The Research Divide: Internet Commons, Scholarly Participation and Pre-print Servers[*]

Version 1.1

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Abstract

In this paper, the notion that Internet-based resources can be viewed using the common-pool resource dilemma framework is questioned. Instead, the author proposes that some, if not most, internet-based resources seek to broaden participation as much as possible. The paper examines arXiv.org, a working paper repository for the physics community and related disciplines, to determine whether participation in an elite scientific community has been democratized by the presence of a freely accessible common resource. The data indicates that participation has not been democratized. In the discussion, the author examines some possible explanations for this.

Key words: Scholarly communication, Internet, Common Property, Participation, e-print, Preprints, Physics, Math, Democratization, Cyberculture

1. Introduction

Recent innovations in computer technology have generated discussion about the applicability of common pool resource (CPR) theories to new technologies (e.g., Andrews, 1995; Gupta et. al., 1995; Smith, n.d.). Most of these papers, however, have focused on that most obvious new commons, the Internet. While this macro-level issue is certainly interesting, little of the data we have regarding this large distributed system is very telling about the group dynamics of Internet users.

In order to better understand the CPR issues for online shared resources, this study looks at a mid-level issue: online participation in a scientific research forum, arXiv.org. The hypothesis for this study, based on what I will loosely call accepted knowledge about the Internet, is that the creation of this common resource for the physics research community and related areas broadened participation in scholarly discussions as measured by posting to the server.

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1.1 Common Pool Resource Theory

Application of CPR theories to internet-based resources may seem counterintuitive to many. Unlike common pool resources such as forests, streams or the air, 'overuse' of the Internet seems as if it should have relatively few consequences. Other views exist—Gupta et. al. (1995:1) have argued that "congestion on the Internet is a present and potentially paralyzing public bad" and that regulation is necessary to place user restrictions and fees on the service. The five years since that argument have proven it to be wrong—network capacity has increased along with usage at a rate that indicates that there is unlikely to be a debilitating overuse.

A 'tragedy of the commons' caused by over-fishing a common resource such as a lake has obvious consequences; if the lake is depopulated due to the actions of a few opportunists, nobody can get fish from the lake after it is dead. Short of massive distributed denial of service attacks or a worm sent out to bring the entire network to a halt, it is difficult to imagine the actions of any number of users creating any real damage to the Internet structure because of its distributed nature. Certainly, short term examples exist, such as the inability of Britannica online to serve the number of hits it received after opening its service for free access. This was corrected rather quickly, however.

For much of the common resources available electronically, the issue is not one of a tragedy of the commons at all. Instead, most web sites are interested in maximizing their use, whether to widely disseminate the information they have made available or to increase the number of eyes that see their banner advertising, thus increasing their revenues. It seems likely that the issues faced by Internet users may not be best understood as a CPR dilemma. Gardner and Ostrom (1990) argue that the first condition of the CPR dilemma is resource unit subtractability. If scientist A downloads a copy of an article on super-string theory from a working paper archive, there is nothing to prevent scientists B (or C, D, or E) from downloading the exact same paper. The resource is not subtractable.

As a result, I would not characterize on-line resource as CPR dilemmas. Gardner and Ostrom (1990) point out that it is a mistake to assume that all CPR situations are dilemmas that must have external solutions. Instead, some CPRs are non-problematic. An example is a lake with finite but large numbers of fish and few fishers whose activities do not deplete the population. Lacking what Ostrom calls suboptimal outcomes, the CPR does not qualify as problematic. I propose that arXiv.org, the topic of this paper, is one of these non-problematic CPRs.

Just because Internet-based resources may not exhibit the characteristics of a CPR dilemma does not mean that they are entirely problem-free. Issues of free-ridership, for instance, may be possible to apply. I would like to argue that the converse of the classical CPR dilemma arises for cyber-resources. Rather than trying to limit participation in a CPR, these cyber-resources seek to increase participation. ArXiv.org, for instance, is often put forward as a democratizing force. Harnad (1999), for instance, typifies arXiv as freeing what he calls Give-Away authors (as opposed to Non-Give-Away authors who get paid to write) from the tyranny of a non-democratic system of journal publication. If more scholars can be persuaded to follow this model, he argues, we will all benefit from the new, larger and more democratic common resource that results.

