The significant yet short-term influence of research covidization on journal citation metrics

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Abstract

COVID-19 has emerged as a significant research hotspot in recent years, leading to a surge in production and citations received by COVID-19 papers. While concerns have been raised about the potential citation boost on journals associated with publishing COVID-19 papers, the extent and mechanisms of such gain remain unclear. This study uses a generalized difference-in-differences approach to examine the impact of publishing COVID-19 papers on journal citations and related metrics in four highly covidized fields. Our results demonstrate that journals starting publishing COVID-19 papers in health sciences fields in 2020 experienced a significant increase in citations compared with other journals. This trend continued in 2021, although to a lesser extent. However, such citation premiums became insignificant for journals starting to publish COVID-19 papers in 2021. In some fields, we also observed that COVID-19 papers increased the citations of non-COVID-19 papers in the same journals, but only for journals starting to publish COVID-19 papers in 2020. Our heterogeneity test indicates that COVID-19 papers published in prestigious journals brought more significant citation premiums to the journals and non-COVID-19 papers in most fields. We finally show that these citation premiums can affect various citation-based journal metrics. Our findings reveal a "gold rush" pattern in which early entrants are more likely to establish their citation advantage in research hotspots and caution against using such metrics to evaluate journal quality.

Keywords: COVID-19; Science of Science; Citation Impact; Scientometrics

Introduction

Since its appearance in late 2019, the COVID-19 pandemic has caused devastating economic and social disruption. The scientific community is among those who responded swiftly to the widespread and disastrous event (1). Scientists have been extensively mobilized to conduct COVID-19-related research to advance knowledge about the virus and develop tools and strategies for controlling the pandemic (2–4). As a result, there has been an unprecedented surge in the production of COVID-19 papers, with many active researchers contributing (2, 5–7): As indexed by Scopus, over 700,000 authors contributed 200,000 COVID-19 papers between January 2020 and August 2021 (8). Across disciplines, 98 of the 100 most-cited papers published in 2020-2021 were about COVID-19 (9). The surge of COVID-19 papers has led to a massive "covidization" of scientific research during the pandemic, making COVID-19 a significant research hotspot in recent years (4, 9, 10).

The COVID-19 research has indisputably contributed immensely to mitigating and controlling the pandemic, from various protection measures to vaccines and Paxlovid. Nevertheless, researchers in the field expressed concerns that too many scientists pivoting from their professional areas to COVID-19 research could result in tremendous wastage and risk science advances (4). It is also concerned that the massive "covidization" of research will elevate citation-based metrics for certain groups in the research evaluation system, where the citation is widely used as a research impact measure despite widespread criticisms (11). Researchers and journals that published COVID-19 research would likely have the advantage in the current science evaluation system for publishing COVID-19 research.

Evidence suggests that COVID-19 research brought more citations than non-COVID-19 research to researchers and journals that published them (9, 12, 13). It is reported that 98% of the top 100 cited papers published in 2020-2021 were about COVID-19 in Scopus (9). Many researchers have achieved citation-based elite status through the disproportionate number of citations received by publishing COVID-19 papers (9). For journals, these highly cited COVID-19 papers may seriously boost the journal-level citation count and derivative metrics, such as the Journal Impact Factor (JIF) (12). Studies estimated that journals associated with a high proportion of COVID-19 papers might see increases in JIF from 2020 to 2021 (14–17). Following research hotspots like COVID-19 seems to bring citation premiums for researchers and journals. However, the extent of such citation premiums and how they may affect evaluations based on citation-derived metrics is unclear.

The COVID-19 pandemic also provides a unique opportunity to unpack the dynamic process of the citation premium brought by research hotspots to journals and researchers. Chasing research hotspots is common in science and can help advance a timely topic and a research field in a short time period (18). It is often assumed that chasing research hotspots can help researchers and journals increase citations and research impact, which is a crucial motivation for such behavior (19, 20). However, whether research hotspots can consistently produce stable citation premiums is uncertain. Early research suggests that as more papers are published in a field, more citations tend to flow toward established canonical papers rather than new ones (21). Of the sudden burst of COVID-19 papers, it is possible that late works might not attract as much attention and citations as early works. It remains to be seen whether the COVID-19 trend will continuously benefit journals through citation premiums and how much benefit is left for the "late coming" journals that publish COVID-19 papers later.

Another goal of this study is to understand the mechanism behind the journal citation premium resulting from COVID-19 papers. Highly cited COVID-19 papers directly increased their home journals' citations (9, 12, 13). However, it is unclear whether the timing of publishing COVID-19 papers matters in boosting citations. We are also unsure if COVID-19 papers would bring citation premiums to non-COVID-19 research published in the same journal, given the potential wide visibility brought by COVID-19 papers. While a citation polarization between COVID-19 and non-COVID-19 papers has been suggested (22), a spillover effect might also occur (23): The increased visibility of a journal due to COVID-19 papers may lead to more citations for non-COVID-19 papers in the same journals than would have occurred without the pandemic. Understanding this mechanism will help us comprehend how a research hotspot, directly and indirectly, influences citations and research performance evaluations.

