frontiers in Education

ORIGINAL RESEARCH
published: 10 February 2022
doi: 10.3389/feduc.2022.809116

Gender Balance in Norwegian Academia: Present State and Future Scenarios

Kyrre Lekve[1]* *and Hebe Gunnes*[2,3]

[1] Simula Research Laboratory, Oslo, Norway, [2] NIFU Nordic Institute for Studies in Innovation, Research and Education, Oslo, Norway, [3] Division for R&D, Oslo Metropolitan University, Oslo, Norway

Gender balance (both sexes being represented by at least 40%) in academia has long been a goal. In this study, we present a model for the inert changes in the proportion of female full professors and associate professors at four research universities in Norway and stipulate future scenarios. Data from 1977 to 2019 were fitted to a sigmoid model. The results indicate that for all full professors, gender balance will be reached sometimes in the mid-2030s. Gender balance among all associate professors is already achieved. However, when the data is split into fields of research and development (fields of R&D), pronounced differences were seen. The results indicate that we will not achieve gender balance among full professors within humanities and the arts, while the proportion of female professors within Natural sciences and Engineering and technology cannot be properly modeled. Contrary, gender balance among associate professors will be achieved within all fields of R&D apart from engineering and technology, while natural sciences cannot be modeled properly. Essentially this model exercise illustrates what will happen with the gender balance in academia if no interventions are made. If so, we might not achieve gender balance in all fields of science.

Keywords: gender balance, women scientists, faculty women, gender inequity, doctoral labor supply, pipeline

Edited by:
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Minh-Hoang Nguyen, Phenikaa University, Vietnam

****Correspondence:***
Kyrre Lekve
kyrre.lekve@simula.no

Specialty section:
This article was submitted to Higher Education, a section of the journal Frontiers in Education

Received: *04 November 2021*
Accepted: *19 January 2022*
Published: *10 February 2022*

Citation:
Lekve K and Gunnes H (2022) Gender Balance in Norwegian Academia: Present State and Future Scenarios. Front. Educ. 7:809116. doi: 10.3389/feduc.2022.809116

INTRODUCTION

Women are consistently underrepresented in the top tiers of the academic world (European Commission DG Research, 2012; European Commission DG Research and Innovation, 2016). Gender imbalance has long been regarded as a problem, and achieving gender equality and empowering all women and girls has been included as the fifth of the 17 UN sustainable development goals adopted in 2015 by more than 150 world leaders (United Nations, 2017). A more gender equal society is perceived to have positive impact on the economy in terms of e.g., economic growth, employment, and productivity (European Institute for Gender Equality, 2017). Governments (e.g., Sweden; Silander et al., 2012) and public bodies strongly argues the importance of fulfilling the potential of women in academic disciplines (Sciences et al., 2007).

In Norway, the difference in employment rate between men and women is low (69.3% vs. 64.9%; Statistics Norway, 2017) and the male/female ratio in the Norwegian government has been close to 50/50 in most years since 1986. As a typical western country there has been more female than male students at Norwegian universities and colleges since the mid-1980s (Rees, 2001; Steinkellner, 2010). However, similar to other western countries, the gender balance in academic positions is far from equal (Rees, 2001; European Commission DG Research, 2012). In 2011, less than one out of four Norwegian full professors were women (Vabø et al., 2012), rising to 30% at the time of this investigation.

According to the Irish Justice department, "gender equality refers to the equal rights, responsibilities and opportunities of women, men, girls and boys. Gender equality is achieved when the different behaviors, aspirations and needs of women and men are equally valued and favored and do not give rise to different consequences that reinforce inequalities" (Department of Justice and Equality, 2017). In Sweden, a political definition of gender equality was formulated in the early 1970s, stating that equality is at hand when no sex makes up more than 40% of a certain group (Silander et al., 2012). We follow this definition when discussing gender balance.

There are numerous hypotheses for gender inequality in academia (see reviews in e.g., Kulis et al., 2002; Silander et al., 2012). Two approaches can explain why there are gender differences. The Human Capital theory (Becker, 1985), hypothesize that women's choices are influenced by expectation to balance work and family obligations, while the Socialization theory (Marini and Brinton, 1984), hypothesize that women and men are socialized into specific gender roles (Silander et al., 2012; see more in the discussion). Ruggieri et al. (2021) use similar concepts, respectively socio-demographic characteristics and women's role and participation in research activities, to analyze differential ratio of scientific production between men and women.

While this investigation examines representation of women in science, gender inequality can be observed in various aspects of academic life. In terms of scientific collaboration, previous work suggest that men and women tend to exhibit different collaborative behaviors across their scientific career, including collaboration patterns, position in the network, degree of homophilic behavior and tendency to have interdisciplinary collaborations (see e.g., Jadidi et al., 2018; Nguyen et al., 2021 for reviews and references). These differences favors males (Nguyen et al., 2021) and has been suggested to be caused by implicit biases and institutional practices (Bayer and Rouse, 2016). Women across the world report strikingly similar challenges in their academic work-life, including work-related stress, unfair work performance appraisals, lack of woman-friendly management and sexual harassment (Fathima et al., 2020). Similar patterns of gender inequality can be observed in Norway, as a typical developed western economy, however, possibly to a lesser degree (Frølich et al., 2019). Frølich et al. (2019) observed that while males tended to choose research-oriented positions, females tended to choose teaching-oriented positions. These differences in choices reinforce the differential distribution of the sexes, as e.g., the health sciences is teaching oriented, while the STEM disciplines (Science, Technology, Engineering, and Mathematics) are more research oriented (Frølich et al., 2019). It is outside the scope of this investigation to address all these topics. We will, however, return to some of these issues in the discussion to provide possible explanations to our results.

There is basically only one theory explaining how gender equality will be achieved in the future without positive measures: According to the "Pipeline problem" (or the "leaky" pipeline; Pell, 1996; Wickware, 1997; Rees, 2001; Bayer and Rouse, 2016; Jadidi et al., 2018) the lack of women in higher academic positions is due to shortage of academic labor supply, possibly due to individual choices in line with the Human capital theory or the Socialization theory (Ehrenberg, 1991). According to this view, there is no glass ceiling (unseen, yet unbreachable barriers keeping women from rising to the top of academia; Cotter et al., 2001) and academia will reach gender equality given enough time since women now are in majority in higher education.

