Scientometrics
https://doi.org/10.1007/s11192-025-05428-6

Knowledge lost, parity gained? COVID-19 and gender gaps in Dutch academia

Jochem Tolsma[1,2] · **Bas Hofstra**[1] · **Anne Maaike Mulders**[1]

Received: 22 December 2024 / Accepted: 18 August 2025

Abstract
We investigated the extent to which the COVID-19 pandemic impacted long-standing gender inequalities in Dutch academia. Dutch academia is an ideal case to gain insight on exacerbated gender differentials due to COVID-19 on employees, because men and women face comparable institutional contexts and any COVID-19 impact becomes visible and measurable fast through potentially decreased yearly publications. We reconstructed the complete publishing careers up till 2022 of more than 8000 Dutch scientists who received a PhD from 1990 onwards and still had an active publication career before the pandemic started. We compared the publication dip between men and women during COVID-19. Our data allowed us to investigate whether the gendered impact of COVID-19 varied across research domains, different PhD cohorts and type of research output. We consistently find that COVID-19 did not have more severe consequences on research output for women than for men.

Keywords Science of science · COVID-19 · Inequality · Gender

Introduction

The COVID-19 pandemic has exacerbated gender inequalities in many countries and in many domains of social and professional life. A cursory glance at the quickly expanding body of work on gender disparities due to COVID-19 highlights that: women and mothers experienced disproportionate reductions in working hours compared to men in the U.S., South Africa, Germany, and Singapore (Casale & Posel, 2021; Landivar et al., 2020; Reichelt et al., 2021), in many countries women's likelihood for unemployment and income was reduced more compared to men (Casale & Posel, 2021; Dang & Nguyen, 2021), Dutch mothers took more care responsibilities than their partners (André et al., 2021), and among breadwinners in the UK, women spent more time on unpaid labor compared to men (Zamberlan et al., 2021).

✉ Jochem Tolsma
jochem.tolsma@ru.nl

[1] Radboud University Nijmegen, Nijmegen, The Netherlands

[2] University of Groningen, Groningen, The Netherlands

Published online: 29 September 2025

Academia appears to be no exception to such patterns related to COVID-19, as early signs of gender disparities are observed in academia as well. In 2020, the gender gap in publications has widened in STEM + medicine fields such as (clinical) medicine, biology, and chemistry (Madsen et al., 2022) in several countries, and the number of preprints with women authors, women first authors, and women senior authors decreased (Andersen et al., 2020; King & Frederickson, 2021; Kwon et al., 2023; Lerchenmüller et al., 2021; Muric et al., 2021; Squazzoni et al., 2020). Additionally, self-reported research activities indicate a growing gap between women and men scientists among STEMM faculty in the USA (Krukowski et al., 2021).

To observe gender gaps in academia is not entirely surprising as a long line of research shows how women academics face many structural barriers in academic work and careers. Compared to men, women are less likely to continue their academic career after obtaining their doctorate, women publish fewer papers per year, women are underrepresentated at prestigious author positions (i.e. first and last) are less likely to obtain influential faculty positions, and find their contributions to be valued less by their peers (Bendels et al., 2018; Broderick & Casadevall, 2019; Hofstra et al., 2020; Kim et al., 2022; Leahey, 2006; Mairesse & Pezzoni, 2015; Mulders et al., 2024; West et al., 2013). The first signs of a widening gender gap due to the COVID-19 pandemic are worrisome insofar that it contrasts a slow-but-steady equalizing gender trend in academia of the last decades where women increasingly populate PhD degrees (Hofstra et al., 2022) and authorships (Huang et al., 2020). Additionally, some equalizing trends are observed in academic tenure. For instance, women in sociology and political sciences are tenured earlier than men in German academia (Lutter & Schröder, 2016; Schröder et al., 2021), and there are no gender effects of childbearing on productivity in German sociology when impact indicators are considered such as received grants (Lutter & Schröder, 2020). As such, gender gaps in academia nowadays seem dependent on the time, the discipline and country context, and the outcome that is being studied.

If some of the equalizing trends progress are lost, the COVID-19 pandemic may have been an unprecedented step back towards gender equality in academia. This is problematic for multiple reasons. First, women academics—perhaps among the most highly educated in comparably gender-progressive social contexts—may disproportionately face the negative consequences of crises. Second, it might show that even contexts that likely have progressive policies in terms of leave or care are not well equipped to equally spread the burdens of exogenous shocks across social groups. Finally, a growing body of work shows how diversity in science fosters innovation and how women uniquely study new research topics related to their own gender (Hofstra et al., 2020; Kim et al., 2022; Nielsen et al., 2017a, b). The lack of gender and sex analysis in COVID-19 clinical studies may be exemplary for such dynamics (Brady et al., 2021): what if women were not able to proportionately contribute their expertise to vaccine research yielding sub-optimal clinical results? Similarly, the social and likely gendered impact of the pandemic on society might remain understudied. In light of these issues, it is key to gain more insight into how the COVID-19 pandemic impacted gender disparities in academic output. This motivates the main research question of this study: to what extent did the COVID-19 pandemic impact productivity (i.e., publication output) differently for women and men in Dutch academia?

Studying gender productivity differences as a result of the pandemic in academic careers is a particularly valuable case, as measuring productivity in academia is relatively straightforward compared to other white-collar occupations (King & Frederickson, 2021). We will bring into sharp focus possible gender inequalities in Dutch academia, a social context where employees experience progressive policies in terms of vacation, care, and

other leave. These and other policies (e.g., salaries, benefits) are mostly institutionalized at the national level through collective labor agreements. This allows us to compare women with men in a context with the same nationally-mandated leave and care policies instead of studying, say, a set of highly-ranked private universities or a set of regional state universities in the US.

The Netherlands scores traditionally high on rankings of gender equality (World Economic Forum, 2024), possibly rendering the growth of output differences during COVID-19 smaller compared to other contexts. Universities in the Netherlands have also paid particular attention to Diversity, Equity, and Inclusion initiatives in recent years (Mulders et al., 2024), possibly (further) reducing productivity differences between men and women scholars compared to other contexts. This is in line with recent work that shows how in countries with less gender inequality, men-women differences in output due to the pandemic are less severe (Kwon et al., 2023). In line with these intuitions, recent work (Madsen et al., 2022) on medicine, biology, and chemistry shows how output of men and women scholars did not grow more different between 2019 and 2020 (a pre-COVID-19 and COVID-19 year) for scientists in the Netherlands. In contrast, Abramo et al. (2022) reaches the opposite conclusion for the Netherlands: women were worse off than men in research output due to COVID-19. This begs the question how men and women scholars in the Netherlands across all disciplines fared before, during, and after COVID-19 with respect to their research output. In sum, it is key to gain more insight into the specific contexts and scope conditions that do and do not exacerbate differences between men and women researchers. This relates back to our point that gender gaps in academia depend on the the time, the discipline and country context, and the outcome: The Netherlands seems an ideal case for this. This is because the Dutch case might be a unique one, as is suggested by the findings of Madsen et al. (2022) such that one may expect that the negative impact of COVID-19 pandemic on publishing output in Dutch academia was equal for women and men. However, relying on the majority of prior literature one may expect that the negative impact of COVID-19 pandemic on publishing output in Dutch academia was stronger for women than for men (Hypothesis 1).

While it is interesting in and of itself to assess whether previous results in different countries can be replicated in the Netherlands, we make several contributions to the literature examining gender productivity gaps due to COVID-19. A first contribution is that we provide a detailed focus on career age, defined as the years since the conferral of the doctorate. Recent work has posed that one explanatory mechanism for a possible gender productivity gap during COVID-19 is found in the general patterns of inequality mentioned before; women experienced reduced working hours and carried most of the childcare and associated unpaid labor responsibilities (King & Frederickson, 2021). That means that, especially among younger women academics, less time could be allocated to writing and publishing research, and especially among these women, stress increased as a result of having to balance care and work responsibilities, whereas men experienced those time restrictions to a lesser extent. One way to test this (child)care-tasks mechanism is to consider gender productivity differences by academic PhD-cohort (i.e., the year in which the PhD was awarded). If women academics disproportionately took up child-caring activities that displaced their research activities, gender productivity differences should be most pronounced for younger academic cohorts who are more likely to face child-caring tasks compared to older ones. We expand the work of Madsen et al. (2022) who studied two specific career stages, by studying both career age as well as its intersection with gender more in-depth by hypothesizing: scholars with career ages likely to coincide with child-rearing responsibilities [i.e., obtained their PhD after 2005; see Fig. 5 (Appendix)] are affected

more negatively by the COVID-19 pandemic than scholars less likely to have child-rearing responsibilities (Hypothesis 2); Women with career ages likely to coincide with child-rearing responsibilities are affected more negatively by the COVID-19 pandemic than men with the same career ages (Hypothesis 3).

Second, we are among the first to take into account the entirety of academic output before, during and after COVID-19. For those scholars in scientific fields that move slightly slower in publishing timelines (e.g., sociology compared to engineering), the productivity dip may have come after 2020—i.e., the focus year of many prior studies (e.g., Kwon et al., 2023; Madsen et al., 2022; Squazzoni et al., 2020). Here we define the 'COVID-years' as 2020 and 2021 and thereby provide a more-complete picture of (longer-term) productivity consequences of the COVID-19 pandemic.

Third, in contrast to much prior work, we study productivity in all academic domains, encompassing all scientific disciplines, from Cultural Anthropology to Aerospace Engineering. This is because we need to be cautious against findings related to COVID-19 and productivity research in prior work that was largely limited to STEM fields, because gender intersects with selection into academic domains [Table 5 (Appendix)], and, by extension, academic authorship. The latter point is reflected in varying submission rates for women and men authors (Bartosch et al., 2023), yet simultaneously journal acceptance rates are equal for women and men in some (Bartosch et al., 2023; Biolková et al., 2023) but not other (Card et al., 2020) fields. Therefore, it is key to gain an understanding if and in what research domains productivity gaps were most prevalent. Prior work on the gender productivity gap during COVID-19 focused primarily on medical or STEM-field research output. Yet, especially the health and life sciences domains were the ones that saw large increases in publications during the COVID-19 pandemic. At the same time, some of these domains historically underrepresent (STEM) or overrepresent (Health) women scholars. Hence, it seems essential to study such domains simultaneously and control for them and to explicitly compare them, while also including the domains with an overrepresentation of women. This allows us to ask the following explorative question: to what extent did the gendered impact of the COVID-19 pandemic vary across research domains (Explorative question 1)?