To investigate the research gaps outlined above, this study used a dataset consisting 6 million publications in over 7,000 journals indexed by Scopus between 2015 and 2022, including 30,010 COVID-19 publications in 3,494 journals published between 2020-2021, in four highly covidized fields (*Biomedical Research*, *Chemistry*, *Clinical Medicine*, and *Public Health & Health Services*) where the impact of COVID-19 is most notable (see **SI Appendix, Table S1**). We quantified the citation premiums brought to journals by COVID-19 papers they published in 2020 and 2021, as well as the resulting changes in common journal impact assessment metrics.

Causal inference and sample construction strategy

This study used the difference-in-differences (DID) method to evaluate the effect of COVID-19 papers on the citation changes of the entire journal and other non-COVID-19 papers. As a common technique for causal analysis, DID allows us to quantify the influence of publishing COVID-19 research while excluding the impact of other citation inflation factors, such as the annually growing publication volume and the extended reference lists in recent publications (24, 25). We used DID to estimate the impact of COVID-19 research on citations impacts based on the following considerations: If the citation change pattern for journals follows a parallel trend before they published COVID-19 papers, but journals that published COVID-19 papers (the treatment group) deviate from the parallel trend that journals never published COVID-19 papers (the control group) are still following, then the deviation should be caused by publishing COVID-19 papers if no other unobserved events interfere.

We obtained research published between 2015 and 2022 by journals in the four target fields from a copy of the Scopus database provided by the International Center for the Study of Research (ICSR) Lab. Journals that published COVID-19 papers became the treatment group. The rest of the journals became the control group. We performed an exact matching between journals in the treatment and control group to improve the comparability (see **Materials and Methods**). The final sample includes 3494 journals in the treatment group (publishing a total of 30,010 COVID-19 papers during 2020-2021) and 3589 "comparable" journals in the control group (see **SI Appendix, Table S2**). The citation counts for the publications are computed up to 2022 using a two-year time window. Due to the potential dynamic treatment effects brought by the time factor (26), we divided the treatment group into two cohorts, the 2020 and 2021 cohorts, including journals that started publishing COVID-19 papers in 2020 and 2021, respectively. Comparing each cohort with the control group allows us to examine whether publishing COVID-19 papers brings the same citation premiums over time. Understanding that citation practices vary by field, we constrained all analyses within the same field.

Results

The covidization of scientific research

The covidization of scientific research during 2020 and 2022 is evident (see **Table 1**). In total, 18 out of 21 fields and about 75% of the 175 subfields published COVID-19 research during the pandemic (see **Materials and Methods** for field classification). During 2020, there were 16,208 COVID-19 papers published by 2,893 journals, accounting for 0.67% of all papers and 10.99% of all active journals in the year. Within the four target fields, COVID-19 papers account for about 1.46% of papers published in 2020, spreading across 2,576

(25.74%) journals. The number of COVID-19 papers, journals publishing them, and contributing authors peaked in 2021, and the heat seemed to cool down in 2022.

(Table 1 near here)

Trends of citation impact

Fig. 1A illustrates the evolution of citation impact for different journal groups since 2015. We see that the average citation per paper in a journal (ACPP) exhibits a slow and stable increase in parallel trends across journal groups in all four fields before 2020. However, potential citation inflation for journals occurred due to publishing COVID-19 papers: The 2020-cohort journals experienced a significant rise by around 38.5%–44.3% in the ACPP and 16.9%-35.6% in the average citation per non-COVID-19 paper in a journal (non-COVID-ACPP) across fields except for *Chemistry*. On the other hand, the 2021-cohort journals show a limited deviation in citation measures from the control group for papers published in 2021. To formally test the pre-treatment parallel trend assumption required by DID, we further used event-study analysis and confirmed the pre-treatment parallel trend (see **SI Appendix, Fig. S1**).

The sharp increase in journal citation measures is highly likely due to the COVID-19 papers they published. As the third row in **Fig. 1A** shows, on average, COVID-19 papers published in 2020 have attracted remarkably more citations than non-COVID-19 papers published in the same year. For example, in *Biomedical Research*, the average citation per COVID-19 paper in a journal (COVID-ACPP) (mean=32.78, 95%CI [27.91, 37.65]) in the 2020 cohort is 4.8 times the concurrent ACPP (mean=6.79, 95%CI [5.90, 7.68]) and 6.5 times the non-COVID-ACPP (mean=5.02, 95%CI [4.47, 5.58]) in the same journals. However, the COVID-ACPP declined sharply in 2021 by around 66.4%–77.2% in the four fields, suggesting that COVID-19 papers' citation impact shrunk quickly. As **Fig. 1C** shows, a small percentage of COVID-19 papers contributed significantly to their home journals' overall citations. However, COVID-19 papers published in 2020 contributed more to their home journals' citation measures than those published in 2021, as suggested by the OLS fitting slopes (β) of the fitted trend lines. It indicates that the high citation peaks due to COVID-19 papers published in 2020 did not extend to those published in 2021.