However, when studying the system in one country (Norway), the development of gender equality may be influences by forces from the outside. Norwegian academia is part of an international labor market, and is thus influenced by international trends, such as an increasing number of internationally mobile researchers. The share of researchers and academic staff in Norway with an immigrant background (i.e., internationally mobile researchers) has increased from 18% in 2007 to 29% in 2018 (Gunnes and Steine, 2020), and an increasing number of applications for vacant professor positions at Norwegian higher education institutions come from abroad (Frølich et al., 2019). The majority of foreigners who apply for vacant professor positions in Norway are male, and we see the highest number of applicants from abroad in natural sciences, engineering and technology. As we will demonstrate that the change in proportions of each gender varies depending on field of R&D, these factors may be influential.

The purpose of this paper is firstly to fit a suitable statistical model to describe the uptake and retention of female academics in accordance with the pipeline model at the two top tiers within four Norwegian research universities. As in other developed countries, professors and associate professors have a central position in Norwegian universities, having extensive academic freedom and autonomy. There are two main paths for an associate professor to obtain a full professorship in Norway. They either apply for a vacant position or they get promotion through the "professor by competence" scheme. Professor by competence imply that you apply for, and receive, promotion to full professor based on research competence (Kyvik, 2015). In 2018, approximately 66% of new full professors got their professorship through this system (Frølich et al., 2019). Secondly, this model is used to present future scenarios for gender balance in Norwegian academia if the development as of 2019 is to continue.

MATERIALS AND METHODS

Data From 1977 to 2019

The Register of Research Personnel is a database operated by NIFU Nordic Institute for Studies in Innovation, Research and Education on behalf of the Research Council of Norway. The register covers researchers/academic staff, as well as supporting staff with tertiary education, who participate in research and development (R&D) in the Norwegian higher education institutions, research institutes and health trusts. The register contains information on position, age, gender, educational background, and doctorate, as well as the institution where the person is employed (department, faculty, field of R&D etc.).

The register does not cover special part time affiliations, with the exception of adjunct associate professors (Professor II). The registry goes back to the 1960s, and is available electronically from 1977 onward, with updates every second year until 2007, then annually. Hence, the data comprise of 28 consecutive registrations of male and female frequencies.

All employees are assigned to a field of R&D, related to their workplace's affiliation. The R&D performing units are asked to specify their R&D activity by field of R&D in the national R&D survey and are assigned to a field of R&D by the "master criteria," i.e., if Mathematics comprise more than half of their R&D activity, the unit is assigned to Natural sciences. There are six fields of science: Humanities and the arts, Social sciences, Natural sciences, Engineering and technology, Medical and health sciences, and Agricultural and veterinary sciences. In this investigation, we have analyzed data from the four oldest research universities in Norway (The University of Oslo, the University of Bergen, UiT The Arctic University of Norway, and Norwegian University of Science and Technology). As there are few professors within Agricultural and veterinary sciences at these four universities, these professors/associate professors are included in Natural sciences in this article. This gives five separate fields of R&D for the following analyses.

Each scientific field were analyzed separately. In addition, separate analyses were performed for full professors and for associate professors. First, the frequencies of females as percentages were calculated. Each separate analysis was based on 28 consecutively sampled percentages. Hence, the study consisted of 10 separate data sets with 28 consecutively sampled percentages.

Modeling Change: The Sigmoid Function

Although a linear model may be adequate for modeling change in a narrow time window, it is not recommended to be used to forecast more than a very few years ahead (Chatfield, 2016). A flexible and well-defined non-linear model will be necessary for the purpose of quantifying future scenarios.

Traditionally, most Norwegian professors have been male, and academia has been dominated by men on all levels. The first female Norwegian student was enrolled at the University of Oslo in 1882, and the first female associate professor in Norway was appointed in 1912 (Nordal et al., 2012). At some point in time, varying by scientific discipline, women started to be appointed to scientific positions. In concordance with the theory of supply of academic labor (Ehrenberg, 1991) one can argue that the change would be expected to be slow at first, then picking up momentum, before leveling off at some level. A sigmoid model (Sokal and Rohlf, 1995; Bolker, 2008; Tveito et al., 2010) has proven to be a useful model for change of this nature, where the population is a mix of two groups. The sigmoid curve has a characteristic s-shape, mimicking the process described above, with an initial phase of stable and low proportion of one group, followed by a phase with increasing proportion of the least frequent group. As the proportion increases, the rate of change slows down, eventually leveling off at some stable (and higher) value (see **Figure 1**).

Hence, we have *a priori* chosen the sigmoid model as a model of the change in proportions of female full professors and associate professors in academia, within different scientific disciplines.

Parametrization of the Model

The class of sigmoid functions include a wide variety of functions. We have applied the logistic model (Bolker, 2008) to fit the data. The logistic model can be parameterized in different ways (Bolker, 2008). Here, a three-parameter version was chosen to model the data. The three parameters correspond to three important properties. Firstly, the initial, stable level of females is characterized by the *lower asymptote* of the sigmoid curve. This level is determined empirically by the early part of the time series. As time goes by, the rate of change is increasing—the proportion of females is growing at an increasing speed (the second derivative of the function is positive). At some point of time, the rate of change starts to decrease. This second key property of the sigmoid function is called the *inflection point*. This is the part of the curve when the rate of change is slowing down. If the inflection point is already passed, we know that the rate of change will slow down. The third key property is the *upper asymptote,* which is of special interest for this work. This is the proportion of females, when the function levels off. This is the prediction of the proportion of female associate professors or full professors in the future (see **Figure 1**).

This parameterization of the logistic function, modeling the proportion of female academics with time, t, is described as follows.

$p(t) = \frac{\beta}{1 + e^{-\alpha[t-\gamma]}}$, where *p(t)* is proportion of females at time *t*

β is the carrying capacity, i.e., the upper asymptote

α is the growth rate

γ is the inflection point

In data sets with a low number of observations, it may be difficult to obtain stable parameter estimates in a model with three parameters. We will therefore compare the above described analyses with an alternative parameterization of the model with two, instead of three parameters. This model is widely used in biology (Maynard-Smith, 1978; Hixon, 2008), and can be expressed as follows.

