The Role of Preprint Servers in the Scientific Process

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Abstract

Preprint servers have become integral components of the modern scientific communication ecosystem. These platforms enable researchers to share manuscripts before formal peer review, accelerating dissemination while raising questions about quality control and research integrity. We examine the historical development of preprint servers from their origins in physics to their expansion across disciplines, analyze empirical evidence on their benefits and limitations, and assess their role in accelerating scientific communication. The COVID-19 pandemic catalyzed unprecedented adoption of preprints in biomedical research, revealing both the potential and challenges of rapid, unreviewed scientific dissemination. We find that preprints provide measurable benefits in terms of speed, citation rates, and open access, while quality concerns appear less severe than initially feared. The integration of preprint servers into the scholarly publishing ecosystem represents a structural transformation of the scientific public sphere, with implications for research evaluation, reproducibility, and the democratization of scientific knowledge.

1 Introduction

Preprint servers are digital repositories where researchers deposit manuscripts prior to formal peer review and journal publication. These platforms fundamentally challenge the traditional journal-centric model of scientific communication by decoupling dissemination from certification [7]. A preprint is typically defined as a complete scientific manuscript that authors post on an open platform before, during, or after submission to a peer-reviewed journal [3]. The manuscript undergoes screening checks rather than full peer review, allowing rapid public availability while retaining author copyright and enabling subsequent journal submission.

The modern preprint movement began in 1991 when physicist Paul Ginsparg established arXiv, initially as a platform for high energy physics papers [7]. The success of arXiv in physics, where it became central to scholarly communication, demonstrated that rapid, open dissemination could coexist with traditional publishing. However, adoption in other fields lagged substantially. The biomedical sciences saw minimal preprint activity until bioRxiv launched in 2013, followed by medRxiv for clinical research in 2019 [10]. The number of preprint servers has since expanded dramatically, with one study identifying 63 servers worldwide by 2019, including 38 launched between 2016 and 2019 [7].

This proliferation reflects a broader structural transformation of scientific communication. Traditional peer-reviewed journals served dual functions: dissemination of research findings and certification through peer review. This coupling created inherent tensions between speed and rigor, accessibility and selectivity. Preprint servers decouple these functions, enabling rapid dissemination while leaving certification to subsequent peer review processes. This separation has generated substantial debate about the role of preprints in maintaining scientific quality while accelerating discovery.

The scientific community remains divided on the merits of this transformation. Proponents argue that preprints democratize science, accelerate discovery, enable community feedback, and establish

Preprint.

priority [15]. Critics raise concerns about quality control, misinformation risks, and the potential for premature or misleading results to influence public opinion and policy [11]. These debates intensified during the COVID-19 pandemic, when preprints became central to rapid information sharing but also highlighted risks of disseminating unreliable findings [9].

This paper examines the role of preprint servers across multiple dimensions. We analyze empirical evidence on their benefits for research dissemination and impact, assess quality and peer review considerations, examine the COVID-19 pandemic as a natural experiment in rapid preprint adoption, explore disciplinary differences in preprint culture, and discuss future directions for integrating preprints into the scholarly ecosystem. Our analysis synthesizes quantitative studies of preprint characteristics with qualitative assessments of researcher experiences and institutional responses.

2 Benefits of Preprint Servers

Preprint servers provide several measurable benefits to individual researchers and the scientific community. The most immediate advantage is speed. Traditional journal publishing involves substantial delays, with months or years between manuscript submission and final publication. Preprints circumvent this delay, making results available within days of submission. Analysis of arXiv papers found that preprints overcome publication delays resulting from peer review, with significant citation advantages for articles with previous preprints [2]. This acceleration has particular value in rapidly evolving fields where timely dissemination affects research directions and resource allocation.

Priority establishment represents another key benefit. By timestamping work with a citable Digital Object Identifier (DOI), preprints enable researchers to establish precedence for their discoveries [16]. This function addresses a fundamental tension in science between the desire to share findings quickly and the need to receive credit for original contributions. Preprints provide a mechanism to do both simultaneously, reducing incentives to delay dissemination until formal publication.

Empirical evidence suggests preprints enhance citation rates. A study of arXiv papers found significant citation advantages for articles with preprints, with effects varying by field [1]. The analysis covered high energy physics, mathematics, astrophysics, quantitative biology, and library and information science, finding that articles with previous arXiv preprints received citations faster and accumulated more citations in most fields except biology. Another study reported that preprint release was associated with a 39% higher rate of citations [16]. However, the causal mechanism remains complex. Analysis comparing preprint and post-publication citations found that high-impact journals both select highly citable articles and augment their citation rates through publication [14]. The journal citation multiplier exceeded 1 for almost all journals studied, with Nature showing a multiplier of approximately 5. This suggests preprints provide citation benefits both through earlier visibility and through selection effects where highly cited work is more likely to be posted as preprints.

