Gender Inequality in Research Productivity During the COVID-19 Pandemic

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We study the disproportionate impact of the lockdown as a result of the COVID-19 outbreak on female and male academics’ research productivity in social science. We collect data from the largest open-access preprint repository for social science on 41,858 research preprints in 18 disciplines produced by 76,832 authors across 25 countries in a span of two years. We find that during the 10 weeks after the lockdown in the United States, although the total research productivity increased by 35%, female academics’ productivity dropped by 13.9% relative to that of male academics. We also show that several disciplines drive such gender inequality. Finally, we find that this intensified productivity gap is more pronounced for academics in top-ranked universities, and the effect exists in six other countries.

Key words: Gender inequality, research productivity, COVID-19

1. Introduction

The Coronavirus 2019 (COVID-19) pandemic has significantly changed the way people live and work. We study how this pandemic shock affected academics’ research productivity using data from the largest open-access repositories for social science in the world—Social Science Research Network (SSRN).\footnote{https://en.wikipedia.org/wiki/Social_Science_Research_Network, accessed June 2020.} We provide evidence that female researchers’ productivity significantly dropped relative to that of male researchers as a result of the lockdown in the United States.

In response to the pandemic, the US and many other countries have mandated their citizens to stay at home. As a result, many people had to carry out both work and household duties at home. Most countries have closed their schools and daycare centers, which has massively increased childcare needs. Given that the childcare provided by grandparents and friends is limited due to the social distancing protocol, most families have to take care of the children themselves. In addition, restaurants have been either closed or do not allowed dine-ins, which has increased the need for...
food preparation at home. Given that women, on average, are burdened with disproportionately more child care, domestic labor, and household responsibilities (Bianchi et al. 2012), they are likely to be more affected than men during the lockdown.

The lockdown has also disrupted how academics carry out their activities. Many countries have closed their universities, so faculties have to conduct research and teaching at home. Conducting scientific research often requires a quiet and interruption-free environment because concentration is critical for creative thinking. The unequal distribution of domestic duties means that female faculties are likely to be disproportionately affected compared with their male colleagues.

Anecdotal evidence provides mixed support (Dolan and Lawless 2020). A recent survey on 4,500 principal investigators reported significant and heterogeneous declines in their time spent on research (Myers et al. 2020). Several journal editors have noticed that while there is a 20-30% increase in submissions as a result of the pandemic, most of this increase can be attributed to male academics (Beck 2020). Amano-Patio et al. (2020) find that a particularly large number of senior male economists, instead of mid-career economists, have been exploring research questions arising from the COVID-19 shock. Others have seen no change or are receiving comparatively more submissions from women since the lockdown (Kitchener 2020). However, there is dearth of systematic evidence on whether and to what extent the shock affects gender inequality in the academia.

In this paper, we use a large dataset on female and male academics’ production of new research papers to systematically study whether COVID-19 has a disproportionate effect on female academics’ productivity. We also identify the disciplines, universities, and countries in which this inequality is intensified. We collect the data on all research papers uploaded to SSRN in 18 disciplines from December 2018 to May 2019 and from December 2019 to May 2020. We extract information on paper titles, author names, author affiliations, and author addresses. We use such information to identify the authors’ countries and institutions. We also use their names and their faculty pages to identify their gender. The final dataset includes 41,858 papers written by 76,832 authors from 25 countries. Our main analysis focuses on academics in the US, and we then perform the same analysis for other countries.

We take a difference-in-differences (DID) approach to estimate the effect. We compute the number of papers produced by female and male academics in each week. We then compare the variations

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2 Women spend almost twice as much time on housework and childcare in the US (Bianchi et al. 2012). There are 8.5 million more single mothers than single fathers in the US (Alon et al. 2020). Even in the gender-egalitarian countries of northern Europe, women do almost two-thirds of the unpaid work (The European Commission 2016). Among heterosexual couples with female breadwinners, women still do most of the care work (Chesley and Flood 2017). The same pattern exists in the academia (Schiebinger and Gilmartin 2010, Andersen et al. 2020). Women professors spend more time doing housework and carework than men professors across various ranks, for example, 34.1 hours versus 27.6 hours per week for lecturers, 29.6 hours versus 25.1 hours per week for assistant professors, and 37.7 hours versus 24.5 hours per week for associate professors (Misra et al. 2012).
in women and men’s research productivity gap before and after the start of the lockdown, and show that the gap increased after the start of the lockdown. We also show that female and male authors’ preprint volume followed the parallel time trend before the lockdown, and we find no significant changes in the research productivity gap in 2019 during the same time of the year. Taken together, these results suggest that the intensified disparity is primarily driven by the pandemic shock.

We find that during the 10 weeks since the lockdown began, female academics’ research productivity dropped by 13.9% compared to that of male academics in the US. The effect persists as we varied the time window since the pandemic outbreak in the analysis. Our findings lend empirical credence to the argument that when female and male academics face a short-term reorganization of care and work time, women become significantly less productive. We also find that the effect is more pronounced in top-ranked research universities. We further show that this effect exists in six other countries.