This argument that internet-based resources are democratizing forces is common in the literature. Hesse et. al. (1993) argue that a computer network called SCIENCEnet increased productivity and participation in the field of oceanography. Other examples of arguments for computer networks increasing scholarly activity and participation are Cohen (1996), Walsh (1996) and Wellman et. al. (1996).

It is important to differentiate between *participation* and *access*. Providing access is relatively simple: put together a web site, submit the URL to search engines, list-servs and your friends, and wait for people to show up and access your information. Participation is an entirely different dimension. To actively participate in a cyber-community, you can't just lurk and be a free-rider using other people's information. You also must be a participant in the behavior necessary to the online community in question. In the case of arXiv.org, it is not enough to read the pre-prints as they become available, you must also post your own work for access and discussion. The problem with internet-based communities for scholars is that providing access has proven easy, while encouraging participation has been more difficult.

In this paper, I will examine the idea that the electronic repository most cited as a model, arXiv.org, has been democratizing participation in the scholarly research forum.

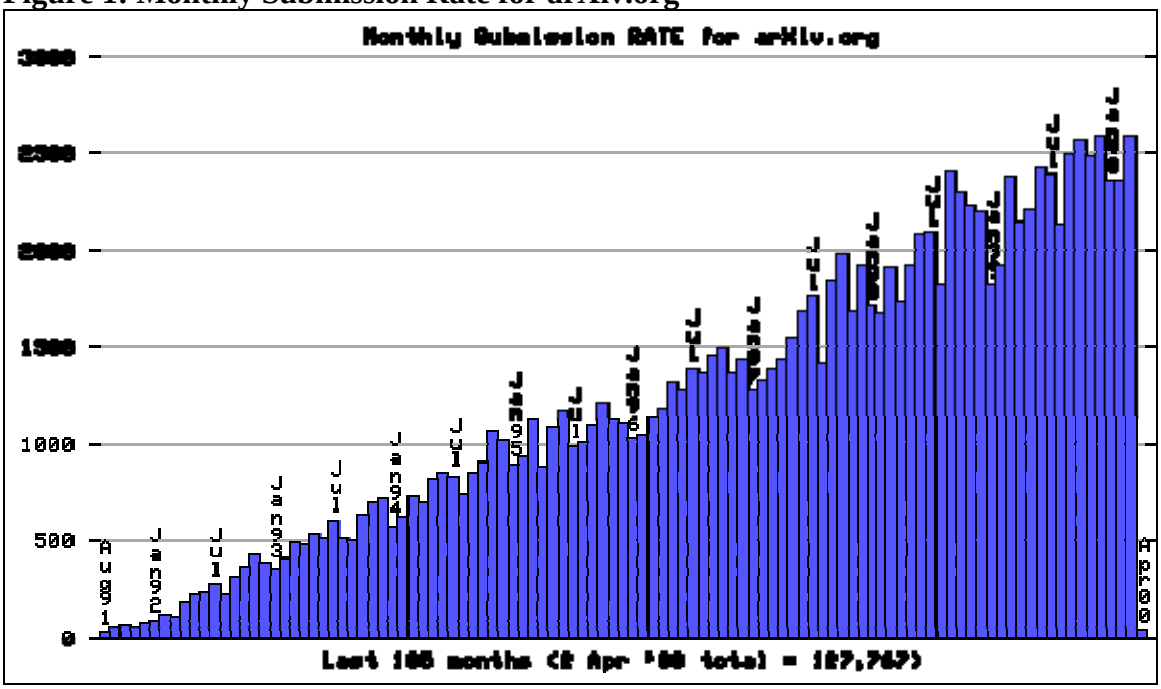
1.3 Arxiv.org

What is now arXiv.org was first started as an e-print archive at Los Alamos National Laboratory in August 1991. Its founder has described its inception:

> The first database, HEP-TH (for High Energy Physics -- Theory), was started in August of '91 and was intended for usage by a small sub community of less than 200 physicists, then working on a so-called "matrix model" approach to studying string theory and two dimensional gravity. (Mermin [Reference Frame, Physics Today, Apr 1992, p.9] later described the establishment of these electronic research archives for string theorists as potentially "their greatest contribution to science.") Within a few months, the original hep-th had quickly expanded in its scope to over 1000 users, and after little more than three years now has over 3600 users. More significantly, there are numerous other physics databases now in operation (see xxx physics e-print archives) that currently serve over 25,000 physicists and typically process more than 40,000 electronic transactions per day (i.e. as of 10/94).
>
> These systems are entirely automated (including submission process and indexing of titles/authors/abstracts), and allow access via e-mail, anonymous ftp, and the World WideWeb. The communication of research results occurs on a dramatically accelerated timescale and much of the waste of the hardcopy distribution scheme is eliminated. In addition, researchers who might not ordinarily communicate with one another can quickly set up a virtual meeting ground, and ultimately disband if things do not pan out, all with infinitely greater ease and flexibility than is provided by current publication media (Ginsparg, 1996).

With the advent of the World Wide Web, the Los Alamos archive became known by its URL: xxx.lanl.gov[1]. Certainly, no one can contest that participation as measured by the numbers of articles posted on the archive has increased over the last decade. As figure 1 shows, the growth in article postings has followed a nearly perfectly linear path.

Figure 1: Monthly Submission Rate for arXiv.org



Source: Retrieved April 2, 2000 from http://arxiv.org/cgi-bin/show_monthly_submissions

The question we hope to answer in this research, however, deals with not just increasing numbers of postings, but in understanding the socio-technical nature of the arXive repository. Our hypothesis is that one possible explanation for the large increase in postings is that the server is proving successful at democratizing participation in the physics research community.

2.0 Results

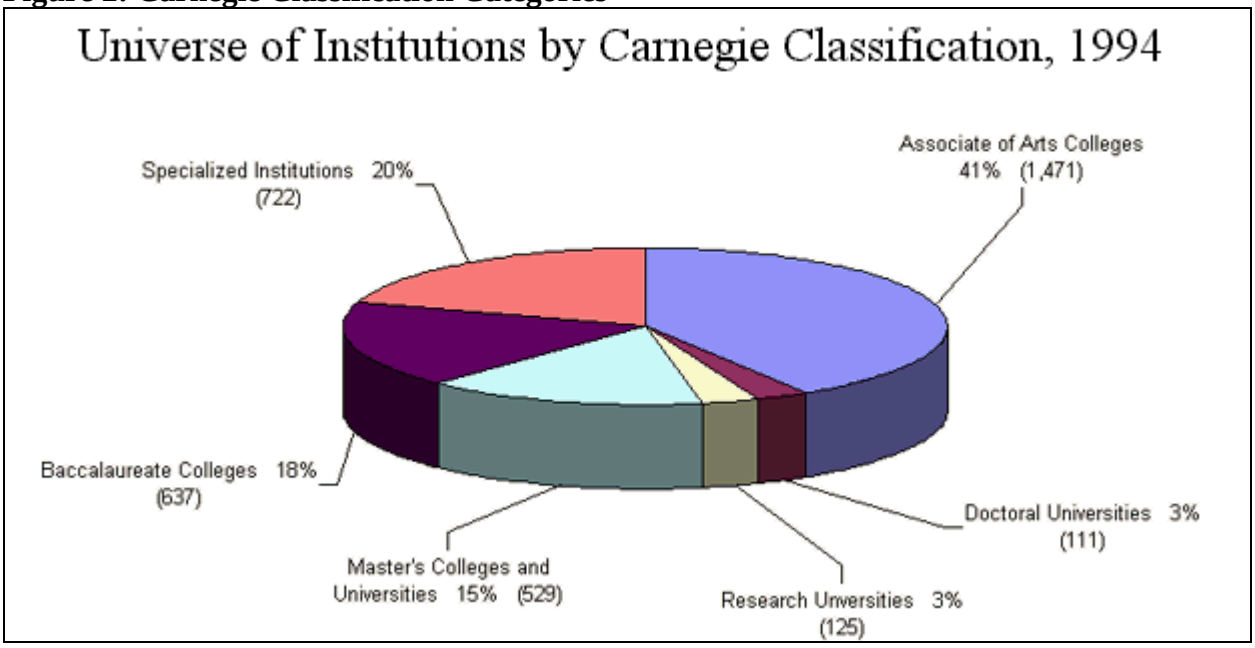
In order to test our hypothesis that participation in the online research communities served by arXiv.org has been democratized over time, we coded 4051 articles from two databases, HEP-TH and MATH, and classified the authors according to their institutional affiliation. These two particular databases were chosen based on the premise that selecting the fields with the least equipment intensivity, we would at least partially be able to factor out the network effects of having large expensive facilities. In other words, 'doing' particle physics experiments requires expensive particle accelerators, large labs and large collaborations. On the other hand, string theory (the major focus of HEP-TH) and other so-called 'chalk and talk' fields can be pursued with very little, if any, specialized equipment. It is at least a reasonable supposition that less prestigious universities trying to raise their profile could choose to hire talented theory specialists

