The Future Information Infrastructure in Economics *

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> For scholars and scientists, paper is not an end but a means. It has served us well for several millennia, but it would have been surprising indeed if this manmade medium had turned out to be optimal for all time. — Steven Harnad, in Okerson and O'Donnell (1995), p. 90.

1 Introduction

Computers have greatly improved the lives of economists. The estimation of econometric models, the manipulation of datasets, word processing, and EconLit are just a few examples of computers' impact. However, computer networks may dramatically change the way we work. Already we have seen hints with electronic mail, mailing lists, on-line card catalogs, access to U.S. government data, and the start of an on-line working paper culture (more than 3,000 on-line working papers at last count; see EconWPA <http://econwpa.wustl.edu>, and WoPEC, <http://netec.mcc.ac.uk/NetEc.html>. Soon, back issues of the AER will go on-line, and across academia, there are more than 300 peer-reviewed electronic journals (see *e·journal* <http://www.edoc.com/ejournal/academic.html>) with hundreds of U.K. journals going on-line in 1996 (Hitchcock, Carr, and Hall (1996)).

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An optimistic vision of the future might best be demonstrated with the following vignette:

> Dr. Smith, reading an article in the latest JPE on-line with his PC in California, was surprised by a footnote that cited a recent article in the AER. He clicked to on the reference, searched the AER article, and quickly found the results of a key regression. He had not followed this literature for several years, and it was counter to his experience. Opening up another window, he tapped into the AEA's on-line archive for the paper's data in Tennessee and retrieved them. He then ran the regression, tried additional diagnostics, and modified the specification. He was surprised to find that the results were quite robust. Curious about other recent results in this literature, he then moved to the paper's references and clicked his mouse on several related papers to jump to their on-line versions via a hypertext link (he was thankful those journals were on-line, as his small library did not carry their paper versions). He then recalled that he could use this procedure for a project he thought about long ago, if he could remember where he saw the data. He then opened up a window to the AEA's database of data in economic publications (an outgrowth of EconLit). He soon found the data on-line at a journal archive in New Zealand. He contacted one of his graduate students in Virginia and they began an on-line audio conference. They opened their word processors in 'conference' mode and began jointly and simultaneously outlining and writing a new article—together editing, modifying, and pasting new regressions results and graphs. In an hour, they had a new paper partially written.[1]

In short, a fully networked world could offer much easier access to the information (working papers, articles, bibliographical information, and data) that lies at the heart of what we do. Rather than visiting the library for a journal you do not subscribe to, or requesting it via Inter-Library Loan if they do not subscribe, or writing or calling an author for his data or working paper, this type of information may be freely available at your desk through your computer.[2]

However, this world exists only in embryonic form,[3] and we are now at a cusp point, and any number of outcomes are possible. The current relationships within and between publishers, libraries, and academics might be maintained with networks simply replacing paper as the means of moving and storing information. Or, entirely new relationships resulting from technological change may arise that are more in keeping with academic principles and traditions. The path to any future is expected to be tumultuous. A recent report by librarians and academic publishers (Scovill (1995)) examines three scenarios for their future, and, in two, some or many publishers and libraries cease to exist. The underlying theme seems to be a common one that during periods of technological change, new technologies not only improve existing practices, but may usher in

[1]When we began this paper (February 1996), we had not thought about "conference" editing of a document. In the beginning of May 1996, we added this idea. That month, Microsoft announced Microsoft NetMeeting, and we used it to edit both this paper and PowerPoint presentations.

[2]Thus, the emphasis in a networked world is not so much on reading material on the computer screen, but rather easy access to material. Of course, you may prefer to print the material locally rather than read it on the screen. Note that since very few readers will print everything they access, an electronic medium should save paper.

[3]Even today the amount of information available on-line is amazing. At live Internet demos, we search the upcoming on-line version of back issues of the AER, and the NBER Macro Historical Database. We have found 6 articles and many data series which mention the proverbial "kitchen sink."

entirely different institutional arrangements. For instance, the Internet may even change the way cars are sold (Taylor (1996)). In such a world, can we expect our "industry" to be unchanged?