Finally, we assess in detail which type of academic publishing output has been affected most by the COVID-19 pandemic and whether this varies between men and women. We compare the impact on all type of publishing output (e.g., preprints, patents, conference proceedings, books(chapters), national/international journal articles) versus journal articles exclusively and, with respect to the latter, whether COVID-19's impact differed by gender and author position (i.e., any authorship place, first-author, last-author). This is important as some prior work has found no increasing gender differences between COVID-19 and non-COVID-19 years in overall publication patterns, yet did find it when considering authorship positions (e.g., see Jemielniak et al., 2023). Yet, as prior work mainly focused on journal publication databases (e.g., Web of Science, Scopus) or preprints, we have little to no insight into how other type of academic output was affected by COVID-19. Distinguishing these output types and authorship positions seems important as each of these reflect academic work, though some may carry more weight in academic careers than others. With respect to author position on journal articles, we assume that first-authored journal articles signal the extent to which scholars were able to carrying out 'own' scientific ideas. With last-authored journal articles we proxy the impact on supervision or leadership tasks during the publication process. For output types and authorship roles, we explore gender differences and answer the following research questions: to what extent is the gendered impact of the COVID-19 pandemic on research output conditional on the type of publication output (all output versus journal articles) (Explorative question 2)?; to what

extent is the gendered impact of the COVID-19 pandemic on research output conditional on authorship position in journal articles (Explorative question 3)?

To achieve these contributions, we reconstruct the entire publishing careers for approximately ~ 8 K PhD recipients from 1990–2022 in the Netherlands with active publishing careers in the three years prior to COVID-19 using the Dutch National Academic Research and Collaborations Information System (NARCIS). NARCIS carries several unique advantages that directly connect to our substantive contributions. First, it contains a near-population of all PhD-recipients at the 13 Dutch research universities, from which we can then select 'active' researchers during COVID-19. Second, because we know when scholars obtained their PhD degree, we can precisely track academic career ages of individual scientists. Third, we were able to collect all publication records through 2022. And fourth, the database does not over- or underrepresent scholars of specific disciplines. In addition, publications are author-disambiguated by design as they are filed by scholars and/or universities themselves, implying we have unique author-period-paper-level data. It thus contains representative, author-disambiguated publication metadata for the slower sciences (e.g., published book metadata for philosophers) up to the faster sciences (e.g., conference proceedings for computer scientists).

Data selection and methods

Our database thus originates from NARCIS, a portal for Dutch researchers that contained metadata on scholars' dissertation, publications, projects, grants, and so forth. NARCIS compiled these metadata from university-specific repositories, which in turn contain curated productivity data that researchers themselves file to their universities.[1] As such, the NARCIS publication database is author-disambiguated by design, which allows us to rely on the hand-curated CVs of scientists and not on disambiguation techniques used in large publication databases that perform better for some (i.e., a context's majority members) but less for other groups (i.e., minorities) and may over- or under-count research output for specific groups.

Our point of departure are scholars who obtained a PhD at one of the 13 comprehensive, full-time Dutch research university between 1990 and 2022 ($N = 95.130$). We exclude the "Open Universiteit" (Open University) as this university is structured differently than the other 13. For instance, it mostly focuses on adult, part-time education. For 16.696 PhD recipients we find listed publications (of any type) in NARCIS which are published after the year they defended their thesis. We reasonably assume these scholars remained in academia after their PhD as they continued to publish after the conferral of their doctorate (Mulders et al., 2024). We want to find out how an exogenous shock such as the COVID-19 pandemic affects the publishing careers of active (i.e., producing research output) scholars. Therefore, we select those researchers that had research output at least once in the three-year time period before the COVID-19 pandemic struck *and* whose first and last output are at least two years apart as indicative of an active 'publishing career'. This led to an effective sample of 8.303 scholars based in the Netherlands. Together, they produced approximately 308 K unique research items.

[1] NARCIS was replaced by The Netherlands Research Portal OpenAIRE on 3 July 2023.

Dependent variables

We are investigating the impact of the COVID-19 pandemic on publishing careers. Given different publication traditions across disciplines, and because different publication types and author positions are expected to be related to prestige and scholar seniority (Marušić et al., 2011), we construct the following five indicators of publishing productivity (per year): (1) the total number of all research output (regardless of author position or output type). These include journal articles, (edited) books, book chapters, conference papers, proceedings, patents, datasets, and so forth; (2) the total number of *journal articles* (regardless of author position); (3) all first-authored journal articles (including sole authored publications; a high prestige position); (4) all middle-authored articles; (5) all last-authored journal publications (excluding sole authored publications; often communicates senior status). We compare dependent variable (1) versus (2) to assess the impact of publication type (Exploratory question 2). We compare (2), (3), (4) and (5) to investigate the differential impact of the pandemic on authorship position (Explorative question 3).

Independent variables

COVID-19 years

The COVID-19 pandemic entered the scene in late 2019. The first cases in the Netherlands were reported in February 2020, and a first so-called intelligent lockdown was declared on March 23, 2020. The years 2020 and 2021 can be considered as the full Corona-years with many COVID-19 mandated social restrictions, among which the obligation to work from home, school closures, evening curfews, and so forth. As from 15 January 2022, after the last complete lock-down, universities opened their doors. First for students and lectures only such that most lectures could take place on campus again. From 15 March 2022 onwards, no obligatory 'corona-rules' were in place anymore and university staff could work and meet at university again at will. Hence, we label the years 2020 and 2021 as the COVID-19 years.

Naturally, publishing takes time; scientific ideas have to be developed, data collected, results reported, and the review process is oftentimes long. Figure 1 depicts for different PhD-cohorts, all research output measured in (mean number of) publications per year from 1990 until 2022. While we observe a significant decline in publishing output in 2020 and 2021, the scientific work of some of the output we observe during these COVID-19 years may have been performed before 2020. Relatedly, although we observe in Fig. 1 that in 2022 the research output bounced back again, it did not not return to the pre-COVID-years level. This decline in mean research output in 2022 may still be an enduring consequence of the constraints due to COVID-19. Here, we will thus most likely underestimate the impact of the pandemic on publishing output by not including 2022 as a 'COVID-19 year'. In the main text we report results where our covariate 'COVID-19 years' refers to 2020 and 2021. We performed sensitivity analyses where we used separate covariates for the year 2020 and 2021 but results were not qualitatively different from the ones presented in the main text.

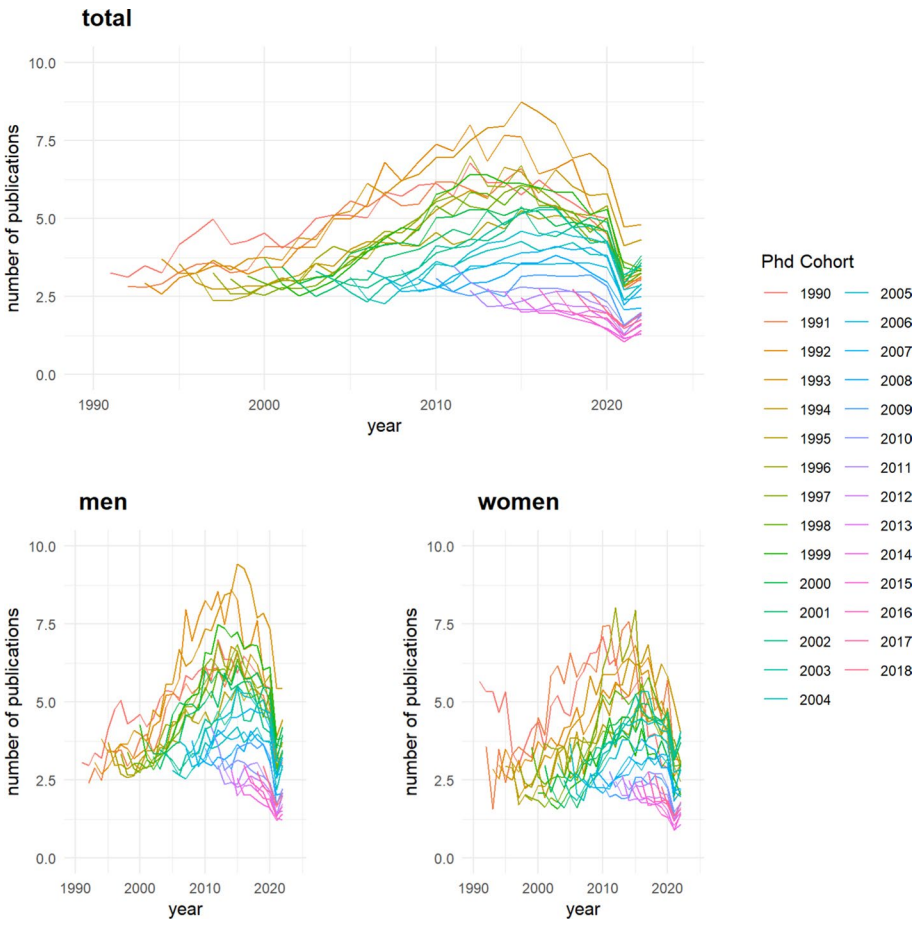

Fig. 1 Mean publications per author per year and PhD-cohort

Gender

We follow standard practice in social studies of science and assign gender on the basis of first names (Hofstra et al., 2020; Huang et al., 2020; Mulders et al., 2024) as gender is not reported in the NARCIS database. First names were gathered from NARCIS or scraped from the full-text dissertation PDFs themselves where names are listed on standard-format title pages. For approximately 10% of scholars a manual internet search was necessary to retrieve a first name (e.g., by querying dissertation or publication titles). We linked these first names to the the Dutch civil registry database from the "Meertens Instituut" that lists name-by-gender frequencies and then assign gender on a majority rule. To increase recall we also used the "GenderizeR" (Wais, 2006) API that consists of first name and gender information for many millions of individuals collected from social media profiles in various countries. Overlap between the two methods is 90.5%, and we prioritize our first method as it is rooted in Dutch registry data. For a small proportion of names without an assigned gender we performed additional manual internet searches. For approximately

1% of our scholars we were unable to find a first name, or to assign a gender to the first name. Based on the last names of these scholars we conclude that non-Dutch names may be somewhat overrepresented among those without an assigned gender.

Career age and PhD-cohort

We measure a career's start year as the year after the doctorate was obtained. This is often the point at which PhDs continue to perform academic science as postdocs or as faculty. Publication output depends on career age with a common drop in output in the first years after a PhD, followed by a period of increasing productivity until productivity starts to plateau and slowly decreases again. Even among our selection of still active scholars we observe these career-age effects (Fig. 2), and we therefore need to take these general career age trends into account when assessing the impact of the COVID-19 years.