[1] Interestingly, the name xxx.lanl.gov had to be changed recently due to problems with researchers in government and other facilities finding their access blocked due to the 'xxx' in the address. The arXiv.org address solves this problem.

since they are relatively 'cheap' in terms of institutional support required for their research. We are not claiming that this necessarily occurs, but it is a useful starting point when selecting the databases.

In order to have a variable that represents the academic status of an institution reasonably well, we used the Carnegie classification of each author's institution (Carnegie Foundation, 1994). While the purpose of the Carnegie categories "is not intended to establish a hierarchy among higher learning institutions" (Carnegie Foundation, 1994), it does serve as a useful variable to group colleges and universities with other like institutions. The categories are based partly on the highest degree conferred and partly on federal funding. Thus while Research Universities all award at least 50 doctoral degrees a year, Research I also receives more than $40 million annually in federal support. This compares to Research II, which receives between $15.5 and $40 million annually. Other categories are broken down similarly according to number and type of degrees awarded and federal funding levels.

Figure 2: Carnegie Classification Categories



Source: Retrieved April 3, 2000 from http://www.carnegiefoundation.org/OurWork/OurWork.htm.

In figure 2, you can see that the 125 research universities in the United States account for only 3% of the total number of degree granting institutions. As you will see below, however, these same few institutions will account for the lion's share of posting on arXiv.org.

Since there is no similar rating of institutional status for international universities, we were not able to come up with the same sort of categorization for non-U.S. institutions. However, we did tally the number of internationally authored articles into a single international category.

2.1 Submission rates to the High Energy Physics (String) Theory Archive

In Table 1, you can see summarized the data from 1993 and 1999 for article submissions to the HEP-TH, the high energy physics (string) theory archive. Several interesting points emerge from this data. First, when looking at the international contributions to the archive, international articles accounted for 74.0% of the postings in 1993, increasing by 3.5% to 77.5% in 1999. This difference is significant to $p < .01$ (as calculated using a two-sample two-tailed z-test for the difference between proportions). This large proportion of the database composed of articles with all non-U.S. authors is interesting. First, it points to one of the difficulties of trying to categorize this data since we cannot accurately assess the status of non-U.S. institutions. Without knowing whether these papers are coming from large, well-funded universities or smaller and more far-flung institutions, we cannot really say whether their participation represents an indication that arXiv is a democratizing influence for international researchers. I suspect, though, that since the rates are high in both 1993 and 1999 that what we are mainly seeing is participation by researchers at prestigious international research centers. This is based somewhat on the knowledge that good internet connectivity has been slower to be adopted in less highly developed countries of the world, and thus would not yet have been strong in 1993. This would also be consistent with the data for the United States discussed below, so it seems a reasonable hypothesis to tentatively accept.