One possible future continues current practices with little improvement in access to information, albeit with that information traveling over networks. Information will still be tucked away in distant libraries where you have no privileges, or at publishers' servers where you must purchase it. Specifically, as described below, publishers and libraries are working on making their current offerings available over the Internet. Certainly, publishers have every incentive (profits) to maintain the status quo (not the distribution method, but their overall position in the exchange of academic information). Thus, under this scenario, the superstructure—the technology of moving and storing information—changes, but no fundamental change takes place in the relationships between the players.

Roes (1994) examines a somewhat different possibility: "electronic document delivery." For scholars, this system is broadly defined as any method of electronic delivery of journal articles or similar material. Today, it supplements a library's collection, and is often implemented with faxed copies of a journal articles not held by the local library.[4] Perhaps the best known document delivery firm is CARL, <http://www.carl.org/>. As Roes (1994) explains, this system could evolve into electronic documents. With electronic document delivery, the implicit assumption is that libraries and publishers play roughly traditional roles—publishers hold copyrights, libraries store journals, and they and users may pay copyright fees for the electronic copies of material. In short, it is another future that roughly maintains the status quo.

Another possibility is that scholarly material becomes freely available on the Internet, but is unorganized and all but impossible to find. Rather than economists placing their material on central servers, or registering it with databases,[5] they simply place them on their own or their department's web sites and expect others to find them. This scenario is similar to one in Scovill (1995), and it could be labeled the "Field of Dreams Approach"—put it out there, and they will find it. This is clearly naive, since at last count, there were tens of millions of web pages; a search at AltaVista, <http://www.altavista.digital.com/> an Internet search engine, found more than 600,000 documents containing the word "economic," and more than 5,000 with "Adam Smith." Clearly, someone searching for the latest working papers on Adam Smith is likely to be in for a rather difficult search. On the other hand, if the author of a working paper used EconWPA, or registered the paper with WoPEc, a quick search of either will quickly locate the paper.

We argue that a different future, with both more easily accessed *and* easily found information, is more consistent with academic traditions and values. This future is now possible with the advent of powerful personal computers[6] connected via networks. In our view, these new tools open up entirely new opportunities for scholarly exchange, and will enable immediate and free access to most any sort of information desired by an academic.

This paper does not offer a formal model, but rather a conceptual view of how computer networks should change the way we work. It is also intended to start a debate in our profes-

[4]Some might say that the ultimate version is one published copy of a journal, with copies faxed to all readers and the publisher compensated by copyright fees paid by each reader.

[5]The former include working papers on central servers like EconWPA, and the later include databases of working papers (WoPEc) and programs (CodEc) <http://netec.mcc.ac.uk/CodEc.html> and (ELSA) <http://elsa.berkeley.edu/>.

[6]Such as a 133 Mhz Pentium, which is now—late 1996—an "entry-level" machine, which rivals the power of mainframes of not long ago.

sion about how we can organize the flow of information that is critical to our professional lives. This paper is also a brief overview of how networks will influence academia; more details can be found in Okerson and O'Donnell (1995), Scovill (1995), Peek and Newby (1996), Hitchcock, Carr, and Hall (1996), and many issues of the *Journal of Electronic Publishing* <http://www.press.umich.edu/jep/JEPtitle.html>, while Bailey (1996) contains a very extensive bibliography.

This paper is organized as follows. The next section looks at academic principles that do not change with technology or institutional arrangements. These are concepts to be kept in mind during this period of technological change in the profession. The third section examines the impact of networks on working papers, journals, and libraries. The fourth address access to data and indices to information. The fifth looks at entirely new opportunities, and the sixth suggests a roadmap for moving to a networked world. A conclusion summarizes these ideas. Thus, this paper examines the entire flow of information in the profession and how it might change with the arrival of computer networks.