Figure 2 once more clearly depicts the impact of COVID-19; for each PhD-cohort we observe a significant research output decline in the penultimate year of their career thus

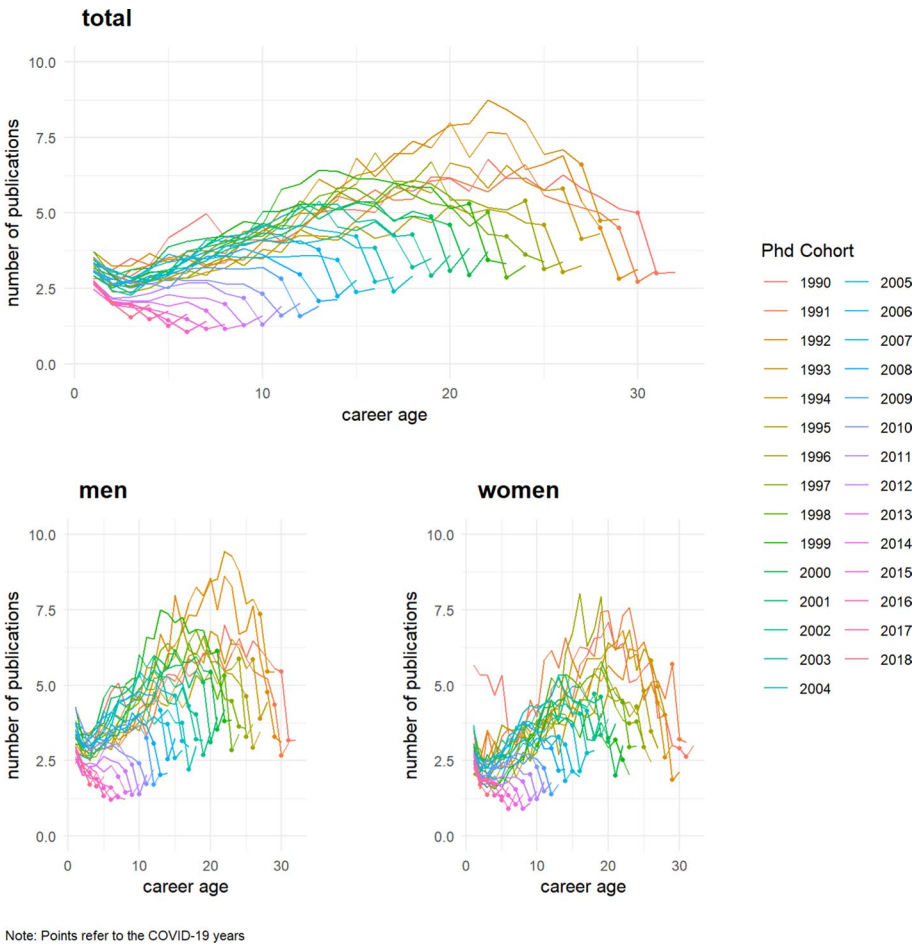

Fig. 2 Mean publications per author by career age and PhD-cohort

far and the third to last year of their career thus far. These are the COVID-19 years. From Fig. 2 we also observe that, in general, at any given career age, older PhD-cohorts in our sample publish more than younger PhD-cohorts. This may reflect that competition to publish is harsher for younger PhD-cohorts. While the relative change in the annual articles published in scientific and technical journals per million people in the Netherlands between 1996 and 2020 was 60 percent (National Science Foundation (via World Bank), 2025), in roughly the same time period, the relative change in the annual number of dissertations awarded was with 79 percent (UNL) substantially higher. An alternative explanation is survivor bias, i.e., scholars that published relatively less during their career are more likely to have left academia at an earlier (career) age. Our sample only includes scholars who published in the years prior to the COVID-19 pandemic and thus especially successful (high-output) scholars remained in our data and this selection on success will be more pronounced for older PhD-cohorts. Regardless of the precise reason, Fig. 2 demonstrates that we also need to account for differences in publication output by PhD cohort when assessing the impact of the COVID-19 years (which we do).

PhD after 2005

We expect the impact of the pandemic to be especially severe for scholars with child rearing responsibilities and, more importantly, especially for women scholars with child rearing responsibilities. Unfortunately, we have no direct access to information on whether individual scholars in our sample had child rearing responsibilities during the pandemic. We assume that especially scholars who received their PhD after 2005 had care responsibilities for young children during the COVID-19 pandemic. This assumption is based on a preliminary analysis for which we linked survey data among Dutch PhDs performed by Statistics Netherlands in 2014 and 2019 ('Gepromoveerdenonderzoek 2014 and 2019' (Maas, Korvorst, Mooren, & Meijers, 2014; Thor & Perez, 2014)) to register data of Statistics Netherlands. The majority of this sample (approximately 71%) becomes parents within fifteen years of obtaining doctorate. For a closer look at childcare responsibilities during COVID-19, we selected only PhD recipients still working in academia in 2020 and, subsequently, calculated for each PhD-cohort the proportion with children younger than 5 (i.e., pre-elementary school age). We observe that, among this sample, especially PhD-cohorts after 2005 had at least one child aged under five [see Fig. 5 (Appendix)].

Based on the same linked survey data, we observed that women academics are on average 32.7 years old and men 33.7 when they become parents. When we look at the timing of parenthood relative to doctorate receipt, men and women are markedly similar. Given that men are older when they get their PhD (mean age PhD receipt = 32.6) than women (mean age PhD receipt = 31.7), both men and women first become parents on average about 1 year after they obtain their doctorate. Therefore, we assume that family formation and childrearing responsibilities occur at similar points in men and women's careers.

Research domain

To assess whether COVID-19 has different consequences for scholars working in different research domains, we assigned research domain to a scholar based on the published output in the five years before COVID-19 and later. We also include the latter output because we assume that scholars started working on this already before or during COVID-19. We used OpenAlex (Massimo et al., 2024) to retrieve the research domain of each of the research

outputs in NARCIS. We turned to OpenAlex for this metric because NARCIS does not report research domain in research output. Our queries from NARCIS to OpenAlex were based on exact matches with an output's DOI or otherwise on title and year of publication. In OpenAlex research output is assigned a topic (OpenAlex, n.d.). OpenAlex distinguishes between 4516 topics and these belong to one of four research domains: Health Sciences, Life Sciences, Physical Sciences, Social Sciences. Subsequently, we determined for each scholar the percentage of their output that fall in each of these domains, thereby doing justice to the fact that scholars may be active in more than one domain. On average, these domain scores are based on 23 publications. For 14 scholars we were unable to determine domain scores (e.g., because of not finding their output in OpenAlex) and these scholars were deleted from our sample. Women score on average higher on the health and social domain [32 and 33 percent respectively, versus 25 and 28 percent for men; Table 5 (Appendix)]. Men score on average higher on the physical domain than women [27 versus 14 percent; Table 5 (Appendix)].

Ethnic background

Scholars' ethnic background is not the focus point of the present contribution, though we need to account for the fact that ethnic inequality in Dutch academia is also enduring besides (and intersecting with) gender inequality (Mulders et al., 2024). The largest traditional minoritized ethnic groups in the Netherlands consist of people with a Moroccan, Turkish or Dutch Caribbean ethnic background (De Haas et al., 2019). While the original migrants predominantly arrived in the 1960s and 1970s, their children, the so-called second-generation, followed their complete educational career in the Netherlands. Ethnic background based educational inequality is still pronounced in the Netherlands but in absolute terms, the number of second-generation migrants that obtain a university degree that qualifies them to pursuit a PhD is clearly increasing. Prior work demonstrated that these minoritized groups are less likely to start a publishing career after their PhD, and stop their academic (publishing) career earlier than majority-Dutch (Mulders et al., 2024). These already disadvantaged groups may have suffered more from the impact of COVID-19 than Dutch majority members as well.

The impact of the COVID-19 pandemic may also be different for scholars who came to the Netherlands from abroad for their PhD and started a career in Dutch academia afterwards, as compared to majority Dutch. While we do not know where PhD recipients lived before they started their PhD, we assume that this group of international scholars are more likely to bear a last name signalling an ethnic background different than Dutch and of the largest 'traditional ethnic minoritized groups'. Thus, in our main analysis we control for ethnic background. Ethnic background was assigned based on the last name of the PhD-recipient in a similar way as for gender, but now with the use of surnames. We labeled scholars whose surname signaled Turkish, Moroccan, Surinamese or Dutch Antillean descent as 'minority I'. and scholars whose surname signaled a different ethnic heritage were labeled as 'minority II'.

University

Finally, we will take into account the university at which the scholar received the doctorate.

The descriptive statistics of our variables are summarized in Table 1. This paper is accompanied by a public replication website (https://coviddutchacademia.netlify.app/) where readers

Table 1 Descriptive statistics at Phd-level ($N = 8303$)

	Mean/prop	SD	Median	Min	Max
All output	48.957	71.528	22.000	2	784
All articles	38.375	61.834	16.000	0	783
First authored articles	33.073	57.953	12.000	0	745
Mid position authored articles	3.835	7.645	2.000	0	310
Last authored articles	1.467	3.412	0.000	0	77
PhD-cohort[a]	2007	7.461	2009	1990	2018
PhD after 2005	0.644			0	1
Gender: men	0.571			0	1
Gender: women	0.420			0	1
Gender: no first name	0.007			0	1
Gender: missing	0.002			0	1
Ethnicity: Dutch majority	0.761			0	1
Ethnicity: minority I	0.014			0	1
Ethnicity: minority II	0.084			0	1
Ethnicity: missing	0.141			0	1
Domain: Health	0.282			0	1
Domain: Life	0.202			0	1
Domain: Physical	0.214			0	1
Domain: Social	0.301			0	1
University: EUR	0.063			0	1
University: LU	0.029			0	1
University: RU	0.209			0	1
University: RUG	0.031			0	1
University: TUD	0.009			0	1
University: TUE	0.020			0	1
University: TI	0.010			0	1
University: UM	0.112			0	1
University: UT	0.050			0	1
University: UU	0.140			0	1
University: UvA	0.095			0	1
University: VU	0.082			0	1
University: WUR	0.150			0	1

[a]The smallest PhD-cohort is 1992 and consists of 70 men and 23 women. For a complete overview of the size of each cohort see our replication website

find the data set on which all results are based, the R code we used for data scraping and wrangling, and all R code to replicate our figures and results reported in the main text, and the results of all robustness analyses.

Analytical strategy

Our dataset is structured as a person-period file; we observe one row per author per year (from the year after the scholar received their PhD until 2022). In total, this leads to 113.984 observations (i.e., scholar-years). Our dependent variables are counts of the yearly number of scientific publications per scholar. The mean number of yearly output (all types, all author positions) among our sample is approximately 3.5, with a maximum of 114 (for a scholar affiliated with CERN) and in Fig. 3 we observe that this distribution is heavily right-skewed for both men and women. Women are more likely to have 0 publications per year than men, men are more likely to have five or more publications per year than women. We assume our count variables follow a *beta negative binomial distribution.* The beta negative binomial distribution uses three parameters to model the location (mean) and shape (e.g. over-dispersion) and fitted the data significantly better (based on AIC) than the more-standard negative binomial distribution which uses only two parameters to model the location and shape of the distribution (Stasinopoulos & Rigby, 2023). To fit our count variables we used the log link: $\mu = exp(\beta X)$. Where μ is the predicted count given X and $exp(\beta_1)$ is the multiplicative effect on the mean count given a one-unit increase in X_1.