While gender inequality has been long documented for academics in terms of tenure evaluation (Antecol et al. 2018), coauthoring choices (Sarsons 2017), and citations received (Ghiasi et al. 2015), the COVID-19 pandemic brings this issue to the forefront. Our study is among the first to rigorously quantify such inequality in research productivity as a result of the pandemic, and our results highlight that this disruption exacerbated gender inequality in the academic world. There are concerns that because all academics will participate together in open competitions for promotions and positions, these short-term changes in productivity will affect long-term career outcomes (Minello 2020). Thus, institutions should take this inequality into consideration when evaluating faculty members.

Our paper is closely related to the stream of literature on productivity, a central topic in operations management. The past studies have examined key determinants for workers’ productivity such as peer effects (Huckman et al. 2009, Song et al. 2018, Tan and Netessine 2019), task variety (Staats and Gino 2012), task sequence (Ibanez et al. 2018), incentive schemes (Chen et al. 2019), clients’ emotions (Altman et al. 2019), workers’ perceived workload (Tan and Netessine 2014), fatigue (KC et al. 2020), and unfairness in aligning workers’ compensations with productivity (Pierce et al. 2020). In particular, multitasking has been shown to reduce productivity for workers who perform complex tasks because of their limited cognitive capacities (KC 2014, Bray et al. 2016, KC 2020). In our context, when working from home, academics are facing an increasing need to allocate their cognitive capacity across house and work tasks, making those who get more distractions from housework struggle from multitasking. The unequal distribution of home responsibilities means that women are more likely to deal with multitasking at home during the lockdown. Our results show the consequence of working from home in that female academics are more negatively affected in research productivity, highlighting gender inequality as an important factor to consider when measuring productivity.
2. Data and Summary Statistics

We collect data from SSRN, a repository of preprints with the objective to rapidly disseminate scholarly research in social science. We gather data on all social science preprints submitted from December 2018 to May 2019 and from December 2019 to May 2020. We extract information on paper titles, author names, author affiliations, and author addresses. We use the authors’ addresses to identify their countries. The COVID-19 outbreak began at different time points across countries, so we collect each country’s start date of lockdown from news sources and the United Nations’ report.\(^3\) We drop authors without addresses or with addresses in more than one country because we cannot determine when these authors were affected by the lockdown. We also drop countries without a sufficient number of authors in our data set. The final data consist of a total of 41,858 papers in 18 disciplines produced by 76,832 authors from 25 countries.

To identify the authors’ genders, we first use a database called Genderize,\(^4\) which predicts the genders based on their first names with a confidence level. About 78% of the authors’ genders were identified with over 80% confidence levels. For the remaining authors, we use Amazon Mechanical Turk to manually search for their professional webpages based on names and affiliations and then infer their genders from their profile photos. Our dataset contains a total of 21,733 female academics and 55,099 male academics.

We aggregate the number of new preprints at the weekly level. We then count the number of papers uploaded by each author in each week. To measure the effective productivity for preprints with multiple authors, when a preprint has \(n\) authors, each author gets a publication count of \(1/n\).\(^5\) Finally, we aggregate the effective number of papers to the gender level: in each week, we count the total number of papers produced by male and female authors separately in each social science discipline.

Figure 1 plots the time trend of preprints in aggregation from December 3, 2019 to May 19, 2020 in the US. The vertical line represents the week of March 11, 2020, which is the start of the implementation of the nationwide lockdown measures in the US.\(^6\) We can observe that male academics, on average, have submitted more preprints than female academics, and that female and male academics’ research productivity evolved in parallel before the lockdown. After the lockdown started, however, male academics significantly boosted their productivity, whereas female academics’ productivity did not change much, indicating an increased productivity gap.

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\(^3\) https://en.unesco.org/covid19/educationresponse, accessed June 2020

\(^4\) https://genderize.io/, accessed June 2020

\(^5\) Note that in many social science disciplines, author names are listed in alphabetical order.

\(^6\) Most universities were closed in the week of March 11, 2020. Source: https://gist.github.com/jessejanderson/09155afe313914498a32bbaa477584fae?from=singlemessage&isappinstalled=0, accessed June 2020.
This graph plots the time trend of the number of preprints for female academics and male academics. The vertical line represents the start of the lockdown due to COVID-19 in the US.

To ensure that our results are not driven by seasonality, we plot the time trend of preprints during the same time window in 2019 in Appendix Figure A.1. We observe a similar pattern before the week of March 11, 2019, but there is no significant change in productivity gap after that week.

We use the authors’ affiliations to identify their universities. To ascertain whether the productivity gap becomes intensified or weakened across top-ranked and lower-ranked research universities, we collect social science research rankings from three sources: QS University Ranking,\(^7\) Times Higher Education,\(^8\) and Academic Ranking of World University.\(^9\) We then use these data to rank US universities.

Table 1 reports the summary statistics for the weekly number of preprints by gender and discipline, as well as split sample statistics prior to or after the lockdown from December 3, 2019 to May 19, 2020, spanning 24 weeks. This sample includes 9,943 preprints produced by 15,494 authors in the US and 21,065 preprints produced by 37,997 authors across all countries. The average number of submissions per week is 444.6 in the US and 877.7 across 25 countries. Notably, while the total research productivity in the US was boosted by 35% after the lockdown, male authors seem to be the main contributors to this increase.