2 Key Academic Principles

When major changes occur in an institution or profession, key values and goals should be kept in mind. For academia, of course, a primary goal is the growth, acquisition, and dissemination of knowledge. It appears that computers and networks may make the goal of obtaining knowledge less expensive with a large drop in the cost of moving, storing, and perhaps generating information.

Many practices in academia foster both the acquisition and dissemination of knowledge.[7] The publication of results is encouraged, if not mandated. Indeed, it is how most members of the academy are judged, and how universities earn their reputations (which is, after all, the major output of a research university). Thus, universities all but demand the greatest dissemination of their scholar's production. To support this, universities pay the salaries of scholars, pay for the libraries full of books and journals which scholars use, pay for travel to conferences, host seminars, and support the editorial offices of journals. Academic associations, rather than maximizing profits, work to support the acquisition and dissemination of knowledge by hosting conferences, journals, abstract services, and the like. Indeed, the AEA is purposely operating at a loss to reduce its assets (Hinshaw (1996)). Individual academics are not usually paid for refereeing,[8] and only some editorial positions offer any remuneration.

Academic information is readily, if not freely, available. Readily available information includes books and journals in libraries, some data from government agencies and many private organizations, journals and monographs in academics' offices, and presentations at conferences. Freely available material generally includes working papers and data from other academics, and a very substantial amount of government data (at least in the U.S.). In general, it could be said that a key principle of academe is the freest possible access to information produced by and for academics.

In a possibly tumultuous transition to a networked world, it is important to keep this principle

[7] When access to information is restricted at universities, culture clashes often develop. For instance, some universities have had conflicts with their microbiologists who do not publish their results in order to protect trade secrets.

[8] Some journals pay a token honorarium, but this is not compensation for the effort expended on refereeing a journal submission. Referees could earn more per hour raking lawns.

of access to information at the lowest possible cost in mind. With a lower cost of disseminating and storing information, not only might the superstructure (the technology of moving information) change, but also the fundamental relationships between academics, libraries, and publishers might change as well.

3 Working Papers, Journals, and Libraries

The impact of the new technology of networking on journals is well explained by Kahin (1995):

> In the networked environment, the pipeline model of publishing collapses. Authors can speak directly to readers. Publishers and libraries find themselves in the same business: providing access to information. Under the old model, publishers saw that books and journals were manufactured and physically delivered; libraries cataloged and archived books and journals from many publishers and made them available to one user at a time. In the new model, these classical functions, and the neat division of labor that characterized the pipeline model, disappear.

In the world of paper communication, libraries and publishers exist for very specific reasons. But, in a networked world, their reasons for existence may lesson or perhaps even disappear. A number of different economic models for electronic journals are presented by Grycz (1992). However, the most revolutionary is Harnad (1995). He presents a holistic view of how the entire journal industry may be upended with the introduction of networks for the benefit of academics (Odlyzko (1995)has a similar view). Harnad first makes the distinction between the "trade" and "esoteric" author. The former expects to be paid for his work; indeed, it may be his livelihood. The latter resides almost entirely in academia: the authors are not, and do not expect, to be paid for their words; the market per work is very small; and they sometimes even pay for their words to reach more readers (such as paying for and sending reprints).[9] Their pay is tied to their recognition and status, which is gained from the words they write. They want those words to be as freely accessible as possible. Harnad is quite clear that his argument holds only for the esoteric author. He then puts the implications best when he says,

> The first step in getting the word to one's peers, however, is to publish it at all, and in the Gutenberg age the only way to do this was through the mediation of the slow and expensive medium of printing and paper distribution. It was because of the high cost of this, the only means of making one's ideas and findings public at all, that esoteric authors have stood ready to go even farther than what has been mentioned so far: They have been willing to make the "Faustian" bargain of trading the copyright for their words in exchange for having them published. From the publishers' standpoint, the bargain was eminently fair: They asked for nothing more than they asked from trade authors, which was the right to protect the product from theft, so costs could be recovered and both author and publisher could make a fair profit. For the trade author, this bargain was not Faustian, because both he and his publisher stood to gain from it—and to lose from theft. But the need to pay a ticket at the door was the last thing