Preprints facilitate community feedback and iterative improvement. Unlike traditional publication, where peer review occurs behind closed doors with limited reviewer input, preprints enable open commentary from the broader scientific community. Many preprint servers allow updates and versioning, creating a record of how manuscripts evolve in response to feedback [16]. This transparency can improve research quality while maintaining a complete record of changes. The ability to incorporate community feedback before formal submission may enhance the final published version, though empirical evidence on this mechanism remains limited.

Open access constitutes a fundamental advantage of preprints. Most preprint servers provide unrestricted access to deposited manuscripts, removing paywalls that restrict access to published literature. This democratization of scientific knowledge benefits researchers at institutions without extensive journal subscriptions, scientists in developing countries, and the interested public [7]. The serials crisis, where journal subscription costs escalated beyond institutional budgets, created strong demand for open alternatives. Preprints emerged alongside other open access mechanisms (institutional repositories, open access journals, shadow libraries) as a path-breaking force in scientific publishing.

3 Quality Control and Peer Review Considerations

The relationship between preprints and research quality remains contested. Critics argue that bypassing peer review risks disseminating low-quality or erroneous research [11]. Proponents counter that preprints undergo screening and that empirical evidence shows minimal quality differences between preprints and published articles.

Most preprint servers implement some form of screening before posting. A systematic review of 44 biomedical and medical preprint servers found that 75% provided details about article screening, with 32% involving researchers with content expertise in the screening process [10]. Screening typically includes checks for scientific content, offensive material, and plagiarism, though standards vary considerably across platforms. The arXiv system employs automatic filtering combined with administrator review and sorting, creating a quality assurance mechanism distinct from traditional peer review [7]. However, this screening differs fundamentally from peer review in depth, rigor, and validation of scientific claims.

Empirical comparisons of preprint and published article quality provide nuanced findings. A study comparing independent samples of bioRxiv preprints and PubMed-indexed articles, plus paired comparisons of preprints and their published versions, found small quality differences favoring peer-reviewed articles [5]. Average quality of reporting was 5.0% higher for published articles in independent comparisons and 4.7% higher in paired comparisons. Larger differences appeared in subjective ratings of clarity in titles and abstracts and ease of locating reporting information. These results suggest peer review produces measurable but modest improvements in reporting quality. Importantly, quality of reporting in preprints fell within a similar range as peer-reviewed articles, supporting the view that preprints represent valid scientific contributions.

Researcher perceptions of preprint quality show interesting patterns. A survey of life scientists who posted COVID-19 preprints found divided opinions on whether preprints improve research quality, with only one-quarter to one-third agreeing and similar proportions disagreeing [4]. Researchers with longer preprint experience expressed fewer concerns about quality assurance, suggesting familiarity reduces quality anxieties. Global North researchers worried more about quality than Global South researchers, indicating cultural or contextual factors in quality perceptions. Despite concerns, other studies found little empirical evidence that preprints are systematically lower quality than published articles [4].

The medical community has expressed particular concern about preprints. A joint editorial from major orthopedic journals argued that medical preprint servers pose serious health and safety dangers [11]. Their concerns included: (1) public inability to distinguish unreviewed preprints from peer-reviewed articles, (2) potential use by unscrupulous investigators to disseminate work unlikely to withstand scrutiny, (3) media reporting of low-quality research harming patient care, (4) possible bias of formal reviewers by public comments on preprints, and (5) journal policies that might exclude previously posted work. These concerns reflect medicine's emphasis on patient safety and the consequences of acting on unreliable information.

However, the absence of pre-publication peer review does not mean preprints lack quality control mechanisms. Approximately 70% of surveyed researchers noted that preprints undergo community quality control, with over 50% referencing internal peer review processes [4]. Some platforms, particularly those following the F1000 Research model, conduct post-publication open peer review. Research Square, bioRxiv, and medRxiv specifically check for potential harm before posting. Research Square provides transparent checklists indicating quality assurance status for each preprint [10]. These mechanisms represent alternatives to traditional peer review rather than its absence.

