

MATHEMATICIANS' VIEWS ON CURRENT PUBLISHING ISSUES: A SURVEY OF RESEARCHERS

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ABSTRACT

This article reports research mathematicians' attitudes about and activity in specific scholarly communication areas, as captured in a 2010 survey of more than 600 randomly-selected mathematicians worldwide. Key findings include:

- Most mathematicians have papers in the arXiv, but posting to their own webpages remains more common;
- A third of mathematicians have published papers in Open Access journals, with speed of publication being seen as the primary advantage over traditional journals, but there is substantial philosophical opposition to OA journal models that charge author fees;
- Tenure and promotion criteria influence publishing decisions even among most tenured faculty members;
- Mathematicians want to keep more rights to their publications than they've been allowed, but they have a high success rate in negotiating with publishers for more;
- Online collaboration tools, such as Google Groups, are not yet widely used for research but their use is expected to rise in the near future.

Reasons behind the mathematics culture of openness were also explored.

INTRODUCTION

The scholarly communication landscape has been changing rapidly, driven by technology-enabled opportunities and by re-evaluation of the interrelationship between traditional publishing processes and the research community. Different sub-communities have responded differently, both in the nature and in the level of responses, as influenced by subject-based and other cultural factors. For many mathematicians, as for high-energy physicists, sharing research results via an e-print repository may be considered mainstream; some new math journals use innovative models of production, support, delivery and access; grant agencies like the US National Science Foundation may follow the lead of the National Institutes of Health in requiring that research funded by them be made publicly accessible; in some high-profile cases like the Polymath blog, Web 2.0 tools are changing how research is being done. The current study aims to investigate the extent of mathematics researchers' participation in these activities and debates, as well as the aspects of mathematics culture that contribute to them and possible implications for the future of mathematics scholarly communication and publishing.

BACKGROUND

Previous studies have indicated that researchers are interested in scholarly communication issues, with attitudes and acceptance of new models and ways of working varying among populations in different fields, academic settings, and countries^{1, 2, 3, 4, 5, 6}. In general, traditional publishing practices continue to be reinforced both by institutionalized structures such as tenure and promotion criteria¹ and by "a fundamentally conservative set of faculty attitudes"⁷. New dissemination practices appear to flourish primarily for in-progress or preliminary communication, rather than for final, formal publication^{8, 9}.

Posting a paper to an individual's web page has been shown to be nearly twice as common as any other method for sharing research informally^{10, 11}. Discipline-based open archives are fairly popular: the proportion of mathematicians depositing research papers in a subject repository has been variously gauged at 38%¹² and 20%⁷, higher than the average for all subjects. Such online self-archiving, officially recommended by the International Mathematical Union¹³, follows the important pre-Internet tradition of sharing mathematics preprints. In pure mathematics, more researchers consider preprints the most essential resource (44%) than journal articles (approximately 33%); this was the highest preprint rating in any discipline, followed by statistics and operational research at 25%⁵. Besides the preprints and published articles usually deposited, a 2009 survey found that 14% of mathematics/statistics faculty members had deposited raw materials such as images or field notes in a repository, and 10% had deposited raw data sets¹⁰.

As with physical scientists and engineers in general⁵, mathematicians are less likely to deposit in an institutional repository than a subject one, by a factor of about two^{12, 7}. Depositing authors usually don't spend the time to contribute to both types of repository^{14, 15}. Lack of time is the top reason given by physical scientists for not depositing their work in a repository, followed by not regarding it as an important dissemination venue⁵. Other barriers include concerns about copyright, publishers' attitudes, the quality of the archive, inadvertent changes to the work, and the deposit procedure^{11, 16, 17, 5}. One study also found that age had an inverse effect on deposit activity¹⁶. Positive motivations for sharing via repositories include altruism, a self-archiving or preprint culture within the discipline, and indirect academic rewards (e.g., through increased visibility)^{4, 16}.