Table 1. High Energy Physics Theory (HEP-TH) (First Authors)

Carnegie Classification	1993 N	1993 %[1]	1993 %[2]	1999 N	1999 %[1]	1999 %[2]	% change[1]	% change[2]
Research I	283	21.2	81.6	305	20.0	88.9	–1.1	7.3 **
Research II	27	2.0	7.8	8	0.5	2.3	–1.5 **	–5.4 **
Doctoral I	5	0.3	1.4	2	0.1	0.6	–0.2	–0.9
Doctoral II	0	0.0	0	1	0.1	0.3	0.1	0.3
MA	7	0.5	2.0	4	0.2	1.2	–0.3	–0.9
Liberal Arts	1	0.1	0.3	1	0.1	0.3	0.0	0.0
Other[2]	24	1.8	6.9	22	1.4	6.4	–0.4	–0.5
International	989	74.0		1179	77.5		3.5 *	
Total[1]	1336	100.0		1522	100.0			
Total[2]	347		100.0	343		100.0		
Total # of articles posted	2091			2825				
Sample size[1]	63.9%			53.9%				
Sample size[2]	16.6%			12.1%				

** $p < .01$, * $p < .05$

1. Percentages and totals calculated with internationally authored articles **included**.
2. Percentages and totals calculated with internationally authored articles **excluded**.

If we look at the U.S. institutions represented in table 1, we don't see any support for the hypothesis that arXiv has served as a democratizing influence as measured in increased participation. The large proportion of articles coming from Research I (82% in 1993) does not decrease but instead increases to 89% in 1999, a statistically significant increase. Note, however, that even as the Research I proportion of articles among U.S. contributors increased, its

[2] The category "Other" in table 1 and subsequent tables refers to institutions not listed in the Carnegie classifications. For the most part, these are laboratories, institutes or private corporate research foundations such as the Institute for Advanced Study at Princeton, Los Alamos National Laboratory, or Microsoft Research.

contribution relative to international contributors decreased slightly, although that decrease was not statistically significant. In other words, while Research I authors increased their participation, international authors increased their participation even more.

We don't see any significant shifts in the rest of the data other than a 5.4% decline in submissions from Research II's. For all other categories, participation was low in 1993 and remained low in 1999.

2.2 Submission rates to the Math Archive

In Table 2, a similar pattern emerges in the data from the mathematics archive. Again we see a large and significant contribution by non-U.S. authors in both 1993 and 1999. Like the physics data, the proportion of this participation increases from 1993 to 1999. In the case of mathematics, the 10.9% increase is statistically significant at $p < .01$.

Table 2. Math (MATH) (First Authors)

Carnegie Classification	1993 N	1993 %[1]	1993 %[2]	1999 N	1999 %[1]	1999 %[2]	% change[1]	% Change[2]
Research I	62	34.1	75.6	249	24.6	72.2	–9.4 **	–3.4
Research II	7	3.8	8.5	39	3.9	11.3	0.1	2.8
Doctoral I	2	1.1	2.4	6	0.6	1.7	–0.5	–0.7
Doctoral II	1	0.5	1.2	6	0.6	1.7	0.1	0.5
MA	5	2.7	6.1	18	1.8	5.2	–0.9	0.9
Liberal Arts	0	0.0	0.0	6	0.6	1.7	0.6	1.7
Other	5	2.7	6.1	20	2.0	5.8	–0.7	–0.3
International	100	54.9		666	65.9		10.9 **	
Total[1]	182	100.0		1011	100.0			
Total[2]	82		100.0	345		100.0		
Total # of articles posted	219			2332				
Sample size[1]	83.1%			43.4%				
Sample size[2]	37.4%			14.8%				

** $p < .01$, * $p < .05$

1. Percentages and totals calculated with internationally authored articles **included**.
2. Percentages and totals calculated with internationally authored articles **excluded**.

For the U.S. institutions represented in the data, we see a small 3.4% non-significant decline in participation by authors from Research I universities, but we don't see a corresponding significant increase in any of the other categories. Instead, the change seems to be fairly evenly spread across the institutions, and could easily be due more to the increase in number of postings over this time period than any other factor.

2.3 Data using all authors for each paper

We also wanted to look at whether there is a difference in the data when we include all authors rather than just the first author of each article in the dataset. In Tables 3 and 4 this data is summarized.