The quality debate ultimately reflects different perspectives on acceptable risk-benefit tradeoffs. Traditional peer review provides quality assurance but delays dissemination and operates opaquely. Preprints offer speed and transparency but with lighter screening. The empirical evidence suggests quality differences are modest, and quality concerns may reflect perception more than validated findings [4]. As one analysis noted, concerns about preprint quality control may represent an opportunity to address longstanding issues in traditional peer review rather than a forced compromise [13].

4 The COVID-19 Pandemic as a Catalyst

The COVID-19 pandemic fundamentally altered scientific communication practices and revealed preprint servers as essential infrastructure for rapid research dissemination. The scientific community responded to the pandemic with unprecedented speed, releasing over 16,000 COVID-19 articles within four months of the first confirmed case, with 6,753 hosted on preprint servers [8]. Within ten months, over 125,000 COVID-19 related articles appeared, including more than 30,000 preprints on bioRxiv and medRxiv alone [9]. This surge represented a paradigm shift in how biomedical research is communicated during public health emergencies.

Analysis of COVID-19 preprints revealed distinct characteristics compared to non-COVID-19 preprints. COVID-19 preprints were accessed more, cited more, and shared more extensively across online platforms [9]. They received greater engagement from both scientific and public audiences. COVID-19 preprints were also shorter and reviewed faster than typical preprints, suggesting adaptations in both author behavior and editorial processing to accommodate urgent information needs. These patterns indicate that the pandemic created conditions favoring rapid, informal dissemination over traditional publication timelines.

The pandemic made preprints visible to broader audiences beyond academic researchers. Journalists and policymakers increasingly relied on preprints to track emerging scientific understanding of SARS-CoV-2 transmission, treatment, and prevention. This visibility highlighted both opportunities and risks. Preprints enabled rapid information sharing that informed public health responses, but also created potential for misinformation when preliminary findings received media attention before validation through peer review [3]. The tension between speed and rigor became acute when decisions affecting millions of people depended on the latest available evidence, regardless of peer review status.

Researcher experiences during the pandemic provide insights into motivations and concerns about preprint posting. A survey of scientists who posted COVID-19 preprints examined whether increased usage represented a temporary phenomenon or a lasting cultural shift [4]. The majority of surveyed researchers expressed willingness to continue posting preprints. However, analysis of preprint server data showed stagnation or decline in preprint numbers after the initial pandemic surge, particularly for life sciences servers. This contradiction between stated intentions and observed behavior suggests that disciplinary norms and practices influence preprint adoption more strongly than external shocks like pandemics.

The pandemic revealed important limitations of preprint infrastructure and culture. While some COVID-19 preprints garnered substantial citations, this success did not translate into routine preprint posting becoming standard practice [4]. The sustainability of preprint publishing practices appeared more dependent on established disciplinary cultures than on demonstrated utility during crises. This finding suggests that expanding preprint adoption requires addressing cultural and institutional barriers rather than simply demonstrating benefits.

The COVID-19 experience also highlighted the need for improved science communication around preprints. Media outlets struggled to appropriately contextualize preprint findings, sometimes presenting preliminary results with certainty inappropriate for unreviewed work. This challenge reflects broader issues in science journalism but became particularly salient when preprints constituted a large fraction of available COVID-19 research. Some have called for clearer labeling and communication strategies to help non-specialist audiences understand the status and limitations of preprint findings.

5 Disciplinary Differences and Cultural Adoption

Preprint adoption varies dramatically across scientific disciplines, reflecting different epistemic cultures, publishing practices, and attitudes toward risk. Physics and mathematics embraced preprints decades ago, while biomedical sciences remained skeptical until recently, and clinical medicine continues to resist in some quarters.

Physics and related fields established preprint culture through arXiv beginning in the early 1990s [7]. In high energy physics, posting to arXiv became normative, with preprints serving as the primary means of initial dissemination. Journal publication remained important for formal certification but often occurred after the research community had already engaged with the preprint. This cultural

norm developed because physicists valued rapid communication, operated within relatively small communities with shared standards, and faced limited risks from premature dissemination of physics results. Studies of arXiv showed substantial benefits, with significant citation advantages in fields like high energy physics, mathematics, and astrophysics [1].

The expansion to biological sciences proceeded slowly despite bioRxiv's launch in 2013. A study of arXiv's quantitative biology section found that preprint submission had become more common but remained a small fraction of total research output in biology [2]. The citation advantage found in other fields appeared only for specific journals like the Journal of Theoretical Biology. This slower adoption reflected cultural differences, including greater emphasis on journal prestige in career advancement, concerns about being "scooped" if methods or data were shared before publication, and worries about disseminating unreliable findings that could misdirect research efforts.