$p(t) = \frac{p(0)\beta}{p(0) + e^{-\alpha t}\left[\beta - p(0)\right]}$, where *p(t)* is proportion of females at time *t*

p(0) is population at time 0 (here 1977)

β is the carrying capacity

α is the growth rate

Following Tveito et al. (2010), we can solve this equation analytically, thus avoiding numerical approximations and local false solutions.

Estimates of variability of the parameters were obtained by bootstrap techniques (Sokal and Rohlf, 1995). Alternative realizations of each data set were generated by $n = 27$ successive samples from binomial distributions. For each data set, a new realization of the 27 time points was obtained by consecutively drawing 27 values from binomial distributions, each with "size" equal to the total number of full professors (or associate

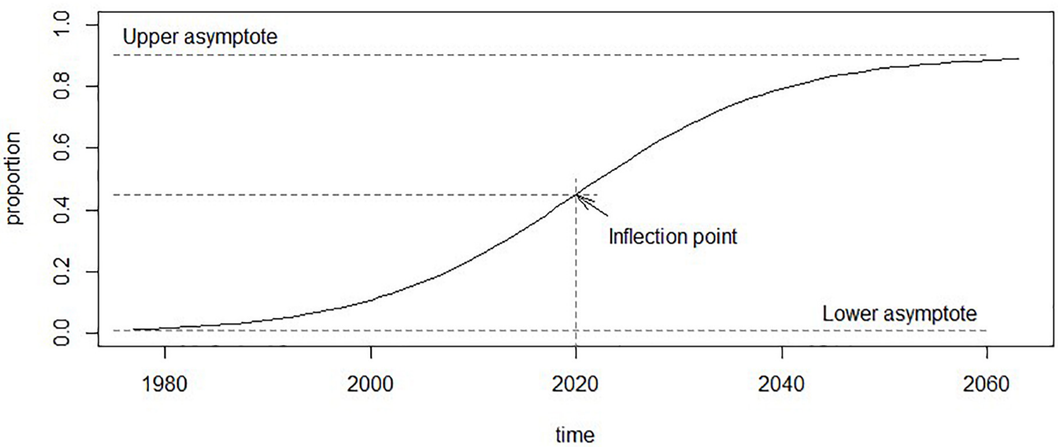

FIGURE 1 | Generalized sigmoid function, with the upper and lower asymptote and the inflection point marked. The logistic function is used to draw the figure.

professors), and p equal to the proportion of females at the corresponding time points. These realizations were then fitted by the logistic three-parameter model. Each data set was resampled 10,000 times, giving model fits and corresponding parameter estimates. These estimates were used to calculate variability of predicted proportions of females.

Future Scenarios

The number of full professors and associate professors within each of the five scientific disciplines has been rising at a very stable, linear manner over the more than 40 years for which data are available. Assuming that the linear trends will continue for the next 50 years, the total numbers of full professors and associate professors in 2,068 can be linearly estimated and added up (from the five scientific fields) to 5,198 and 2,610, respectively. These estimated numbers of full professors or associate professors within each of the scientific disciplines are then multiplied by the modeled proportions of female full professors or associate professors within each of the scientific field.

Software

The analyses were performed using R 3.4.3 (Venables and Ripley, 2013). The nls routine was used to fit the logistic models, and rbinom was used for the resampling.

RESULTS

Observed Numbers, 1977–2019

The total number of full professors rose from 538 in 1977 (19 females, 519 males), to 2,630 in 2019 (815 females and 1,815 males)—a 4.9-fold increase in total number. The respective numbers for associate professors rose from 680 (71 females and 609 males) to 1994 (942 females and 1,052 males)—a 2.9-fold increase in total numbers. The proportion of female full professors has thus increased from 3.5 to 31% in 42 years, but the proportion has still not reached the chosen definition of gender equality; both sexes being represented by at least 40%. Simultaneously, the proportion of associate professors has increased from 10.4 to 47.2% and gender balance for the total numbers is thus reached.

The proportions of female professors at the four Norwegian universities 1977–2019, total numbers, and stratified by fields of Research and Development (fields of R&D), are shown in **Figure 2**. The corresponding proportions of associate professors are shown in **Figure 3**. The proportion of females increase by time for all scientific fields, overall. However, the level and the pace vary greatly between scientific fields, with humanities and the arts, social sciences and medical and health sciences having the highest proportions of female professors in 2019, and medical and health sciences having the highest proportion of associate professors in 2019. The natural sciences and engineering and technology had similar proportions of female professors and of associate professors, and both disciplines have had a lower proportion of females compared with the other scientific disciplines since 1987.

Estimated and Predicted Gender Distribution for Full Professors

The results from fitting the observed numbers for full professors to the three-parameter logistic model, and stipulated future scenarios based on simulated data from bootstrapping techniques are displayed in **Figure 4**. We observe that some of the sigmoid models for the resampled data cannot be fitted properly and the upper asymptote is above one, which does not give meaning (e.g., medical and health sciences in **Figure 4**). The simulated data for Natural sciences did not fit to the logistic model (see "Natural sciences" in **Figure 4**). The proportion of female full professors in engineering and technology could not be bootstrapped at all (although the point estimates for the model can be found).

The predicted upper asymptote for humanities and the arts was 0.36, for social sciences 0.43, and for medical and health sciences 0.80. These estimates for the new, stable proportion of females was reached in 2039 and 2032 for humanities and

