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Publication rate expressed by age, gender and academic position – A large-scale analysis of Norwegian academic staff

Kristoffer Rørstad*, Dag W. Aksnes

NIFU – Nordic Institute for Studies in Innovation, Research and Education, Wergelandsveien 7, NO-0167 Oslo, Norway

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ABSTRACT

This study investigates how scientific performance in terms of publication rate is influenced by the gender, age and academic position of the researchers. Previous studies have shown that these factors are important variables when analysing scientific productivity at the individual level. What is new with our approach is that we have been able to identify the relative importance of the different factors based on regression analyses (OLS) of each major academic field. The study, involving almost 12,400 Norwegian university researchers, shows that academic position is more important than age and gender. In the fields analysed, the regression model can explain 13.5–19 per cent of the variance in the publication output at the levels of individuals. This also means that most of the variance in publication rate is due to other factors.

1. Introduction

It is well known that there are large differences in the publication output between scientists: a relatively small proportion of scientists contribute to the majority of the publications. In 1926 Lotka formulated the famous inverse square law of productivity, which states that the number of authors producing n papers is approximately $1/n^2$ of those producing one (Lotka, 1926). This means, for example, that of all authors in a given field, 60 per cent will have produced just one publication. A large number of later studies have confirmed that there exists a highly skewed productivity pattern in scientific publishing (e.g. Allison & Stewart, 1974; Price, 1986; Reskin, 1977). However, it has also been shown that the differences in scientific publication rate at the level of individuals are fewer than indicated by Lotka, and that Lotka's law overestimates the number of papers produced by the most prolific scientists (Kyvik, 1991; Potter, 1981).

The reason for the skewed distribution, and for individual publication rate differences more generally, has also been the topic of many subsequent studies. Here, attention has been directed towards factors attributed to social dynamics (e.g. cumulative advantage, the Matthew effect (Merton, 1968)) and to more specific factors like age and academic position of the scientists. In this study, we are focusing on the latter set of factors. We ask whether scientific publication rate can be expressed by the age, gender and academic position of the researchers. If so, to what extent do these variables have any effect on scientific performance in terms of publication output? Previous research has shown that all these variables have an effect on scientific productivity, but the results of the different studies have not been entirely consistent.

First, the scientific publication rate has been found to increase within the hierarchy of academic positions: professors are the most prolific personnel while people in lower academic positions tend to publish fewer publications per year (see e.g.

* Corresponding author. Tel.: +47 22595179.
E-mail addresses: Kristoffer.rorstad@nifu.no (K. Rørstad), Dag.w.aksnes@nifu.no (D.W. Aksnes).

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Abramo, D'Angelo, & Di Costa, 2011; Aksnes, Rørstad, Piro, & Sivertsen, 2011; Allison & Stewart, 1974; Kyvik, 1991; Tien & Blackburn, 1996). These findings are not surprising. The junior personnel are less experienced as researchers. As knowledge is cumulative, a scientist in a senior position is more likely to have better abilities to do research and write articles (Tien & Blackburn, 1996). Moreover, senior personnel often have lead roles in the research process and may be involved in many research projects at the same time, resulting in more publications. In addition, the pattern may be partly explained by a pre-selection effect. In order to be promoted to a senior position, universities often apply publishing activity as a major criterion. To be appointed to a professor or an equivalent senior position, one already needs a long publication list. Primarily the most able and prolific staff will be given the opportunity to advance within the hierarchy of positions.

Second, studies on gender have shown that female scientists tend to publish fewer publications than their male colleagues. This pattern has been found across many fields and nations (e.g. Abramo, D'Angelo, & Caprasecca, 2009; Cole & Zuckerman, 1984; Kyvik & Teigen, 1996; Long, 1992; Xie & Shauman, 1998). However, usually the proportion of female researchers decreases within the hierarchy of positions. Particularly among professors, there are few females while there is more gender balance among PhD students (see e.g. European Commission, 2012). One possible explanation for the gender difference is that women occupy fewer of the highest academic posts and also are less integrated in the scientific community, for example by positions/membership in scientific associations and on the editorial boards of journals (Bentley & Blackburn, 1992; Cole & Zuckerman, 1984; Luukonen-Gronow & Stolte-Heiskanen, 1983; Prpic, 2002; Puuska, 2010; Xie & Shauman, 1998). Nevertheless, studies have also shown that differences in publication rate among men and women can be found at all levels of academic positions (Aksnes et al., 2011; Kyvik, 1991). As an explanation of the gender differences, it has been suggested that women and men choose differently (Ward & Grant, 1996). While women devote more time to teaching and administrative work, male scientists focus more on research and supervision of PhD students. However, a recent study on Dutch social scientists found that young female researchers outperformed young male researchers in terms of number of publications (van Arensbergen, van der Weijden, & van den Besselaar, 2012).

Finally, the relationship between age and publication rate has been found to be curvilinear in several studies. The average production of publications increases with age and reaches a peak at some point during the career and then declines (see for instance Aksnes et al., 2011; Barjak, 2006; Cole, 1979; Gonzalez-Brambila & Veloso, 2007; Kyvik, 1990). However, Kyvik (1990) also noted that the researchers with more recognition keep publishing frequently after their less-recognised colleagues reached their peak.

In this large-scale study, we have investigated the influence of age, gender and scientific position on scientific publication rate. This is done separately within major academic fields. While most previous studies have investigated these variables individually, we in this multivariate study have analysed all three factors at the same time (cf. Puuska, 2010; Shin & Cummings, 2010). Our objectives have been to identify the variables which are most influential in terms of explaining differences in publication rates, and whether the same factors are influential across all academic fields.

Most previous studies which have investigated these factors have measured the publication output of each scientist during a certain period. In this study, we have used the publication output per scientist per year as a measure (not the average for a longer period). As a result, the figures are adjusted for the time a researcher has been employed in an academic position.

Typically, previous studies which have addressed these questions have been restricted to the data available from larger bibliometric databases, in particular the *Web of Science* (Thomson Reuters). Such analyses often produce a distorted picture of the research output in some disciplines, in particular the social sciences, arts and humanities, where a substantial share of relevant journals or books are not indexed in the Web of Science (Hicks, 2004). This study, on the other hand, is based on complete publication data (scientific and scholarly publications) for all researchers employed at Norwegian universities. As a result, the social sciences and humanities are fully covered in our analyses.

Norway is well suited as a case for analysing this issue. Unique datasets are available not only on the research output but also on the research staff. Norway's higher education sector comprises four traditional universities, four specialised universities as well as a number of university colleges. The academic career system consists of PhD candidates, postdocs, associate professors and full professors as the main positions. After obtaining a PhD degree, one is entitled to apply for permanent positions as associate professor or temporary positions as postdocs. Contrary to many other countries, associate professors are eligible to apply for promotion to full professor on the basis of their individual research competence (in accordance with international or national standards within the subject area), irrespective of vacant professorships (Olsen, Kyvik, & Hovdhaugen, 2005).

It should be noted initially that in previous literature, scientific productivity often has been used as concept for the input–output relationship, typically expressed as the number of publications of a researcher during a given time period. Productivity may have connotations to efficiency, which is a more complex issue, involving consideration of optimal time use, spending of resources, etc. We have therefore in this study mainly used publication rate as a concept for the relationship, which previously usually have been termed publication productivity.

2. Methods and data

In our study, we applied the Norwegian publication database *Current Research Information System in Norway* (Cristin). This database includes all types of scientific and scholarly publications, in all fields of research in the higher education sector. Bibliographic data are collected through a common documentation system used by all institutions, resulting in

Table 1
Number of persons and observations by field of science.