In Tables 3 and 4, we can see that included the additional authors for each database does not alter the general direction of the data in any significant way. As in tables 1 and 2 where we considered only the first author, we see that the submissions are dominated by authors at Research I universities, a pattern that does not change considerably in the 1999 data. In the HEP-TH data, the increase in articles from Research I authors and the decrease in authors from Research II and Doctoral I categories are all statistically significant. In the MATH data, none of the changes are statistically significant.

Table 3. High Energy Physics Theory (HEP-TH) (All non-international Authors)

	1993		1999		
Carnegie Classification	**N**	**%**	**N**	**%**	**% change**
Research I	433	79.9	543	88.6	8.7 **
Research II	54	10.0	13	2.1	–7.8 **
Doctoral I	10	1.8	2	0.3	–1.5 *
Doctoral II	1	0.2	1	0.1	–0.1
MA	8	1.5	6	1.0	–0.5
Liberal Arts	2	0.3	3	0.5	0.1
Other	34	6.3	45	7.3	1.1
Total Authors[3]	580		670		
Total Articles	349		350		
Mean number of authors	1.66		1.91		15.1 **

** p < .01, * p < .05

Table 4. Math (MATH) (All non-international Authors)

	1993		1999		
Carnegie Classification	**N**	**%**	**N**	**%**	**% change**
Research I	83	74.1	363	72.5	–1.6
Research II	8	7.1	58	11.6	4.4
Doctoral I	2	1.8	6	1.2	–0.6
Doctoral II	4	3.6	10	2.0	–1.6
MA	5	4.5	23	4.6	0.1
Liberal Arts	0	0.0	7	1.4	1.4
Other	10	8.9	34	6.8	–2.1
Total Authors	125		551		
Total Articles	80		350		
Average authors per article	1.56		1.57		0.6

** p < .01, * p < .05

Probably the most interesting element of this pair of tables is the increase in the mean number of authors per paper in the HEP-TH database. In 1993, the mean was 1.66 and this increased to 1.91 in 1999. This 15.1% increase is statistically significant (as determined by a t-test) and indicates that, at least for these two years, there is an increase in collaboration. However, it does not appear that there are increased collaborations across categories. Thus, our hypothesis that an Internet based repository will democratize participation in this scientific research community cannot be accepted.