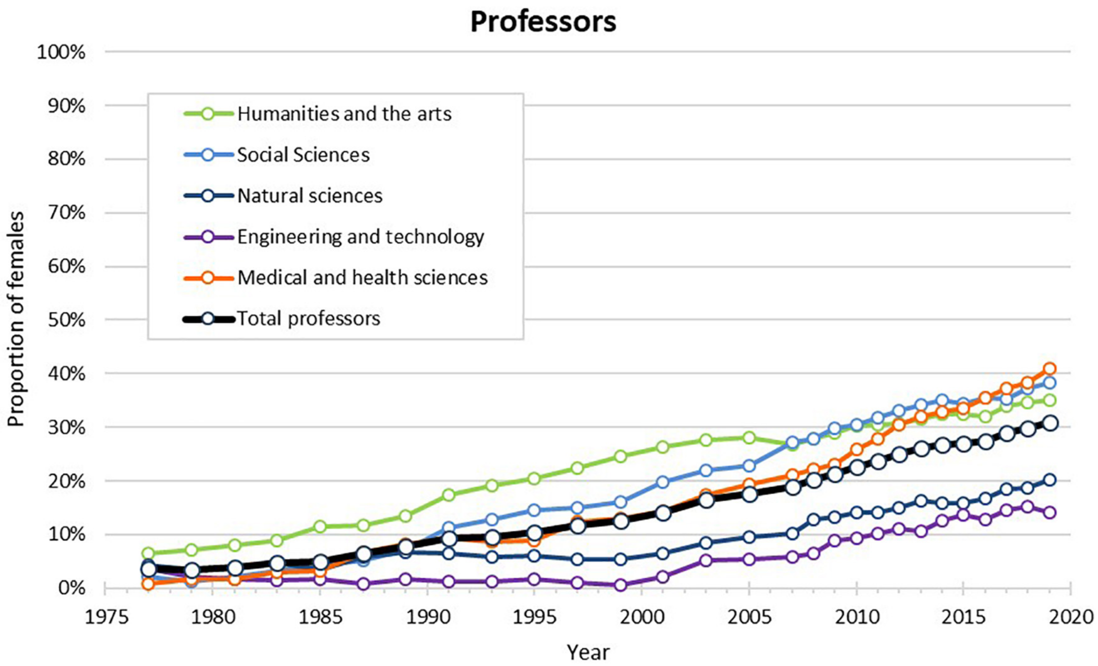

FIGURE 2 | Proportion of female professors at four Norwegian universities 1977–2019.

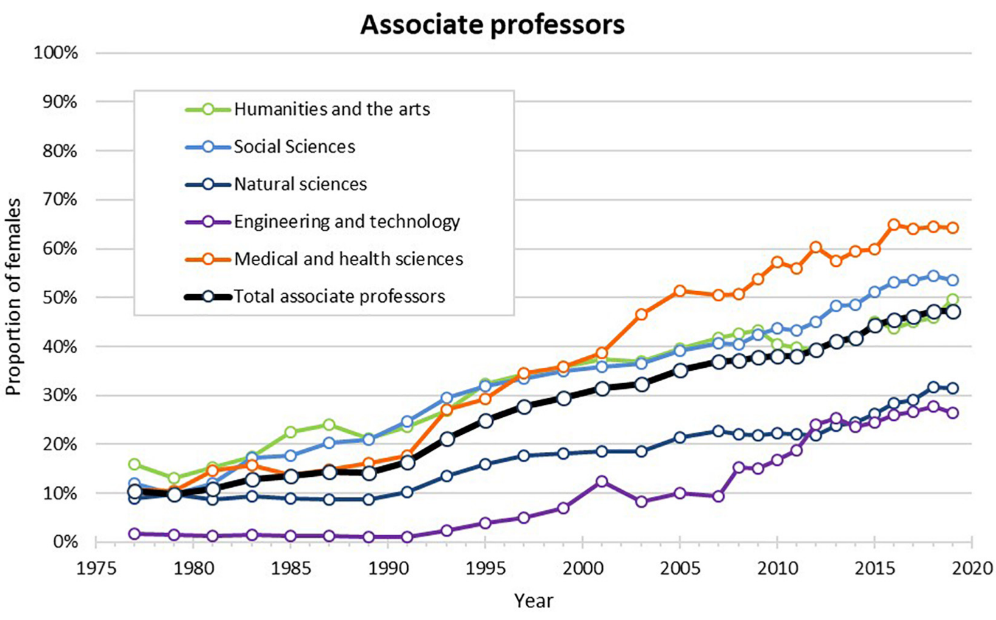

FIGURE 3 | Proportion of female associate professors at four Norwegian universities 1977–2019.

the arts and social sciences respectively, while for medical and health sciences the asymptote did not stabilize within the model period. The corresponding prediction intervals (90% bootstrap interval) at these points of time was (0.32, 0.39) and (0.38, 0.47) for humanities and the arts and social sciences, respectively, while for medical and health sciences the prediction interval goes from 0.58 to a non-sense value above 1 (see **Figure 4**). Thus, with this model, gender balance will likely not be achieved for full professors in humanities and the arts within the model period. Even though the model predicts a new stable proportion of 80% females among the full professors in medical and health sciences, this future scenario is the one that is encumbered with most variability and non-sense estimates (i.e., upper asymptote estimated above 100%).