Open Access journals provide a formal publishing path for sharing research broadly, and there are more than 200 OA journals in mathematics and statistics¹⁸. Not surprisingly, the main motivation for authors who have published their work in OA journals is the underlying principle of free reader access^{19, 12}. However, that factor has low importance to most faculty members, including those in mathematics, when choosing a journal for publication^{7, 1}. Discussion within the mathematics community has indeed largely centered on containing or reducing, rather than eliminating, journal prices^{20, 21, 22}. For mathematicians who have published in OA journals, additional important reasons are perceptions of faster publication, larger audiences, high prestige, higher citation rates, and editorial board quality¹², similar to those for other fields^{19, 23, 12}. Authors may unknowingly over-report their OA publishing, since further investigation has shown that researchers often conflate OA journals with online journals generally⁶.

Authors who have not published in OA journals primarily cite lack of familiarity with any in their field and inability to identify a suitable one, including 24% and 22% of mathematicians, respectively. Those proportions may decline, as a recent meta-analysis shows that awareness of and publishing in OA journals have increased over time²⁴. Additional reservations given by mathematicians were low journal prestige, lack of funds for author charges, and objection in principle to author charges¹². Not all OA journals charge author fees, as recognized by nearly three quarters of researchers²³. Other common objections to OA journals are perceived lack of peer review and inadequate archiving^{8, 23, 24}.

A journal's reputation or prestige, which is cited on both sides of the OA debate, is very important in author motivations overall¹. Other journal characteristics strongly influencing authors' publishing decisions include wide readership by scholars in the field, speed of publication, availability in both print

and electronic versions, proper management of online content, lack of author charges, and ability to post some version of the paper on a web page^{9,1,7}. Tenure and promotion practices are also quite significant¹, such that nearly 30% of mathematics and statistics faculty members “strongly agree that tenure and promotion practices ‘unnecessarily constrain’ their publishing choices”⁷.

Beyond the ability to post their papers on a web page, there is little evidence authors are interested in their intellectual property rights. Between a quarter and a third of authors don’t know their employing institution’s policy on copyright in their papers^{5,9}, and those that have copyright are likely to relinquish it at the point of publication, with greater or lesser degrees of concern^{1,9}. For authors who don’t accept a publisher’s standard copyright assignment form, the most common alternatives are signing an exclusive license agreement (which may be equally restrictive), amending the standard form, and attaching an addendum^{9,1}.

Mathematicians have been quicker to exploit developing technologies for sharing research results than for conducting research collaborations. A majority attach greater value to traditional peer interaction formats, such as conferences, than to online interactions via listservs, wikis or blogs, compared with 10% who definitely value online interactions more; these proportions are similar to those for faculty members overall^{7,10}. At least in some fields, email and telephone have been shown to be the most common communication mechanisms used for research².

METHODS

The present survey was administered online in December 2010, with invitations sent to 3,045 unique authors of mathematics research articles and proceedings papers since 2001. These were randomly selected from a sample frame drawn from Web of Science's Science Citation Index Expanded. Best efforts were made to obtain an appropriate sample frame, through keyword searches using top-level vocabulary from the Mathematics Subject Classification²⁵ and limiting to the WoS subject areas “Mathematics,” “Mathematics, Applied,” or “Statistics & Probability.” Nevertheless, potential sample bias includes the choice of search keywords, Web of Science’s selective coverage of journals, limitation to corresponding authors who provided email addresses that still work (in some cases, several years later), and delivery of the survey in English only. As with any online survey, the results reflect the views only of those with internet access.

Survey responses were received from 627 authors, with one reminder having followed the initial invitation; this is a 21% response rate compared to the number of invitations sent, with the effective response rate somewhat higher, since an unknown number of email addresses would not have been currently-used ones. This compares favorably with response rates for other surveys on this topic¹). The survey was delivered via the University of Minnesota’s instance of the open-source LimeSurvey, using the Token setting so that only those invited could respond, once only. The responses were exported to a spreadsheet for further statistical analysis and for thematic grouping of open-ended responses. Forty-three responses were excluded, since they responded only to the demographic and none of the substantive questions. Of the 584 usable responses, some participants chose to skip some questions, some questions only appeared in response to specific previous answers, and participants could choose multiple answers for several questions. For these reasons, the results often have a total number of responses different from 584 and will therefore be reported, unless otherwise specified, as percentages of those answering the particular question or in ranked order. As a very rough gauge of accuracy, the

maximum margin of error for questions answered by 500-600 people is approximately $\pm 4\%$, at the 95% confidence level.

