nevertheless, the knowledge on gender differences in international research collaboration is inconclusive (Poole & Bornholt, 1998, Larivière et al. 2011, Vabø, 2012).

Expanding the knowledge gaps on gender gaps

In this study, we draw upon the methodological approach of three previous studies – presented below – using a Norwegian dataset with additional variables missing 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 Web of Science (WoS) data from the period 2008-2012 to study differences in international co-authorship in 5,5 million papers with more than 27 million authorships. The dataset included information on the gender of the authors. Females 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 of 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, D'Angelo & Murgia's (2013) analyses 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 being analysed, except for the international dimension. This study only included researchers in tenured academic positions.

A third relevant study is Uhly, Visser and Zippel's (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 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 & Persson, 1996). At the same time, most studies on gender differences in research collaboration have been conducted based on surveys (Abramo, D'Angelo & Murgia, 2013).

The main result of Uhly and colleague's (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 children). The results lead 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 study, we aim at filling a 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. Important dimensions of the study are:

- The application of a database which, 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 able to provide a better coverage of the Social Sciences and Humanities, in particular.

- We analyse the issue at the level of fields and disciplines. The importance of comparing by fields has been documented by e.g. Kyvik & Reymert (2017) and Abramo, D'Angelo & Murgia's (2013), with the latter study arguing (p. 819) 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".
- We take the *academic position* of the researchers into account. Two previous Norwegian studies have found that older academic staff are less inclined than their younger colleagues to participate in international research networks (Kyvik & Reymert, 2017; Kyvik & Olsen, 2008).

In sum these factors enable us to test, first, 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, as we believe international collaboration may 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 may 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

The 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 a 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). In addition to bibliographic data on the publications, the database contains information on individual characteristics of the researchers (gender, age, and institution). The researchers were assigned to five broad domains (Social sciences, Humanities, Natural sciences, Technology and Medical/health sciences), based on the field distribution of their publication output.

The data material consists of 5,554 researchers from the four largest universities in Norway (University of Oslo, University of Bergen, University of Tromsø – The Arctic University of Norway and The Norwegian University of Science and Technology (NTNU)). The study is limited to professors, associated professors, postdocs and PhD students with at least one publication during the time period analyzed. Their publication output during the period 2015-2017, in total accounts for 43,641 publications (Table 1).

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

	Number of researchers			*Number of publications*		
Major fields	*Men*	*Women*	*Total*	*Men*	*Women*	*Total*
Humanities	420	363	783	2,009	1,445	3,454
Social sciences	513	522	1,035	2,709	2,357	5,066
Natural sciences	902	408	1,310	10,815	3,016	13,831
Technology	662	183	845	6,545	1,572	8,117
Medical and health sciences	747	834	1,581	7,719	5,454	13,173
Total	3,244	2,310	5,554	29,797	13,844	43,641

Female researchers constitute 41.6 per cent of the study population, while they only account for 31.7 per cent of the publications. The female shares of the researchers vary greatly by field. It is highest in Medical and health sciences (52.8 per cent), Social sciences (50.4 per cent) and

Humanities (46.4 per cent); considerably lower in Natural sciences (31.1 per cent) and Technology (21.7 per cent). The female shares of the publication output, however, does not coincide be representation of researchers. Women publish less than men in all fields, while it is in Technology where female researchers publish most equally to men: 21.7 per cent women account for 19.4 per cent of the output, i.e. a publication output just 2.3 percentage points lower than expected based on representation of researchers. This female under-representation of the publications is moderate in Social sciences (3.9 percentage points) and Humanities (4.5); and high in Natural sciences (9.3) and Medical and health sciences (11.3).

The analyses are carried out by fields of research, academic positions, and their scientific production. The latter is a factor that we find essential when studying gender differences in international collaboration. Without a stratification of the study population to different levels of scientific production, important nuances are lost. We have split the sample in three groups based on publication volume. The first group, is the researchers with (on average) less than a publication a year (31.5 per cent of the sample), the second group is the researchers with 1-3 publications a year on average (46.3 per cent of the sample), and the third group is the bulk of very productive researchers with on average of more than 3 publications each year (22.1 per cent of the sample).