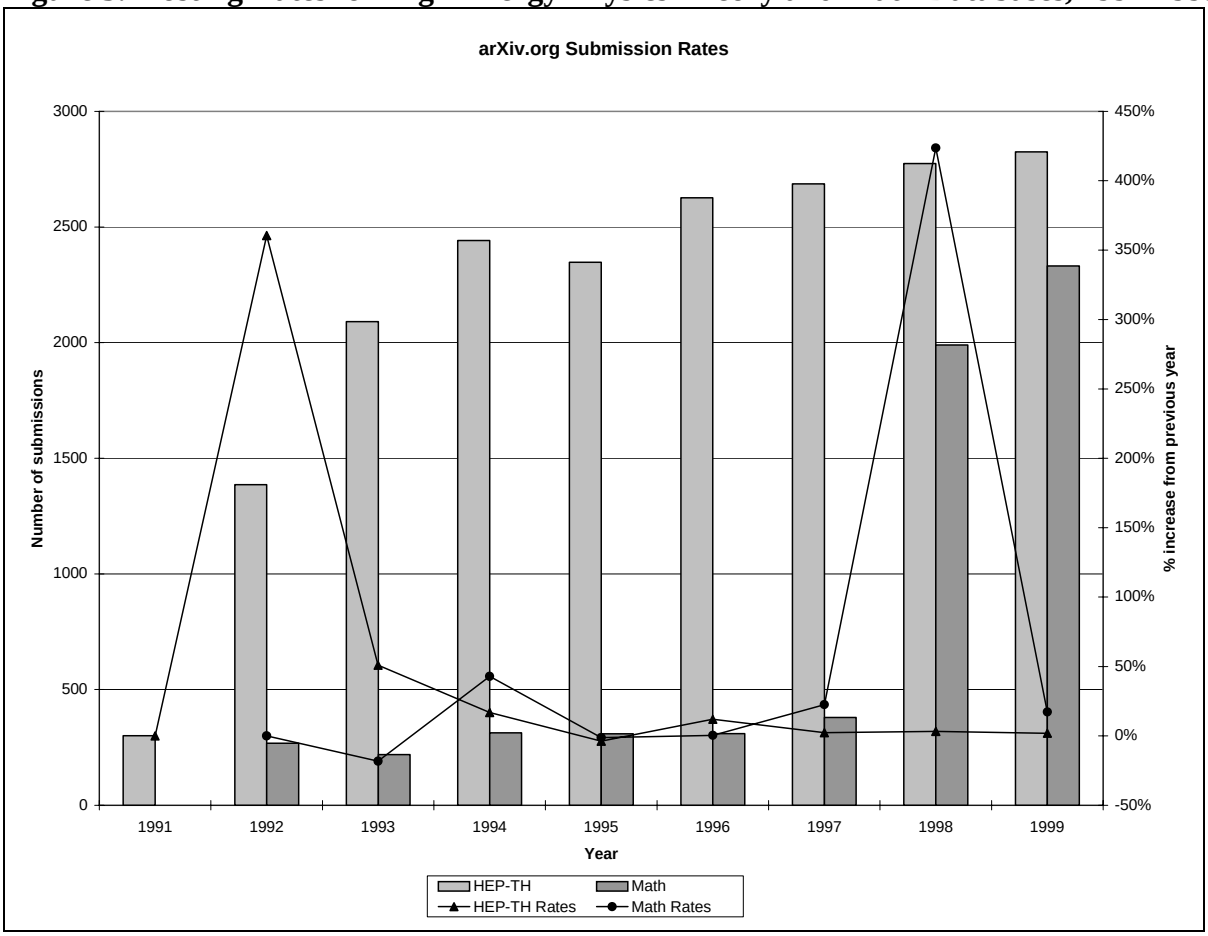
[3] Total authors and articles may not equal the other categories since some articles would have had both international and American authors, resulting in the international authors not being coded for classification, but nevertheless being counted in the total number of authors for the paper.

2.4 Posting rates and Institutional Affiliations

Since it appears that our data does not support the notion that the Internet and the presence of an easily accessible web-based archive of research articles increases the variety of scholars participating in the scientific research community, we should look next at some explanations for why this data does not support this commonly held and asserted belief.

In figure 3, we start to see the first clue that our original thinking may have been misleading. Remember that in figure 1, we saw the linear growth in submission rates for the arXiv.org working paper repository. This graph is easily accessible to visitors to the site, and certainly lends the impression that submissions are increasing at a relatively steep rate. In figure 3, on the other hand, a very different picture emerges. When we look at individual databases in the archive, we do not see phenomenal growth rates after an initial one to two year growth spurt. In the case of HEP-TH, this period of strong growth was centered in 1992 and 1993. After 1993, however, growth rates were less than 10% annually. Thus, while there is generally growth in the submission numbers, it is not nearly as steep a line as that in the overall repository.

Figure 3. Posting Rates for High Energy Physics Theory and Math Databases, 1991-1999



Similarly for MATH, there is a large period of growth, this time centered on the 1998 time period. This recent change in widespread use of the repository allows us to look at the previous

data in this paper as similar to a before and after picture (although at this point, we can't really presume to know before or after *what*). In our MATH data, even though we looked at two time periods with very different rates of submission, the general socio-technical nature of the postings did not change significantly. This is further indication that this particular repository is not acting as a particularly democratizing influence.

Another indication of this trend come if we look at the sources of submissions in regard to specific institutional affiliations. In table 5 is summarized data for any institution with at least ten articles in any given year in either database. For the HEP-TH database, the most striking result is that in 1993, three institutions (Princeton, MIT and Texas A&M) account for over 5% of the total authorship each. In 1999 again Princeton and MIT each accounted for over 5% of the total authorship submitted to the archive. This is striking, and certainly suggests at least one explanation for submission trends: that having a network of active scholars co-located geographically increases participation rates.