[9] On the other hand, academic textbook writers are "trade" authors

> an esoteric author would have wanted to impose by way of a deterrent for his already minuscule potential readership.
>
> So for the esoteric author, there was always a conflict of interest built into the act of publishing: One wants to get the words out there to everyone who might be interested, but one agrees to erect a price-tag as a barrier, to cover the costs (not one's own, but those of the publisher) and a fair return (again not to oneself, but to the publisher who had incurred the costs).
>
> Now that all this has been spelled out, the news: With the advent of electronic publication, the Faustian era for esoteric authors is now over. The reason is that the per-page cost—if one reckons it properly—is so much lower for purely electronic publication that it no longer makes sense to recover it on the subscriber model of trade publication.

He details journal's costs, where he speaks from experience—he edits both the paper journal *Behavioral and Brain Sciences* from Cambridge University Press and the electronic journal *PSYCOLOQUY* <http://www.princeton.edu/~harnad/psyc.html>, sponsored by the American Psychological Association. There are two components to costs: distribution costs and "first copy" costs (all the costs up to distribution). Clearly, distribution costs for an electronic journal approach the trivial. He argues that the savings for first copy costs of a totally electronic journal over a paper journal are on the order of 70-90%.

With drastically lower first copy costs and virtually zero distribution costs (more accurately, very low costs borne by others), Harnad then goes on to argue that these much smaller costs should be borne by those who benefit from the research: the author's universities, funding bodies, societies, and libraries. In other words, such journals would be supported by a small page fee paid by these organizations. The works will then be freely accessible (not free, as the costs are covered by others, but freely available). Harnad thus provides a roadmap to Kahin's view consistent with academic values—the freest possible access to scholarly information. No longer will academics have to make trips to the library for journals they do not subscribe to, and Inter-Library Loan might even become extinct. Information becomes more "free" because of technological change.[10]

The welfare and efficiency of Harnad's system is interesting. As pointed out by Ordover and Willig (1978), journals can be thought of as quasi-public goods because one can subscribe to one personally, or go to the library and read a shared one. In Harnad's system, journals become a pure public good (in distribution) with the cost of providing this good borne by those who benefit from it: the authors and their sponsors. Thus, in some sense, the optimal number of journals will be produced since those who benefit from the journals financially support the journals. Making journals a public good also has a nice symmetry with the knowledge they represent, which, as Arrow (1962) noted, is a public good. In addition, as pointed by Varian (1995), electronic journals, with what are thought to be substantial first copy costs and very low distribution costs, face decreasing average costs, thus making it difficult to recover costs if goods are priced at marginal cost. But,

[10]Note that this does not necessarily mean the material is not copyrighted; rather, the restrictions on use would simply fall—the rights holder permits copying. This sort of copyright is common in some software, and the best example is the GNU GNU () "copyleft"—copying is permitted, and the program can even be resold, but resellers cannot restrict further copying. What is claimed to be the world's second most popular version of Unix, Linux, which is built by thousands of volunteers around the world, is "copylefted."

with Harnad's system, journals are priced at zero and the costs are borne by those who benefit from publication: the authors and their sponsors.

Also, as articles are produced by academics for reasons other than selling them, it is doubtful that an electronic world will produce more (or less) articles than the current hard copy system produces (however, the number of *journals* could rise or fall, but the overall quantity of output of economists is likely to relatively unaffected by this new technology). Electronic journals will and do exist, providing the refereeing, editorial (and selection) value added that they currently do in hard copy. Most of the value of a hard copy journal is the refereeing and editorial process and this does not change. What is different is that publishers as such are non-extant, and the distribution of the product—articles—becomes nearly free. Since the product is produced anyway, efficiency dictates that it be distributed freely with any costs borne by universities, societies, or libraries. If hard copy is desired, then the individual reader bears the printing cost which she should.