Field of science	Number of persons	Number of observations
Humanities	1340	3691
Social sciences	1979	5821
Natural sciences	3151	9558
Engineering and technology	1912	4757
Medicine	4021	11,974
Total	12,403	35,798

complete, verifiable and structured data for use in bibliometric analysis (Schneider, 2009; Sivertsen, 2010). In the database, publication output is reported by the institutions as standard bibliographic references, which are analysable by publication channel and type of publication. A dynamic authority record, covering 19,000 controlled scientific and scholarly publication channels ensures that non-scientific publications are not entered into the system.[1] National publishing boards in each discipline are responsible for the approval of publishing channels according to specific national criteria and guidelines (e.g. only journals, series, and book publishers with peer review systems can be approved). Publication data from professional bibliographic data sources (e.g. the Web of Science) are imported to the Cristin system, to facilitate the registration of publications by the employees. At institutions, there are local routines to check that all publications have been registered. Thus, missing publications by researchers is likely to be a very minor problem and overall the publication data have excellent quality. The database is therefore well-suited to publication analyses across subject fields, as a large scale database, with complete coverage of all peer-reviews scientific and scholarly publication output, including journal articles, monographs, book chapters and conference series.

As a basis for the study we selected the four major Norwegian universities (University of Oslo, University of Bergen, The Norwegian University of Science and Technology in Trondheim, and the University of Tromsø) which account for about 70 per cent of the total publication output of the higher education sector in Norway. Our analysis covers the 7-year period from 2005 to 2011.

To provide information on individual characteristics of the researchers (field of science, position, age and gender), the bibliographic database was coupled with another database, the *Norwegian Research Personnel Register* (providing the official Norwegian R&D statistics, compiled by NIFU). This database contains individual data for all researchers in the higher education sector and institute sector in Norway (with biennial data from 1977 to 2007, and annual data from 2008). The researchers have unique IDs in both the Research Personnel Register and the Cristin publication database. However, the IDs are not identical. The linking is based on data on the full name of the researchers as well as their institutional affiliations. For a large number of individuals, there is a one-to-one correspondence, and homonyms (different people with identical names) do not represent a problem. In our study we have linked researchers with identical names manually using available data and information.

The coupling of these two databases resulted in a dataset we analysed, containing about 12,400 people in almost 35,800 observations (i.e. publication numbers per years). Thus, there are on average almost three observations per person analysed. Non-publishing personnel have not been included in the study as only people who have published are registered in the database. This may be regarded as a limitation of our study as the inclusion of the non-publishing researchers could possibly increase the publication rate differences between genders, age groups and positions. Probably, many of the researchers who are not found in the database (and have not published) are newly appointed, and thus unproductive. Others have not published, for a variety of reasons. Although it would have been preferable to have data on non-publishing personnel included, the advantage of our approach is that the analysis is based on people who evidently are active researchers. Moreover, biases caused by mobile researchers are reduced. When a researcher is newly appointed at a particular university, it usually takes some time before the research ends up in publications.

In the analysis, all persons were assigned to five major fields; the humanities, social sciences, natural sciences, engineering and technology and medicine (cf. Table 1). This assignment was based on the departments' reporting of their scientific profile in national R&D statistics (departments select from a list of 58 scientific subfields within the five main domains). We have previously analysed publication rate at subfield levels, partly based on the same data material. This analysis shows that the largest differences in publication patterns and rates are found across the broad fields (Piro, Aksnes, & Rørstad, 2013). Within each field the publication pattern is more uniform, although with notable exceptions. Based on these findings we decided not to include subfield as a variable in the present study.

Publication output has been measured as article equivalents per person per year. In this calculation, co-authored publications are fractionalised among the authors. Moreover, monographs are weighted as equal to five articles (in journals or books) in order to make the research efforts behind different types of publications comparable. The weighting of books is based on Kyvik's summary of such weighting procedures from other studies, which shows that most studies equate 4–6 articles to one full monograph (Kyvik, 1991). The Norwegian and Danish performance based funding model also equals one

[1] The list can be downloaded at: https://dbh.nsd.uib.no/publiseringskanaler/Forside?sok.avansert=true&request_locale=en.

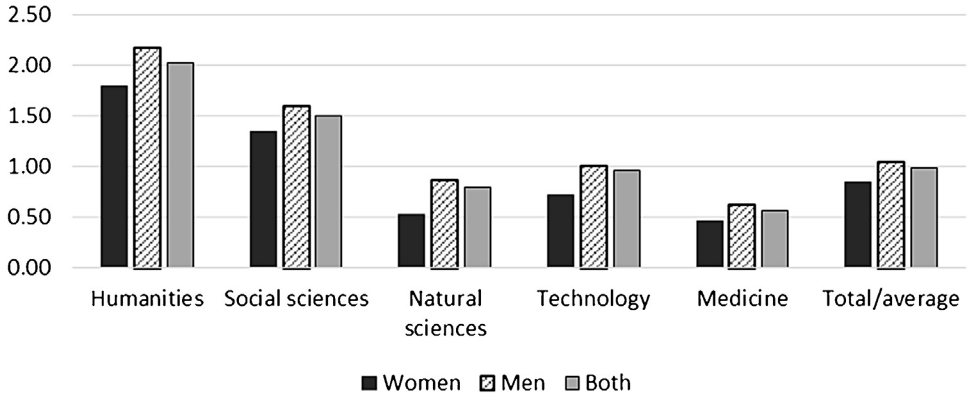

Fig. 1. Article equivalents (mean) by fields and gender ($N = 35,798$).

monograph with five regular journal articles (Sivertsen, 2010). In the Flemish performance-based funding system for university research books are assigned a weight factor of 4 articles (Engels, Ossenblok, & Spruyt, 2012). The weighting principle is admittedly somewhat random as no empirical investigation has been carried out of the time and efforts needed for different types of publications. It should be noted that monographs accounts for a very small proportion of the publications, overall 2.6 per cent, and only in the humanities and the social sciences this publication type has a certain volume (proportions: 10.5 and 6.6 per cent of the observations). We have shown the publication pattern for books weighted in Fig. 1 and non-weighted in Fig. 2.

In our analysis, we included four main academic positions: professors, associate professors, postdocs and PhD students. In addition, physicians/medical doctors were included for medicine. The researchers were divided into 5-year age categories. Although we might lose some of the information, age intervals simplify the descriptive presentation and are easier to interpret. The descriptive statistics also show that the age categories behave linearly. It should also be added that there is a time-lag from the research is carried out till the research appear as published articles (usually 1–2 years or longer).

Our study involves cross-sectional data. We have analysed a 7-year period but have used annual publication counts and have not traced the development of the publication rate of the individual researchers over a period. For each researcher there is a maximum of seven observations, but for many individuals we have fewer observations because they have not been employed during the entire period or have not published particular years (cf. Table 1). The age and position of the researchers have been adjusted accordingly. For example, a person who was promoted from associate professor to full professor in 2009 is included as an associate professor for the 2005–2008 observations and as a professor for the 2009–2011 observations. Cross-sectional methodology is generally regarded as having more weaknesses than longitudinal methodology (Allison & Stewart, 1974; Stephan, 1996). No doubt, a longitudinal study would have provided interesting complementary results. As the study does not focus on analysing changes in publication rate at the individual level over time, we have chosen a cross-sectional approach. It should also be added that the norms for publication behaviour have changed during recent decades (e.g. by an increasing number of authors per publication and number of publications per person (Kyvik & Olsen, 2008)), and this complicates the interpretation of results obtained by longitudinal methods.

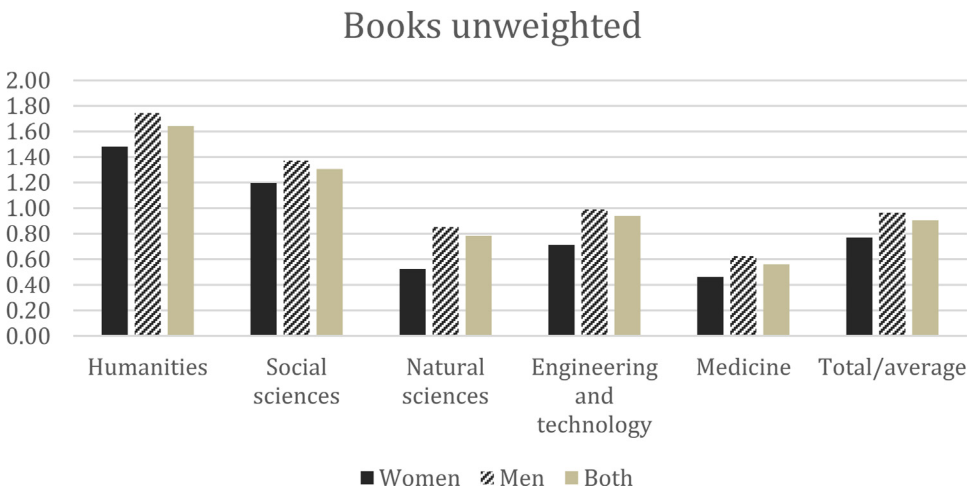

Fig. 2. Article equivalents (mean) (books unweighted) by fields and gender ($N = 35,798$).