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\(^7\) Available at [https://www.topuniversities.com/university-rankings/university-subject-rankings/2020/social-sciences-management](https://www.topuniversities.com/university-rankings/university-subject-rankings/2020/social-sciences-management), accessed June 2020.

\(^8\) Available at [https://www.timeshighereducation.com/world-university-rankings/2020/subject-ranking/social-sciences#!/page/0/length/25/sort_by/rank/sort_order/asc/cols/stats](https://www.timeshighereducation.com/world-university-rankings/2020/subject-ranking/social-sciences#!/page/0/length/25/sort_by/rank/sort_order/asc/cols/stats), accessed June 2020.

\(^9\) Available at [http://www.shanghairanking.com/FieldSOC2016.html](http://www.shanghairanking.com/FieldSOC2016.html), accessed June 2020.
About 78% of the preprints fall under multiple disciplines.\textsuperscript{10} Note that when computing the total preprints, we count the paper only once when aggregating across disciplines to avoid multiple counting. When computing the number of preprints in each discipline, we separately count all of the papers classified under each one. We observe substantial variations across disciplines. Among 18 disciplines, Political Science, Economics, and Law received the most submissions, whereas Geography, Criminal Justice and Education received the fewest submissions. While there is a large increase in productivity in several disciplines, such as Economics, Political Science, Finance, Health Economics, and Sustainability, after the COVID-19 outbreak, other disciplines showed no obvious increase. A few disciplines, such as Anthropology, Cognitive, and Information Systems, even experienced a decline.

### Table 1 Summary Statistics

| Level | Weekly no. of preprints | All observations | Before Lockdown | After Lockdown |
|-------|-------------------------|------------------|-----------------|----------------|
|       |                         | Mean | Std. dev | Max | Min | Total | Mean | Std. dev | Mean | Std. dev |
| All   | Accounting              | 19.5 | 7.2     | 40  | 9   | 468   | 17.9 | 6.3      | 21.8 | 8.2      |
|       | Anthropology            | 85.0 | 21.5    | 141 | 63  | 2,040 | 93.9 | 24.0     | 72.5 | 6.9      |
|       | Cognitive               | 11.3 | 9.2     | 31  | 1   | 271   | 14.1 | 11.1     | 7.4  | 3.2      |
|       | Corporate               | 14.1 | 6.5     | 27  | 3   | 339   | 12.2 | 6.5      | 16.8 | 5.8      |
|       | Criminal                | 15.4 | 6.7     | 27  | 4   | 370   | 12.8 | 6.7      | 19.1 | 4.9      |
|       | Economics               | 133.2| 54.2    | 237 | 37  | 3,197 | 106.6| 39.1     | 170.5| 51.6     |
|       | Education               | 17.9 | 7.0     | 36  | 7   | 429   | 16.9 | 7.4      | 19.2 | 6.7      |
|       | Entrepreneurship        | 9.9  | 5.3     | 22  | 2   | 238   | 10.2 | 4.9      | 9.5  | 5.9      |
|       | Finance                 | 91.7 | 34.5    | 139 | 25  | 2,201 | 78.5 | 35.5     | 110.2| 24.0     |
|       | Geography               | 8.2  | 3.3     | 17  | 3   | 196   | 7.5  | 2.7      | 9.1  | 4.0      |
|       | Health Economics        | 8.4  | 10.1    | 47  | 0   | 202   | 3.0  | 2.1      | 16.0 | 12.1     |
|       | Information Systems     | 15.6 | 7.3     | 39  | 7   | 374   | 17.4 | 8.6      | 13.1 | 4.2      |
|       | Law                     | 98.5 | 24.3    | 142 | 44  | 2,365 | 94.1 | 26.7     | 104.7| 20.1     |
|       | Management              | 33.4 | 11.4    | 56  | 12  | 802   | 33.4 | 13.3     | 33.4 | 8.6      |
|       | Organization            | 20.5 | 11.5    | 44  | 3   | 491   | 16.9 | 10.2     | 25.5 | 11.7     |
|       | Political Science       | 167.9| 50.5    | 255 | 85  | 4,030 | 142.1| 39.0     | 204.1| 42.8     |
|       | Sustainability          | 22.8 | 11.9    | 66  | 8   | 546   | 18.1 | 5.9      | 29.3 | 15.1     |
|       | Women/Gender            | 18.0 | 4.7     | 28  | 10  | 431   | 17.2 | 4.4      | 19.0 | 5.2      |

The table summarizes the weekly number of papers from December 2019 to May 2020. The sample includes 15,494 authors from the United States and 37,997 authors across all countries. In total, there are 9,934 preprints produced by US authors, 2,493 of which are produced by 3,877 female researchers and 7,441 are produced by 11,617 male researchers. We gather the country-specific lockdown time to split our sample to before and after the lockdown for each country.

### 3. Empirical Results

In this section, we identify the effect of the COVID-19 outbreak on research productivity. We first elaborate our identification methodology that leverages the exogenous pandemic shock by using

\textsuperscript{10} Authors self-classify their own preprints into disciplines when they upload their papers. SSRN reviews and approves these classifications.
a DID regression. We then report the estimation results of gender inequality in the US, across universities, and across countries.