The survey invitation, questions, and full results are available at www

RESULTS AND DISCUSSION

Demographics of respondents

The survey responses included a wide range for each demographic factor: researchers in various mathematics areas, of various ages and employment situations, from all geographic regions of the world (see Tables 1a-e). Therefore it is hoped that the results may be considered roughly representative. The predominance of tenured faculty members may be due to the long duration of that career stage, and more specifically to the stability of a tenured professor's email address over the decade represented in the sample frame. Since nearly 10% of respondents identified their research area as mathematical statistics, references in the following discussion to "mathematicians" may be understood to include statisticians as well.

Table 1a. In which region do you primarily live?		
	Number of individuals	Percentage of survey respondents
Africa	10	2%
China	58	10%
Japan	8	1%
Asia (except China and Japan)	44	8%
Australia/New Zealand	10	2%
UK	30	5%
European Union (except UK)	198	34%
Other European countries (except EU or UK)	33	6%
Middle East	28	5%
Canada	22	4%
USA	120	21%
Mexico or Central/South America	17	3%
no answer	6	1%

Table 1b. What is your age?		
	Number of individuals	Percentage of survey respondents
26-35	99	17%
36-45	183	31%
46-55	146	25%
56-65	106	18%
66-75	38	7%
76 or over	6	1%
no answer	6	1%

Table 1c. What is your current position?		
	Number of individuals	Percentage of survey respondents
Undergraduate student	1	<1%
Graduate student	6	1%
Temporary faculty member	35	6%
Tenure-track faculty member	59	10%
Tenured faculty member	406	70%
Other college/university position	13	2%
Researcher working in government	26	5%
Researcher working in industry	7	1%
Retired	24	4%
Other/no answer	7	1%

Table 1d. How many research papers of which you are author or co-author have been published in peer-reviewed journals since 2001?		
	Number of individuals	Percentage of survey respondents
1-5	45	8%
6-15	190	33%
16-25	138	24%
26-35	86	15%
36-45	49	8%
more than 45	76	13%

Table 1e. In which area of mathematics does your research primarily lie?		
	Number of individuals	Percentage of survey respondents
General	6	1%
Mathematical Logic and Foundations	10	2%
Combinatorics	48	8%
Abstract Algebra	50	9%
Number Theory	13	2%
Real and Complex Analysis	44	8%
Ordinary and Partial Differential Equations	79	14%
Geometry	46	8%
Topology	24	4%
Probability Theory and Stochastic Processes	49	8%
Mathematical Statistics	53	9%
Numerical Analysis	56	10%
Theoretical Computer Science	16	3%
Mechanics	10	2%
Mathematical Physics	27	5%
Operations Research and Mathematical Programming	20	3%
Game Theory, Economics, Social & Behavioral Sciences	3	<1%

Mathematical Biology	17	3%
Systems Theory	11	2%
Information and Communication Theory	2	<1%

Research Collaboration Tools and Methods

E-mail and face-to-face meetings are by far the most popular communication mechanisms for research collaborations, used usually/always by 92% and 70% of respondents, respectively. Use of telephone/internet phone is the most variable, with roughly a third using it usually/always and a third using it rarely/never. None of the other collaboration methods given, ranging from posted letters to wikis, are frequently used by more than a few; in fact, 75-85% use them rarely or never (see Table 2). The proportion specifying online collaboration tools they've used is therefore not large (125 respondents), but nevertheless users of the most popular methods totaled 9-10% of the overall survey population. These top tools were Google Groups/Yahoo! Groups and some sort of file-sharing mechanism, when combining the specific choice mentioning NetFiles, Dropbox, and Syncplicity with similar write-in entries such as Subversion (see Table 3). These methods may soon become more common, since a third of the survey respondents expect their use of online collaboration tools to increase in the next year, while almost none expect it to decrease.