(Fig. 1 near here)

Citation premium due to COVID-19 papers

DID allows us to quantify the substantial citation premium for journals that published COVID-19 papers. As **Fig. 2A** shows, compared with journals in the control group, a 1% increase in COVID-19 papers in 2020-cohort journals on average leads to about 0.48 (95%CI [0.20, 0.76]) more ACPP in *Clinical Medicine*, 0.35 (95%CI [0.16, 0.55]) in *Biomedical Research,* and 0.33 (95%CI [0.10, 0.55]) in *Public Health & Health Services*. Most 2020-cohort journals (69.37%) continued to publish COVID-19 papers in 2021, which brought significant but minor citation advantages to those journals. However, the ACPP of 2021-cohort journals makes no difference from the control group, suggesting little citation premium brought to 2021-cohort journals.

The results further suggested that publishing COVID-19 papers increases the citations for non-COVID-19 papers in the same journals in selected fields (See **Fig. 2B**). Compared with journals in the control group, a 1% increase in COVID-19 papers in journals within the 2020 cohort would boost the non-COVID-ACPP in the same journals by 0.07 (95%CI [0.02, 0.11]) in *Biomedical Research* and 0.17 (95%CI [0.04, 0.29]) in *Public Health & Health Services.* For journals in the 2020 cohort, the COVID-19 papers published in 2021 continue to benefit the citations received by non-COVID-19 papers in the same journal. For journals in the 2021 cohort, publishing COVID-19 papers does not attract more citations for their non-COVID-19 papers in the same journal. In *Public Health & Health Services*, the increase in COVID-19 papers may even lead to a slight decrease in the citations received by non-COVID-19 papers in journals within the 2021 cohort (See **Fig. 2B**).

We confirmed that the main results mentioned above are robust and insensitive to certain factors based on additional robustness tests, including an in-time placebo test, an in-space placebo test, a balanced panel test, an ACPP alternative measure-based test, a binary treatment-based DID test, and additional tests with control variables (see **SI Appendix Text and Fig. S3-S7**).

Heterogeneity analysis

Besides factors controlled in sample construction, journal prestige and accessibility are two other major journal-level factors that can potentially affect their citations (27). We conducted a heterogeneity test to examine if the COVID-19 papers' citation premium differs between journals with different such attributes. We split journals into subgroup pairs for heterogeneity analysis based on their prestige and OA status. We first created two pairs of journal subgroups based on journal prestige. The first pair includes a set of journals within the top 25% prestige measures (25% high-prestige) and 75% prestige measures (75% low-prestige). The second pair includes 50% high- and 50% low-prestige journal groups. We also created a journal group pair based on their OA status: OA and non-OA journal subgroups.

To validate our conclusions, we quantified the effect gaps per 1% increase of COVID-19 papers between each pair of journal subgroups (see **Table 2**). We found that publishing COVID-19 papers in 2020 increased the journal and non-COVID-19 papers' citations more for high-prestige journals than for low-prestige journals in all fields except *Chemistry*. Additionally, OA journals' citation counts were boosted more than non-OA journals' citation counts by COVID-19 papers published in 2020 in *Public Health & Health Services*. In contrast, most subgroup pairs have insignificant or weak heterogeneous effects from publishing COVID-19 papers in 2021. However, for the 2020-cohort journals, we still observed significantly larger citation effects for high-prestige journals in 2021 in most fields.

(Table 2 near here)

Moreover, we analyzed the parallel trend over time for each subgroup in the heterogeneity test. We also replicated the same specifications used in the main results to determine if any subgroup differed significantly from the main findings. Our analysis demonstrated that the estimated results were qualitatively similar to the previous main results, strengthening the validity of our estimations for journals with varying levels of prestige and accessibility (see **SI Appendix, Fig. S8-S10**).

Impact on journal metrics

Hypothetically, the citation boost brought by COVID-19 papers should ripple across various citation-based journal metrics. To examine the potential impact, we presented a reconstructed JIF for the journals in our dataset (see **Materials and Methods**). We investigated if the JIF ranks of journals within the same field would be swayed by COVID-19 in 2021-2022 when the JIF first included the citations to 2020's publications. As **Fig. 3A** shows, 2020-cohort journals in *Biomedical Research*, *Medicine*, and *Public Health & Health Services* experienced a significant boost in their JIFs in 2021. Specifically for 2020-cohort journals, we found that a greater proportion of these journals saw an increase in JIF rank in 2021. Journals that published a high share of COVID-19 papers tended to have significant increases in rank (see **Fig. 3B**). We also compared journal ranks by two Scopus-based metrics (SJR and SNIP; see **Materials and Methods**) in 2020 and 2021 for journals within the 2020 cohort and found a similar pattern (see **SI Appendix, Fig. S2)** and found similar patterns. Our findings suggest that, at least in the early stage, citation-based journal metrics are likely to be impacted by the previously suggested COVID-19 premium for 2020-cohort journals.