3.1. Identification

Our identification exploits the lockdown as a result of the COVID-19 outbreak as an exogenous shock that has caused substantial disruptions on academic activities, requiring academics to conduct research, teach, and carry out household duties at home. The validity of our approach resides in the assumption that the shock is exogenous with respect to the researchers’ anticipated responses. If a particular gender group of researchers anticipated and strategically prepared for the shock by accelerating the wrap-up of their current research papers, among others, this could confound the treatment effect. In reality, this possibility is unlikely because of the rapid development of the situation. We adopt the DID methodology, a common approach used to evaluate people’s or organizations’ responses to natural shocks (Seamans and Zhu 2013, Cui et al. 2019, Calvo et al. 2019). We perform the DID analysis using outcome variables in two levels: the total number of preprints aggregated across all disciplines and the number of preprints in each discipline.

We first compare the productivity gap between female and male researchers prior to and after the pandemic outbreak using the following model specification with the aggregate-level data:

\[
\log(\text{Preprints}_{gt}) = c + \text{Female}_g + \beta \text{Female}_g \times \text{Lockdown}_t + \gamma_t + \epsilon_{gt},
\]

(1)

where \(g\) denotes the gender, \(t\) denotes the week, \(\log(\text{Preprints}_{gt})\) represents the logged number of preprints uploaded for gender \(g\) during week \(t\), \(\gamma_t\) is the time fixed effect, and \(\epsilon_t\) is the error term. The time fixed-effect \(\gamma_t\) includes a set of weekly time dummies that control for time trends. The dummy variable \(\text{Female}_g\) equals 1 if gender \(g\) is a female academics, and 0 otherwise. The dummy variable \(\text{Lockdown}_t\) equals 1 if week \(t\) occurs after the lockdown measure was adopted (i.e., the week of March 11, 2020), and 0 otherwise. Its main effect is absorbed by the time fixed effects. The coefficient \(\beta\) estimates the effect of lockdown on female academics’ research productivity relative to male academics productivity.

We also use the discipline-level panel data to estimate the effect with the following DID specification:

\[
\log(\text{Preprints}_{igt}) = c + \text{Female}_g + \beta \text{Female}_g \times \text{Lockdown}_t + \gamma_t + \delta_i + \epsilon_{igt},
\]

(2)

where \(i\) denotes each discipline, \(\delta_i\) is the discipline fixed effect that captures the time-invariant characteristics of discipline \(i\), \(\log(\text{Preprints}_{igt})\) represents the logged number of preprints uploaded for discipline \(i\) during week \(t\). The time fixed effect \(\gamma_t\) controls for time trends. The dummy variable \(\text{Female}_g\) equals 1 if gender \(g\) is a female academics, and 0 otherwise. The dummy variable \(\text{Lockdown}_t\) equals 1 if week \(t\) occurs after the lockdown measure was adopted (i.e., the week of March 11, 2020), and 0 otherwise. Its main effect is absorbed by the time fixed effects. The coefficient \(\beta\) estimates the effect of lockdown on female academics’ research productivity relative to male academics productivity.

\[11\] COVID-19 was regarded as low risk and not a threat to the US in late January (Moreno 2020) and no significant actions had been taken other than travel warnings issued for four countries until late February (Franck 2020). It quickly turned into a global pandemic after the declaration of the World Health Organization on March 11, 2020 followed by the nationwide shelter-in-place orders within a week. Source: [https://www.cdc.gov/nchs/data/icd/Announcement-New-ICD-code-for-coronavirus-3-18-2020.pdf](https://www.cdc.gov/nchs/data/icd/Announcement-New-ICD-code-for-coronavirus-3-18-2020.pdf), accessed June 2020.
to discipline \(i\) for gender \(g\) during week \(t\), and \(\epsilon_{igt}\) is the error term. As before, we include the time fixed effect \(\gamma_t\).

### 3.2. Results

Table 2 reports the estimated effect of the pandemic shock on research productivity at the aggregate level using Equation (1). Table 3 reports the estimated effect at the discipline level using Equation (2). In each analysis, we use 14 weeks before the lockdown as the pre-treatment period and 6 weeks, 7 weeks, ... and 10 weeks after the lockdown as the post-treatment periods. The analyses yield consistent results. First, consistent with our summary statistics, the results show that fewer preprints are produced by female academics than male academics in general. Second, since the lockdown began, there has been a significant reduction in female academics’ productivity relative to their male colleagues’, indicating an exacerbated productivity gap in gender. The coefficient of the interacted term in Column (1) of Table 2 suggests a reduction of 17.9% in females’ productivity over the six-week period after the lockdown relative to the males’, and the coefficient of the interacted term in Column (5) suggests an average reduction of 13.9%.