	Usually or Always	Sometimes	Rarely or Never
E-mail	89%		
Face-to-face meetings	68%		
Telephone/internet phone/Skype	35%	31%	29%
Instant messaging/chat			68%
Letter sent by mail/post			74%
Online communication or collaboration tools, such as a wiki or blog, Facebook, or Google Docs			76%
Virtual meeting/video conference			77%
Fax			77%

	Number of individuals	Percentage of survey respondents
a file-sharing space, such as NetFiles, Dropbox, Syncplicity [& Subversion]	60	10%
Google Groups or Yahoo! Groups	54	9%
a collaborative writing website, such as Google Docs, Zoho, ScribTeX	32	6%
a wiki, such as PBwiki/Pbworks	15	3%
a citation-sharing tool, such as del.icio.us, RefWorks, Zotero	11	2%
a course management system, such as moodle, Blackboard, WebCT	10	2%
a blog, such as The Polymath blog	7	1%
LinkedIn or Facebook	6	1%
Twitter	2	<1%
Total	125 [†]	21% [†]

[†] (respondents could choose more than one answer)

Publishing Decisions

When selecting a publication venue for a research paper, the factors most important to authors are a journal's quality and reputation, inclusion in literature indexes, and lack of author fees; these are “very important” to more than half the respondents. The other relevant factors, with combined ratings for very/moderately/somewhat important, are shown in decreasing order of importance in Table 4. Coverage in literature indexes ranked unexpectedly high, but the other most important factors—publication speed, a large number of readers, long-term availability, lack of author fees, specialized journal scope and readership—match well with those identified in previous studies^{9,1,7}; over 80% of mathematicians find them at least somewhat important. Notably, the costs to readers/libraries are less important than author fees. “Tenure and/or promotion criteria” are ranked 13th out of 14 factors, but this still means well over half of mathematicians generally, as for tenured faculty members specifically, find them at least somewhat important in their publishing decisions (see Table 5). Most respondents (57%) also find it at least somewhat important that a journal has both print and online versions. One-half find the online more important, while one-tenth find the print version more important, the latter proportion consistently increasing with increasing age. Many respondents wrote in other factors that are important for submission, half of which (134 of 268) concerned the editing/reviewing process. The journal’s Impact Factor, as calculated by ISI, was mentioned 22 times.

	Very+Moderately+Somewhat Important
The journal's quality and reputation*	99%
Speed of publication	93%
Inclusion in literature indexes, like MathSciNet or Web of Science*	91%
Large number of readers	91%
No page charges or other author fees*	87%
Specialized journal scope and readership	86%
Assurance of long-term availability	85%
An online version of the journal	78%
The publisher or scholarly society associated with the journal	78%
Low or no access costs to readers worldwide	74%
Low subscription costs to libraries	70%
The journal's policies on author rights	66%
Tenure and/or promotion criteria	59%
A print version of the journal	58%

*"Very important" to more than half of respondents

	Very important	Moderately important	Somewhat important	Not at all important
Tenure-track faculty members	20%	29%	29%	19%
Tenured faculty members	12%	24%	23%	28%

Intellectual Property

About two-thirds of respondents report that the author/researcher, rather than their employing institution, has the copyright in their papers (see Table 6). Notably, one-fifth are unsure of their institution's policy; even if this average is somewhat lower than the levels found in previous studies^{9,5}, uncertainty among the US and UK groups is not (32% and 39%, respectively).

Table 6. At your employing institution/agency/company, who owns the copyright in your research papers prior to publication?	
The employer owns the copyright	6%
You as the researcher/author own the copyright	69%
Not sure	20%
Not applicable	5%

Close to 90% of mathematicians find it at least somewhat important to retain the rights to email their papers, post an author-created version on their websites, use parts in their future works, and distribute copies to their students. (The survey questions intentionally did not distinguish between pre- and post-refereeing author-created versions.) Of the specific rights listed, the least popular is “copyright;” not only did 20% of respondents say it's not at all important to retain, but many fewer give any rating for this factor (only 386 responses, compared with 455-482 responses for the other items in the same list). This may perhaps indicate some uncertainty about what copyright entails, but possibly the bullet item was just overlooked, as it was the first—and shortest—entry in the list. Several open-ended comments indicate that some mathematicians don't know or don't care about author rights issues: “I don't usually think much about this aspect of publishing” and “I have to say that I generally just ignore any associated author rights and do what I like with my paper.” A few remarks recognize the role preprints play in disseminating research results, outside the legal bounds of formal publishing; implicit in this is that prior distribution of a preprint isn't a deal-breaker for mathematics publishers, as it can be for those in medicine or other fields.