The unit for the analyses is the individual researchers. 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 period. In other words, all individuals count equally as one unit in the analysis regardless of how many publications they have published. By this, we avoid that the analysis is biased towards highly productive researchers. However, such a dichotomous measure is deprived of essential information. Whilst it provides us the shares of men and women that are involved in international collaboration, we do not know anything about the degrees of internationalization among the individuals. For example, in two groups (100 men and 100 women), we may find that 54 per cent of the men have international co-authors, while 57 per cent of the women have international co-authors. Women here appear to be more international oriented than men.

If, on the other hand, the measure is the percentage of international co-authored publications, we may find that in the female group, on average 35 per cent of the publications have international co-authors, while 39 per cent of the men's publications have international co-authors. We now have two results that pull in different directions. We believe both measures are important to consider. The first is a measure of how many *individuals* that have international co-authors, while the second is a measure of how many *publications* that have international co-authors. The two factors provide complementary information on gender differences in international collaboration. What is needed is measure that takes both factors simultaneously into account. We therefore suggest a simple measure combining both *presence* and *scope* of international collaboration, which we call the Gender Difference Collaboration Index (GDCI). The GDCI is calculated as:

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

Where *m/w* is the total number of men/women in the study sample, and *m int/w int* is the number of men/women with international collaboration. Pub tot is the total number of publications and pubs int is the number of publications with internationally collaboration. The GDCI varies between -1 (complete gender difference in favor of women) to 1 (complete gender difference in favor of men).

We first present gender differences in both sets of analysis (gender differences based on dichotomous distribution of yes or no with regard to international collaboration, and gender differences based on shares of publications with international collaboration), before we present GDCIs for each indicator in multivariate analyses.

Results

Overall, 56 per cent of the female researchers were involved in international collaboration measured by co-authorship. The corresponding figure for men was 66 percent. Thus, our study shows that overall male researchers more often are involved in international collaboration than their female colleagues. However, as expected there are large differences across domains (Figure 1). International collaboration is much more frequent in the Natural sciences, Medical and health sciences and Technology compared with Humanities and Social sciences. This holds for both genders. In the Humanities less than one third of the researchers have publications involving international collaboration. There are gender differences in all domains. The gap is largest in the Social sciences where the proportion for men is 44 per cent and 36 per cent for women. The gap is smallest in Humanities (the difference is three percentage point).

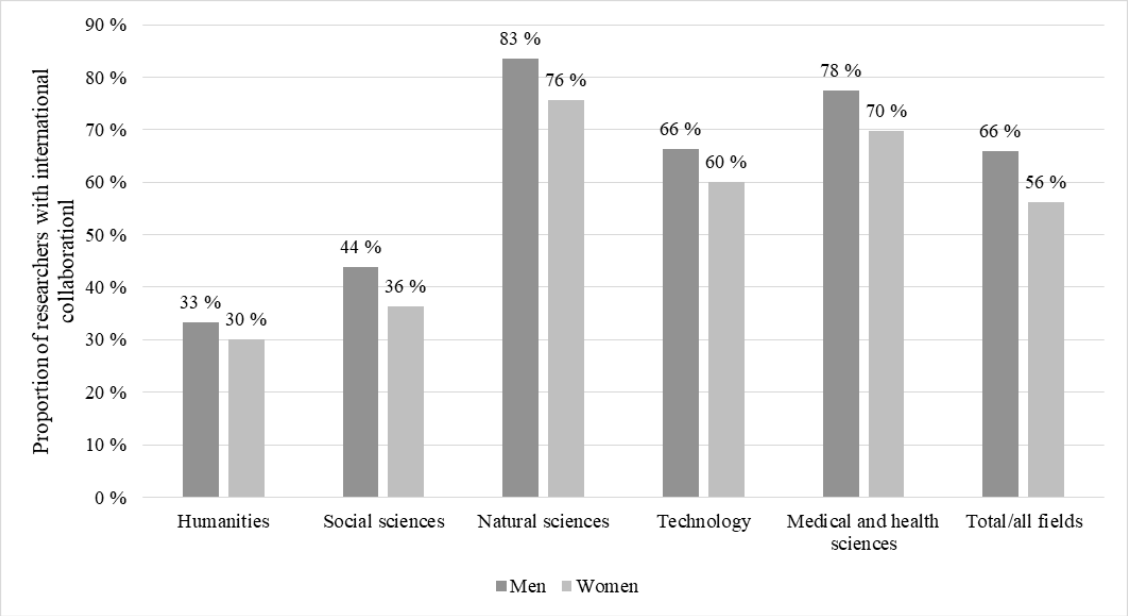

Figure 1. Proportion of researchers involved in international collaboration by fields and gender