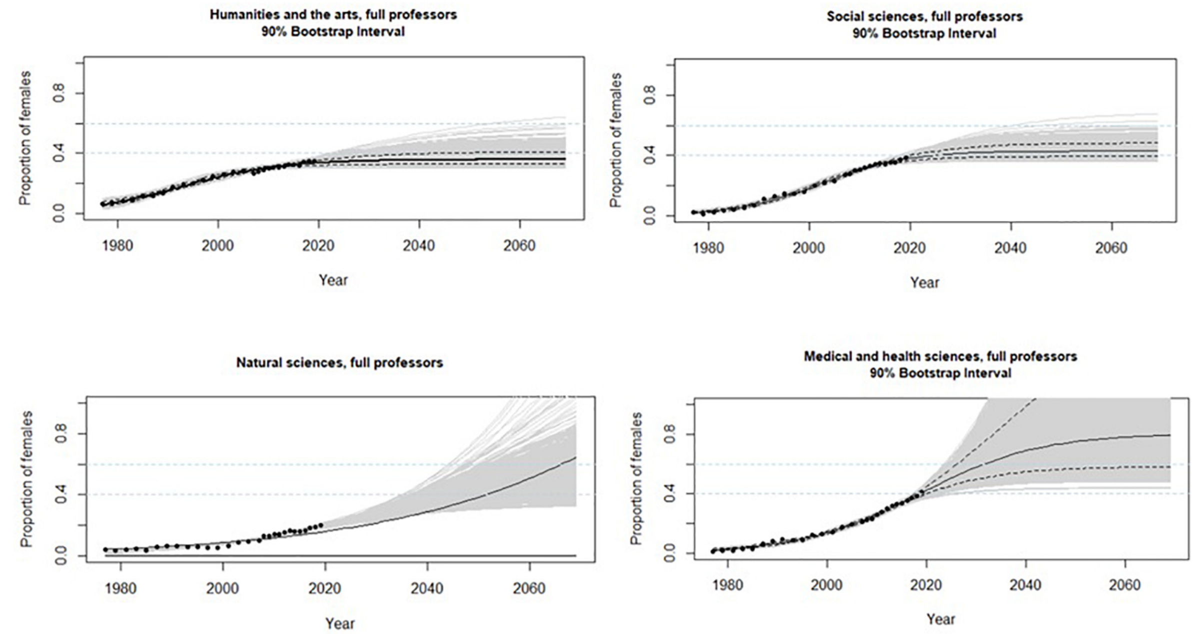

FIGURE 4 | Observed percentages of female professors are black dots. Fit of data to a three parameter logistic model to the observed data is displayed as a black, thin line, extrapolated to the right of the observation span (to 2069). Light gray thin lines are the estimated sigmoid curves based on each of 10,000 bootstrapped time series. The corresponding median is the solid black line. Within the observation span, the bootstrap median estimate is very close to the fitted model based on the observations. Also, 90% quantiles for the bootstrap sigmoid estimates are displayed as dotted lines. Stippled, blue lines give the interval of gender balance (0.40, 0.60). For Engineering and technology and Natural sciences, no parameters could be estimated.

The estimate of the upper asymptote for the proportion of female full professors in humanities and the arts was almost equal to the estimate from the analytic calculation of the two parameter logistic model (0.367 vs. 0.38). For the social sciences, the corresponding estimates were 0.43 vs. 0.39, for the median bootstrapped estimate and the analytic model, respectively. The analytic solution for engineering and technology provided an estimate of the upper asymptote of 0.15. However, the fit of the data to the model was poor. For Natural sciences and medical and health sciences neither the calculation of the upper asymptote nor the model fit was good.

In summary, the models predicted that in total, the proportion of female full professors will continue to rise from the observed 31% as of 2019, achieving gender balance (i.e., more than 40% of each gender) in 2038, and reaching 50% somewhere around the year 2059. Gender balance will not be reached for professors within humanities and the arts, and the data does not permit a good fit to the model for Natural Sciences and Engineering and technology. However, the estimated proportion of female full professors does not seem to reach a stable level (see **Figure 5**).

Estimated and Predicted Gender Distribution for Associate Professors

The results from fitting data for associate professors to the three parameter logistic model, and stipulated future scenarios based on simulated data from bootstrapping techniques, are displayed in **Figure 6**. The predicted upper asymptote, i.e., the new, stable proportion of females for humanities and the arts is 0.49, for social sciences 0.67, for engineering and technology 0.37 and for medical and health sciences 0.76. The data for Natural sciences did not converge to a stable asymptote. These estimates for the new, stable proportion of females was reached for humanities and the arts in 2041 [the prediction interval at this point of time of (0.46, 0.53)], for social sciences in 2059 (0.56, 0.88), for engineering and technology in 2038 (0.30, 0.52), and for medical and health sciences in 2061 (0.69, 0.85), while the estimate continued to rise for Natural sciences over the modeled period.

The resampling procedures worked well for most of these data, resulting in 90% prediction intervals mostly within 0.0 and 1.0, especially for humanities and the arts, social sciences and for medical and health sciences (**Figure 6**).

The results from calculating the upper asymptote analytically by the two parameter logistic model confirmed the main results. The results were similar for humanities and the arts (with, respectively, 0.49 for three parameters vs. 0.53 for two parameters) and for medical and health sciences (almost equal at a proportion of 0.76 vs. 0.75). Some discrepancy was found for social sciences (0.67 vs. 0.61), but both models indicate that gender equality will be obtained. For engineering and technology, the asymptotes were quite similar (0.37 vs. 0.39), but the fit of the model was less accurate. The asymptote could not be found for Natural sciences.

In summary, the model predicts that the total proportion of female associate professors will continue to rise from the observed 47% as of 2019, passing 50% in 2023 and leveling off