The subsequent question was designed to allow comparison of actual rights retained with those deemed important (see Table 7). About half the respondents are unsure whether they have the specified rights or not. The right most commonly recognized as held is posting an author-created version on one's own website, cited by 45%; this has also been judged one of the most important. The “copyright” item again has the fewest responses, but the highest awareness of not having it; that only 17% report retaining copyright indicates a gap with authors' desires, since 59% of respondents felt it was at least somewhat important to retain copyright. There are also notable gaps surrounding the right to post the publisher's version of a paper on their website, which 22% of respondents think they can do, compared with 83% who think it's important and with 10% of publishers who allow it²⁶.

	Very+Moderately+Somewhat Important	Perceived Held by Author	Publishers permit**
Email copies to others	90%	41%	??
Re-use part or all in future papers/books	87%	34%	84%
Post an author-created version on website	89%	45%	60 [†] -80%
Distribute photocopies to students	86%	41%	96%
Others at university use copies in teaching	81%	35%	96%
Deposit an author-created version in the arXiv or other online repository	82%	40%	45-65%
Post the publisher's version on own website	83%	22%	10%
Copyright	59%	17%	19% [†]

**Except as noted, publisher data from ²⁶
[†]From ²⁷

Despite such mismatches, only 16% of mathematics authors (91 respondents) report having tried to improve the terms of publication, whereas most have signed a publisher-provided author agreement, either before (27%) or after (59%) reading it (participants could report more than one action). Among those who have negotiated with publishers to retain more author rights, 92% report they are usually or always successful. Successful negotiation is spread across the various demographic groups and not limited to long-established researchers; in fact, 26-35-year-olds appear somewhat more likely to have acted to retain more rights, with no less success. The most common approaches specified are attaching an addendum to or amending the terms of the contract.

Publishing in Open Access Journals

A full third of mathematicians report they have published at least one article in an OA journal (see Table 8), and almost all of these give at least one specific example. The most popular OA journal mentioned (16 times) is the *Electronic Journal of Combinatorics*. It should be noted that only 179 of the 244 verifiable titles given (including duplicates) are in fact OA journals. Thus 27% of the cases in which an author thinks s/he has published in an OA journal actually involve a traditional subscription-supported journal, presumably because they themselves have easy online access to it. This is much better than the 65% error level found in a 2005 study ⁶, but indicates that a gap in recognizing OA journals persists. Furthermore, a few respondents list the arXiv as an answer for this question (which occurred before the questions specifically about OA repositories), so some mathematicians may not make a firm distinction between online journals and preprints. Subtracting the 34 individuals who listed only the arXiv or non-OA titles, the adjusted OA participation rate drops to 27%.

	Number of individuals	Percentage of survey respondents
No	259	44%
Not Sure	109	19%
Yes	193	33%

The most striking demographic variation was by subject. Looking only at subject categories with more than 40 respondents, researchers in Combinatorics and Probability Theory & Stochastic Processes are the most likely to have published in OA journals (46-51%), whereas those in Abstract Algebra, Numerical Analysis, and Geometry are the least likely (22-26%); those in Mathematical Statistics and Ordinary and Partial Differential Equations are very close to the overall average.

The top five reasons for publishing in an OA journal are the same as for journals in general, which may indicate that OA journals are mature enough to compete on an even basis (see Table 9). The lack of author fees becomes relatively more important (rising from #5 to #3), and indeed mathematicians preferentially choose OA journals that don't have them: 71% of the verified OA examples given do not charge author fees. Of the factors specific to OA journals, there is little awareness of the possible OA citation advantage, although more respondents see greater visibility through web search engines. There are very few instances of institutions/grantors covering OA author fees, and even fewer of grant-awarding bodies requiring OA publication.