Figure 2 shows the corresponding figures using the proportions of publications involving international collaboration as indicator. Gender differences are observed across the two different measures but now the gender differences are reduced. The most evident reduction in gender gaps is observed in Natural sciences, where a seven-percentage point higher share of men was involved in international collaboration (Figure 1), while the share of the publications that involve international collaboration is just two percentage points higher for men (Figure 2). Similar results are observed when we study academic position instead of scientific domain (not shown in figures).

In Tables 2-4 we present the results split by gender, publication volume, scientific domain and academic position simultaneously. In Tables 2-4 we only report numbers for groups with more than 20 researchers. In Table 2 we report the percentage of men/women that *have* collaborated internationally (yes or no,), while we in Table 3 report the shares of publications with international co-authors.

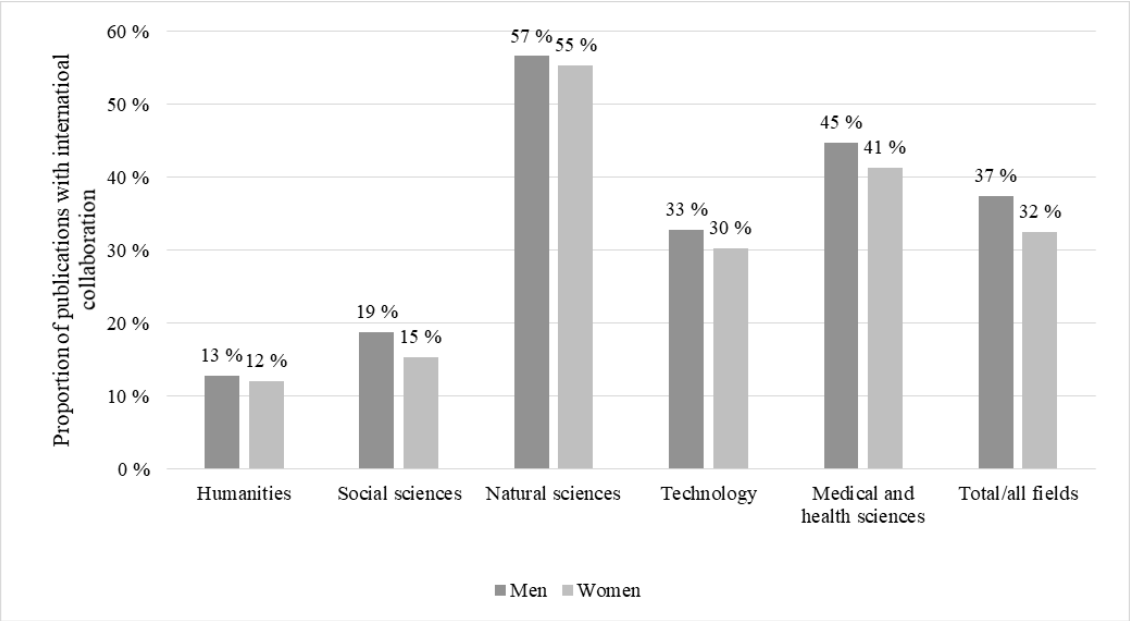

Figure 2. Average proportion of international co-authorship per individual by fields and gender

Table 2: Proportion of researchers involved in international collaboration by fields, 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/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 %**

Table 3: Average proportion of international co-authorship per individual by fields, 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/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 %**

In both tables, there is a clear association between the publication volume and international collaboration. Therefore, there is also a clear tendency that the degree of internationalization concurs with academic position, where foremost professors have the highest shares. Comparing academic fields, researchers in Humanities (32 per cent) and Social Sciences (40 per cent) have the lowest shares of international co-publications, and Technology (65 per cent), Medical and health sciences (73 per cent) and Natural sciences (81 per cent) being far more international (Table 2). The same rank order is also found when comparing shares of publications that involved international co-authorship (Table 3). Here, the lowest share is found in Humanities (12 per cent) and the highest in Natural sciences (56 per cent).