(Fig. 3 near here)

Discussion

COVID-19 has been one of the most remarkable research hotspots in the recent decade. Using COVID-19 as a case, we contributed new knowledge about how research hotspots could boost the journal citation impacts by investigating the dynamic process and mechanisms of citation premium brought by COVID-19 papers. By comparing the effect of COVID-19 papers on journal citations, we found that for health sciences fields, in contrast to the initial surge of citations when COVID-19 papers began, the citation premium soon declined in 2021, leaving limited opportunities for late-entry journals to benefit from the citation boost. This finding confirms the previous hypothesis that the citation premium for late published COVID-19 papers would be restricted as the pool of COVID-19 papers grew up (9). Similarly, for other research hotspots beyond COVID-19, such as graphene, it is also observed that new publications had decreasing scientific impact as the research field became saturated (28).

However, not all journals completely lost the citation premium brought about by COVID-19 in 2021. Albeit to a lesser extent, publishing COVID-19 papers in 2021 can still boost a journal's citation impact if the journal had already published COVID-19 papers in 2020. For other journals, we did not find evidence supporting that the citation premium continued to exist for COVID-papers published in 2021. These findings provide evidence for a "gold rush" pattern, where early entrants in an emerging and fast-evolving field are more likely to establish their advantage and gain broad and long-term benefits (21, 29). While the gold rush may also open a "window of opportunity" (28) for late-coming journals to derive citation benefits from the topic's popularity, our study suggests that the window of opportunity for COVID-19 is closing quickly.

Our study found that in addition to directly contributing citations, COVID-19 papers may increase the citations of non-COVID-19 papers in the same journal. This phenomenon exists in *Biomedical Research* and *Public Health & Health Services fields*. The finding supports the spillover effect for the citations boosted by research hotspots. Known cases of the spillover effect in citations include that a journal's open-data policy may increase the citations received by papers published before the policy starts due to an overall increase in the journal's reputation (30). Similarly, journals publishing COVID-19 papers may benefit from an increased journal impact, which further increases the visibility of non-COVID-19 papers and amplifies the total citations for the journal. However, the "gold rush" pattern also applies here, as journals publishing COVID-19 papers in 2020 continued to show the spillover effect in 2021, while other journals did not. This further highlights the importance of being an early entrant in a research hotspot.

The heterogeneity test shows that COVID-19 papers published in high-prestige journals increased the journal and non-COVID-19 papers' citation impact more in most fields in 2020. This finding can be associated with the evidence that prestigious journals gain more citation benefits from publishing COVID-19 papers than low-prestige journals (22). It is possible that COVID-19 papers published in prestigious journals attracted more attention and citations than those in low-prestige journals, even when the quality is similar (31). However, it should be noted that the heterogeneous effects cannot be interpreted causally because we did not control for omitted variables or reverse causality.

In conclusion, this study suggests that journals publishing early COVID-19 papers are more likely to share shrinking but lasting citation premiums, double-contributed by COVID-19 and non-COVID-19 papers. It highlights the benefits of timely research and publishing in emerging and frontier topics, which is also supported by other empirical evidence (32). Moreover, as shown by the results, JIF and other citation-based journal metrics can be boosted by the citation premium, though it may only restrict to a short term.

Therefore, our study cautions against using quantitative citation-based journal metrics to evaluate the quality of journals or their publications, especially those based on citations of COVID-19 publications. Given the instability of journal citations in response to scientific trends, the scientific community should evaluate journals using multidimensional metric matrices and break away from a monoculture of citations.

Materials and Methods

Data source and COVID-19 paper identification. We used a Scopus dataset copy from ICSR Lab, Elsevier. Journal articles or reviews published in English were included in our analysis. Following a similar approach adopted by some previous research (8, 9), we retrieved COVID-19 papers by searching the web interface of Scopus using the following query: *TITLE-ABS-KEY(sars-cov-2 OR 'coronavirus 2' OR 'corona virus 2' OR covid-19 OR {novel coronavirus} OR {novel corona virus} OR 2019-ncov OR covid OR covid19 OR ncovid-19 OR 'coronavirus disease 2019' OR 'corona virus disease 2019' OR corona-19 OR SARS-nCoV OR ncov-2019) AND PUBYEAR > 2018 AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re"))*. This query identifies articles or reviews whose titles, abstracts, or keywords contain COVID-19-related terms and were published after 2018. As of January 2023, the query returned 50,684 unique records. These records were matched with the Scopus dataset copy to identify COVID-19 papers. Given the time when COVID-19 started, we further restricted the COVID-19 papers to those published from 2020 and onwards based on the publication year information from the Scopus dataset.

Field classification. We assigned the field for each journal by adopting the journal classification system developed by Science-Metrix (33), which classifies journals in Scopus into 20 fields and 174 subfields (excluding article-level classification). We selected four fields, i.e., *Biomedical Research, Chemistry, Clinical Medicine*, and *Public Health & Health Services,* in the analyses due to their higher shares of journals publishing COVID-19 research (see **SI Appendix, Table S1**).

Exact matching. An exact matching was conducted on the sample by subfield (the finest level of classification defined by Science-Metrix) and journal open-access (OA) status between the treatment and control groups, forming 352 subclasses of journals belonging to the same subfield and OA status. We kept 222 subclasses with at least one journal in the treatment group and at least one in the control group for further analysis.