The OA journal's quality and reputation	76%
Speed of publication	58%
No page charges or other author fees	39%
Inclusion in literature indexes, like MathSciNet or Web of Science	38%
Large number of readers	35%
The publisher or scholarly society associated with the OA journal	33%
No costs to libraries or readers worldwide	33%
Assurance of long-term availability	27%
Greater visibility through web search engines	27%
Specialized journal scope and readership	26%
The OA journal's policies on author rights	20%
Tenure and/or promotion criteria	8%
Higher citation rate for OA journals compared with subscription-based journals	8%
Institution or grant-awarding body covered the author fees	4%
Requirements of grant-awarding body	3%

The motivations of those choosing not to publish in an OA journal emphasize quality/reputation, as in the other scenarios, but lack of awareness is a substantial issue: 40% of these respondents (and thus 27% of the whole survey sample) either have not previously heard of the OA journal model or are not aware of any OA journals in their field, or both (see Table 10). The objection to author fees appears to be based on principle rather than expediency: twice as many cite "unwillingness to pay" compared to "inability to pay" as an influencing factor, and some comments indicate that payment for publication brings the quality and integrity of the article/journal into question. The perception that OA journals aren't peer-reviewed adequately (or at all) ⁸ may be decreasing, cited by only 16%. Fear of easy plagiarism is one of the least-common factors; previous findings that it was a significant barrier might not have sufficiently distinguished online journals in general from OA ones ¹¹. Concern about the OA journal being available over the long term is higher than, and largely separate from, concern that it has no print version (only 19 respondents cited both).

The OA journal's quality and reputation	45%
Not aware of any OA journals in your field	31%
Unwillingness to pay requested author fees	28%
Satisfaction with traditional subscription-based journals, print or online	28%
Unsure if included in literature indexes, like MathSciNet or Web of Science	20%
Unsure of long-term availability	17%
Inadequate peer review procedures	16%
Had not previously heard of the OA journal model	15%
Inability to pay requested author fees	14%
Tenure and/or promotion criteria	12%
No print version of the OA journal	9%
Compared with subscription-based online journals, easier for others to plagiarize your work	4%
Availability to inappropriate readers	3%

Publishing in Hybrid Open Access Journals

Mathematicians across the board appear to be both less aware and less approving of hybrid compared with pure OA journals. Only 18% of those responding to the question indicate they have chosen to make an article Open Access within a hybrid OA journal (the actual level is likely lower, since the write-in reasons suggest that some respondents did not clearly understand the question). The top reasons given for choosing the OA option are “Increased number of readers” and “Greater visibility through web search engines,” followed by “Higher citation rate for OA papers compared with subscription-restricted papers” and “No access costs to readers worldwide.”

Of the respondents who have not taken the OA option in a hybrid OA journal or are not sure, the most common reason cited is never having been offered this option. As with pure OA journals, nearly twice as many respondents are unwilling rather than unable to pay the author fee (comments: “Unwillingness to pay requested authors fees is an understatement: I find this system scandalous.” “I do not trust people paying to be published”). This may partly explain the lower participation level for the (paid) OA option in hybrid journals, compared with that for pure OA journals, some of which have no author fees. Three respondents specifically mentioned that they prefer the pure OA journal model.

But a substantial number of respondents, when considering either OA or hybrid OA journals, indicate that they are satisfied with traditional subscription-based journals.

Reviewer Considerations

The important factors in decisions to serve as reviewers are broadly similarly to those from the author perspective, although the publisher or scholarly society associated with the journal becomes relatively more important (#2, compared with #9). Lack of author fees is less highly ranked (#10) but continues to matter to half the respondents, which provides further evidence that this is a consistent principle beyond personal self-interest; correspondingly, compensation for the reviewer/editor is ranked last, although it is at least somewhat important to 34%.