Clinical medicine has shown particular resistance to preprints. The joint editorial from major orthopedic journals explicitly stated they would not accept manuscripts previously posted to preprint servers [11]. Their reasoning emphasized patient safety: medical research directly informs clinical practice, and disseminating unvalidated findings could harm patients if clinicians act on preliminary results. This stance reflects medicine's risk-averse culture and the direct consequences of research errors. Other medical journals adopted more permissive policies, with some (like The Lancet and BMJ) explicitly supporting preprints, while others (like JAMA) remained cautious.

These disciplinary differences relate to fundamental characteristics of scientific fields. Physics and mathematics deal primarily with theoretical constructs and experimental results with limited immediate real-world consequences. Errors are concerning but rarely dangerous. Biomedical research has direct implications for health interventions, creating higher stakes for reliability. The pace of research also differs: physics results may remain relevant for years or decades, while biomedical research rapidly accumulates, making early dissemination more time-sensitive. Social structures matter too. Physics has relatively small, cohesive communities where reputation-based quality control functions effectively, while biomedical research spans diverse subfields with less shared context.

Journal policies significantly influence preprint adoption. Authors must consider whether posting a preprint will disqualify their manuscript from their target journal. The historical Ingelfinger rule, adopted by many prestigious journals, prohibited publication of work previously disseminated elsewhere [11]. As some journals relaxed this restriction while others maintained it, authors faced strategic decisions about whether preprint benefits outweighed potential publication venue limitations. The gradual shift toward preprint-permissive policies by major journals reduced this barrier but heterogeneous policies continue to create uncertainty.

Institutional and funder policies also shape adoption. Some funding agencies explicitly support or encourage preprint posting as part of open science mandates. Universities increasingly recognize preprints in promotion and tenure decisions, though practices vary widely. The statement that "many funders and universities also have policies that forbid the consideration of preprints in their assessment processes" [3] highlights ongoing institutional barriers to preprint recognition as legitimate scholarly output.

Geographic differences appear in preprint adoption patterns. Research from the Global South showed different quality concerns than Global North researchers [4], suggesting cultural or resource-related factors influence attitudes. Open access aspects of preprints may have particular value for researchers at institutions without extensive journal subscriptions, creating stronger incentives for adoption in resource-limited settings.

6 Future Perspectives and Integration

The role of preprint servers in scientific communication continues to evolve as the ecosystem adapts to their presence. Several developments will shape their future integration into scholarly publishing and research evaluation.

Integration with traditional publishing has moved beyond simple coexistence toward more complex relationships. Some journals now actively collaborate with preprint servers, offering streamlined submission processes where authors can transfer manuscripts directly from preprint servers to journals. Overlay journals publish peer review reports on preprints without creating separate publication venues, leveraging preprints as the version of record [4]. This model separates dissemination (via preprints)

from certification (via peer review reports), potentially reducing publishing costs and delays. However, the same analysis noted concerns about journals offering to publish preprints without peer review in exchange for article processing charges, potentially exploiting authors while undermining quality control.

Sustainability and business models remain open questions. Early preprint servers operated through institutional support or community funding, but the proliferation of servers has created diverse ownership structures. Some servers are owned by nonprofit academic groups, scientific societies, or funding organizations, while others are owned or partly owned by for-profit publishers or companies [10]. The long-term viability of different models remains uncertain. Nonprofit servers must secure ongoing funding without reliance on subscription or publication fees, while commercial servers must balance profitability with community needs. The failure of PeerJ Preprints, which ceased accepting new submissions in 2019, demonstrates that proliferation does not guarantee sustainability [10].

Preprints play an increasingly important role in open science and reproducibility initiatives. By enabling early data sharing and method dissemination, preprints can facilitate replication attempts and meta-analyses before formal publication [12]. Preprints broaden who can review research, when review occurs, and how feedback is provided, potentially improving research quality through diverse community input. Evidence suggests that data availability statements and preprint sharing correlate with better data sharing practices [6], indicating that preprint culture aligns with broader transparency and reproducibility goals.

Research evaluation systems must adapt to incorporate preprints appropriately. Traditional metrics like journal impact factors cannot be applied to preprints, requiring alternative approaches to assessing research quality and impact. The temptation to use preprint citation counts as proxy measures for quality poses risks, as citation patterns differ systematically between preprints and published articles [14]. Evaluation systems should recognize preprints as evidence of productivity and dissemination while maintaining careful assessment of research quality through peer review and expert judgment. The statement that preprints should be considered valid scientific contributions [5] reflects growing acceptance, but institutional policies lag behind this recognition.