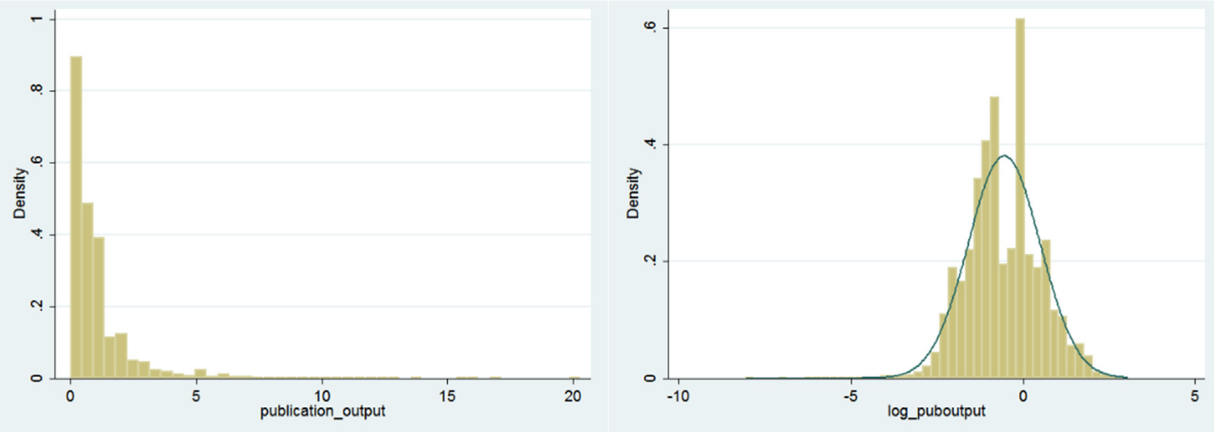

Fig. 3. Distribution of numbers of average article equivalents per person per year and natural logarithmic numbers (N = 35,798).

In order to be able to make regression models on our data, we recoded our variables. First, positions were recoded to numerical categorical variables, then dummy variables were used for each position (1 if present and 0 if not present). Gender was also recoded the same way (men = 0 and women = 1). Age groups were categorised into an ordinal variable i.e. 20–24 years = 1, 25–29 = 2, 30–34 = 3 and so forth. The response variable ranged from 0.0003 to 20.33, which after log transformation amounted to between −8.06 and 3.01.

The publication rate varies significantly among the individuals, and is not normally distributed. A histogram of our publication indicator shows a positive skew in Fig. 3. A common way to eliminate skewness is to transform the data to naturally logarithmic scale. Density charts of the logarithmic of the publication indicator for each major field are shown in the Annex. These charts show that the observations for natural sciences, engineering and technology and medicine, have a normally distributed shape. However, for the humanities and social sciences, the logarithmic of the publication rate was not normally distributed. This means that the data in the latter two fields violate linear regression assumptions and such regression analysis can only be conducted with satisfactorily results in the first three fields.

We analysed the publication output by fields of sciences, academic position, age groups and gender. Regression analysis was performed on three of the major fields separately in order to investigate whether one regression model is valid for all fields.

Since we previously have found that age and publication rate often have a curvilinear relationship, we include the power of age in our regression model. Our assumption that publication rate (number of article equivalent per person per year) is a function of gender, age and scientific position, our regression model can be written as:

$$\mathrm{Log}(Y) = \beta_0 + \beta_1 * \mathrm{age} + \beta_2 * \mathrm{age}^2 + \beta_3 * \mathrm{gender} + \beta_4 * \mathrm{position} + \varepsilon \quad (1)$$

We recognise that a reverse causality between publication rate and academic position may be present, as scientific publication output is one of several criteria for advancement within the academic career system. In order to investigate this problem further, we rearranged the data in such way that one researcher represented one observation. A new “career-change-variable” was also introduced. Out of the 12,304 researchers, 10,594 researchers, accounting for about 85 per cent, had the same position throughout the period, whilst the rest, 1809 (i.e. 15 per cent) had a career change during the period. The purpose of this analysis was to investigate whether researchers with a career change had a higher average publication rate in term of publication output, than those who were in the same academic position.

The result of the analysis showed that a career change did not have any effect on publication rate as this variable was not significant for none of the major field. The publication rate for each researcher can therefore be related by the position the researcher had during the studies time period. Our data are thus suitable to examine publication rate by academic levels.

3. Results

The distribution of the population by fields in terms of numbers of researchers and observations is given in Table 1. Medicine is the largest field and accounts for about one-third of the population, in terms of both persons (4021) and observations (11,974). With about 1340 persons and about 3700 observations, humanities is the smallest field, but with a sufficiently large population to analyse separately.

Fig. 1 shows the average numbers of article equivalents per person per year by gender and fields. This figure shows that there are major inequalities in the publication rate across fields. Corresponding results were also found by Piro et al. (2013), and justify the decision to carry out regression analysis of each field separately.

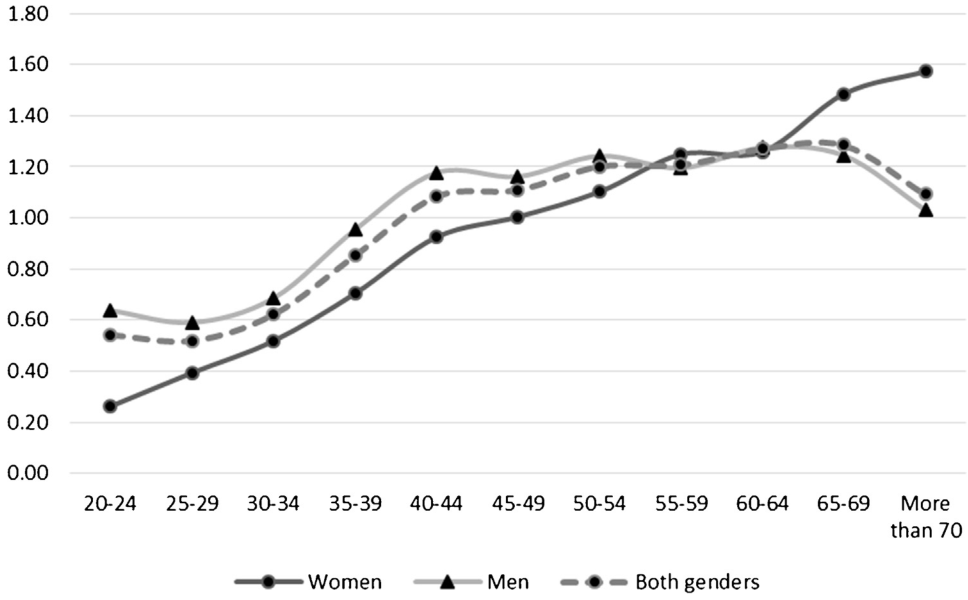

Fig. 4. Article equivalents (mean) by gender and age groups for all fields ($N = 35{,}798$).

Fig. 4 shows the publication rate for the whole population by age group and gender. The publication rate of women increases continuously by age, in an almost straight line (the lower darker line in Fig. 4), while the publication rate of men shows a curvilinear shape. Overall men have higher publication rate than women up to the age of 55–59 years.

The persons over 70 are mainly emeritus professors who have formally retired. Only the persons who are still active researchers are included (i.e. have published at least one publication). It should be noted that this group of persons is rather heterogeneous and the extent they are still involved in research may vary. Some are very active and spend much time on research, others do research only occasionally. The total number of observations by this group is 673, or less than 2 per cent, and do not make any difference for the analysis. Hence, they were not excluded from the data.