The arXiv and Other Sharing Mechanisms

In addition to formal publication, mathematicians follow the widespread practice of posting their papers on their websites; 47% do so always or usually, while only 19% never have. The arXiv is also a regular sharing mechanism for 30% of respondents; another 26% have deposited at least one paper in it, or had a co-author do so, and only 12% aren't aware of it (see Table 11). Thus over half of mathematicians have at least one paper in the arXiv; this result is higher than reported in previous studies of mathematicians^{12,7}, but is roughly consistent with actual numbers of math arXiv submissions when compared with the number of papers indexed in MathSciNet (in 2010, about 17,500 and 100,000, respectively)^{28,29}, given that the average author publishes five papers per decade³⁰. Most survey respondents expect to continue contributing to the arXiv or other online repositories at the same level they currently do, but some expect to increase (23% of those answering the question, 16% of overall respondents). The trend of the arXiv statistics also suggests a continued increase in math submissions²⁸. The main motivation for depositing in the arXiv is early dissemination of research findings (see Table 12). Over half of the depositors also cite making previously published work more available, making unpublished work available, and providing free access to readers worldwide as factors influencing their decision. Among several other popular reasons, 43% simply think it is standard practice for researchers in their field. On average, each contributor chose five factors influencing their decision to contribute to the arXiv, so its appeal is multifaceted.

Not aware	12%
Aware but never used	15%
Read papers by others	17%
Co-author has posted joint paper	9%
Posted own paper(s)	17%
Regularly post own papers	30%

Early dissemination of your research findings	76%
Better availability and visibility of your previously published work]	59%
Availability and visibility of your work not previously published	58%
No access costs to readers worldwide	58%
Responsibility to share research	48%
Reputation of the arXiv	47%
Assurance of long-term availability	45%
Greater visibility through web search engines	44%
Standard practice for researchers in your field	43%
Your professional reputation	35%
Higher citation rate for OA papers compared with subscription-restricted papers	10%
Requirements of grant-awarding body	3%
Tenure and/or promotion criteria	3%
Department/institution/employer requirement	2%

The most obvious demographic effect is decreasing participation with increasing age, in line with previous studies¹⁶. (This effect is not observed in the responses about OA journal publishing). There is considerable variation by subject, with researchers in Geometry and Abstract Algebra being more likely

than average to contribute regularly, and those in Numerical Analysis and Mathematical Statistics less likely. (The arXiv's actual submission data show a roughly similar distribution ²⁸.) Chinese mathematicians are less likely to contribute regularly: only 11% of 36 respondents, whereas 42% have read arXiv papers by others.

For mathematicians who are aware of the arXiv but haven't deposited papers in it, most simply haven't yet found a reason why they should contribute. Three of the top four factors cited are satisfaction with traditional journals, not seeing a sufficient advantage, and standard practice; moreover, nine respondents comment that they simply hadn't thought about it, and some didn't choose or write in any reason at all (see Table 13). Together, these account for 57% of the individuals in this category (after controlling for respondents who chose multiple answers within this thematic group). Others do have specific concerns, the most common (24%) being uncertainty about having the rights to deposit. The fear of being plagiarized is notably greater than among those avoiding OA journals: 13% versus 4%. The time required for the deposit process, as well as its difficulty, are barriers for some (12% and 10%, respectively), but not to the extent found in previous studies ⁵. The potential harm to future publication prospects was cited by 11%. No other factor was chosen by more than a few percent of respondents in this category, so mathematicians do not commonly share many of the concerns found in previous studies, such as the risk of inadvertent changes to their papers.

Satisfaction with traditional subscription-based journals, print or online	27%
Unsure if allowed by existing publication contracts	26%
Insufficient advantages	21%
Standard practice for researchers in your field	18%
Easier for others to plagiarize your work, compared with subscription-based online journals	14%
Time required by deposit process	14%
Potential harm to future publication prospects	12%
Difficulty of deposit process	11%
Your ability to retain copyright of your research paper	7%
Unsure of long-term availability	6%
Reputation of the arXiv	6%
Potential for unwanted changes to your work	5%
Availability to inappropriate readers	5%
Tenure and/or promotion criteria	4%
Your professional reputation	2%

In line with previous findings ¹⁴, most arXiv contributors do not also contribute to an institutional repository; only 15 respondents contribute regularly to both. Compared with the arXiv, institutional repositories are much less well known or used by this population. Over half of respondents don't know if their institution has one. The participation rate is much lower, with only 9% contributing regularly, and a top reason is that the institution requires it. (Institutional norms may account for participation among all European researchers being 3 or 4 times as high as that of US ones. Indeed, three-quarters of US researchers are unaware of a repository at their institution, considerably higher than that in almost all other regions.) Of equal importance is making previously published research available. IRs play less of a role in early dissemination of research results and in sharing of unpublished work. On average, IR contributors cited three motivating factors, so the advantages are apparently not as multifarious as for the arXiv. Few respondents have been influenced by the long-term archiving function and greater

visibility through web search engines, which some institutions emphasize when promoting their IRs. Among those who have chosen not to contribute to their institution’s repository, the most commonly-cited factors are largely similar to the arXiv case, with seeing insufficient advantages to doing so as the top reason.