| Table 2 Impact of Lockdown on Gender Inequality |
|-------------------------------------------------|
| Variables                                      | Dependent variable: No. of preprints (in logarithm) in aggregation |
|                                                 | 6 weeks | 7 weeks | 8 weeks | 9 weeks | 10 weeks |
| Female                                          | -1.013*** | -1.013*** | -1.013*** | -1.013*** | -1.013*** |
|                                                 | (0.054) | (0.054) | (0.053) | (0.053) | (0.053) |
| Female \(\times\) Lockdown                     | -0.197** | -0.199*** | -0.173** | -0.159** | -0.150** |
|                                                 | (0.068) | (0.064) | (0.067) | (0.066) | (0.064) |
| Time Fixed Effects                              | Yes     | Yes     | Yes     | Yes     | Yes     |
| Observations                                    | 40      | 42      | 44      | 46      | 48      |
| \(R^2\)                                         | 0.981   | 0.982   | 0.982   | 0.982   | 0.983   |

This table reports the estimated coefficients and robust standard errors (in parentheses) in Equation (1). The coefficients for 6, 7, 8, 9 and 10 weeks since the lockdown are presented in columns (1)–(5), respectively. Significance at \(\ast p < 0.1; \ast\ast p < 0.05; \ast\ast\ast p < 0.01\).

We then repeat the analysis as in Table 2 for each discipline separately. Table 4 reports the coefficients of the interacted term, \(Female_g \times Lockdown_t\), for each discipline. We find that the gender differences significantly intensified in several disciplines, namely, Criminal, Economics, Finance, Health Economics, Political Science, and Sustainability.

Table 5 replicates the DID analysis using Equation (2) for a subset of academics based on the rankings of their affiliated universities. Due to our focus on social science, we use the 2020 QS World University Ranking for social sciences and management as the main analysis. We separately

\[e^{\text{coefficient}} - 1\]

\[\text{It is possible that some authors are affiliated with more than one academic institutions. We use the highest ranked institution as their affiliation in such cases.}\]
analyze academics in universities ranked in the top 10, 20,..., and 100. The results show that the COVID-19 effect is more pronounced in top-tier universities and that this effect in general decreases and becomes less significant as we include more lower-ranked universities. We find similar results when using the two other rankings, as shown in Appendix Table A.1.

Finally, we examine how the estimated gender inequality varies across countries by replicating the analysis for academics in each country. Figure 2 illustrates the impact on the productivity gap graphically by plotting the estimates of the interacted term with 90% and 95% confidence intervals, of which a negative value represents a drop in female academics’ research productivity relative to male academics’. We can observe that most countries—21 out of 25 countries—experienced

### Table 3  Impact of Lockdown on Gender Inequality at the Discipline Level

| Variables                  | 6 weeks | 7 weeks | 8 weeks | 9 weeks | 10 weeks |
|----------------------------|---------|---------|---------|---------|----------|
| **Female**                 |         |         |         |         |          |
|                           | -0.791*** | -0.791*** | -0.791*** | -0.791*** | -0.791*** |
|                           | (0.042)  | (0.042)  | (0.042)  | (0.042)  | (0.042)  |
| **Female × Lockdown**      |         |         |         |         |          |
|                           | -0.140*  | -0.148** | -0.162** | -0.157** | -0.142** |
|                           | (0.076)  | (0.072)  | (0.068)  | (0.065)  | (0.063)  |
| Discipline Fixed Effects   | Yes      | Yes      | Yes      | Yes      | Yes      |
| Time Fixed Effects         | Yes      | Yes      | Yes      | Yes      | Yes      |
| Observations               | 720      | 756      | 792      | 828      | 864      |
| R²                         | 0.837    | 0.836    | 0.839    | 0.841    | 0.841    |

This table reports the estimated coefficients and robust standard errors (in parentheses) in Equation (2). The coefficients for 6, 7, 8, 9 and 10 weeks since the lockdown are presented in columns (1)–(5), respectively. Significance at *p < 0.1; **p < 0.05; ***p < 0.01.

### Table 4  Impact of Lockdown on Gender Inequality in Each Discipline

| Discipline              | 6 weeks | 7 weeks | 8 weeks | 9 weeks | 10 weeks |
|-------------------------|---------|---------|---------|---------|----------|
|                          | (1)     | (2)     | (3)     | (4)     | (5)      |
| Accounting              | -0.282  | -0.311* | -0.248  | -0.213  | -0.192   |
| Anthropology            | -0.015  | 0.049   | 0.123   | 0.112   | 0.127    |
| Cognitive               | -0.184  | -0.091  | -0.166  | -0.200  | -0.131   |
| Corporate               | -0.021  | -0.091  | -0.285  | -0.380  | -0.324   |
| Criminal                | -0.395** | -0.350* | -0.417** | -0.295  | -0.296   |
| Economics               | -0.248*** | -0.248*** | -0.212** | -0.208** | -0.181** |
| Education               | -0.146  | -0.088  | -0.102  | -0.010  | 0.082    |
| Entrepreneurship        | -0.138  | -0.085  | -0.108  | -0.105  | -0.136   |
| Finance                 | -0.401* | -0.404** | -0.391** | -0.391** | -0.387** |
| Geography               | -0.266  | -0.246  | -0.298  | -0.314  | -0.189   |
| Health Economics        | -0.767** | -0.784*** | -0.896*** | -0.870*** | -0.786*** |
| Information Systems     | 0.033   | 0.042   | 0.070   | 0.070   | 0.060    |
| Law                     | 0.081   | 0.088   | 0.097   | 0.140   | 0.149    |
| Management              | -0.056  | -0.011  | -0.075  | -0.013  | -0.019   |
| Organization            | 0.069   | 0.169   | 0.157   | 0.148   | 0.115    |
| Political Science       | -0.262*** | -0.252*** | -0.233*** | -0.232*** | -0.221*** |
| Sustainability          | -0.687** | -0.673*** | -0.644*** | -0.637*** | -0.589*** |
| Women/Gender            | -0.238  | -0.090  | -0.139  | -0.103  | -0.072   |
| Observations            | 40      | 42      | 44      | 46      | 48       |