COVID-19 happened for all scholars from different PhD-cohorts in the same period, namely in 2020 and 2021, but at different points in their career. Therefore, we decided to use career age as the 'time' variable in our regression analyses and not period. Our strategy to assess the impact of the COVID-19 years was to predict the trend in yearly publications by career age for all PhD-cohorts combined, and to include a dummy variable which indicated whether for each specific scholar this time point (i.e., career age) coincided with

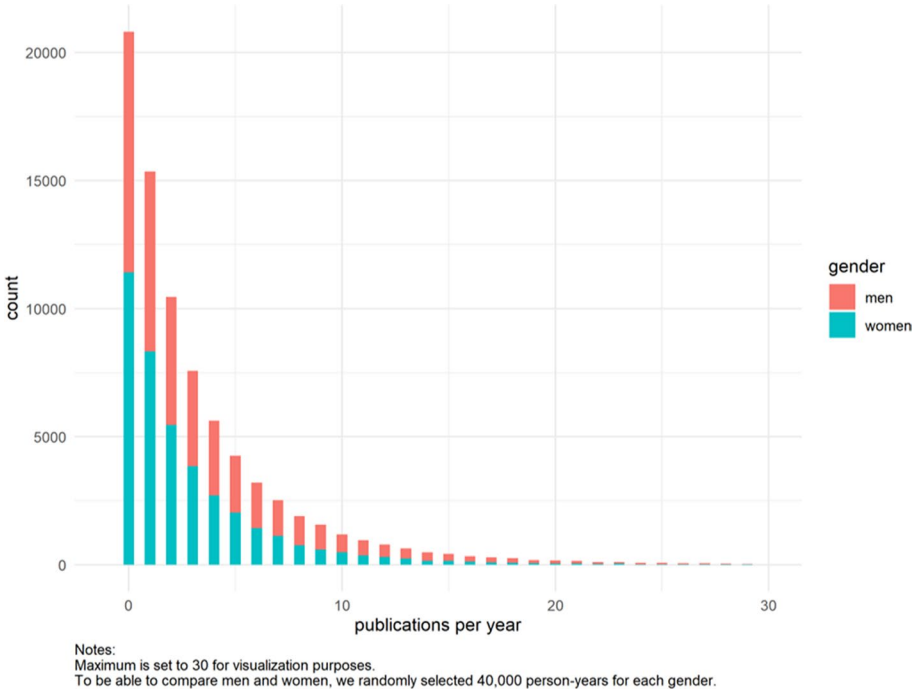

Fig. 3 Histogram of yearly number of publications per author

a COVID-19 year, while controlling for our covariates (i.e., PhD-cohort, gender, research domain, ethnic background, and university). An alternative strategy is discussed in the robustness paragraph below. All our analyses are performed in R (R Core Team, 2021), our models are estimated with the package gamlss (Rigby & Stasinopoulos, 2005).

Results

In Fig. 4, we plotted the observed number of research output at different career ages. The grey box plots in the background illustrate once again that the distribution of the number of yearly publications at different career ages are skewed (and especially among men). The orange line refers to the mean number for scholars who at that career point did *not* experience COVID-19. As expected this line is very close to the overall observed mean number of yearly publications, as indicated by the points in the box plots. The blue line refers the

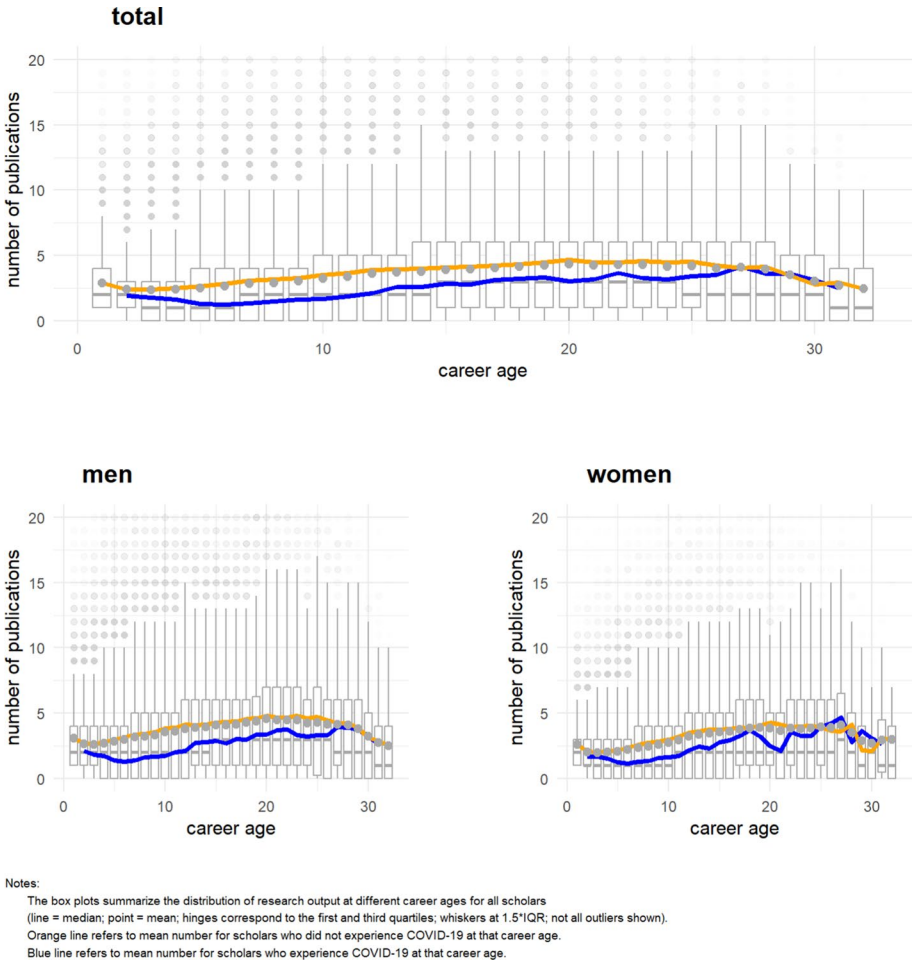

Fig. 4 Observed distribution of yearly number of publications at different career ages

mean number of yearly publications for scholars who *did* experience COVID-19 at this point in their career. We observe that in the first several of years after one's PhD, COVID-19 did not have a severe impact in publishing output, yet this increases for scholars later in their career where the distance between the orange and blue line becomes larger. In general, the impact of COVID-19 seems to be larger for men than women, as indicated by the larger distance between the orange and blue line. At (very) late career stages (26 years after having received a PhD), COVID-19 did not seem to impact publishing careers anymore. In sum, Fig. 4 gives a clear impression that the pandemic impacted publication output, and indicates that men were stronger affected than women and that the impact depended on career age.

Next, we turn to the results of our multivariate beta negative binomial models (see Table 2). In Model 1, we modeled the career age trend in publications using bsplines (with quantile knots and three degrees of freedom). To assess the impact of the COVID-19 years we included one indicator for the years 2020 and 2021 and we included main effects for gender, research domain, PhD cohort, ethnic background, and university. Unsurprisingly, we observe that the pandemic resulted in significantly less academic output in those years ($\beta = -0.409, p = 0.000$). The average marginal effect of experiencing COVID-19 is -1.256. Thus, on average scholars produced 1.256 outputs (e.g., papers, preprints, etc.) less per year during the COVID-19 pandemic. Note that this is on an average of 3.5, indicating a COVID-19 productivity drop of about one-third ($(1 - exp(-.409)) * 100\% \approx 34\%$), a considerable amount of knowledge was 'lost' during COVID-19.

In line with prior work we observe that women scholars output less than men, namely $exp(-.126) * 100\% \approx 88\%$ of what men produce. Publication output is highest in the Health domain (the reference category). Each later PhD cohort publishes less ($\beta = -0.019, p = 0.000$) and both ethnic minoritized groups publish less than Dutch majority member scholars (both $p = 0.000$). The largest group (Moroccan, Turkish, and Dutch Caribbean) produce about $exp(-.254) * 100\% \approx 78\%$ of the research output of Dutch majority members.

To test hypothesis 1 in which we formulated the expectation that the impact of COVID-19 on publication output was stronger for women than for men, we included the interaction term between 'gender: women' and 'COVID-19 years' in Model 2. Contrary to Hypothesis 1, but in line with findings of Madsen et al. (2022), the impact of COVID-19 on research output was not more severe for women scholars in the Netherlands, as indicated by the non-significant interaction term ($\beta = 0.010, p = 0.652$). Expressed in average marginal effects based on Model 2, the decrease in yearly publication output as a result of COVID-19 for women was 1.137 and for men 1.317, which corresponded to an average marginal interaction effect of -.180; the average reduction in yearly publication output due to COVID-19 was .180 *less* for women than for men. Parity was gained during the pandemic.

To assess whether these results depended on our operationalization of COVID-19 years, we re-estimated Model 2 but now with separate indicators for the year 2020 and 2021 (and separate interactions with gender). From this model we learn that the reduction in research output was especially acute in 2021 ($\beta = -0.185, p = 0.000$ and $\beta = -0.683, p = 0.00$, respectively for the estimated impact of 2020 and 2021). But once again, we did not find corroborative evidence that the pandemic hit women in science harder than men; both interaction terms with gender were not significant (see replication website). We thus refute hypothesis 1. These results also make it unlikely that the impact of COVID-19 pandemic would become apparent at different time periods for men and women. Thus while our time window only extends to 2022 and not beyond, it is unlikely—although with our data we

Table 2 Impact COVID-19 on yearly publication output (Negative Beta Binomial; career age as time variable)

	Model 1			Model 2			Model 3			Model 4		
	B	*SE*	*P*	*B*	*SE*	*P*	*B*	*SE*	*P*	*B*	*SE*	*P*
Intercept	1.456	0.020	0.000	1.456	0.020	0.000	1.324	0.025	0.000	1.312	0.025	0.000
COVID years	− 0.409	0.011	0.000	− 0.411	0.014	0.000	− 0.283	0.023	0.000	− 0.188	0.032	0.000
Gender (men = ref.)												
Women	− 0.126	0.007	0.000	− 0.127	0.007	0.000	− 0.161	0.011	0.000	− 0.162	0.011	0.000
Domain (health = ref.)												
Life	− 0.179	0.014	0.000	− 0.179	0.014	0.000	− 0.307	0.017	0.000	− 0.296	0.018	0.000
Physical	− 0.099	0.013	0.000	− 0.099	0.013	0.000	− 0.147	0.015	0.000	− 0.138	0.016	0.000
Social	− 0.245	0.011	0.000	− 0.245	0.011	0.000	− 0.357	0.013	0.000	− 0.332	0.014	0.000
PhD-cohort	− 0.019	0.001	0.000	− 0.019	0.001	0.000	− 0.019	0.001	0.000	− 0.019	0.001	0.000
Ethnicity (Dutch majority = ref.)												
Minority I	− 0.254	0.035	0.000	− 0.254	0.035	0.000	− 0.317	0.039	0.000	− 0.317	0.039	0.000
Minority II	− 0.183	0.014	0.000	− 0.182	0.014	0.000	− 0.196	0.016	0.000	− 0.195	0.016	0.000
COVID*women				0.010	0.022	0.652	0.068	0.038	0.070	0.073	0.038	0.053
PhD after 2005							− 0.013	0.016	0.427	− 0.013	0.016	0.438
COVID*PhD > 2005							− 0.248	0.031	0.000	− 0.245	0.031	0.000
women*PhD > 2005							− 0.047	0.017	0.006	− 0.046	0.017	0.007
COVID*women*PhD > 2005							− 0.010	0.049	0.835	− 0.014	0.049	0.766
COVID*life										− 0.095	0.046	0.039
COVID*physical										− 0.070	0.039	0.073
COVID*social										− 0.215	0.037	0.000
Efron's R^2	0.077			0.077			0.088			0.088		
AIC (*df*)	528,812 (*df* = 32)			528,808 (*df* = 35)			528,197 (*df* = 43)			528,167 (*df* = 46)		

For reasons of parsimony, the estimates of the following variables are not shown: bsplines; gender: no first name; gender: missing; ethnicity: missing; university. Similarly, the estimated shape parameters (sigma and nu) are not shown

$N_{\text{person-years}} = 113{,}782$; $N_{\text{persons}} = 8289$

cannot completely rule it out—that the gendered impact becomes more visible after 2022, when research output already started to recover (Figs. 1, 2).