Few mathematicians have deposited anything other than research papers in any of these repositories; software is the most common other format, cited by 21 depositors.

How Open is Mathematics?

As the scholarly communication behavior and motivations of the mathematicians surveyed here differ substantively from other surveyed populations, it is interesting to explore their perceptions of the overall mathematics culture concerning research dissemination. A quarter of respondents report that mathematicians are equally likely to share their research, compared with other scientists (see Table 14). Their most common explanation is that their field doesn’t differ from other science fields, while some respondents consider mathematics as an average between fields more likely to share (like physics) and fields less likely (like biology/medicine). Among the small minority of respondents who think mathematicians would be less likely to make their research openly accessible, there is not much agreement on why: a few cite conservative attitudes or say there’s no need for OA because others in the same specialized area usually have access anyway.

Table 14. In your opinion, how likely are mathematicians to make their research openly accessible, compared with researchers in other science fields?	
Less likely	9%
Equally likely	26%
More likely	65%

Nearly two-thirds of respondents giving an opinion feel that mathematicians would be more likely than others to make their research openly accessible. The most frequent reason given is the lower prospect for economic gain, compared with fields in which patents and immediate commercial applications are more common; this may be implicit in additional comments citing less competition/competitiveness. The low financial investment to do mathematics research is also cited several times; as one respondent puts it, there are “no large costs usually involved in research for a paper . . . hence no feeling that others are getting a free ride at your expense.” An interrelated explanation is that math focuses on ideas rather than data; the latter may not only have confidentiality restrictions but are also more likely to be viewed as property to be held.

Many respondents also describe mathematics as generally having an open culture, in which sharing is the norm: “my colleagues share easily new results;” “a lot of colleagues of my generation use the arXiv;” “more of a tradition to submit work to the community for direct peer comments before publishing than in empirical sciences.” Comments like this connote expectation as well as established infrastructure making it easy to share, which together suggest the notion of a critical mass having been reached (“Because we have already largely begun... for example in probability 3 of the 4 best journals are free through the Institute of Mathematical Statistics;” “most math journals allow self-archiving”). Another common reason given is that mathematicians want to disseminate their research widely, at least partly to gain professional recognition. Others explain that open exchange of information is vital to the process of mathematics research, which relies on collaboration (“Mathematicians find that open

access to the full text of their papers is essential to progress. Making a paper openly accessible is more likely to establish priority than to lead to plagiarism.”). Several comments recognize that open dissemination is a good thing in itself (one respondent mentions the importance of access by those in developing countries, and another that “mathematicians want their papers openly available because they are just nice people”), as well as having compelling advantages such as speed.

CONCLUSION

These survey results suggest that research mathematicians are selectively embracing new modes of communication and publishing, particularly as they contribute to improved quality and speed of dissemination, although still influenced by traditional frameworks such as institutional reward structures. Given the strong sense that mathematics benefits from a culture of sharing, there will likely be further uptake of open channels through which to conduct and communicate research, including online collaboration tools, the arXiv, and community-supported OA journals. Continuation of the author-pays OA journal model may rely on developing measures that “insulate peer review and editorial decision-making from monetary considerations”³¹. The disconnect between the author rights mathematicians want and those they have traditionally kept deserves to be better known. This could be addressed both by publishers continuing to adapt their standard publishing agreements in light of their authors’ expressed values, and by mathematicians becoming more aware of convenient and effective ways to retain the rights they find important.

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APPENDIX 1. Survey Questions [link; Include importable LimeSurvey format as well as browsable form]

APPENDIX 2. Complete Data [link]

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