To a very large degree, Harnad's vision is reality in one field: high energy physics. In 1990, less than 100 high energy physicists started a list of electronic mail addresses and, via this list, sent their research papers around the world to each other. Paul Ginsparg, a physicist at Los Alamos National Laboratories and a very competent programmer, created what is now known as the "E-Print Archives" at Los Alamos <`http://xxx.lanl.gov`>, of which **hep-th** (high-energy physics—theory) is the most successful. It was envisioned as, and is now, a fully automated preprint server. Submissions are made by authors, writing in TEX or, LATEX. The software now automatically creates PostScript and Acrobat PDF files from these submissions. Readers access the system via the Internet by e-mail, ftp, and the web. Submissions are not only indexed (full body indexing as the submissions are made in TEX or LATEX), but citation references are created so that each paper not only contains a list of references in the paper, but also a list of works cited by this paper. The paper thus has its own built-in citation index. [11]

There are many reasons for this archive's success.[12] It began with a core of researchers who used the archive; they all wrote using TEX; they were technologically adept at e-mail;[13] the peer review process for high energy physics had broken so that journal publication was (and is) not the selection process as we know it in our profession;[14] preprints were very costly to some institutions requiring budgets of $20,000; there was more international involvement, or at least collaboration, than we usually have; and research results were demanded on a timely basis (days rather than years).

One of the major fears about the E-Print Archive was that with no peer review or selection process, and given the experience on Usenet physics groups, the archive would be cluttered with noise rather than signal. This did not happen, and it appears that there is some self-selection process so that the noise has remained on Usenet while there is little on the archive.

[11] Ginsparg (1996) explains many of it features, philosophy, and outlook for the future.

[12] Success can be measured in a number of ways—number of accesses to the archive, typically 70,000 accesses per day from over 35,000 users in 70 countries; number of submissions, typically 200 per month to the most successful area, hep-th; number of preprints stored, over 20,000. Most if not all high-energy physicists do not consult hard copy journals anymore—only the archive. Also some senior physicists sometimes don't bother with paper publications—presumably their sponsors have learned how to value their contributions to the archive with measures such as citations.

[13] The archive operated in its first year solely as an e-mail based server.

[14] They called their "working" papers preprints, but that was not an optimistic name. Most papers are published, and published within 6 months of submission with very few revisions.

Harnad favors peer-review;[15] unlike some proponents of electronic journals, he feels it plays a useful role. After all, there is no fundamental reason why electronic journals cannot be peer-reviewed; at one level, it is simply a different means of distributing the articles which constitute a journal.

Clearly, the linchpin in Harnad's argument is the reduction in first copy costs with a totally electronic journal. Some find his arguments implausible (Scovill (1995), p. 15), but others, such as Odlyzko (in Okerson and O'Donnell (1995), p. 119), are convinced. This is now known as the 70-30 debate—are first copy costs reduced by 30% or 70%? The answer seems to lie in how much copy-editing is done by the journal. Some editors do no copy editing and other editors may rewrite a submission, investing days in the process. The current paper journals nourish a subsidization of poor copy submissions since papers must be reformatted and typeset before publication.[16] Also, our profession has a very heterogenous set of styles among journals, and there is little reason to choose one over another. Hence, an author has little incentive (and none from the journal/publisher) to submit good copy or style. This is not true with electronic submissions, and in the future we may see journals reject articles which do not obey the journal's style. Springer-Verlag sometimes requires submission of LaTeX in a Springer style, and no copy-editing is done. Whatever the author submits is published. This lowers the copy-editing cost to zero. With electronic journals, the author who writes poor copy (regardless of the content) can be forced to bear the cost of his actions—either by a journal charge for copyediting of the particular article, or by rejecting the article for poor editing and style.[17]

With an electronic journal, the distribution costs are virtually zero (these small costs are paid by those who pay for networks). With totally electronic submission, first copy costs would fall dramatically as illustrated by *PSYCOLOQUY*, the *Electronic Journal of Combinatorics*, <http://ejc.math.gatech.edu:8080/Journal>, the *Electronic Journal of Differential Equations*, <http://ejde.math.swt.edu/>, and *Geometry and Topology*, and <http://www.maths.warwick.ac.uk/gt/>.[18] Thus, with the remaining first copy costs supported either by institutions (a time honored tradition in academia by well-endowed departments), or with small page fees paid by authors or their sponsors,[19] the journals will be freely available. All the journals mentioned earlier in this paragraph are freely available are based on this model.