With Model 3, we assess hypothesis 2, our 'child-rearing hypothesis'. In line with our expectation we observe that the impact of the pandemic was more severe for scholars who we assume to have had child care tasks during the lockdown period, that is scholars who received their PhD after 2005 ($\beta = -0.248, p = 0.000$). However, as Model 3 also shows, it is not the case that dealing with the COVID-19 pandemic while also having child-rearing responsibilities had a stronger negative impacted on publishing output for women than for men, as indicated by the non-significant three-way interaction effect ($\beta = -0.010, p = 0.835$). Based on this we thus need to refute hypothesis 3.

As a robustness check we also used an alternative strategy to test hypothesis 3. That is, we estimated Model 2 (Table 2) separately for two PhD cohorts (cohort 1: PhD received 2011–2018, cohort 2: PhD received 1992–1999), making the likely assumption that child-rearing responsibilities will be more prevalent among PhD cohort 1 than among PhD cohort 2. But also with this alternative strategy we did not find corroborative evidence for hypothesis 3: we did not observe that COVID-19 had a stronger negative impact for women, neither for PhD cohort 1 nor 2 (see replication website).

In Model 4, we added the interaction terms between COVID-19 years and research domain. It turns out that for scholars active in the Health domain (the reference category) the pandemic had the least impact; as indicated by the negative and significant interaction terms between COVID-19 and the other three research domains. This confirms our intuition that the Health domain suffered a reduction in research output to a lesser extent compared to other domains, likely because of bursts in research output *on COVID-19 itself*. The pandemic hit scholars active in the social domain—notably where women are overrepresented—the hardest ($\beta = -0.215, p = 0.000$) compared to the Health domain.

We argued that publication cultures vary across research domains as do gender (and ethnic background) inequalities. The (gendered) impact of the pandemic may also vary across research domains and simply controlling for research domain may be not enough to rule out that in some research domains women were more negatively impacted by the pandemic than men. Thus, to assess the extent to which the gendered impact of the COVID-19 pandemic varied across research domains (i.e. Explorative question 1) we re-estimated Model 2 (of Table 2) but now for each research domain separately. The full model results are available on our replication website. In all research domains the pandemic had a negative impact on research output but in none of the four distinguished research domains, we observe any corroborative evidence for a differential impact of COVID-19 across women and men scholars, as indicated by the non-significant estimated 'COVID-19 * women' interactions of $\beta = -.125, p = .254$, $\beta = .200, p = .097$, $\beta = .135, p = .213$ and $\beta = 0.060, p = .446$, respectively for the Health domain, Life domain, Physical domain and Social domain. Thus, while some research domains were hit harder by the pandemic than other, our results showed no gendered impact of the COVID-19 pandemic in the four distinguished research domains. Finally, we tested whether the the 'COVID-19 * women' interactions varied significantly in strength across research domains—even though they were insignificant—but this was not the case (see replication website). Thus our answer to explorative question 1 is that the gendered impact of the pandemic did not vary across research domains.

In Model 5, we subsequently included interaction terms between COVID-19 and ethnic background and university respectively, but the estimates of the variable of interests are hardly affected and for reasons of parsimony therefore only included in the appendix (Table 6). Although not the focus of the present contribution, it is notable that this additional model does demonstrate that scholars with an ethnic minority background were

Table 3 Predicting yearly publication output per year (Negative Beta Binomial)

	All output			All articles			First-authored articles			Middle-authored articles			Last-authored articles		
	B	*SE*	*P*	*B*	*SE*	*P*	*B*	*SE*	*P*	*B*	*SE*	*P*	*B*	*SE*	*P*
Intercept	1.456	0.020	0.000	1.190	0.026	0.000	0.596	0.030	0.000	− 0.127	0.039	0.001	− 1.826	0.070	0.000
COVID	− 0.411	0.014	0.000	− 0.383	0.017	0.000	− 0.373	0.018	0.000	− 0.415	0.035	0.000	− 0.376	0.054	0.000
Gender (men = ref.)															
Women	− 0.127	0.007	0.000	− 0.190	0.009	0.000	− 0.232	0.010	0.000	0.046	0.015	0.003	− 0.216	0.025	0.000
COVID*women	0.010	0.022	0.652	0.007	0.025	0.777	0.028	0.027	0.306	− 0.003	0.051	0.948	0.165	0.079	0.036
Efron's R^2	0.077			0.102			0.120			0.039			0.027		

For reasons of parsimony, the estimates of the following variables are not shown: bsplines; gender: no first name; gender: missing; ethnicity; domain; university. Similarly, the estimated shape parameters (sigma and nu) are not shown

$N_{\text{person-years}} = 113{,}782$; $N_{\text{persons}} = 8289$

more affected by the pandemic than Dutch majority member scholars; for scholars with a Turkish, Moroccan, Surinamese or Dutch Antillean background (i.e., minority group I) the estimated interaction effect was $\beta = -.183, p = 0.107$ and for scholars with an other ethnic background $\beta = -.162, p = 0.000$ [Table 6 (Appendix)].

Next we turn to assessing differences in the gendered impact of COVID-19 across different research output types (Explorative question 2) and authorship position in journal articles (Explorative question 3; Table 3). We use the same model specification as in Table 2, Model 2. Since each consecutive indicator of academic productivity—all output, all journal articles, first-authored articles, middle-authored articles, last-authored articles—is more selective (Table 1), it is no surprise that the estimated intercepts become smaller in Table 3 moving from the left- to the right-hand result columns. Overall, the COVID-19 pandemic had a consistent negative impact, regardless of output type and, for journal articles, authorship position. There are clear gender inequalities that becomes more severe the higher the 'status' of the specific output; as can be illustrated by the estimated main effects of women of $\beta = -0.127, p = 0.000$ and $\beta = -0.232, p = 0.000$ for the dependent variables moving from 'all output' to '1st authored articles', respectively.

In line with our previous results, we do not observe that the impact of COVID-19 was more severe for women than for men. This finding holds if we look at all output combined and if we focus on journal articles only and, if we focus on journal articles, both for first-authored articles and last-authored articles. To illustrate, with respect to journal articles (regardless of author position) the AME for women during non COVID-19-years is -0.539 and during COVID-19-years this is smaller -0.356. Thus, the gender gap in publishing journal articles became smaller in absolute terms during COVID-19; the average marginal interaction effect is 0.184. For last-authored journal articles, the impact of COVID-19 was even *less* severe for women compared to men, also in relative terms, as indicated by the positive and significant interaction effect of $\beta = 0.165, p = 0.036$. This latter finding may indicate that senior women were less likely than senior men to cut their supervision time during COVID-19.

Answering explorative question 2, we conclude that the gendered impact of the COVID-19 pandemic did not depend on output type. But with respect to explorative question 3, we tentatively conclude that the gendered impact of COVID-19 on research output did depend on authorship position as women experienced a smaller decrease in last-authored journal articles during COVID-19 than men, but did not experience a different reduction in first-authored journal articles during COVID-19 than men.

Robustness checks

Our main results are based on a modelling strategy in which we did not account for the fact that our observations are nested within scholars and time (i.e., career age). Because adding random components to our original model led to convergence issues, we turned to Twoway Fixed Effects models using the package fixest (Bergé, 2018) to assess the possible consequence of ignoring the (unbalanced) nested structure of our data. As dependent variable, we used the log transformed count of yearly publications (logging after we added 1 to all raw scores) since beta negative binomial distributions are not yet supported by this package. We included fixed effects both for scholars and career age. As independent variables we added our COVID-19 years indicator and the interaction between this dummy and gender. Once again we observe a clear negative and significant impact of COVID-19 ($\beta = -0.284, p = 0.000$) but also that women were less negatively impacted by the pandemic, as indicated by the positive interaction term ($\beta = 0.039, p < 0.010$; see replication website).

Finally, while we had used career age as our time variable because of a better data fit, a different strategy would be to use publication year (i.e., period) as indicator of time. As a final robustness check we therefore estimated a Twoway Fixed Effects model with scholar and period as fixed effects. To closely resemble the modelling strategy of Madsen et al. (2022), we used the yearly article output as dependent variable in this case (log transformed after adding 1 to the raw scores). The variable of interest is the interaction of gender with the fixed effect of period and is the only included within-level variable. We ran the model for early career scholars (PhD obtained in 2014, 2015 or 2016; $N = 1310$) and mid career scholars (PhD obtained in 2008, 2009 or 2010; $N = 1242$) separately. We used the pre-COVID-19 year 2019 as our reference year. The results of this difference-in-differences model are summarized in Table 4. We observe no negative interactions for the COVID-19 years (2020 and 2021) by women. Many of the papers published in 2022 are likely to have been submitted or started during the pandemic but the absence of the negative interaction with the post-COVID year 2022 by women makes it unlikely that a possible gendered impact of the pandemic will only be become visible after the pandemic. These findings are consistent for both the early career as well as the mid career scholars. Hence, similar to our earlier main results we do not find corroborative evidence that COVID-19 had a more severe impact on research output for women than for men using this alternative modeling strategy.