Citation measures. We measured the citation impact of a journal using ACPP. To understand the potential impact of COVID-19 papers, we also calculated the COVID-ACPP and the non-COVID-ACPP for these journals (see **SI Appendix, Table S3**). We calculated the citation using a two-year time window: the citations received by papers within and after the year of publication. Because our Scopus copy was extracted on October 21, 2022, for a fair comparison across years, we imputed the citation counts for the last two months of 2022 by using the average for the first ten months of 2022. We excluded journal self-citations (citations within the same journal) to avoid the potential influence of citation manipulation in the main results. We also replicated the results using total citations (without excluding self-citations) in the robustness check.

Citation-based journal metrics. We used three citation-based journal metrics to investigate their relationships with the publishing of COVID-19 papers: reconstructed Journal Impact Factor (JIF), SCImago Journal Rank (SJR), and Source Normalized Impact per Paper (SNIP) (34). Clarivate proprietarily releases JIF in its yearly published *Journal Citation Report* based on the Web of Science database. To incorporate JIF in our analysis, we reconstructed a simulated JIF for every journal indexed by Scopus, using the same methodology and Scopus data. The formula is:

$$JIF_{ij} = \frac{C_{i,j,j-1} + C_{i,j,j-2}}{N_{i,j-1} + N_{i,j-2}} \quad [1]$$

where JIF_{ij} is the JIF for journal i in year j, C_{ijk} is the number of citations made in year j to journal i 's past publications published in year k, and N_{ij} is the number of journal i's publications in year j. SJR and SNIP were originally calculated based on Scopus dataset. Hence, we adopted both metrics directly without changes. Methodologically, SJR considers the prestige of the citing sources and the closeness between cited and citing sources (35), while SNIP normalizes the journal's citation performance based on field (36). Both metrics are based on the citations made in the present year to publications in the past three years.

Difference in differences (DID). We used the generalized DID technique to compare the citation counts of the journals in the treatment and control groups before and after treatment (publishing COVID-19 papers) at different levels of COVID-19 publishing intensity (37, 38). The COVID-19 publishing intensity is measured by the percentage of COVID-19 papers (scaled from 0-100) for a journal in a given year (22). It equals 0 for the years before publishing COVID-19 research. We selected the five years before the COVID-19 pandemic (2015-2019) as the pre-treatment period, and 2020-2021 as the in-treatment period. Following Yadav et al.'s (39) specification incorporating the heterogeneity by cohort, we estimated the following fixed-effect regression specification as the baseline specification:

$$Y_{ij} = \sum_{t=2015}^{2021} \sum_{d=2020}^{2021} \beta_{td} R_{it} D_{id} T_{jt} + \lambda_i + \delta_j + \epsilon_{ij} \quad [2]$$

where i, and j denote the ith individual journal and jth year, respectively. Y denotes the outcome variables of interest, including the ACPP and the non-COVID ACPP. R is the treatment variable, the percentage of COVID-19 research in a journal. D_{id} is a cohort dummy variable that equals 1 if the ith individual journal starts publishing COVID-19 papers in the year of d, belonging to the d-cohort. T_{jt} is a dummy year variable that equals to 1 if $j = t$. λ and δ denote the journal and year-fixed effects, respectively, capturing unobservable journal- and year-specific factors, such as the journal field, specialty, OA status, and yearly changes of citing sources.

We are interested in the coefficients β_{td}, the estimated differences per 1% of COVID-19 research in journals between the d-cohort and the reference group, i.e., journals that never published COVID-19 research in year t. $\beta_{2020,2020}$ and $\beta_{2021,2021}$ measure the impact of publishing COVID-19 research on ACPP in 2020 and 2021, respectively, under the assumption of the pre-treatment parallel trend. $\beta_{2021,2020}$ represents the 2020 cohort's advantage in ACPP in 2021 after publishing COVID-19 research in 2020. Due to the multiple periods for individual journals, we clustered the standard errors at the individual journal level (40).

Heterogeneity test. We checked whether the citation effect from COVID-19 research depends on journal features using heterogeneity analysis. For journal features, we assigned journals into groups based on journal prestige (high- and low-prestige journals) and OA status (OA and non-OA journals). $X\%$ high-prestige journals are defined as journals whose 2020 SJR and SNIP are in the top $X\%$ of the affiliated subfields, and low-prestige journals include the rest. We chose the year 2020 because it supposedly captures journal prestige without potential citation inflation boosted by COVID-19 research. The heterogeneity test estimated the following specification.

$$Y_{ij} = \sum_{t=2015}^{2021} \sum_{d=2020}^{2021} (\beta_{td} + \hat{\beta}_{td} I_i) R_{it} D_{id} T_{jt} + \lambda_i + \delta_j + \epsilon_{ij} \quad [3]$$

Where I_i is a binary variable denoting the ith journal's group by prestige and OA status. $\hat{\beta}_{td}$ shows the heterogeneous effect between two journal groups according to the definition of I_i.

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Data, Materials, and Software Availability

The aggregated dataset and codes are available on GitHub (https://github.com/UWMadisonMetaScience/covidcites). For research purposes, readers can contact the ICSR Lab for access to the Scopus data.