3.1. Analysis of natural sciences

Table 2 shows the average number of article equivalents per person per year by academic position and gender. Overall, we can observe an increase in publication rate from PhD students to professors in the natural sciences. Moreover, for all positions female scientists tend to have lower publication rates than their male colleagues. On average, men have 0.34 more article equivalents annually than women. The overall gender difference is larger than in the individual position categories due to a larger share of female researchers in the categories with lowest publication rate (PhD students and postdocs).

Divided by age groups, curvilinear relationships between publication rate and age can be seen with several peaks. In addition, men have higher publication rate than women in all but one age interval.

In order to test whether these variables can be used to predict the publication rate level, we carried out an ordinary least squares regression analysis. The results from our regression model show that both gender and academic position are statistically significant variables, while age and age squared are not. As seen in Fig. 5, the publication rate does not have a linear or a curvilinear relationship as assumed. The change in publication rate in per cent, caused by a variable, is given by the unstandardised regression coefficient B, and can be expressed as $e^B - 1$. The regression analysis thus shows that women publish about 22 per cent fewer publications (article equivalents) on average than their male colleagues are at same age and

Table 2
Article equivalents (mean) by academic position and gender in the natural sciences ($N = 9558$).

Academic position	Women	Men	Both genders	Diff., men – women
Professors	0.91	1.14	1.11	0.23
Associate professors	0.61	0.86	0.80	0.25
Postdocs	0.44	0.65	0.59	0.21
PhD students	0.35	0.48	0.43	0.13
Total/average	0.53	0.87	0.79	0.34

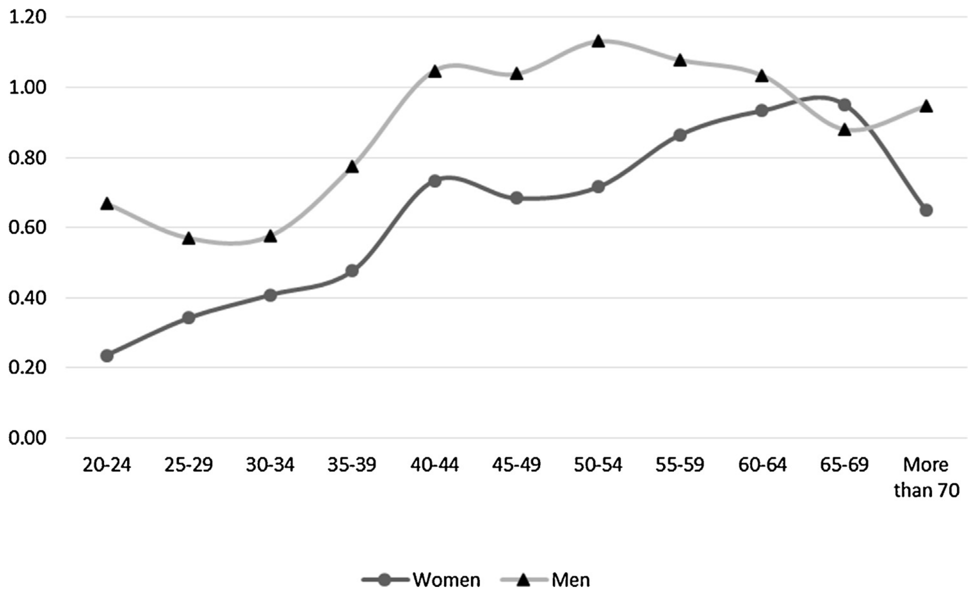

Fig. 5. Article equivalents (mean) by gender and age groups in natural sciences ($N = 9558$).

Table 3
Regression analysis of natural sciences.

Variables	Std. beta	*B* coef.	Std. Err.	*t*-Value	$P > t$	[99 per cent Conf. Int.]	
Age group	−0.06	−0.02	0.025	−0.97	0.332	−0.074	0.025
Age group squared	−0.06	0.00	0.002	−1.11	0.266	−0.006	0.002
Gender	−0.10**	−0.25	0.024	−10.42	0.00	−0.301	−0.206
Professors	0.16**	0.33	0.032	10.47	0.00	0.271	0.395
Associate professors	*Ref. value*						
Postdocs	−0.17**	−0.44	0.038	−11.52	0.00	0.164	0.289
PhD student	−0.29**	−0.66	0.040	−15.81	0.00	−0.746	−0.582
Constant term		−0.32	0.058	−3.79	0.00	−1.099	−0.869

R-squared = 0.1345, *F*-value = 247.33, *N* = 9558.
** Significant at 0.01 level.

in same academic position. Moreover, professors have on average about 40 per cent higher publication output than associate professors, while postdocs and PhD students have about 35 and 50 per cent lower, respectively (Table 3).

3.2. Analysis of engineering and technology

Table 4 shows that researchers within engineering and technology have slightly higher publication rate (with 0.96 article equivalents per person per year) than their colleagues within natural sciences (with 0.79) (see also Fig. 1 and Fig. 2). Not surprisingly, professors are the most prolific personnel, followed by associate professors, postdocs and PhD students. In this field, women account for less than 20 per cent of the observations and they publish 0.30 less article equivalents on average than men. The gender differences in publication rate range from 0.08 for professors to 0.20 for postdocs.

Table 4
Article equivalents (mean) by academic position and gender in engineering and technology ($N = 4754$).

Academic position	Women	Men	Both genders	Diff., men – women
Professors	1.47	1.55	1.54	0.08
Associate professors	1.07	1.09	1.09	0.02
Postdocs	0.62	0.82	0.78	0.20
PhD students	0.52	0.61	0.59	0.09
Total/average	0.71	1.01	0.96	0.30

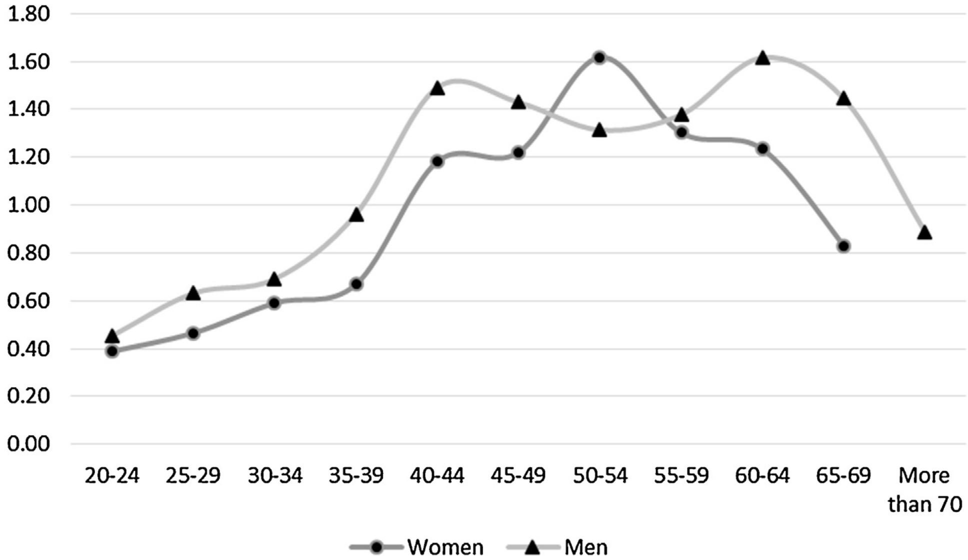

Fig. 6. Article equivalents (mean) by age groups in engineering and technology ($N = 4754$).

If we look at publication rate by age, there are different patterns for men and women (cf. Fig. 6). For both genders, publication rate increases by age up to about 40–44 years, then declines for men, while women remain at the same publication rate for their next 5 years. While women reach a publication peak around their mid-fifties, their male colleagues have a slight decrease, and then further increase their publication output rate to a peak in their sixties. This publication pattern indicates that age and age squared should be included in a regression analysis for predicting publication rates in engineering and technology.