Table 4 Two-way fixed-effects model for yearly article output (Gaussian; period as time variable)

	Early career scholars			Mid career scholars		
	B	*SE*	*P*	*B*	*SE*	*P*
Year2009*women				− 0.066	0.080	0.411
Year2010*women				− 0.062	0.067	0.354
Year2011*women				− 0.074	0.057	0.194
Year2012*women				− 0.040	0.053	0.454
Year2013*women				− 0.041	0.049	0.404
Year2014*women				− 0.039	0.049	0.431
Year2015*women	0.071	0.065	0.276	− 0.009	0.045	0.836
Year2016*women	0.084	0.046	0.070	− 0.032	0.042	0.452
Year2017*women	0.033	0.039	0.394	− 0.027	0.041	0.514
Year2018*women	0.007	0.037	0.858	− 0.018	0.037	0.637
Year2020*women	0.003	0.038	0.935	0.007	0.039	0.852
Year2021*women	0.025	0.039	0.529	0.074	0.043	0.086
Year2022*women	0.085	0.039	0.030	0.041	0.044	0.349
Overall R^2	0.53			0.524		
within R^2	0.001			0.001		

For reasons of parsimony, the estimates of the fixed effects are not shown: scholars; year. Scholars with missing values on gender were removed from the analysis, 'men' serves as reference category

Early career scholars: $N_{observations}$ 8888; $N_{persons}$ 1310

Mid career scholars: $N_{obervations}$ 14,959; $N_{persons}$: 1242

Based on these results we graphically summarized predicted publishing rates for men and women and, for women, the counterfactual trend if they had similar 2019–2022 trajectories as men. The difference between the counterfactual trend and the predicted trend is what Madsen et al. (2022) interpret as the average treatment effect for women (see replication website)

Discussion

The COVID-19 pandemic has had a huge impact on scientific productivity. The scholarly output related to COVID-19 surged, with many journals trying to expedite their decision cycles (Miller & Tsai, 2020; Nane et al., 2022). But in general, research activities slowed down and research output declined. We find that in the Netherlands in our sample, the average output declined by approximately 33 per cent during COVID-19 in 2020 and 2021. Previous cross-national comparative work reported reductions in research output closer to 15 per cent (e.g., Abramo et al., 2022; Madsen et al., 2022) but because these studies relied on preprint repositories or focused on specific disciplines (mostly medical or STEM-fields) and were not yet able to also include the (complete) COVID-19 year 2021—in which we even observed a stronger reduction of scholarly output than in 2020—impact has likely been underestimated in prior work. A simple calculation then informs us that, the comparatively small, Dutch academic system 'lost' at least (as only a set of active *faculty* are included here) 20,000 units of research output during two years of the COVID-19 pandemic ($\approx 1.2 \times 2$ COVID-19 years 2020 and 2021 $\times \sim$ 8K scholars).

The COVID-19 pandemic has exerted an unequal impact on men and women. This disparity is evident not only in infection risk and clinical outcomes—where men generally exhibit greater susceptibility to severe disease and higher fatality rates, whereas women face a heightened risk of developing long-term post-COVID-19 symptoms (e.g., Fernández-de-las-Peñas et al., 2022; Gebhard et al., 2020)—but also in the labor market where the pandemic exacerbated existing inequalities and also women were disproportionately affected by the pandemic compared to men (e.g., Casale & Posel, 2021; Dang & Nguyen, 2021; Graham et al., 2021; Landivar et al., 2020; Reichelt et al., 2021; Zamberlan et al., 2021). In line with this, the prevailing narrative with respect to gender disparities in academia is that in science too, women were hit harder by the pandemic than men (Andersen et al., 2020; King & Frederickson, 2021; Krukowski et al., 2021; Kwon et al., 2023; Lerchenmüller et al., 2021; Madsen et al., 2022; Muric et al., 2021; Squazzoni et al., 2020). Accordingly, we anticipated that women in Dutch academia would experience a more substantial drop in scholarly output compared to men. This expectation, however, was not empirically self-evident, as prior work has revealed cross-national variations in these trends, with findings for the Netherlands being mixed: Madsen et al. (2022) reported no increasing gender gaps, whereas Abramo et al. (2022) identified increases in gender disparities.

In this contribution, we settled the debate on scholarly gender disparities during COVID-19 in the Netherlands. To this end, we examined the gendered impact of COVID-19 on research output among over 8000 researchers with active publishing careers in the years preceding the pandemic. This sample represents scholars in all universities and in all science domains in the Netherlands. Our time window included the entire duration of the pandemic and utilized comprehensive (precisely author-disambiguated) research output. This output includes peer-reviewed journal articles, preprints, book chapters, and other output, rather than solely relying on preprints repositories or one single scholarly metadata corpus. Our approach addresses important limitations of prior studies, although we acknowledge that our study carries its own shortcomings (detailed later). Our primary finding indicates that women in academia were not disproportionately negatively affected by the pandemic compared to men, at least not with respect to different types of and various roles in research output. Not in their absolute number of yearly publications but also not in relative terms. These results resemble the findings by Madsen et al. (2022) who reported

no gendered impact of COVID-19 in the Netherlands in basic medicine, biology, chemistry, and clinical medicine. Our findings contrast those of Abramo et al. (2022) who report that women deposited fewer papers than men in large repositories (e.g., BioRxiv) during COVID-19. We add to this evidence by now providing concrete evidence across all scientific domains in the Netherlands showing no gendered effect of COVID-19 on productivity. And in contrast to Kwon et al. (2023) who find that the number of lead authorships during COVID-19 decreases for women scientists, we find that the number of last authorship positions (arguably a "senior position") slightly increases for women versus men during COVID-19.

Our results were robust across various operationalizations of yearly output (including total output, journal articles, first-authored, middle-authored, and last-authored journal articles), different modeling strategies (e.g., employing a beta negative binomial distribution versus a Gaussian distribution for log-transformed outcome variables, modeling time as either career age or period), and the inclusion or exclusion of key control variables such as research domain, PhD cohort, ethnic background, institutional affiliation, and so forth. With respect to gender gaps in the absolute number of yearly publications, our results indicated that these even reduced during COVID-19. At first glance this seems a positive result, as gender inequality in research output seemed to have decreased in absolute terms. However, we do need to keep in mind that pre-COVID-19, women's research output was lower than that of men—in part because women scholars are more likely to work part-time than male scholars, perform more committee work, are likely pulled in more teaching and possible more supervisory roles. Importantly, women faced similar *relative* reductions in output as men across nearly all research output.

The Netherlands scores relatively high on rankings of gender equality compared to other countries and Dutch academia in particular is known for the autonomy it gives to its employees and its progressive policies in terms of leave or care. However, it would be too soon to conclude that the relatively low levels of gender inequality pre-COVID-19 in the Netherlands mitigated the possible unequal impact of the pandemic across women and men scholars (cf., World Economic Forum, 2024). Gender inequality in Dutch academia is still present and does not show convincing trends to more parity after the PhD-stage (Mulders et al., 2024). We thus need more replication studies in other countries with similar high-quality data on a near-population of active scholars representing all disciplines to reach this conclusion, especially because observed patterns of gender inequality during COVID-19 seem to depend on the selection of dependent variables on which the analyses are based.

Our descriptive statistics revealed that the reduction in scholarly output was less pronounced for (very) early career—likely former PhDs with dissertation papers in the publication pipeline—and (very) late career researchers—senior scholars with many papers in the publication pipeline at any moment. Career age thus seemed to matter during the pandemic. In line with this, we find tentative corroborative evidence for our hypotheses that especially scholars of PhD cohorts whom we considered most likely to have had caregiving responsibilities for young children during the pandemic (i.e., those who obtained their doctorate after 2005) were the most negatively affected by the pandemic. We say 'tentative' because for scholars who received their PhD after 2010, we did not find this effect and these scholars too can be assumed to have had caregiving tasks. But regardless of the precise cut-off point used, we did not observe that especially women from more recent PhD-cohorts were negatively impacted by the pandemic.

The output of younger PhD cohorts was substantially lower than for older cohorts before (and after) COVID-19 (cf., Yildirim & Eslen-Ziya, 2020), which may have 'protected' against severe drops in scholarly output (i.e., it was already low), echoing our interpretation

why women were not more negatively affected by the pandemic than men. However, we lacked direct information on scholars' caregiving responsibilities and instead proxied this underlying mechanism by career stage. Our indirect indicator may have been too crude, potentially capturing more general career age or cohort effects rather than specific caregiving dynamics. An alternative, more substantive explanation could be that these scholars indeed successfully continued to publish under highly challenging conditions by working long hours, potentially placing them at a higher risk for burnout and other health issues. A future study could therefore consider a longer observation period of research output *after* COVID-19 to observe whether output declines at later years due to this reason.

Our unique data allowed us to assess whether the (gendered) impact of COVID-19 varied across four distinct research domains: Health Sciences, Life Sciences, Physical Sciences, Social Sciences. The drop in yearly publications was least pronounced for Health Science scholars and most pronounced for scholars of the Social Sciences—both these research domains know an overrepresentation of women. This may not come as a surprise as especially at the beginning of the pandemic, COVID-19 related research predominantly took place within the Health Sciences and many journals embraced fast review and open science practices to speed up discovery. Only later did research on the social outcomes of the pandemic gained traction. Moreover, especially for social scientists, data collection possibilities (e.g., (lab) experiments, face-to-face surveys, fieldwork) were severely impeded, postponed, or cancelled by the pandemic. That being said, in none of these four research domains did we find supportive evidence that especially women were negatively impacted by the restrictions that came with COVID-19. Researchers in some domains likely disproportionately relied on older or already collected data to continue their research activities during COVID-19.

Although the speed—or slowness—of publishing differs across research disciplines, due to differences in the review process and the time between formal acceptance and the actual publication (Hadavand et al., 2024), we observed a negative impact of the pandemic on publishing output in 2020 and 2021 in all research domains but hardly any *gendered* impact of the pandemic in these years. Could any such gender differences become more visible from 2023 moving forward? Our time window extends to 2022 thus we cannot answer that question. Yet, because we observed that research output started to recover already in 2022 and we saw no prior gender differences due to COVID-19, we assume it is unlikely that this rate of recovery varies between women and men scholars.

The pandemic forced academics to reset priorities and may have caused shifts not only in the time spend on care-taking tasks versus work tasks but also with respect to specific research activities. Scholars may favor activities leading to a type of scholarly output (e.g., contributions to books versus journal articles) and prioritize pursuing 'own' scientific ideas—presumably more often leading to first-authored or single authored papers—over supervision tasks—presumably more often leading to last-authored journal articles. While we did not formulate an explicit hypothesis with respect to possible gendered patterns herein, we explored whether the gendered impact of COVID-19 depended on type of output and author position on journal articles. In general and replicating prior findings (Larivière et al., 2013), gender gaps in scholarly output are more pronounced in the more 'prestigious' type of outputs: in journal articles versus all output, or in first and last authored journal articles versus any author position. Once again, we did not observe that women's research output was more negatively affected during COVID-19 in the Netherlands. In contrast, the impact of COVID-19 was less severe for women than for men for *last authored* journal articles. Based on the results of our study we hypothesize that during crisis women and men in academia prioritize different tasks. Though women are last authors at lower rates compared to men overall, this difference thus *decreased* during the COVID-19 years.