This table reports the estimated coefficients based on Equation (1) for each discipline. The coefficients for 6, 7, 8, 9 and 10 weeks since the lockdown are presented in columns (1)–(5), respectively. Time fixed effects at the weekly level are included in all regressions. Standard errors and estimates of other variables are omitted for brevity. Significance at *p < 0.1; **p < 0.05; ***p < 0.01.
a decline in female researchers’ productivity. In addition to the US, six countries have shown statistically significant declines, namely, Japan, China, Australia, Italy, the Netherlands, and the United Kingdom. Note that because SSRN is a repository primarily used by US researchers, SSRN’s preprints for other countries might be limited in number, which might weaken our ability to detect changes.

In short, we find that the lockdown has adversely affected female researchers’ productivity relative to that of male researchers. We also find a large heterogeneity of such gender inequality across disciplines, universities, and countries.

4. Robustness Checks

In this section, we report several robustness tests. Specifically, we check the parallel trends assumption and conduct falsification tests to ensure that our estimated effects are not idiosyncratic.

**Parallel trends.** The key identification assumption for the DID estimation is the parallel trends assumption: before the COVID-19 shock, female and male researchers’ productivity would follow the same time trend. In Appendix Figure A.1, which presents the time trends of preprints in 2019, the visual inspection shows two gender groups’ parallel evolving before the shock. We then test this assumption by performing a similar analysis to Seamans and Zhu (2013), Cui et al. (2019) and Calvo et al. (2019), where we expand Equation (1) to estimate the treatment effect week by week before the shock. Specifically, we replace Lockdown$_t$ in Equations (1) with dummy variables Time$_t^\tau$, where $\tau \in \{-14,-13,\ldots,-2,-1,0\}$ and Time$_t^0 = 1$ if $\tau = t$ and 0 otherwise, indicating the relative $\tau$th week to the outbreak,

$$\log(Paper_{it}) = c + Female_i + \sum_{\tau=-14}^{-1} Time_t^\tau + \sum_{\tau=-14}^{-1} \beta_{\tau} Female_i \times Time_t^\tau + \epsilon_{it}. \quad (3)$$
Figure 2  Impact of Lockdown on Gender Inequality across Countries

This graph plots the estimates of the interacted term with 90% and 95% confidence intervals in each country. The negative values represent female academics’ research productivity drop relative to male academics’ across countries.

The benchmark group is the week of the pandemic outbreak. The coefficients $\beta_{-14}$ to $\beta_{-1}$ identify any week-by-week pre-treatment difference between the female and the male researchers, which we expect to be insignificant. We then repeat the same analysis with our discipline-level data.

Appendix Table A.2 presents the estimation results. The test results show no pre-treatment differences in the research productivity trends between female and male academics, which support the parallel trends assumption.

**Falsification test.** To show that our estimate effects are not an artifact of seasonality, we test whether such decline in female productivity also existed in 2019. Appendix Table A.3 reports the summary statistics in 2019. We repeat the same analysis specified in Equation (1) for the same time window in 2019. If our results simply capture seasonality, we would be able to find significant effects in 2019. Appendix Table A.4 reports the falsification test results. The placebo-treated average treatment effects are insignificant, implying that women’s productivity did not decline significantly in the previous year.
5. Conclusions

Our paper adds to the long-standing literature on gender equality, an important topic in social science. For example, the literature has shown evidence of fairness in parental leaves (Lundquist et al. 2012), inequality in tenure evaluation (Sarsons 2017, Antecol et al. 2018), recognition received (Ghiasi et al. 2015), compensation (Pierce et al. 2020), and job hiring (Fernandez-Mateo and Fernandez 2016). Researchers have therefore investigated business innovations to help empower women (Plambeck and Ramdas 2020). The COVID-19 crisis brings a long existing issue to the forefront—the limitations faced by women who often contribute more in childcare and housework. We contribute to the literature by providing direct tests on the impact of the pandemic shock on gender inequality in the academia.

We show that since the lockdown began, women have produced 13.9%–17.9% less research papers compared to men in the US. We also find that the effect exists in several disciplines and among top-ranked universities. Finally, we find that the increase in productivity inequality is significant in seven countries.

Our findings suggest that if the lockdown is kept in place for too long, female academics in certain disciplines at top-ranked universities are likely to be significantly disadvantaged. Thus, universities thus need to take this potential gender inequality into account as they implement policies such as tenure clock extensions to the faculty in response to the pandemic.

Our study has a few limitations. First, our study focuses on social science disciplines and, thus, the findings may not be generalizable to other disciplines. Second, we have limited information about the researchers in our dataset. Future research could collect additional information such as their parental status to directly test the mechanism underlying the observed empirical patterns.