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Figures and Tables

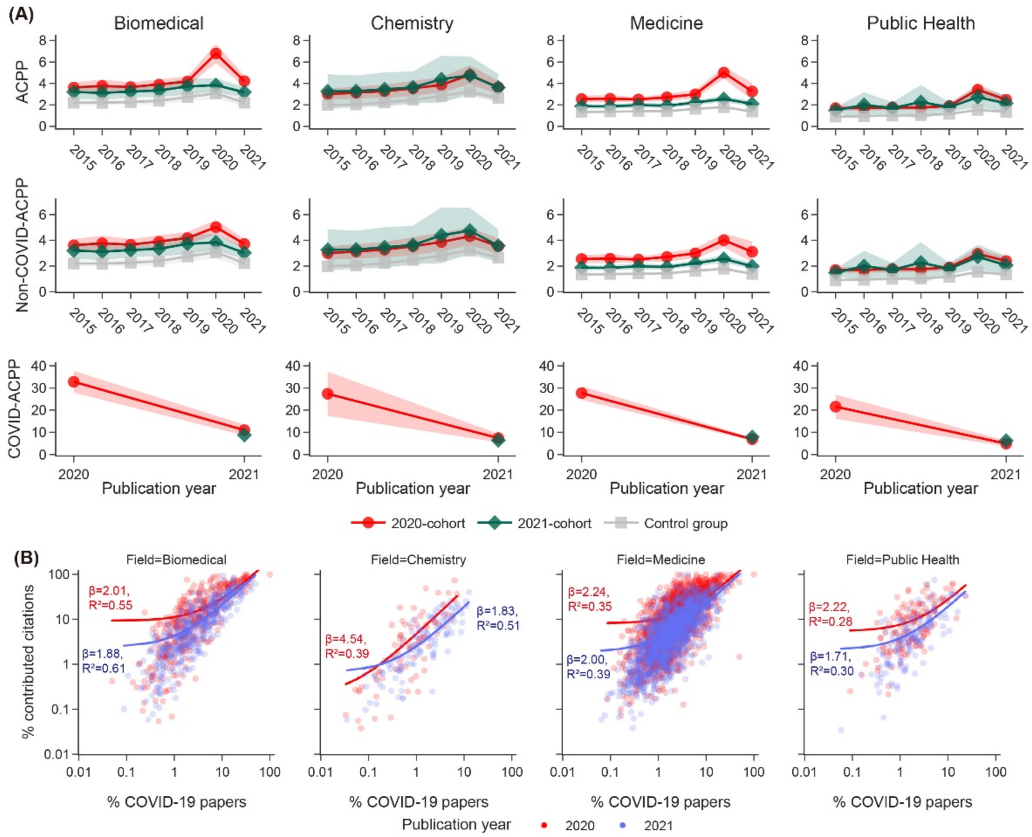

Fig. 1. The citation impact of journals by COVID-19 publishing status. All citations were calculated using a two-year time window. (A) The evolution of ACPP, non-COVID-ACPP, and COVID-ACPP from 2015-2021. The markers show the mean values of the year. The shaded areas show 95% confidence intervals. (B) The relationship between the percentage of COVID-19 papers in a journal and the percentage of citations contributed by COVID-19 papers during a two-year time window. Trend lines were fitted using OLS. Both horizontal and vertical axes are on the log scale.