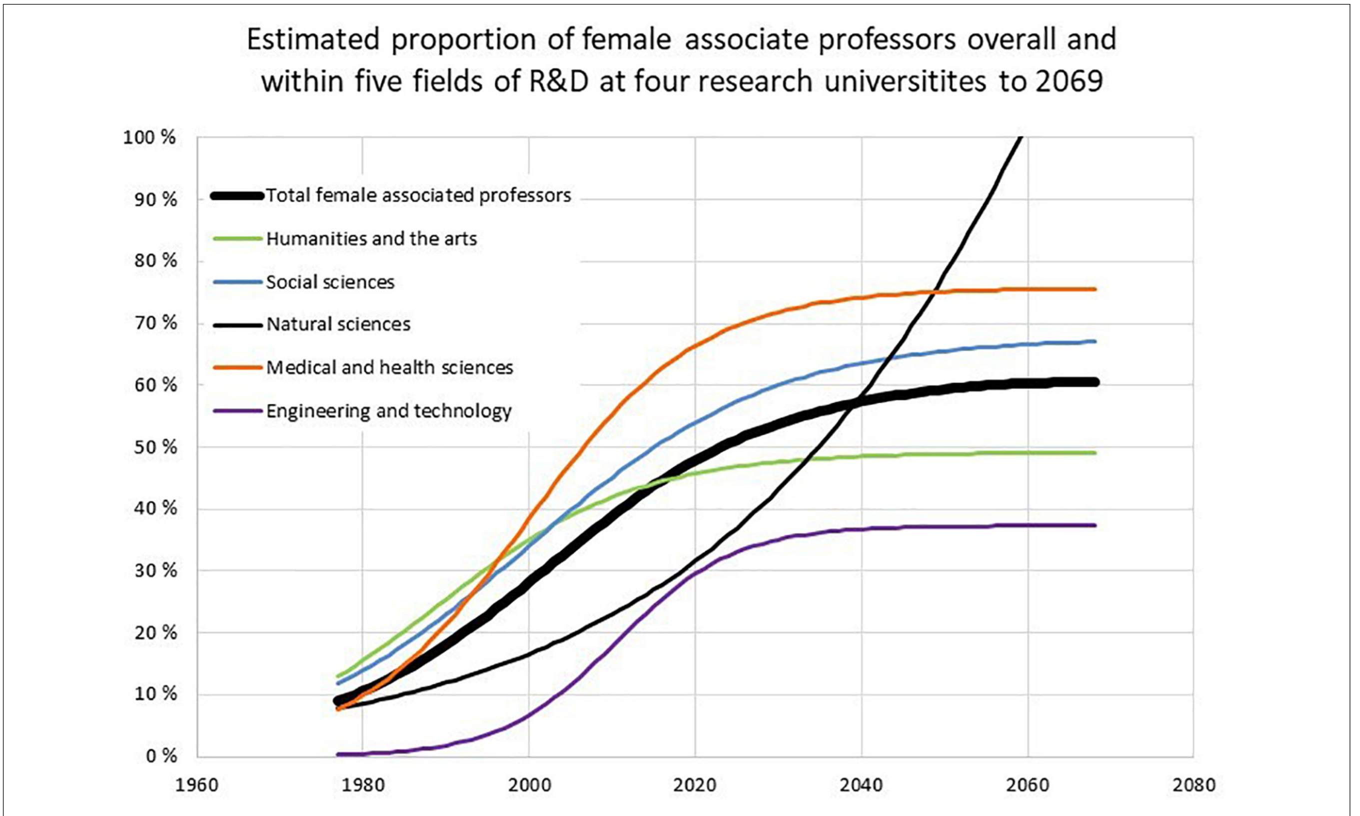

FIGURE 5 | Estimated proportion of female professors in four scientific fields at universities to 2069.

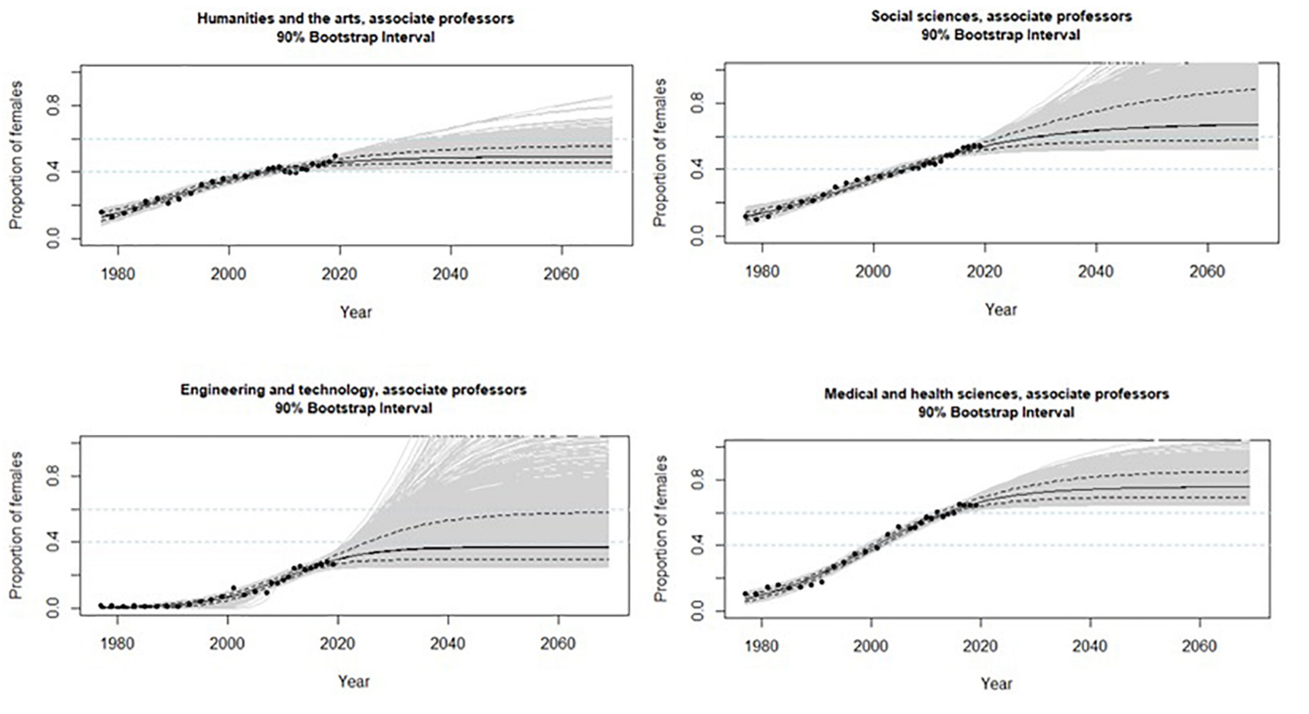

FIGURE 6 | Fit of data to a three-parameter logistic model for *associate* professors displayed as a thin black line. Fit of data for each of the 10,000 resampled time series are displayed in light gray lines, while the median (solid black line very similar to the point estimate) and 90% quantiles (dotted lines) are also displayed (see **Figure 4** for details).