The regression analysis of engineering and technology gives a model where all variables are significant. The size and sign of the beta coefficients provide information on the extent publication rate correlates to each of the independent variables. All of the variables are significant and both age and age squared are more influential statistically than gender. However, by comparing the regression coefficients, the difference between men and women is slightly larger ($B = 0.17$) than at 5 years older ($B = 0.12$). As for the natural sciences, professors are the most prolific personnel in engineering and technology, and a corresponding pattern of declining publication rates can be seen within the hierarchy of academic positions. Explained variance in this model is about 15 per cent, and the model is slightly more powerful than what we found for natural sciences (13.5 per cent) (Table 5).

3.3. Analysis of medicine

Table 6 shows the publication rate by academic position and gender within the field of medicine. Overall men have higher publication rate than their female colleagues, but female professors and associate professors are slightly more productive than their male colleagues. On average, a male researcher within medicine publishes 0.63 articles per year, while a female researcher produces 0.47 articles, which gives a difference of 0.16 articles per year.

Table 5
Regression analysis of engineering and technology.

Variables	Std. beta	*B* coef.	Std. Err.	*t*-Value	*P* > *t*	[99 per cent Conf. Int.]	
Age group	0.31**	0.12	0.03	3.8	0.00	0.06	0.18
Age group squared	−0.33**	−0.01	0.00	−4.58	0.00	−0.02	−0.01
Gender	−0.07**	−0.17	0.03	−5.18	0.00	−0.23	−0.10
Professors	0.16**	0.31	0.05	6.12	0.00	0.21	0.41
Associate professors	*Ref. value*						
Postdocs	−0.13**	−0.32	0.06	−5.73	0.00	−0.43	−0.21
PhD student	−0.24**	−0.43	0.06	−7.72	0.00	−0.54	−0.32
Constant term		−0.55	0.10	−5.34	0.00	−0.75	−0.35

R-squared = 0.1509, *F*-value = 140.56, *N* = 4754.
** Significant at 0.01 level.

Table 6
Article equivalents (mean) by academic position and gender in medicine (N = 11,974).

Academic positions	Women	Men	Both genders	Diff., men – women
Professors	0.97	0.95	0.96	−0.01
Associate professors	0.71	0.66	0.69	−0.05
Postdocs	0.40	0.47	0.43	0.07
PhD students	0.28	0.31	0.29	0.04
Medical doctors/physicians	0.38	0.50	0.47	0.12
Total/average	0.47	0.63	0.57	0.16

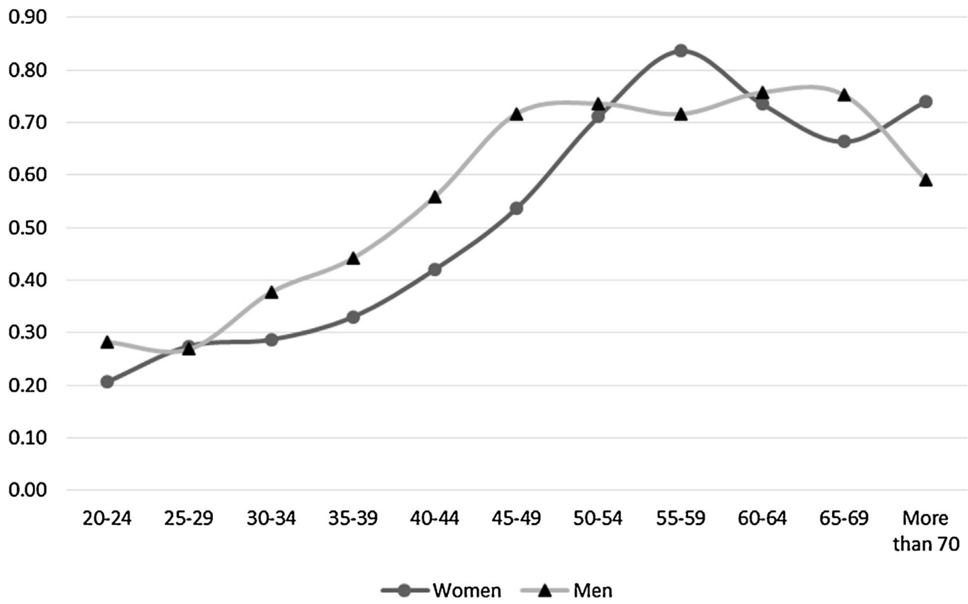

Fig. 7. Article equivalents (mean) by age groups, medicine (N = 11,974).

Scientific publication rate as a function of age is shown in Fig. 7. The publication rate pattern is similar to the one found for engineering and technology. Women (the darker grey line) have lower publication rate than their male colleagues within the same age group, up to their mid-fifties. Then they become equally productive, and in their late fifties a publication rate peak can be seen, where female researchers have higher publication rate than their male colleagues.

The results of the regression analysis are shown in Table 7. About 19 per cent (R-squared = 0.1895) of the variance is explained in our regression model, and is thus a little more powerful than the models for both natural sciences and engineering and technology. All variables are also shown to be significant. Age and its squared term is the most important variable, followed by academic position, while gender is the least important variable – but still significant. The average

Table 7
Regression analysis of medicine.

Variables	Std. beta	*B* coef.	Std. Err.	*t*-Value	*P* > *t*	[99 per cent Conf. Int.]	
Age group	0.40**	0.15	0.018	8.31	0.00	0.117	0.190
Age group squared	−0.35**	−0.01	0.001	−7.72	0.00	−0.014	−0.008
Gender	−0.04**	−0.08	0.017	−4.9	0.00	−0.117	−0.050
Professors	0.15**	0.31	0.032	9.54	0.00	0.243	0.369
Associate professors	*Ref. value*						
Postdocs	−0.12**	−0.35	0.037	−9.56	0.00	−0.422	−0.279
Medical doctors/physicians	−0.20**	−0.40	0.031	−13.02	0.00	−0.466	−0.344
PhD student	−0.28**	−0.59	0.034	−17.24	0.00	−0.656	−0.522
Constant term	–	−1.23	0.066	−18.68	0.00	−1.360	−1.102

R-squared = 0.1895, F-value = 39.61, N = 11,974.
** Significant at 0.01 level.

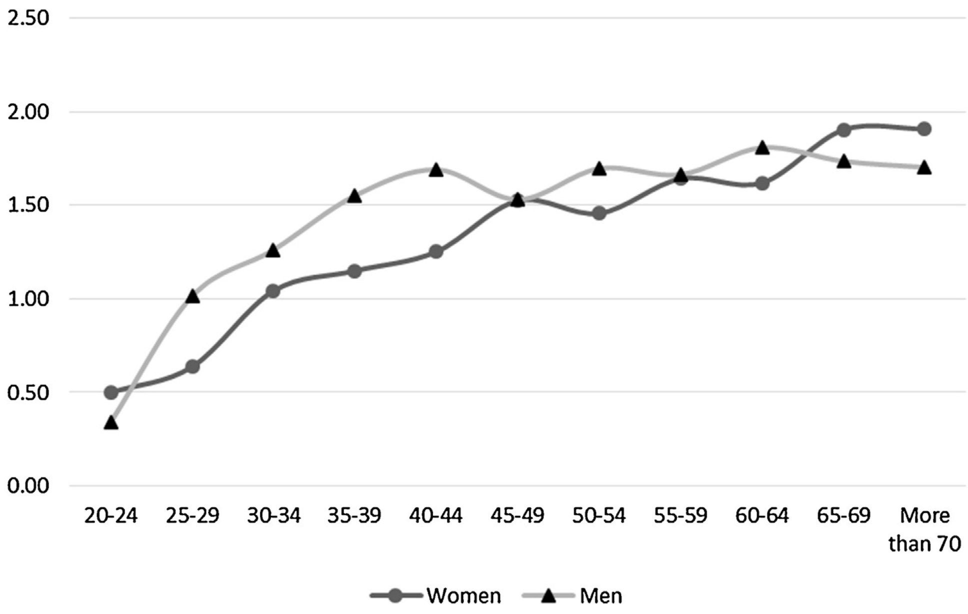

Fig. 8. Article equivalents (mean) by age groups, social sciences ($N = 5821$).

difference in publication rate between the genders is only 8 per cent in favour of men; however at 5 years older the publication rate of both men and women will on average increase by 17 per cent.