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Appendix

Figure A.1  Time Trends of US Preprints from December 2018 to May 2019

This graph plots the time trend of the number of preprints for female academics and male academics. The vertical line represents the placebo lockdown week (the week of March 11) in 2019.
Table A.1  Robustness to Different University Rankings

| Universities by Times ranking | Dependent variable: No. of preprints (in logarithm) by discipline |
|------------------------------|---------------------------------------------------------------|
|                              | 6 weeks | 7 weeks | 8 weeks | 9 weeks | 10 weeks |
| Top 10                        | −0.209*** | −0.230*** | −0.198*** | −0.185*** | −0.181*** |
| Top 20                        | −0.177*** | −0.222*** | −0.205*** | −0.204*** | −0.214*** |
| Top 30                        | −0.227*** | −0.253*** | −0.228*** | −0.228*** | −0.228*** |
| Top 40                        | −0.157*** | −0.211*** | −0.196*** | −0.196*** | −0.202*** |
| Top 50                        | −0.114    | −0.147**  | −0.130*   | −0.138**  | −0.146**  |
| Top 60                        | −0.126*   | −0.143*   | −0.131*   | −0.137**  | −0.147**  |
| Top 70                        | −0.142*   | −0.157**  | −0.141**  | −0.143**  | −0.143**  |
| Top 80                        | −0.139*   | −0.154**  | −0.140**  | −0.131*   | −0.130**  |
| Top 90                        | −0.134*   | −0.146**  | −0.137**  | −0.133*   | −0.135**  |
| Top 100                       | −0.124    | −0.129*   | −0.125*   | −0.118*   | −0.118*   |
| Observations                  | 720      | 756      | 792      | 828      | 864       |

| Universities by ARWU ranking  | Dependent variable: No. of preprints (in logarithm) by discipline |
|------------------------------|---------------------------------------------------------------|
|                              | 6 weeks | 7 weeks | 8 weeks | 9 weeks | 10 weeks |
| Top 10                        | −0.232*** | −0.255*** | −0.233*** | −0.214*** | −0.222*** |
| Top 20                        | −0.259*** | −0.297*** | −0.271*** | −0.260*** | −0.256*** |
| Top 30                        | −0.261*** | −0.305*** | −0.268*** | −0.264*** | −0.259*** |
| Top 40                        | −0.136*   | −0.188**  | −0.171**  | −0.176*** | −0.171*** |
| Top 50                        | −0.104    | −0.156**  | −0.132*   | −0.133**  | −0.139**  |
| Top 60                        | −0.171**  | −0.154*** | −0.154*** | −0.143*** | −0.114*   |
| Top 70                        | −0.080    | −0.125*   | −0.109    | −0.113*   | −0.120*   |
| Top 80                        | −0.123    | −0.128*   | −0.117*   | −0.118*   | −0.120*   |
| Top 90                        | −0.099    | −0.105    | −0.095    | −0.093    | −0.096    |
| Top 100                       | −0.090    | −0.094    | −0.086    | −0.084    | −0.089    |
| Observations                  | 720      | 756      | 792      | 828      | 864       |

This table reports the estimated coefficients in Equation (1) across universities with different rankings. The coefficients for 6, 7, 8, 9 and 10 weeks since the lockdown are presented in columns (1)–(5), respectively. Time fixed effects at the weekly level are included in all regressions. Note that we omit reporting standard errors and estimates of other variables for brevity. Significance at *p < 0.1; **p < 0.05; ***p < 0.01.
| Variables          | No. of preprints (in logarithm) in aggregation | No. of preprints (in logarithm) by discipline |
|-------------------|-----------------------------------------------|---------------------------------------------|
|                   | (1)                                           | (2)                                         |
| Female × Time − 14 | −0.231                                        | −0.189                                      |
|                   | (0.430)                                       | (0.352)                                    |
| Female × Time − 13 | −0.013                                        | 0.157                                       |
|                   | (0.430)                                       | (0.335)                                    |
| Female × Time − 12 | −0.377                                        | −0.202                                      |
|                   | (0.430)                                       | (0.309)                                    |
| Female × Time − 11 | 0.060                                         | 0.219                                       |
|                   | (0.430)                                       | (0.302)                                    |
| Female × Time − 10 | −0.030                                        | −0.054                                      |
|                   | (0.430)                                       | (0.210)                                    |
| Female × Time − 9  | −0.028                                        | −0.213                                      |
|                   | (0.430)                                       | (0.243)                                    |
| Female × Time − 8  | −0.144                                        | −0.146                                      |
|                   | (0.430)                                       | (0.258)                                    |
| Female × Time − 7  | −0.101                                        | −0.031                                      |
|                   | (0.430)                                       | (0.234)                                    |
| Female × Time − 6  | −0.363                                        | −0.413**                                    |
|                   | (0.430)                                       | (0.250)                                    |
| Female × Time − 5  | 0.355                                         | 0.314*                                      |
|                   | (0.430)                                       | (0.214)                                    |
| Female × Time − 4  | 0.130                                         | 0.063                                       |
|                   | (0.430)                                       | (0.224)                                    |
| Female × Time − 3  | 0.098                                         | −0.051                                      |
|                   | (0.430)                                       | (0.218)                                    |
| Female × Time − 2  | 0.069                                         | 0.056                                       |
|                   | (0.430)                                       | (0.239)                                    |
| Female × Time − 1  | 0.092                                         | 0.190                                       |
|                   | (0.430)                                       | (0.219)                                    |
| Observations       | 24                                            | 540                                         |
| $R^2$              | 0.894                                         | 0.808                                       |