In most fields, and in most academic positions, 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 2 and 3): Researchers with 1-2 publications in Medical and health sciences, researchers with 3-9 publications in Technology, and researchers with 10 or more publications in 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 lowest on the other. In Table 4 we therefore present GDCI values in all categories (with more than 20 researchers), so that we can find one unified expression of the gender inequality. In addition to GDCI values, we report size- adjusted GDCIs (summed to 100, based only on cells with n≥20, where GDCIs are adjusted for sample

size, i.e. the GDCIs are multiplied by the number of respondents). This enables us to identify in which categories the origins of the gender equality can be found, and we may decompose the relative contribution of each category to the total inequality. For example, a very high gender inequality based on a very small sample, adds very little explanation to the total inequality, whereas a low/modest inequality in a very large sample, may add much explanation for the total gender inequality.

Table 4: 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*	*GDCU*	*n (M/W)*	*Size adj.GDCI*
Humanities	0.000	(147/159)		0.000	(226/173)		-0.006	(47/31)	-0.45 %
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	0.015	(169/216)	+5.61 %	0.024	(276/247)	+12.19 %	-0.034	(68/59)	-4.19 %
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	0.016	(242/164)	+6.31 %	-0.009	(391/180)	-4.99 %	0.000	(269/64)	
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	0.068		+13.14 %	-0.020	(298/85)	-7.44 %	0.021	(214/49)	+5.36 %
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/health sci	-0.019	(164/292)	-8.41 %	0.022	(317/382)	+14.93 %	0.041	(266/160)	+16.96 %
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 %			
Total	0.025	(872/880)	40.62 %	0.017	(1508/1067)	+23.36 %	0.055	(864/363)	+36.02 %

The first observation in Table 4, is that it is in the group of less productive researchers (1-2 publications) that we find the highest 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 per cent of total size adjusted GDCIs) compared to the middle group (3-9 publications, 23 per cent). The common characteristics for most categories where women have higher GDCIs than men, is that the relative contribution of the females does not add much to the total numbers, as the GDCIs in favour of women are primarily based on very low samples (often in combination with low GDCIs). If we discretionary choose 5 per cent size adjusted GDCI as the threshold for important gender inequality, there are only two categories (female postdocs in Natural sciences and associate professors in Medical and health sciences with 1-2 publications) where women have substantial higher size adjusted international collaboration index than men. Among men, on the other hand, there are numerous such examples. The strongest contributions to men's higher degree of international collaboration is found for PhD students in Technology and Medical and health sciences (1-2 publications) and professors in Medical and health sciences (10 or more publications).

At a more general level, we would like to emphasise three main findings of Table 4: *First,* we find the strongest gender differences in internationalization in Medical and health sciences. Here, among the least productive researchers, women have more international

collaboration, but the pattern is opposite for researchers with 3-9 publications, and the male dominance becomes even more pronounced for the most productive researchers, especially professors (17 per cent of total GDCIs).

Second, in the Natural sciences, the gender inequalities are almost completely opposite. Here, women are more international collaborative in the mid-group (3-9 publications), and at the level of the most productive researchers there are no gender differences at all. In both Humanities and the Social Sciences, women are more international than men in the most productive group, but the differences are so small, that they hardly contribute to the overall gender inequality.

Third, much of the gender imbalance stems from researchers with just 1-2 publications, and especially from researchers in recruitment positions. Male PhD students contribute to 11.5 per cent of total size adjusted GDCIs in Technology, in Medical and health sciences the corresponding figure is 9.6 per cent.

Discussions and conclusions

Our study shows that there are distinct gender differences in international research collaboration in Norway. However, women and men are not equally distributed. 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. Still, in the majority of categories where fields, academic positions and productivity are analysed separately, shares of international collaboration are slightly higher for men than for women.

If one wants to address solutions to reduce the gender gap in international collaboration, it is important to take both measures of international collaboration into account (how many have been involved in international collaboration, and the frequency of such collaborations), and analyse different layers that may contribute to lower international collaboration for women. Our results suggest that gender differences are particularly pronounced at an early phase of the researchers' careers, and less pronounced at later stages. At the level of fields, the gender gap is largest within Medicine and health sciences.

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