In terms of prioritizing research activities, this may suggest that men rather than women dropped roles related to the mentoring of younger scholars during COVID-19. In turn, this may (partly) explain why women researchers report more work-life balance issues than men (Deryugina et al., 2021). Compared to men scholars, women did not drop roles in either the work or life domain: women attempted to do it all simultaneously. A hypothesis waiting to be more rigorously scrutinized.

While our main conclusion is that women were not more negatively affected by the pandemic than men, this certainly does not generalize to all minoritized groups in Dutch academia. Although not the focus of this contribution, in our explanatory model we did include ethnic background. We hereby made an (admittedly crude) distinction between scholars whom we expected to have a second-generation migration background (with roots in Morocco, Turkey, Suriname or Dutch Antilles) and migrants likely to have migrated to the Netherlands themselves (i.e., first-generation migrants) to start a PhD and pursue a career here. Our results indicate that ethnic minoritized groups were more negatively affected by the pandemic than Dutch majority member scholars. We encourage future work to lay bare the unique experiences of ethnic minoritized groups in academia before, during, and after the pandemic.

Several limitations to our study merit attention. We relied on a unique, relatively large data set consisting of scholars who received a PhD in the Netherlands and who still had an active publishing career pre-COVID. But although all universities and disciplines are represented in our data, it remains a sample and not population data. Scholars who obtained a PhD outside the Netherlands but were working in one of the Dutch universities pre-COVID were not included in our sample. This group may have endured more negative effects, as for example we observed for scholars with an ethnic minoritized background. Similarly, early-career scholars without an active publishing career pre-COVID were not included in our sample. Their publishing careers may have started later (or hardly at all) due to COVID-19, something we could not detect as a result of our sampling procedure. This may have led to an underestimation of the gendered impact of the pandemic, because women form a growing group in the more recent PhD cohorts. So much so, that they are currently the majority of PhD recipients. Thus, even though our finding that the women in our sample were not more negatively affected by the pandemic than their male counterparts was very robust, we need to be cautious to generalizing our results to the total population of scholars active in Dutch academia before and during the pandemic.

We acknowledge that our data lacks measures that could help us to directly observe the data generating mechanisms as to why the pandemic reduced scholarly output. For example, as mentioned above, we used a proxy for child-rearing responsibilities because we lacked information on the presence of young children in scholars' families or whether scholars made use of formal and informal childcare services before and during the pandemic. Similarly, yearly scholarly output will to a large extent depend on how much time scholars can or even 'must' devote to research activities, yet we did not have data on employment contracts (e.g., relative amount of management, research and teaching obligations, service work, tenure track, etc.) nor on the actual hours per week scholars devoted to research before and during the pandemic. Perhaps women were protected through part-time employment (cf., Bertogg et al., 2021). To dig deeper in the impact of the pandemic on life and its path dependency in academia, and more specifically on time spend on research activities, we need to combine big data (from publication repositories) with detailed data (large-scale surveys and national register data). An approach we aim to take in future work.

To assess patterns of gender and ethnic background inequality in academia, scholars have used different type of data and samples. We should at least acknowledge that not only type of scholarly output studied but also data quality itself may impact the patterns

observed, and possibly more so than the different sampling and modelling strategies employed.

In this contribution we demonstrated that in the Netherlands, the COVID-19 pandemic had a substantial impact on scholarly output. Crucially, we pinpointed that this impact was even more acute in 2021 than in 2020. The productivity loss was most severe for scholars in the Social Sciences, a discipline that overrepresents women. Similar to other national contexts and time periods, gender gaps in Dutch scholarly output are ubiquitous and significant across different scientific domains and in various types of scholarly output. Yet, we failed to find any evidence that gender gaps in research productivity *increased* during COVID-19 in the Netherlands.

Appendix

See Fig. 5, Tables 5, 6.

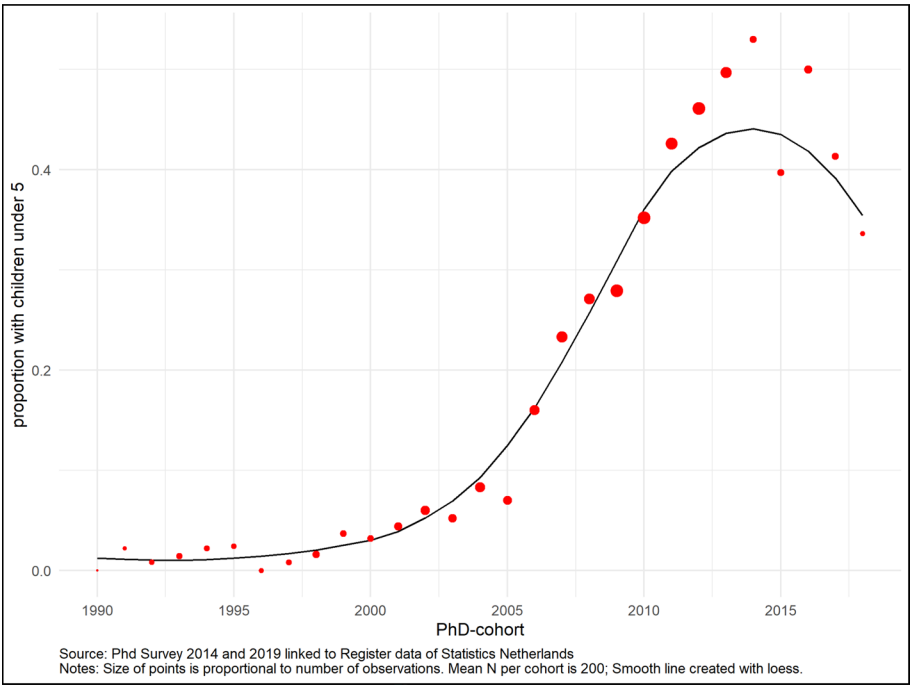

Fig. 5 Proportion of scholars within each PhD-cohort with at least one child aged under 5 in 2020

Table 5 Research domain by gender

	Men ($N=4740$)		Women ($N=3488$)	
	Prop	*SD*	Prop	*SD*
domain: Health	0.253	0.354	0.325	0.375
domain: Life	0.201	0.303	0.205	0.310
domain: Physical	0.267	0.372	0.143	0.287
domain: Social	0.279	0.385	0.327	0.396

Table 6 Predicting yearly publication output per year (negative beta binomial)

	Model 5		
	B	*SE*	*P*
Intercept	1.286	0.025	0.000
COVID-19 years	0.111	0.050	0.026
Gender: women	− 0.162	0.011	0.000
Domain: life	− 0.296	0.018	0.000
Domain: physical	− 0.153	0.016	0.000
Domain: social	− 0.337	0.014	0.000
PhD-cohort	− 0.020	0.001	0.000
Ethnicity: minority I	− 0.294	0.042	0.000
Ethnicity: minority II	− 0.175	0.017	0.000
COVID*women	0.074	0.038	0.050
PhD after 2010	− 0.024	0.016	0.137
COVID*PhD > 2010	− 0.136	0.032	0.000
Women*PhD > 2010	− 0.045	0.017	0.009
COVID*women*PhD > 2010	− 0.016	0.049	0.740
COVID*life	− 0.096	0.051	0.061
COVID*physical	0.059	0.047	0.213
COVID*social	− 0.173	0.040	0.000
COVID*minority I	− 0.183	0.114	0.107
COVID*minority II	− 0.162	0.046	0.000
University: LU	0.283	0.039	0.000
University: RU	0.666	0.018	0.000
University: RUG	0.824	0.024	0.000
University: TUD	0.740	0.085	0.000
University: TUE	0.907	0.027	0.000
University: TI	0.599	0.049	0.000
University: UM	0.594	0.020	0.000
University: UT	0.322	0.025	0.000
University: UU	0.441	0.022	0.000
University: UvA	0.625	0.020	0.000
University: VU	0.669	0.022	0.000
University: WUR	0.754	0.020	0.000
COVID*LU	− 0.155	0.090	0.085
COVID*RU	− 0.471	0.052	0.000
COVID*RUG	− 0.064	0.074	0.388
COVID*TUD	0.107	0.143	0.454
COVID*TUE	− 0.307	0.087	0.000
COVID*TI	− 0.648	0.138	0.000
COVID*UM	− 0.023	0.056	0.674
COVID*UT	− 0.765	0.078	0.000
COVID*UU	− 1.160	0.062	0.000
COVID*UvA	− 0.557	0.061	0.000
COVID*VU	− 0.249	0.062	0.000
COVID*WUR	− 0.216	0.058	0.000
Efron's R^2	0.091		

Table 6 (continued)

	Model 5		
	B	*SE*	*P*
AIC (*df*)	527,411 (*df* = 61)		

For reasons of parsimony, the estimates of the following variables are not shown: bsplines; gender: no first name; gender: missing; ethnicity: missing. Similarly, the estimated shape parameters (sigma and nu) are not shown

$N_{\text{person-years}} = 113{,}782$; $N_{\text{persons}} = 8289$

Declarations A CBS microdata access grant (€7.500) with the title 'Social Networks as Change Agents for Equal Career Opportunities of Dutch PhDs?' allowed us to construct Fig. 5 (Appendix).

References

Abramo, G., D'Angelo, C. A., & Mele, I. (2022). Impact of Covid-19 on research output by gender across countries. *Scientometrics, 127*(12), 6811–6826. https://doi.org/10.1007/s11192-021-04245-x

Andersen, J. P., Nielsen, M. W., Simone, N. L., Lewiss, R. E., & Jagsi, R. (2020). Meta-research: COVID-19 medical papers have fewer women first authors than expected. *eLife, 9*, Article e58807.

André, S., Yerkes, M. A., & Remery, C. (2021). De invloed van de coronacrisis op de relatieve verdeling van zorg door moeders en vaders: Een longitudinaal perspectief. *Mens & Maatschappij, 96*(3), 331–356.

Bartosch, J., Lohmeyer, N., Auschra, C., & Jackson, G. (2023). Gendered publication patterns in socio-economic review. *Socio-Economic Review, 21*(3), 1273–1289.

Bendels, M. H. K., Müller, R., Brueggmann, D., & Groneberg, D. A. (2018). Gender disparities in high-quality research revealed by Nature Index journals. *PLoS ONE, 13*(1), Article e0189136. https://doi.org/10.1371/journal.pone.0189136

Bergé, L. (2018). Efficient estimation of maximum likelihood models with multiple fixed-effects: The R package FENmlm. *CREA Discussion Papers*, (13).

Bertogg, A., Kulic, N., & Strauss, S. (2021). Protected through Part-time Employment? Labor Market Status, Domestic Responsibilities, and the Life Satisfaction of German Women during the COVID-19 Pandemic. *Social Politics: International Studies in Gender, State & Society, 29*(4), 1236–1260. https://doi.org/10.1093/sp/jxab048

Biolková, M., Moore, T., Schindler, K., Swann, K., Vail, A., Flook, L., & Spears, N. (2023). Investigation of potential gender bias in the peer review system at reproduction. *Learned Publishing, 36*(1), 25–30.