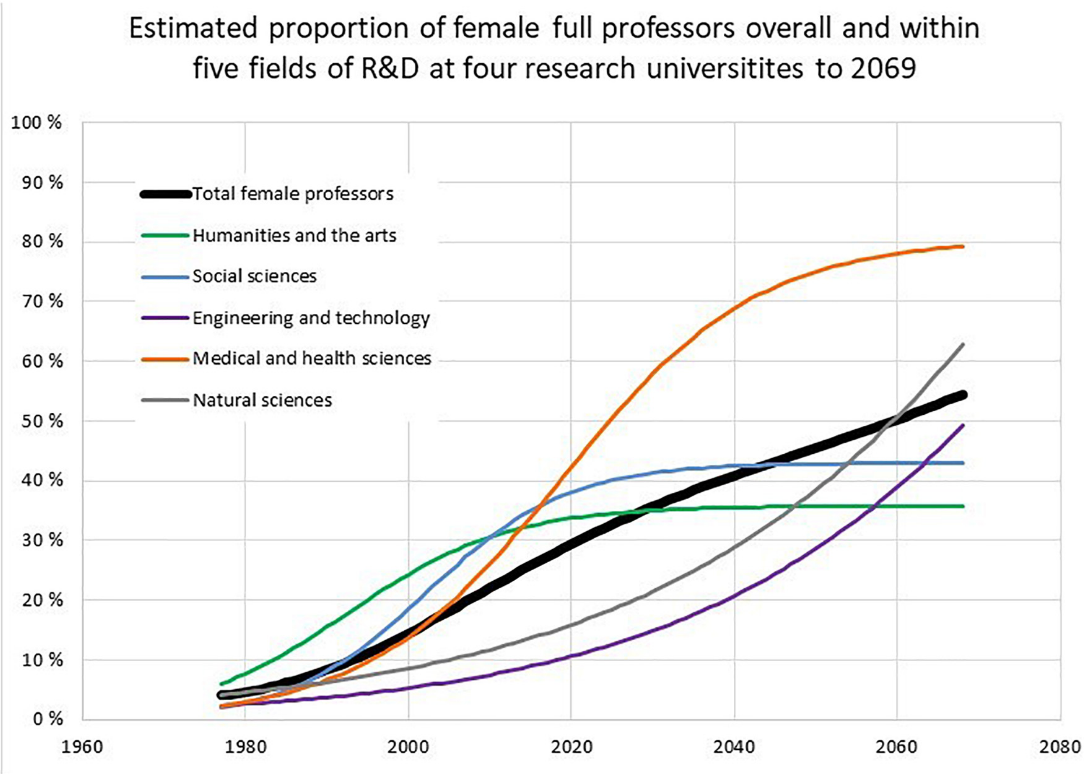

FIGURE 7 | Estimated proportion of female associate professors in four scientific fields at universities to 2069.

in the late 2040s, stabilizing at about 60% (**Figure 7**). Gender balance among associate professors will be reached for four of the five scientific fields, while the data does not permit a good fit to the model for Natural Sciences.

DISCUSSION

We observe that overall gender balance for associate professors in four Norwegian universities is already achieved as of 2019, whereas the overall proportion of female full professors is quite far from the goal of 0.4 (i.e., at least 40% of either gender). According to the modeling exercise, we stipulate that overall gender balance among full professors may be expected in the late 2030's.

This overall estimate hides, however, profound differences between fields of R&D. The forecasts indicate that gender balance among professors will not be achieved in the humanities within the next 20 years. Within Natural sciences and Engineering and technology, the increase in the proportion of female professors is low, and the data could not be fitted to the model. In contrast, the high rate of change in the gender ratio in the medical and health sciences implicate that an excess of 60% of the full professors will be women from the early 2030s, again violating the gender balance. However, the prediction error of this forecast is substantial. Gender balance is within the error bounds of this forecast.

Gender balance among associate professors is already obtained in humanities and the arts and the social sciences. According to the models applied here, these scientific fields are likely to maintain gender balance over the subsequent decades. Gender balance will not be achieved for associate professors within Engineering and technology. In the medical and health sciences, gender balance was obtained as early as 2003, passed 60% in 2016, making it likely that the field will be strongly dominated by female associate professors within 2040. In forecasting the future proportion of female associate professors in engineering and technology, instability of the estimates was a problem. This resulted in large prediction errors which makes this forecast less reliable (see **Figure 6**). In Natural sciences, the rate of change is low, and the data could not be fitted to the model.

The historical trend has been an increase in the total number of associate professors in the humanities and the social sciences, with a moderate increase in engineering and technology and medical and health science, but with a *decrease* in the total number of associate professors in Natural sciences. If these trends prove to be faulty, the proportion of female associate professors will change. The proportion of females is especially low in engineering and technology and Natural science. If these fields of R&D increase, the overall proportion of female associate professors will actually *decrease*. In addition, as mentioned above, the data for engineering and technology does not seem to be well modeled and should not be fully trusted. As we pointed out in the introduction, these fields of R&D are also prone to high foreign recruitment, predominantly of male scientists. This will likely further inhibit the development toward gender balance for these fields of R&D.

Model/Statistical Considerations

Forecasting far into the future is discouraged due to the inevitable high prediction error and the estimates are bound to be wrong. The forecasts provided here should therefore merely be regarded as potential scenarios, displaying the inert development of the numbers if the model assumptions are fair, and all social and political conditions in the Norwegian society remain the same. The most basic assumption of this paper—that a sigmoid model is a good representation of the historical and future development of gender balance in academia may be questioned, but a better model is hard to find when the data are as sparse as those of this investigation. The model fit seems to be best when the time series reveals a true development, i.e., when the proportion of females have started to increase (and even when the inflection point is passed, i.e., that the rate on increase is slowing down). For engineering and technology and Natural sciences, where still few females have academic positions, the model performed less strongly. Furthermore, a steady influx of (predominantly) male scientists to positions within these fields of R&D may further reduce the fit of the data to the model.

Gender Balance—What Can Be Learned?

Although the analyses predict that overall gender balance is or will be achieved at four traditional Norwegian research universities if the present state is continued, this is no longer the case when the data are split into scientific fields. In humanities and the arts, engineering and technology and Natural sciences, our modeling exercise cannot confirm that gender balance will be achieved within the next two decades for full professors (but will be achieved for associate professors within humanities and the arts and engineering and technology). Additionally, for the medical and health sciences, the modeling effort points to a situation with a strong dominance of women in the years to come (a proportion for 80% female full professors and 76% for associate professors)—an opposite gender imbalance.

The gender composition within a field of research and development is a combination of different rates of recruitment and exits of the sexes. If recruitment is the problem, as explained by the theory of labor force supply balance (Ehrenberg, 1991; the "pipeline"), what is needed will be to recruit even more girls into the STEM-subjects (Science, Technology, Engineering, and Mathematics) in school and into these fields of R&D in the universities. It has traditionally been observed, however, that the pipeline is "leaky"—at each stage of the academic career, women are disappearing at a higher rate than men (Rees, 2001; Jadidi et al., 2018). Thus, it is not precise to hypothesize one glass ceiling: instead of one barrier at the very top of academia, there exist a sorting mechanism throughout the academic workplace (Monroe and Chiu, 2010).