This table reports the estimated coefficients of the interacted term, Female × Time, in Equation (3). The coefficients for 6, 7, 8, 9 and 10 weeks since the lockdown are presented in columns (1)–(5), respectively. Note that we omit reporting estimates of other variables for brevity. Time fixed effects at the weekly level are included in all regressions. Significance at *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$. 
Table A.3  Summary Statistics for December 2018 - May 2019

| Discipline (US only) | All observations | Before March 2019 | After March 2019 |
|----------------------|------------------|-------------------|------------------|
|                      | Level            | Weekly no. of preprints | Mean | Std. dev | Max | Min | Total | Mean | Std. dev | Mean | Std. dev |
| All Disciplines      | All              | 401.0 69.6 535 267 9,333 | 406.4 | 75.8 | 393.3 | 58.9 |
|                      | Female author    | 103.0 17.2 131 62 2,413 | 102.1 | 15.1 | 104.4 | 19.7 |
|                      | Male authors     | 298.0 57.9 424 205 6,920 | 304.3 | 65.7 | 288.9 | 42.7 |
|                      | Accounting       | 21.0 6.3 34 10 505 | 21.9 | 6.6 | 19.9 | 6.2 |
|                      | Anthropology     | 76.3 19.9 115 41 1,832 | 69.4 | 20.9 | 86.1 | 14.0 |
|                      | Cognitive        | 17.0 7.7 38 7 407 | 20.5 | 7.9 | 12.0 | 3.7 |
|                      | Corporate        | 17.5 5.9 30 8 420 | 17.2 | 5.6 | 17.9 | 6.4 |
|                      | Criminal         | 16.3 5.6 32 6 390 | 14.9 | 6.4 | 18.2 | 3.8 |
|                      | Economics        | 212.0 50.9 348 133 5,089 | 225.7 | 55.7 | 192.9 | 37.9 |
|                      | Education        | 15.3 5.2 29 6 366 | 15.3 | 5.2 | 15.2 | 5.6 |
|                      | Entrepreneurship | 16.1 5.6 28 8 387 | 18.7 | 5.3 | 12.5 | 3.6 |
|                      | Finance          | 89.7 21.3 148 66 2,153 | 95.0 | 25.2 | 82.3 | 11.8 |
|                      | Geography        | 13.6 6.3 29 5 327 | 11.9 | 4.9 | 16.0 | 7.5 |
|                      | Health Economics | 4.3 4.2 22 0 104 | 3.3 | 1.7 | 5.8 | 6.1 |
|                      | Information Systems | 20.2 5.8 36 10 485 | 22.0 | 6.4 | 17.7 | 3.9 |
|                      | Law              | 143.1 32.6 211 76 3,434 | 135.4 | 36.3 | 153.8 | 24.4 |
|                      | Management       | 32.4 11.8 57 8 778 | 34.7 | 11.1 | 29.2 | 12.5 |
|                      | Organization     | 24.8 7.8 43 15 594 | 27.2 | 8.4 | 21.3 | 5.7 |
|                      | Political Science| 166.3 28.3 225 124 3,991 | 172.5 | 30.9 | 157.6 | 22.8 |
|                      | Sustainability   | 38.8 23.9 105 14 930 | 34.1 | 16.7 | 45.2 | 31.3 |
|                      | Women/Gender     | 19.4 8.4 40 4 466 | 20.9 | 9.9 | 17.4 | 5.8 |

The table summarizes the weekly number of papers from December 2018 to May 2019. In total, there are 9,333 preprints produced by 14,767 US authors, 2,413 of which are produced by 3,876 female researchers and 6,920 are produced by 10,891 male researchers. We gather the country-specific lockdown time to split our sample to before and after the lockdown for each country.

Table A.4  Falsification Test

| Dependent variable: No. of preprints (in logarithm) in aggregation | 6 weeks | 7 weeks | 8 weeks | 9 weeks | 10 weeks |
|------------------------------------------------------------------|---------|---------|---------|---------|---------|
| Female × Lockdown                                                | 0.042   | 0.061   | 0.088   | 0.080   | 0.057   |
| Observations                                                     | 40      | 42      | 44      | 46      | 48      |
| R²                                                               | 0.980   | 0.980   | 0.979   | 0.980   | 0.980   |

The dependent variable is the number of preprints (in logarithm) in aggregation, and the independent variable is the interaction between gender and the lockdown time. The table reports the estimated coefficients of the interacted term, Female × Lockdown, in Equation (1). The coefficients for 6, 7, 8, 9 and 10 weeks since the lockdown are presented in columns (1)–(5), respectively. Note that we omit reporting estimates of other variables for brevity. Time fixed effects at the weekly level are included in all regressions. Significance at *p < 0.1; **p < 0.05; ***p < 0.01.