Brady, E., Nielsen, M. W., Andersen, J. P., & Oertelt-Prigione, S. (2021). Lack of consideration of sex and gender in COVID-19 clinical studies. *Nature Communications, 12*(1), 1–6.

Broderick, N. A., & Casadevall, A. (2019). Gender inequalities among authors who contributed equally. *eLife*. https://doi.org/10.7554/elife.36399

Card, D., DellaVigna, S., Funk, P., & Iriberri, N. (2020). Are referees and editors in economics gender neutral? *The Quarterly Journal of Economics, 135*(1), 269–327.

Casale, D., & Posel, D. (2021). Gender inequality and the COVID-19 crisis: Evidence from a large national survey during south africa's lockdown. *Research in Social Stratification and Mobility, 71*, Article 100569. https://doi.org/10.1016/j.rssm.2020.100569

Dang, H.-A.H., & Nguyen, C. V. (2021). Gender inequality during the COVID-19 pandemic: Income, expenditure, savings, and job loss. *World Development, 140*, Article 105296.

De Haas, H., Castles, S., & Miller, M. J. (2019). *The age of migration: International population movements in the modern world*. Bloomsbury Publishing.

Deryugina, T., Shurchkov, O., & Stearns, J. (2021). COVID-19 disruptions disproportionately affect female academics. In *AEA Papers and Proceedings*, *111*, 164–168. American Economic Association 2014 Broadway, Suite 305, Nashville, TN 37203.

Fernández-de-las-Peñas, C., Martín-Guerrero, J. D., Pellicer-Valero, Ó. J., Navarro-Pardo, E., Gómez-Mayordomo, V., Cuadrado, M. L., Arendt-Nielsen, L. (2022). Female Sex Is a Risk Factor Associated with Long-Term Post-COVID Related-Symptoms but Not with COVID-19 Symptoms: The LONG-COVID-EXP-CM Multicenter Study. *Journal of Clinical Medicine*, *11*(2), 413. https://doi.org/10.3390/jcm11020413

Gebhard, C., Regitz-Zagrosek, V., Neuhauser, H. K., Morgan, R., & Klein, S. L. (2020). Impact of sex and gender on COVID-19 outcomes in Europe. *Biology of Sex Differences*, *11*(1). https://doi.org/10.1186/s13293-020-00304-9

Graham, M., Weale, V., Lambert, K. A., Kinsman, N., Stuckey, R., & Oakman, J. (2021). Working at Home. *Journal of Occupational & Environmental Medicine, 63*(11), 938–943. https://doi.org/10.1097/jom.0000000000002337

Hadavand, A., Hamermesh, D. S., & Wilson, W. W. (2024). Publishing economics: How slow? Why slow? Is slow productive? How to fix slow? *Journal of Economic Literature, 62*(1), 269–293. https://doi.org/10.1257/jel.20221653

Hofstra, B., Kulkarni, V. V., Galvez, S.M.-N., He, B., Jurafsky, D., & McFarland, D. A. (2020). The diversity–innovation paradox in science. *Proceedings of the National Academy of Sciences, 117*(17), 9284–9291.

Hofstra, B., McFarland, D. A., Smith, S., & Jurgens, D. (2022). Diversifying the professoriate. *Socius, 8*, 23780231221085120.

Huang, J., Gates, A. J., Sinatra, R., & Barabási, A.-L. (2020). Historical comparison of gender inequality in scientific careers across countries and disciplines. *Proceedings of the National Academy of Sciences, 117*(9), 4609–4616.

Jemielniak, D., Sławska, A., & Wilamowski, M. (2023). COVID-19 effect on the gender gap in academic publishing. *Journal of Information Science, 49*(6), 1587–1592.

Kim, L., Smith, D. S., Hofstra, B., & McFarland, D. A. (2022). Gendered knowledge in fields and academic careers. *Research Policy, 51*(1), Article 104411.

King, M. M., & Frederickson, M. E. (2021). The pandemic penalty: The gendered effects of COVID-19 on scientific productivity. *Socius, 7*, 23780231211006976.

Krukowski, R. A., Jagsi, R., & Cardel, M. I. (2021). Academic productivity differences by gender and child age in science, technology, engineering, mathematics, and medicine faculty during the COVID-19 pandemic. *Journal of Women's Health, 30*(3), 341–347.

Kwon, E., Yun, J., & Kang, J. (2023). The effect of the COVID-19 pandemic on gendered research productivity and its correlates. *Journal of Informetrics, 17*(1), Article 101380.

Landivar, L. C., Ruppanner, L., Scarborough, W. J., & Collins, C. (2020). Early signs indicate that COVID-19 is exacerbating gender inequality in the labor force. *Socius, 6*, 2378023120947997.

Larivière, V., Ni, C., Gingras, Y., Cronin, B., & Sugimoto, C. R. (2013). Bibliometrics: Global gender disparities in science. *Nature, 504*(7479), 211–213.

Leahey, E. (2006). Gender differences in productivity: Research specialization as a missing link. *Gender & Society, 20*(6), 754–780.

Lerchenmüller, C., Schmallenbach, L., Jena, A. B., & Lerchenmueller, M. J. (2021). Longitudinal analyses of gender differences in first authorship publications related to COVID-19. *British Medical Journal Open, 11*(4), Article e045176.

Lutter, M., & Schröder, M. (2016). Who becomes a tenured professor, and why? Panel data evidence from german sociology, 1980–2013. *Research Policy, 45*(5), 999–1013.

Lutter, M., & Schröder, M. (2020). Is there a motherhood penalty in academia? The gendered effect of children on academic publications in german sociology. *European Sociological Review, 36*(3), 442–459.

Maas, B., Korvorst, M., Mooren, F. van der, & Meijers, R. (2014). *Careers of doctorate holders in the netherlands, 2014. Rapport centraal bureau voor de statistiek*.

Madsen, E. B., Nielsen, M. W., Bjørnholm, J., Jagsi, R., & Andersen, J. P. (2022). Author-level data confirm the widening gender gap in publishing rates during COVID-19. *Life*. https://doi.org/10.7554/elife.76559

Mairesse, J., & Pezzoni, M. (2015). Does gender affect scientific productivity? A critical review of the empirical evidence and a panel data econometric analysis for french physicists. *Revue Économique, 66*(1), 65–113.

Marušić, A., Bošnjak, L., & Jerončić, A. (2011). A systematic review of research on the meaning, ethics and practices of authorship across scholarly disciplines. *PLoS ONE, 6*(9), Article e23477. https://doi.org/10.1371/journal.pone.0023477

Massimo, A., Trang, Le., Corrado, C., Alessandra, B., & June, C. (2024). openalexR: An r-tool for collecting bibliometric data from OpenAlex. *The R Journal, 15*, 167–180. https://doi.org/10.32614/RJ-2023-089

Miller, R. C., & Tsai, C. J. (2020). Scholarly publishing in the wake of COVID-19. *International Journal of Radiation Oncology*Biology*Physics, 108*(2), 491–495. https://doi.org/10.1016/j.ijrobp.2020.06.048

Mulders, A. M., Hofstra, B., & Tolsma, J. (2024). A matter of time? Gender and ethnic inequality in the academic publishing careers of dutch PhDs. *Quantitative Science Studies*. https://doi.org/10.1162/qss_a_00306

Muric, G., Lerman, K., & Ferrara, E. (2021). Gender disparity in the authorship of biomedical research publications during the COVID-19 pandemic: Retrospective observational study. *Journal of Medical Internet Research, 23*(4), Article e25379.

Nane, G. F., Robinson-Garcia, N., van Schalkwyk, F., & Torres-Salinas, D. (2022). COVID-19 and the scientific publishing system: Growth, open access and scientific fields. *Scientometrics, 128*(1), 345–362. https://doi.org/10.1007/s11192-022-04536-x

Nielsen, M. W., Alegria, S., Börjeson, L., Etzkowitz, H., Falk-Krzesinski, H. J., Joshi, A., & Schiebinger, L. (2017). Opinion: Gender diversity leads to better science. *Proceedings of the National Academy of Sciences, 114*(8), 1740–1742.

Nielsen, M. W., Andersen, J. P., Schiebinger, L., & Schneider, J. W. (2017b). One and a half million medical papers reveal a link between author gender and attention to gender and sex analysis. *Nature Human Behaviour, 1*(11), 791–796.

OpenAlex. (n.d.). *OpenAlex: End-to-end process for topic classification*. Retrieved from https://docs.google.com/document/d/1bDopkhuGieQ4F8gGNj7sEc8WSE8mvLZS/edit#heading=h.5w2tb5fcg77r

R Core Team. (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/

Reichelt, M., Makovi, K., & Sargsyan, A. (2021). The impact of COVID-19 on gender inequality in the labor market and gender-role attitudes. *European Societies, 23*(sup1), S228–S245. https://doi.org/10.1080/14616696.2020.1823010

Rigby, B., & Stasinopoulos, M. (2005). Generalized additive models for location, scale and shape,(with discussion). *Applied Statistics, 54*(3), 507–554.

Schröder, M., Lutter, M., & Habicht, I. M. (2021). Publishing, signaling, social capital, and gender: Determinants of becoming a tenured professor in german political science. *PLoS ONE, 16*(1), Article e0243514.

Squazzoni, F., Bravo, G., Grimaldo, F., Garcıa-Costa, D., Farjam, M., & Mehmani, B. (2020). *No tickets for women in the COVID-19 race? A study on manuscript submissions and reviews in 2347 elsevier journals during the pandemic (preprint)*.

Stasinopoulos, M., & Rigby, R. (2023). *Gamlss.dist: Distributions for generalized additive models for location scale and shape*. Retrieved from https://CRAN.R-project.org/package=gamlss.dist

Thor, J. van, & Perez, S. A. (2014). *Resultaten gepromoveerdenonderzoek 2019*.

Wais, K. (2006). Gender prediction methods based on first names with genderizeR. *The R Journal, 8*(1), 17–37. https://doi.org/10.32614/RJ-2016-002

West, J. D., Jacquet, J., King, M. M., Correll, S. J., & Bergstrom, C. T. (2013). The role of gender in scholarly authorship. *PLoS ONE, 8*(7), Article e66212.

World Economic Forum. (2024). *Global gender gap 2024*. World Economic Forum.

Yildirim, T. M., & Eslen-Ziya, H. (2020). The differential impact of COVID-19 on the work conditions of women and men academics during the lockdown. *Gender, Work & Organization, 28*(S1), 243–249. https://doi.org/10.1111/gwao.12529

Zamberlan, A., Gioachin, F., & Gritti, D. (2021). Work less, help out more? The persistence of gender inequality in housework and childcare during UK COVID-19. *Research in Social Stratification and Mobility, 73*, Article 100583.