Policy implications extend to multiple stakeholders. Funders must decide whether to require or encourage preprint posting as part of grant terms, balancing rapid dissemination benefits against potential quality concerns. Journals must establish clear policies on preprint acceptance, ideally converging toward common standards to reduce author uncertainty. Professional societies and disciplinary organizations can shape norms through position statements and member guidance. Universities need policies that appropriately weight preprints in hiring, promotion, and tenure decisions without incentivizing hasty posting of immature work.

The relationship between preprints and the broader open access movement will influence future development. Preprints emerged partly from the serials crisis and desire for open alternatives to expensive journal subscriptions [7]. They represent one component of a structural transformation of the scientific public sphere, alongside institutional repositories, open access journals, and data sharing mandates. The analysis concluded that open access publishing can transform scientific communication toward public sphere ideals only when complemented by systematic support for nonprofit publication infrastructures. This perspective suggests preprints alone cannot solve problems in scientific publishing without broader systemic changes.

Technological developments may enable new preprint functions. Post-publication peer review platforms linked to preprints could provide transparent, iterative quality assessment. Citation tracking and altmetrics can measure preprint impact and usage patterns. Integration with research data repositories and code sharing platforms can make preprints nodes in a broader open research infrastructure. However, realizing this potential requires coordination across platforms, standards for metadata and interoperability, and sustainable technical infrastructure.

The challenge of science communication to non-specialist audiences requires ongoing attention. Media reporting of preprints during COVID-19 demonstrated both the public interest in accessing latest research and the difficulty of appropriately contextualizing preliminary findings [3]. Developing norms and tools to help journalists, policymakers, and the public understand preprint status and limitations could mitigate misinformation risks while preserving rapid dissemination benefits.

7 Conclusion

Preprint servers have transformed scientific communication by decoupling dissemination from certification, enabling rapid sharing of research findings before formal peer review. Evidence from multiple disciplines and contexts demonstrates measurable benefits: faster dissemination, citation advantages, priority establishment, community feedback opportunities, and open access to scientific knowledge. The COVID-19 pandemic revealed preprints as essential infrastructure for rapid information sharing during public health emergencies, while also highlighting challenges in quality control and science communication.

Concerns about research quality appear less severe than critics initially feared. Empirical comparisons show modest differences between preprint and published article quality, with preprints falling within the range of peer-reviewed work. Screening processes, community feedback, and post-publication review provide quality control mechanisms distinct from but complementary to traditional peer review. The evidence suggests that preprints represent valid scientific contributions deserving recognition in research evaluation.

Disciplinary differences in adoption reflect varying epistemic cultures, risk tolerances, and publishing practices. Physics and mathematics embraced preprints decades ago, while biomedical sciences adopted them more slowly, and clinical medicine remains divided. These differences relate to fundamental field characteristics, including the consequences of disseminating unreliable findings and the social structures enabling reputation-based quality control.

The integration of preprints into the scholarly ecosystem continues to evolve. Relationships with traditional journals range from competition to collaboration, with emerging models like overlay journals offering new approaches to peer review and publication. Sustainability remains uncertain as diverse ownership structures and business models compete. Preprints increasingly function as infrastructure for open science and reproducibility efforts, though research evaluation systems lag in appropriately recognizing preprint contributions.

The structural transformation of the scientific public sphere enabled by preprints has implications beyond individual researcher benefits. Democratizing access to scientific knowledge, accelerating discovery, and increasing transparency serve broader societal interests in research efficiency and public engagement with science. However, realizing this potential requires systematic support for nonprofit preprint infrastructure, convergence toward common policies and standards, improved science communication practices, and cultural shifts in how research quality and impact are assessed.

The role of preprint servers in the scientific process is not to replace traditional publishing but to complement it, providing rapid dissemination while peer review provides certification. This division of labor can serve science and society by accelerating discovery without sacrificing quality standards. The evidence accumulated over three decades of arXiv and one decade of bioRxiv suggests preprints have earned their place in the scientific communication landscape. The challenge ahead is to refine practices, address legitimate concerns, and ensure that preprint infrastructure serves the public interest in advancing knowledge.

Author Biography

Rachel So is an AI scientist. She focuses on the impact of artificial intelligence on the scientific process and academic publishing. Her work bridges traditional concerns about authorship ethics with emerging questions about the role of AI in knowledge production. Rachel aims to develop frameworks that maintain research integrity while acknowledging the growing presence of AI in academic workflows.

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