3.4. Analysis of social sciences

As shown in Fig. 1, researchers in social sciences have higher publication rate than researchers in the natural sciences, engineering and technology and in medicine in terms of article equivalents. While a researcher in social sciences produces on average 1.5 articles per year, colleagues in the hard sciences produced somewhere between 0.6 and 1.0 articles per year on average. One possible explanation for these differences is a different publication pattern in the social sciences compared with the previously studied fields. In the social sciences, one publication has in general fewer authors than a publication in medicine, natural sciences and technology. In addition, researchers in the social sciences publish more monographs.

On average, a professor publishes about 1.77 article equivalents per year. In contrast to the other major fields, postdoc fellows have higher publication rate than the associate professors, with 1.53 and 1.44 article equivalents, respectively. PhD students have on average 0.96 article equivalents per year. For all academic positions, men have slightly higher publication rate than their female colleagues, on average 0.25 publications per person per year.

Publication rate versus age for researchers in the social sciences is shown in Fig. 8. Overall, the publication rate shows a less steep increase by age compared with the hard sciences, but male researchers have higher publication rate than their female colleagues at the same age, except for at the end of their career.

3.5. Analysis of humanities

Scholars in the humanities have overall higher publication rate than research personnel in all the other major fields (see Fig. 1). On average, a researcher within this field produces 2.02 article equivalents per year, which is twice as much as the average for the whole population of all fields. The main reason is a different publication pattern, which has similarities to the one found for the social sciences, albeit with an even higher proportion of monographs. The publication rate versus age for researchers in the humanities is shown in Fig. 9.

Male professors publish on average 2.39 article equivalents per year, and have higher publication rate than their female colleagues, who have an average output of 2.08 article equivalents per year. Male professors publish on average 2.52 article equivalents per year, and have higher publication rate than their female colleagues, who have an average output of 2.08 article equivalents per year (Table 9). Male PhD students are also slightly more productive than females, but for associate professors and postdocs, the gender difference is minor.

The publication rate pattern as a function of age and gender shows that male researchers have higher publication rate than their female colleagues for all age groups except in their early forties. Overall, the publication rate increases by age, but the relationship is not linear, and the curve has several peaks.

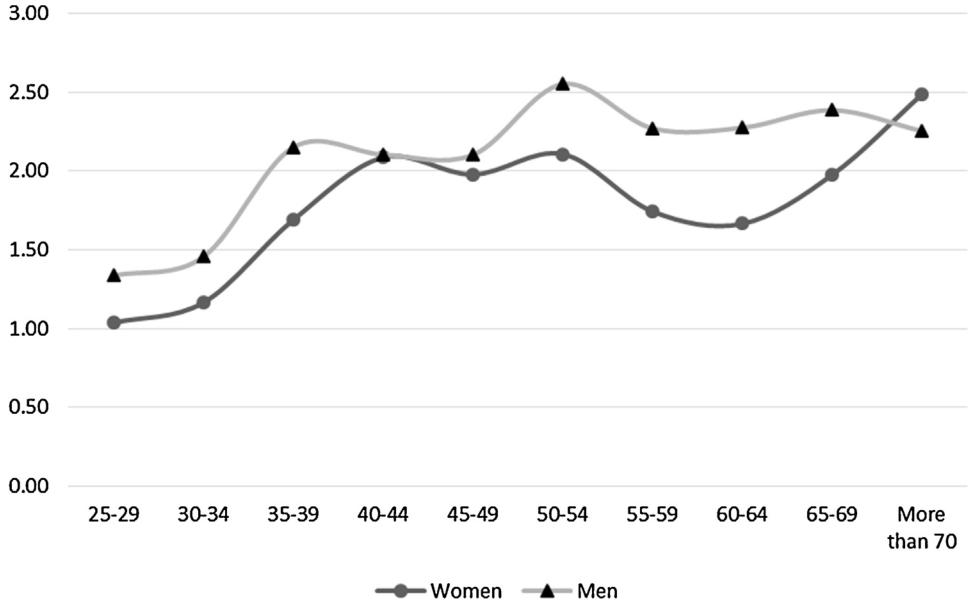

Fig. 9. Article equivalents (mean) by age groups in the humanities ($N = 3691$).

3.6. Regression analysis – comparative perspectives

The regression analysis shows that the variables have different influence on the average publication rate when comparing fields. While age seems to be an important variable in both technology and medicine, it does not have the same importance in natural sciences, compared to the other variables analysed. The publication rate difference between male and female is however significant for the three mentioned field, with the largest gender differences in natural sciences and the lowest in medicine. In natural sciences, age is not significant while gender accounts for 22 per cent of the publication rate difference between male and female scientists, when all other variables are constant. The publication rate difference between gender in engineering and technology is 15 per cent in favour of men. For a scientist in technology, a 5-year age interval, accounts for 12 per cent higher publication output, on average. In the medical field, the difference in publication rate is rather small between men and women, with only 8 per cent in favour of men. Getting 5 years older will however, account for about 17 per cent in increased publication output, on average.

If we look at the publication rate differences between professors and associate professors, it is about the same for the three major fields (*B*-coefficients around 0.31–0.33) equals to around 35–40 per cent in favour of professors. Associate professors publish again, more than their less experienced colleagues who are in postdoc-positions, and the difference is almost identical for the natural sciences and engineering and technology ($B = -0.44$ i.e. 35 per cent less) while it is a bit less in medicine ($B = -0.35$ i.e. 30 per cent). The publication rate differences between PhD student and associate professors are larger across the fields. The largest difference is found in natural sciences ($B = -0.66$ equals to 48 per cent) while it is smallest in engineering and technology ($B = -0.43$ equals to about 35 per cent).

In the academic system, there is a hierarchy where one starts as a PhD student and end up as professor. This means that the two explanatory variables academic position and age may be highly correlated with each other (collinearity). In the analysis, particular attention has been directed towards this potential problem. Table 13 shows the age distribution in per cent for each academic position. Table 14 shows the correlation between each of the variables. The largest positive correlation is between age and professors with the value of 0.6, while the correlation between age and PhD students is equally associated negatively. Not surprisingly, the younger researchers are mainly holding junior positions such as PhD and postdoc fellowships, while the elder and more experienced researchers are associate and full professors. However, the researchers in each of the academic positions are included in several age groups (for example, professors in age groups from 30 to 70 years, and PhD students from 20 to 50 years). For this reason, we have include age as an explanatory variable in the regressions to be able to measure the effect of this variable within each of the academic positions. In addition, new regressions without age and age squared were conducted for each of the three major fields. If we compare the new regression results with the results where age and age squared were included in the regressions, we find only minor differences. The standard errors for each of the position variables remained at the same level, and the explained variance (*R*-squared) slightly dropped when age and age squared were excluded. For example, in the field medicine, the regression analysis without age and age squared, resulted in an *R*-squared value of 0.17. This indicates that including age and age squared only contribute to a minor part of the publication rate. However, the *B*-coefficient for professors increased significantly when age and age squared were excluded, from 0.31 to 0.63. Overall, the results of this analysis indicate that the collinearity between age group and academic position is of relatively minor importance.

4. Discussion and conclusions

As described in Section 1, a large number of previous studies have analysed publication rate at an individual level. Overall, our findings confirm several of the established findings on this issue: the differences among genders, age groups and types of academic personnel.

A persistent finding is that female researchers tend to publish fewer publications than men. Based on a review of several studies completed since the 1990s, Larivière, Vignola-Gagné, Villeneuve, Gélinas, and Gingras (2011) conclude that women tend to publish between 70 and 80 per cent as many publications as men. This is also in the range of what we have found in this large-scale study of more than 12,000 Norwegian university researchers. Female researchers have overall approximately 20 per cent lower publication counts than men, although there are significant variations across fields and academic positions. The descriptive statistics (Tables 2, 4, 6, 8 and 10) show that there are seven categories (combinations of academic positions and fields) where female researchers have 20–32 per cent lower publications counts than men, six categories where the publication counts are 10–20 per cent lower publication counts, and six categories with 0–10 per cent difference. In addition, there are two categories with a contrary pattern where female researchers have slightly higher publication counts than men (2–8 per cent higher). The deviating findings of van Arensbergen et al. (2012) (cf. Section 1) that young female researchers are more productive than young male researchers do not find support in our study. However, *within* an age group the gender differences in publication rate are usually smaller than when the whole population is analysed. This is due to the fact that there are relatively more women in junior positions (Table 11).