Table 5. Author Affiliations with more than 10 articles in sample (all authors)

	Carnegie	HEP-TH		Math	
Institution	**Classification**	**1993**	**1999**	**1993**	**1999**
Brandeis University	R2	*10*	*8*	2	2
California Institute of Technology	R1	13	16	0	7
Cornell University	R1	*13*	*5*	2	3
Harvard University	R1	16	30	6	21
Institute for Advanced Study	R1	14	33	4	4
Massachusetts Institute of Technology	R1	38	47	**2**	**14**
New York University	R1	**3**	**10**	0	3
Ohio State University	R1	**0**	**10**	0	5
Princeton University	R1	50	44	4	4
Rutgers University	R1	11	20	**3**	**21**
Stanford University	R1	14	26	0	9
State University of New York, Stony Brook	R1	25	13	5	5
Syracuse University	R2	*16*	*0*	0	1
Texas A&M University	R1	29	16	4	14
University of Alabama, Tuscaloosa	D1	*10*	*0*	0	2
University of California, Berkeley	R1	15	25	4	21
University of California, Santa Barbara	R1	26	31	0	9
University of Chicago	R1	14	20	1	8
University of Pennsylvania	R1	**6**	**28**	4	5
University of Rochester	R1	*11*	*9*	1	1
University of Southern California	R1	*11*	*9*	1	3
University of Texas, Austin	R1	17	16	3	1
Yale University	R1	15	10	0	5

Note: Shaded institutions had more than 10% of the coded articles in at least one database in a year, indicating a large contribution to the archive. Institutions in bold indicate those that did not meet the criteria in 1993 (10 for HEP-TH, 4 for MATH), but increased their contributions in 1999 (10 for either database). Institutions in italics decreased from meeting the above cutoff criteria in 1993 and not in 1999.

Also note the institutions indicated in bold. These are those institutions where participation increased a great deal between the two years from very low to high. In all three instances of this in HEP-TH, the universities are Research I institutions (NYU, Ohio State, and U. Penn), as are the two in MATH (MIT and Rutgers). More interesting are the universities indicated in *italics*, with have decreased numbers of authors, in two cases down to zero. One can speculate that in

the HEP-TH data concerning Syracuse and U. of Alabama, Tuscaloosa (neither of which are Research I colleges), the 1993 participation may have been due to one or a few active scholars who have since moved on to more prestigious universities, although further research would be needed to confirm or disprove this speculation.

3.0 Discussion

In this study, we chose to assess whether arXiv has been successful in democratizing participation in the physics research community for several reasons. Coming out of conversations and public debates about the Digital Divide, we were interested in looking at a group where we could assume that interested parties who had something to contribute would have a reasonably high level of competence to participate, but not necessarily all the resources. Less well-funded universities generally provide faculty members with less funds for research, less travel funds to attend meetings and conferences, and fewer computer resources. While not necessarily falling on the wrong side of the Digital Divide, faculty at these institutions could be seen as suffering from information inequality.

Choosing to look at this elite scientific community is in contrast to studying something like a site directed to the public for the discussion of investment advice. In that case, many of the people accessing the information would not have enough knowledge about investing to realistically contribute. Physicists and related disciplines, on the other hand, have an entrance fee—you have to start with an advanced degree.

Physics and math professors may find themselves at institutions that are not Research I for a number of reasons, including a tight job market, an interest in teaching over research, personal preferences for a type of college or a geographic area, family reasons to live in a certain area, and others. An underlying question for this research in this context is that for scientists participating in highly specialized research, where does information sit among the constellation of resources that drive their participation in research? Other resources include funding levels, facilities, office space, research assistance, teaching loads, committee assignments, administrative jobs, and so on.

As a common pool resource, arXiv.org is not clearly increasing the variety of participation in scholarly discourse. This study found that even though most colleges and universities in the U.S. can be assumed to have at least some level of internet access by 1999, there are very low levels of participation outside of Research I universities on the elite scientific working paper repositories that we looked at. There are a number of possible explanations for this which we hope to explore in further research. It is possible that participation in this particular virtual community, for instance, is much more likely for scholars also participating in face-to-face collaborations. Another related possibility is that researchers who may begin a career at a smaller institution but who aspire to participate in high-level research seek to move to more highly ranked institutions early in their careers. Other explanations are also possible.

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