The study by Jog (1995) of six academic journals shows that the typical journal costs $70,000 per year to produce. Typesetting (9%), printing (28%), and shipping (12%) account for almost 50% of the costs of the journal, which are print based expenses. Administration expense was 25%, while editorial expense was 23%. Both of these expenses may be reduced for electronic journals (possibly to $0 as it appears to have been with the EJC). Administration can be automated and handled electronically while editing cost can be shifted onto the author where it belongs. Currently,

[15] But he wholeheartedly proposes that all scientific writing should be made electronically available, before peer review and possibly to cause peer review.

[16] Science journals commonly have page charges which were originally implemented to cover typesetting and copy editing costs, but now those charges are a general levy to all articles and not just those that are poor copy or in the wrong style.

[17] Some math journals reject any submission that is not in AMS-TeX and most psychology and education journals reject submissions that are not in APA format.

[18] The *EJC* requires submission in AMSTeX, and upon final editorial acceptance of the manuscript, it is electronically published automatically without human intervention.

[19] The surprisingly low average cost of a paper in the E-Print Archive at Los Alamos is detailed below.

due to retyping the submitted paper for printing purposes, copy-editing is done by the journal.

We can also compare the cost of the E-Print Archive at the Los Alamos, described above, to the AER. Paul Ginsparg of Los Alamos received a one million dollar grant for 2.75 years. The archive had 1,185 papers posted in one month (June 1996), or approximately 14,000 papers per year, which works out to an average cost of $27.63 per paper.[20] Through the year ending August, 1996, the AER published 175 articles (long, short and proceedings) with costs of $881,000 (Deloitte-Touche (1995)). That works out to an average cost of $5,034 per article. Admittedly there is an editorial, referee and copy editing process with the AER, as well as distribution. If the figures above in Jog hold true, approximately $2,000 per article are due to printing and shipping.

For the near future, mixed paper and electronic journals are likely. It would seem that a fee based paper version, and a freely available electronic version, would lead many to abandon the paper version. However, if paper versions are priced at cost, this will not harm the journal financially *if* its first copy costs are otherwise supported, as described above. While this sounds unappealing, lower and mid-level journals are now being canceled by libraries. Thus, the model described above could well be their savior—in the current subscription model, they could fold, much as the scholarly monograph market has in other areas of academia.

It is also useful to look at the cost of using paper journals. For their readers, paper journals carry a high opportunity cost. If the desired journal is in your office (taking up precious shelf space), it probably will not take too long to find the article.[21] More likely, it will be in the library, entailing a round trip of perhaps half an hour (assuming the journal is carried by the library and it is correctly shelved). Finally, if a local copy is not available, Inter-Library Loan must be used, and the delay will be measured by days or weeks.[22] In the on-line world described above, any journal can be read with just a few clicks of a mouse.

Looking beyond costs, according to Harnad, there is little role left for libraries, and even less for publishers (at least with their current business model based on subscriptions). Libraries and publishers, not surprisingly, tend to see the future in different terms—they see networks as simply adding another distribution method to their customers.[23] And in the transition phase, librarians see one more demand on their budgets from paper journals who charge extra for the electronic version.[24]

[20]The grant was for software development with little for ongoing maintenance. Ongoing costs per article might be one order of magnitude less, if not two.

[21]Even though you might have the journal, it is faster and easier to search for an article with an online journal than to look through the shelves and each year's index of the paper journal.

[22]Even a relatively common journal like the *Southern Economic Journal* has less than 3,000 subscribers (almost evenly split between institutional and personal ones), requiring many to experience the IIL delay.