Also when it comes to publication differences within the hierarchy of academic positions our results corroborate the findings of several previous studies (see e.g. Aksnes et al., 2011; Allison & Stewart, 1974; Kyvik, 1991; Tien & Blackburn, 1996). Professors are the most prolific personnel in all fields analysed and across both genders. Our results show that the

Table 8
Article equivalents (mean) by academic position and gender in social sciences ($N = 5821$).

Academic position	Women	Men	Both genders	Diff., men – women
Professors	1.72	1.79	1.77	0.07
Associate professors	1.38	1.49	1.44	0.10
Postdocs	1.45	1.65	1.53	0.20
PhD students	0.81	1.11	0.96	0.30
Total/average	1.35	1.60	1.51	0.25

Table 9
Article equivalents (mean) by academic position and gender in humanities ($N = 3691$).

Academic position	Women	Men	Both genders	Diff., men – women
Professors	2.08	2.52	2.39	0.44
Associate professors	1.83	1.92	1.88	0.09
Postdocs	1.85	1.94	1.89	0.08
PhD students	1.12	1.31	1.22	0.19
Total/average	1.79	2.17	2.02	0.38

Table 10
Regression summary for natural sciences, engineering and technology and medicine.

B-coefficients	Natural sciences	Engineering and technology	Medicine
Variables			
Age group	−0.02	0.12	0.15
Age group squared	0.00	−0.01	−0.01
Gender	−0.25	−0.17	−0.08
Professors	0.33	0.31	0.31
Associate professors ref.			
Postdocs	−0.44	−0.44	−0.35
PhD student	−0.66	−0.43	−0.59
Physicians			−0.40
R-squared	0.13	0.15	0.19

publication rate of associate professors is generally 20–30 per cent lower than the one of the professors (varying from 19 per cent for the social sciences to 29 per cent for engineering and technology). Postdocs have a clearly lower publication rate than associate professors in three of the fields analysed, while it is almost identical or slightly higher in the other two. Naturally, the publication rate is lowest for the group of PhD students, this holds for all fields analysed.

In terms of publication frequency, our study has revealed quite large age differences. The publication rate increases with time, typically to the age of 40–50 in the fields analysed.

As described in Section 1, several previous studies have identified an inverted U-shaped publication pattern (e.g. Cole, 1979; Costas, van Leeuwen, & Bordons, 2010; Fox, 1983). One previous study (Diem & Wolter, 2013) found that both physical age and academic age (i.e. years after obtaining a PhD degree) have an effect on publication rate.

Is some of the field analysed we also find an age-related rise and decline pattern. This is most distinct in engineering and technology (Fig. 6). However, there are also fields where the publication rate does not decline for the oldest personnel (e.g. the social sciences, Fig. 8). This means that we cannot interpret age decline as a general finding of our study. Within the scope of this article, we are not able to discuss possible reasons for the patterns identified, but various theories have been developed both to explain gender and age differences in productivity (see e.g. Kyvik, 1991).

Scientific publication rate is strongly skewed at the level of individuals: this holds for all fields, positions and age groups. Our study has shown that publication rate in terms of article equivalents can be expressed as a function of gender, age, age squared and academic position in all the fields investigated (the natural sciences, engineering and technology, and medicine). The amount these variables can account for the change in publication rate, varies from 13.5 per cent for natural sciences, 15 per cent for engineering and technology and 19 per cent for medicine. This shows that our models have reasonable explanatory power. We have found that age and academic position are more important than gender statistically, though all variables are significant.

In the analysis, we have focused on three variables that have been shown to be important in previous studies. The data material consists of researchers of four different Norwegian universities. However, we did not include institution as a variable. As the selected universities do not differ in terms of working conditions and time available to spend on research, we did not expect any significant differences between the institutions in terms of publication rate. In a second regression analysis, we did include institution as a variable to control for organisational differences in terms of publication rate. This second analysis showed no or only minor, improvements to our models.

Although there are no overall differences at institutional level when it comes to working conditions and time available for research, there are important variations at the level of positions. Norwegian R&D statistics also include data on time available for research, according to academic positions, institutions, and domains (R&D equivalents). These data show that tenured personnel tend to have ~40 per cent of their time to spend on research, while the figures for PhD students and postdocs are around 70–80 per cent. These differences are mainly due to the fact that the tenured personnel have much greater teaching obligations. If we had applied the R&D equivalents on the publication data in our study, the differences in the publication rate levels across groups of academic personnel would have been even larger. On the other hand, it is not uncommon that PhD students and postdocs carry out much the time consuming empirical investigations (e.g. laboratory and field work) while the tenured scientific staff are managing the project. Within a research group led by a professor, the professor will typically get her/his name on all publications produced by the group, while the PhD students and postdocs will be authors only in the publications they have been directly involved in (Kyvik, 1991).

It can be concluded that most of the variance in publication rate at the individual level is due to other factors than those investigated. Previous studies have suggested that publication rate also depends on a wide range of factors that cannot easily be measured, such as: the availability of research funds; teaching loads; equipment; research assistants; workload policies; departmental culture and working conditions; organisational context; and talent and hard work (see e.g. Dundar & Lewis, 1998; Kyvik, 1993; Ramesh & Singh, 1998). Moreover, the process of cumulative advantage (Merton, 1968) implies that minor differences early in a career may result in substantial differences in achievement by the end of a career. Success in scientific careers may depend on the ability of the scientists themselves but also on luck (cf. the distinction between *virtu* and *fortuna* by Turner & Chubin, 1979). Publication rate studies at an individual level that do not take all factors into account can therefore only show part of the picture.

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Annex.

See Tables 11–15 and Fig. 10.

Density charts of the logarithmic of the publication output indicator for each major field are shown in Fig. 10.

Table 11
Numbers of observations by field of science, position and gender.

Field of science/position	Women	Men	Total
Humanities	1434	2257	3691
Professor	512	1228	1740
Associate professor	459	577	1036
Postdoc	200	176	376
PhD student	263	276	539
Social sciences	2240	3581	5821
Professor	764	2006	2770
Associate professor	609	812	1421
Postdoc	299	226	525
PhD student	568	537	1105
Natural sciences	2066	7492	9558
Professor	428	3501	3929
Associate professor	323	1067	1390
Postdoc	505	1244	1749
PhD student	810	1680	2490
Engineering and technology	849	3905	4754
Professor	118	1378	1496
Associate professor	64	329	393
Postdoc	163	532	695
PhD student	504	1666	2170
Medicine	4645	7329	11,974
Professor	719	2463	3182
Associate professor	511	446	957
Postdoc	743	640	1383
PhD student	1926	1171	3097
Physician/medical doctor	746	2609	3355
Total	11,234	24,564	35,798

Table 12
Numbers of observations (article equivalents) by fields and age groups ($N = 35{,}798$).

Field of sciences	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	More than 70	Total
Humanities		100	355	497	449	424	429	477	516	372	72	3691
Natural sciences	33	1222	1964	1311	929	963	918	776	709	524	209	9558
Medicine	15	694	1682	1547	1360	1422	1569	1470	1268	708	239	11,974
Social sciences	3	194	685	749	686	730	787	753	690	435	109	5821
Engineering and technology	25	1069	1306	552	462	337	310	232	248	169	44	4754
Total	76	3279	5992	4656	3886	3876	4013	3708	3431	2208	673	35,798

Table 13
Distribution of observations by academic positions and age groups, per cent by age group ($N = 35{,}798$).

Academic position	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	More than 70
Professors	0	0	0	3	8	15	19	19	19	13	4
Associated prof	0	0	6	18	20	17	13	11	8	5	1
Postdoc	0	5	38	34	14	5	2	1	0	0	0
PhD	1	32	39	15	7	3	2	1	0	0	0
Physicians	0	1	4	9	13	16	17	17	14	6	2
Total	0	9	17	13	11	11	11	10	10	6	2

Table 14
Correlation matrix.