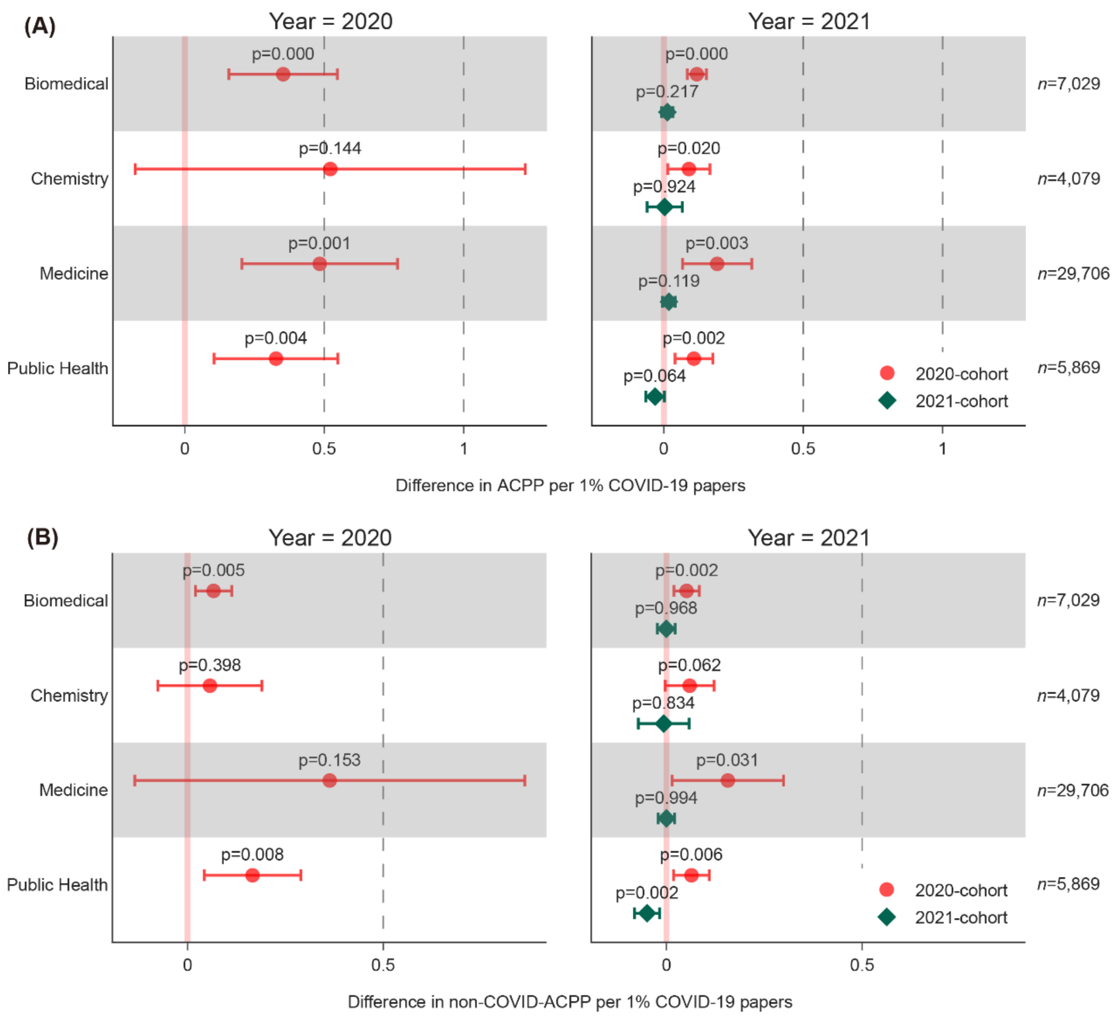

Fig. 2. Quantification of journal citation premiums due to COVID-19 papers. See **Data and methods** for regression specifications. The number of observations (*n*) for each field is shown on the right. Horizontal error bars indicate the 95% confidence intervals. (A) Effect of publishing COVID-19 papers on ACPP. (B) Effect of publishing COVID-19 papers on non-COVID-ACPP.

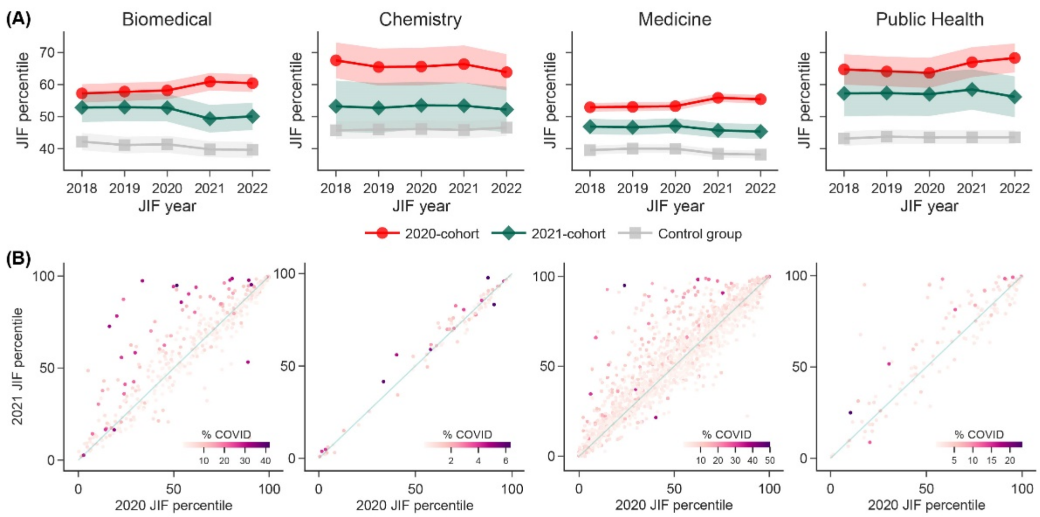

Fig. 3. Journal rank changes based on reconstructed journal impact factor (JIF). JIF calculation is introduced in **Materials and Methods**. A journal's JIF rank in a given year is represented by its JIF percentile among all journals within the same field. The 100th percentile indicates the highest JIF rank in a field. (A) The evolution of JIF from 2018-2022. The markers show the mean values of the year. The shaded areas show 95% confidence intervals. (B) Comparison of 2020 and 2021 JIF for 2020-cohort journals. Each point represents a journal. Points above the diagonal (shown as a light green line) have higher JIF ranks in 2021 than 2020. Points are colored according to the corresponding journal's percentage of COVID-19 papers.

Table 1. Papers, journals, authors, subfields and citations associated with COVID-19 research.