This imbalance of exit rates can again be a result of push forces (e.g., discrimination within academia or dissatisfaction with the working conditions) or pull forces (e.g., better salary or better working conditions) from the outside (Silander et al., 2012). As reports indicate (Monroe et al., 2008), we can be rather certain that discrimination is still a fact in academia. We can, however, observe two interesting and possibly contradictory conjectures about the pull forces: Firstly, there does not seem to be any systematic differences between countries following the gender gap in salary (European Commission DG Research, 2012). The stability of the proportion of female professor also in countries where the salary gap has decreased, furthermore confirms that this rate does not seem to be influenced by the general development of salary in society. On the other hand, the scientific field with the most females in Norway is within health sciences. This is probably a field with weak pull forces as salaries are low and working conditions are known to be exhausting outside academia.

The lesson from this exercise is that for certain fields of science (i.e., humanities and the arts), gender balance will not be achieved as a result of recruitment from below for the highest tier of academic life within the next 50 years. For other scientific fields (i.e., engineering and technology and mathematics/natural sciences), the change in the proportion of female full/associate professors is still too slow to fit to the proposed model.

Policy Implications

The most obvious policy implication conclusion to draw from this investigation is that targeted initiatives and actions must be undertaken to increase the proportion of the underrepresented gender in selected fields of R&D rather than across the board to achieve the goal of gender balance in academia. The findings in this investigation may be useful in prioritizing how to implement measures to address gender imbalances in science. A recent study by Ruggieri et al. (2021) confirms that gender disparities in scientific production still persist, and particularly in STEM disciplines, while the gender gap is the closest to parity in medical and agricultural sciences (Agricultural and veterinary sciences are included in Natural sciences in this investigation, due to a low number of researchers). To develop accurate measures to counter gender imbalances in the STEM disciplines, we must take into consideration particular characteristics of these scientific disciplines.

In general, we can organize measures to improve women's position in science according to the framework outlined in the introduction about the two approaches that can explain why there are gender differences (the Human Capital theory/socio-demographic characteristics and the Socialization theory/women's role and participation in research activities). One category of measures addresses the general work conditions of (female) scientists, while the second addresses the scientific process. A recent investigation confirms that fewer women than men have access to two of the success factors that women themselves assess in the questionnaires as being among the most important for success in higher education: access to a mentor and the opportunity to gain scientific merit (Barriere et al., 2021)—one from each of the two groupings of factors.

Fathima et al. (2020) found that work-related stress was the most common challenge faced by the female scientists in their investigation, by 71.5%. This is a central issue related to the Human Capital Theory. When these same female scientists were asked what factors may reduce the work-related stress and improve work-life balance, they highlighted flexible work timings, woman-friendly management policies, fair appraisal and mentorship. Men probably also experience work-related stress, but in this context, we are looking for factors that affect women and men disproportionally. What we observe is that women have long breaks in their career (Fathima et al., 2020), and notably longer than men (Frølich et al., 2019). As seniority seem to be the most important factor for scientific performance (Jadidi et al., 2018), measures that reduce gender imparity in child rearing will be expected to reduce gender differences in science and representation, and reduce the "leakage of the pipeline" at critical point in the career of scientists (Jadidi et al., 2018). While paid maternity leave is common for scientists around the world, only a small fraction have access to maternity leave exceeding 6 months (Fathima et al., 2020). We can expect that if patterns related to child bearing and rearing are changed, this will have disproportional positive effects uniformly experienced across scientific fields.

If we investigate the women's role and participation in research activities (the Socialization theory), we can observe that several of the factors important for the differential ratio of scientific production between men and women are more specific to the STEM disciplines. The *productivity puzzle* refers to the unknown causes of the lower publication rate of women compared to men in various fields (Cole and Zuckerman, 1984). Jadidi et al. (2018) claim to have solved this puzzle, and conclude that "the simple explanation [is] that men are more productive on average because they have a larger fraction of senior authors." However, the differences in publication pattern consist of many elements, including, e.g., that women publish significantly fewer papers in fields where research is expensive, discrimination in the peer-review process, inferior employment positions (being a professor or a postdoc), less international collaboration, smaller networks and a lower probability of repeating previous collaborations than males (Zeng et al., 2016; Jadidi et al., 2018). By addressing some of these sub-processes of publication work and culture, we may expect a disproportional positive effect on women. Furthermore, while both the gender imbalance and the publication frequency are highest within the STEM disciplines, we may expect a larger positive effect within these scientific fields. Examples from developing countries, e.g., Vietnam, demonstrates that strong emphasis on publications motivates young researchers and empowers a rising number of female researchers (Vuong, 2019). Of special interest in this respect is use of Open Access (OA).

Use of Open Access may be beneficial to women (Nguyen et al., 2021; Ruggieri et al., 2021; Vuong et al., 2021). On the positive side, the open-access (OA) publishing model can help improve researchers' outreach, thanks to its accessibility and visibility to the public. The hypothesis being that scientists from minority groups or with less reputation might perceive OA publishing as an effective strategy to gain more recognition in the scientific community. OA publishing offers greater perceived visibility and impact, and this could be a critical factor when female scientists consider a place to publish (Nguyen et al., 2021). On the negative side, the cost of publishing OA might make it expensive for female researchers, who often have fewer resources than male researchers. The article processing charge (APC) may be a barrier that limits publication in OA channels. Vuong et al. (2021) find that gender inequality might have created more barriers toward OA publishing among Vietnamese female scientists. In a study analyzing the experience with OA publishing of United Kingdom-based researchers, male scientists are found to be more experienced than female ones (Zhu, 2017).

While the effects on gender disparity remains to be established, measures that seeks to reduce the differences in publication pattern between may all be expected to have positive effect on women's position in academia.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

KL conducted the analyses and did most of the writing. HG prepared the data and contributed with guidance for analysis. KL and HG jointly contributed to the interpretations and conclusions. Both authors contributed to the article and approved the submitted version.

FUNDING

The early phase of the work in this article was funded by base funding by the Research Council of Norway to NIFU Nordic Institute for Studies in Innovation, Research and Education.

ACKNOWLEDGMENTS

Agnete Vabø of Oslo Metropolitan University provided insight and discussions of issues of gender in academia. Kathrine Frey Frøslie of the Norwegian University of Life Sciences provided invaluable guidance in the modeling effort.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.