	Publication output	Age group	Age group squared	Gender	Professor	Ass prof	Postdoc	Physicians
Publication ouput	1.00							
Age group	0.25	1.00						
Age group squared	0.24	0.99	1.00					
Gender	−0.01	−0.16	−0.17	1.00				
Professors	0.33	0.61	0.61	−0.20	1.00			
Ass prof	0.11	0.06	0.06	0.06	−0.31	1.00		
Postdoc	−0.08	−0.28	−0.28	0.08	−0.30	−0.16	1.00	
Physicians	−0.19	0.15	0.15	−0.06	−0.24	−0.13	−0.13	1.00
PhD	−0.27	−0.60	−0.60	0.15	−0.45	−0.13	−0.23	−0.19

Table 15
Observations by fields of sciences, academic position, age groups and age ($N = 35789$). W = women, M = men.

Age/gender	20–24		25–29		30–34		35–39		40–44		45–49		50–54		55–59		60–64		65–69		Above 70		Total
Field of sciences	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	
Humanities			44	56	152	203	235	262	213	236	182	242	152	277	149	328	159	357	128	244	20	52	3691
Professors						2	8	19	25	80	74	124	81	207	90	250	125	294	95	204	14	48	1740
Associate prof				1	9	27	76	103	97	94	85	105	61	65	58	75	34	63	33	40	6	4	1036
Postdoc			1	2	25	37	90	75	63	45	13	10	7	4	1	3							376
PhD			43	53	118	137	61	65	28	17	10	3	3	1									539
Social sciences	1	2	93	101	317	368	352	397	296	390	274	456	286	501	270	483	222	468	103	332	26	83	5821
Professors					4	7	8	48	46	145	106	272	154	380	171	388	168	397	84	290	23	79	2770
Associate prof			2		25	34	92	136	129	174	109	162	95	106	83	88	52	66	19	42	3	4	1421
Postdoc			3	3	58	74	113	93	67	36	28	6	21	8	7	4	2	2					525
PhD	1	2	88	98	230	253	139	120	54	35	31	16	16	7	9	3		3					1105
Natural sciences	9	24	410	812	581	1383	358	953	184	745	174	789	152	766	92	684	47	662	46	478	13	196	9558
Professors				3	3	13	14	115	59	366	109	591	100	642	62	582	35	590	37	426	9	173	3929
Associate prof		2	1	13	30	99	77	262	70	195	44	136	47	115	29	98	12	72	9	52	4	23	1390
Postdoc	1		38	86	221	571	191	415	37	126	13	42	3	4	1								1749
PhD	8	22	371	710	327	700	76	161	18	58	8	20	2	5		4							2490
Engineering and technology	3	22	247	822	285	1021	124	428	79	383	49	288	27	283	14	218	15	233	6	163		44	4754
Professors					1	10	11	90	29	203	31	200	16	252	10	203	14	222	6	154		44	1496
Associate prof				2	21	36	8	74	14	94	9	63	7	25	4	15	1	11		9			393
Postdoc			8	52	82	299	48	121	20	44	5	12		4									695
PhD	3	22	239	768	181	676	57	143	16	42	4	13	4	2									2170
Medical and health sciences	7	8	401	293	957	725	803	744	647	713	585	837	536	1033	350	1120	247	1021	94	614	18	221	11974
Professors					1	2	5	23	55	94	134	268	158	454	150	543	132	544	72	397	12	138	3182
Associate prof				1	17	18	57	74	104	94	91	61	106	74	58	62	67	34	8	23	3	5	957
Postdoc			16	14	234	208	262	220	119	102	57	60	35	24	16	6	3	5	1	1			1383
PhD	6	6	373	251	662	413	378	239	236	126	147	74	98	37	25	24	1	1					3097
Physicians	1	2	12	27	43	84	101	188	133	297	156	374	139	444	101	485	44	437	13	193	3	78	3355
Total	20	56	1195	2084	2292	3700	1872	2784	1419	2467	1264	2612	1153	2860	875	2833	690	2741	377	1831	77	596	35798

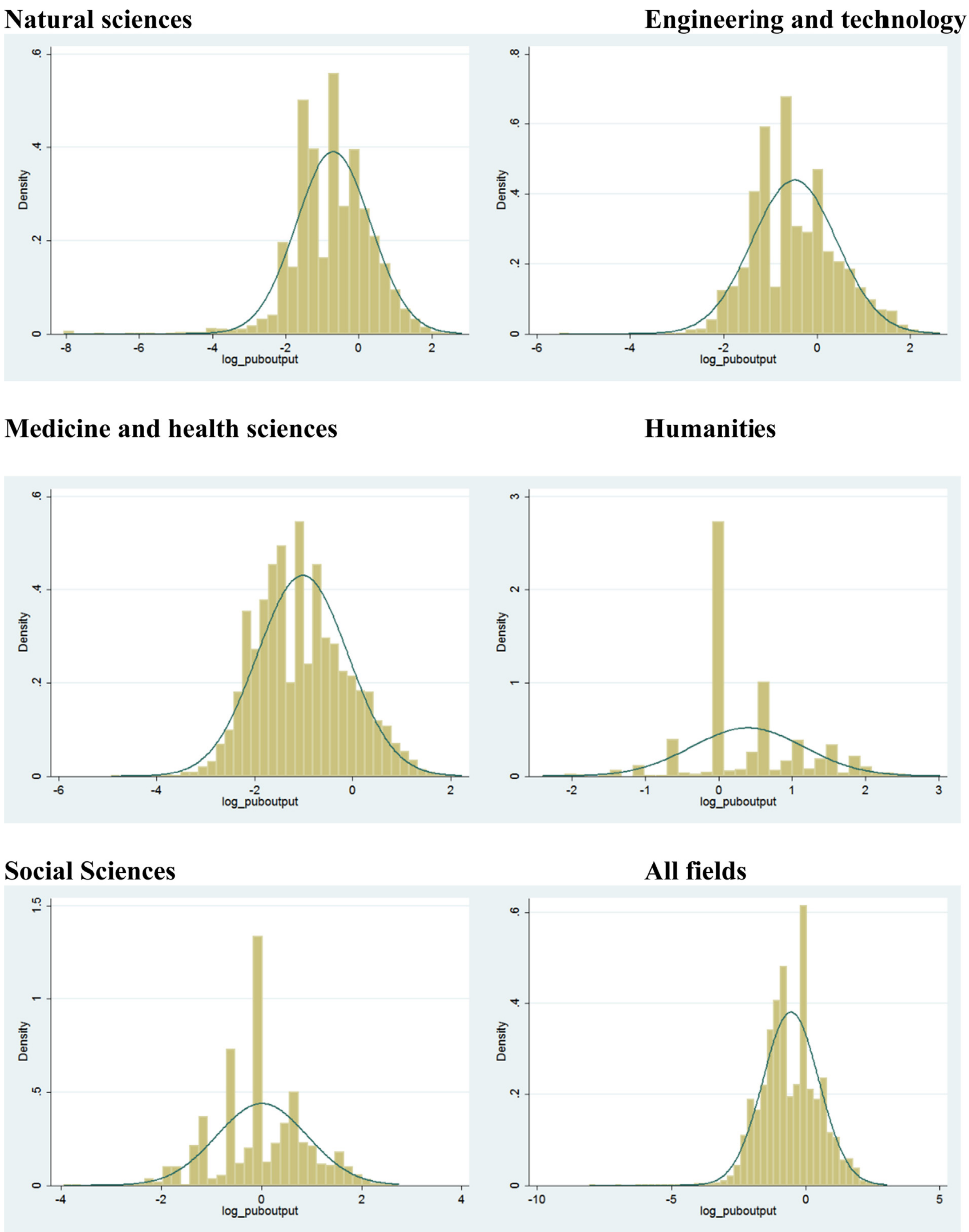

Fig. 10. Density charts log(article equivalents) of all major fields separately and for all fields.

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