	COVID-19 paper		**Associated Journals**		**Associated authors**		**Associated fields**		**Associated subfields**		**2-Year citations**	
	#	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**
All fields												
2020	16,208	0.67%	2,893	10.99%	105,847	1.89%	18	85.71%	112	64.00%	842,375	8.43%
2021	18,414	0.68%	3,259	12.38%	145,954	2.29%	18	85.71%	122	69.71%	237,714	3.06%
2022	10,083	0.51%	2,299	9.92%	91,104	1.65%	18	85.71%	113	64.57%	19,582	2.01%
Total	44705	0.63%	4571	15.97%	279679	2.51%	18	85.71%	131	74.86%	1099671	5.87%
Biomedical Research, Chemistry, Medicine, and Public Health & Health Services												
2020	14,513	1.46%	2,576	25.74%	95,312	3.13%	4	100.00%	59	100.00%	718,817	15.42%
2021	15,756	1.39%	2,810	27.67%	127,404	3.62%	4	100.00%	58	98.31%	190,495	5.89%
2022	8,722	1.11%	1,971	22.04%	79,730	2.70%	4	100.00%	58	98.31%	15,656	4.60%
Total	38991	1.34%	3861	33.58%	248562	3.99%	4	100.00%	59	100.00%	924968	11.23%

Table 2. Heterogeneity analysis of COVID-19 research effects by journal factors. Numbers in brackets show the 95% confidence interval. *** p<0.001, ** p<0.01, * p<0.05.

Journal cohort	Publication year	Biomedical	Chemistry	Medicine	Public Health
Outcome variable: ACPP					
25% high vs. 75% low-prestige					
2020-cohort	2020	0.794***	1.412	1.154***	0.725***
		[0.403, 1.185]	[-0.271, 3.096]	[0.701, 1.607]	[0.368, 1.081]
2021-cohort	2021	-0.263	-0.189	0.102	0.035
		[-0.678, 0.152]	[-0.790, 0.411]	[-0.074, 0.277]	[-0.219, 0.288]
2020-cohort	2021	0.145***	0.181*	0.496*	0.091
		[0.071, 0.219]	[0.040, 0.322]	[0.035, 0.957]	[-0.046, 0.228]
50% high vs. 50% low-prestige					
2020-cohort	2020	0.625***	0.810	1.085***	0.553**
		[0.335, 0.915]	[-0.329, 1.949]	[0.597, 1.573]	[0.214, 0.892]
2021-cohort	2021	-0.211	-0.172	0.079	-0.027
		[-0.489, 0.066]	[-0.693, 0.350]	[-0.019, 0.178]	[-0.213, 0.158]
2020-cohort	2021	0.109***	0.086	0.348*	0.070
		[0.053, 0.166]	[-0.042, 0.213]	[0.082, 0.614]	[-0.035, 0.175]
OA vs. subscription-based					
2020-cohort	2020	0.088	1.175	-0.182	0.555**
		[-0.212, 0.389]	[-0.453, 2.804]	[-0.542, 0.177]	[0.142, 0.968]
2021-cohort	2021	0.072	-0.173*	0.062	-0.035
		[-0.009, 0.152]	[-0.318, -0.027]	[-0.035, 0.159]	[-0.101, 0.031]
2020-cohort	2021	-0.024	-0.105	-0.115	-0.042
		[-0.083, 0.035]	[-0.242, 0.032]	[-0.308, 0.079]	[-0.161, 0.076]
Outcome variable: non-COVID-ACPP					
25% high vs. 75% low-prestige					
2020-cohort	2020	0.123*	0.398**	0.249	0.356**
		[0.018, 0.229]	[0.099, 0.697]	[-0.278, 0.777]	[0.096, 0.617]
2021-cohort	2021	-0.313	-0.235	-0.022	-0.060
		[-0.785, 0.159]	[-0.848, 0.378]	[-0.173, 0.129]	[-0.304, 0.185]
2020-cohort	2021	-0.004	0.128*	0.309	0.048
		[-0.085, 0.078]	[0.028, 0.228]	[-0.167, 0.785]	[-0.035, 0.130]
50% high vs. 50% low-prestige					
2020-cohort	2020	0.129**	0.236*	0.989	0.302**
		[0.052, 0.207]	[0.022, 0.451]	[-0.157, 2.135]	[0.101, 0.502]
2021-cohort	2021	-0.252	-0.219	0.032	-0.084
		[-0.566, 0.062]	[-0.751, 0.313]	[-0.064, 0.128]	[-0.257, 0.088]
2020-cohort	2021	0.001	0.047	0.308	0.054
		[-0.057, 0.060]	[-0.080, 0.173]	[-0.014, 0.630]	[-0.023, 0.131]
OA vs. subscription-based					
2020-cohort	2020	0.017	0.218	-0.301	0.418**
		[-0.060, 0.094]	[-0.070, 0.506]	[-0.857, 0.255]	[0.164, 0.673]
2021-cohort	2021	0.037	-0.186*	0.054	-0.040
		[-0.040, 0.115]	[-0.333, -0.039]	[-0.037, 0.145]	[-0.108, 0.028]
2020-cohort	2021	0.006	0.127***	-0.110	-0.021
		[-0.050, 0.063]	[0.063, 0.190]	[-0.321, 0.102]	[-0.111, 0.069]
N		7,029	4,079	29,706	5,869