[23]Individually and together they are working on a number of projects that add distribution of their material by networks. The NSF, NASA and ARPA are funding the $24 million Digital Libraries program at Carnegie Mellon, the University of California (Berkeley), the University of Michigan, the University of Illinois, the University of California (Santa Barbara), and Stanford University NSF (); Johns Hopkins Press along with its collaborators has its Muse Project MUSE (); Elsevier and nine U.S. universities have Tulip TULIP (); Academic Press has IDEAL Press (); and Pica is a joint project with Kluwer and Dutch libraries Pica (). Perhaps the largest move is a number of British publishers will make hundreds of their journals available on-line through U.K. libraries this year (Hitchcock, Carr, and Hall (1996)).

[24]Project MUSE at Johns Hopkins Press charges additionally for the electronic version though the subscription is institutional, so that any faculty of a subscribing library can access the electronic journal.

Of course, any move to the system that Harnad proposes is likely to be interesting, to say the least. Sufficient technology already exists,[25] and the economics appear to be largely favorable (if first copy costs of an all-electronic journal are truly dramatically lower), but there are many "social" issues still to address: will promotion, tenure, and annual review committees accept electronic publications?;[26] how much will entrenched interests fight changes?; will authors submit "good" papers to start-up electronic journals?; can universities supply all of us with 17 inch color screens and a printer?; etc.

There are some important issues with electronic journals and electronic posting of papers. First, a paper may reside on a home page of an author and also in a "journal". As we have argued that electronic journals have very low publication costs, so there is little concern whether the article is viewed from the home page or from the journal itself. Since the journal should have the most up-to-date version (at publication time), readers would be well advised to obtain their copy from the journal.

Second, anyone can post a paper on a server on the Net. As distributing hard copy working papers is costly, they are limited in their distribution. Not so with electronic posting. Due to costs, most academics receive relatively few hard copy working papers—selection is often for the wrong reason—cost. With an electronic world, how does one keep from being swamped with a glut of papers? We estimate that there may be 20,000 working papers produced in economics each year[27]. In the electronic world, one may have access to these 20,000 papers and selection, via some method, is extremely important. If anything, in the electronic world, the importance and use of a journal becomes greater than it is in the hard copy world. Journals provide a significant means of selection, while search mechanisms, notification lists (either from a server or directly from the author), even and word of mouth provide others. And the electronic era allows other models of selection—a possible model is that readers rate papers posted on servers, and you would consult the ratings to limit your search of interesting articles. Such a system has existed on the Net for movies since 1991 (<http://uk.imdb.com/organization>), and Hal Varian has proposed a similar system for academic articles.[28] There are many such rating systems under developement.[29] For example, Wisewire <http://www.empirical.com/emc/wisewire.html> takes an approach which is easily adaptable to academics. Topics are called *U-Zines*; we can imagine topics by JEL classifications). Again anyone can rate within a topic (or start a new topic), and the server (like a journal) then shows you papers which, by its software, determine similar interests to yours by your rating of papers.[30] While many hi-tech solutions have been proposed, it is interesting to note that

[25]Web browsers such as Netscape either with their standard html, or with a freely available Adobe Acrobat reader, are sufficient to display almost anything one may write. The CD-ROM version of the JEL uses Adobe Acrobat, and the reader is distributed on each CD-ROM. And Adobe Acrobat technology and the web are being used in a move in the U.K. by a number of U.K. publishers to put hundreds of journals on-line in U.K. libraries (Hitchcock, Carr, and Hall (1996)).

[26]The UK has legislated that in review of grants, electronic publications must be weighed equally with hard copy publications.

[27]The 20,000 may be conservative, since with 270 journals indexed in EconLIT and say 40 to 50 articles per journal, there are possibly 10,000 articles published each year.

[28]Papers in Informational Economics, <http://alfred.sims.berkeley.edu/pages/PIE.html>.

[29]See <http://www.sims.berkeley.edu/resources/collab/>.

[30]However, it is important to realize the current methods of selection are inherently messy: waiting for working papers to arrive, talking to local and remote colleagues, checking the JEL, waiting for the latest journals to arrive in the mail, and visiting a library for the latest journals. It may be unrealistic, and perhaps unfair to expect the on-line

on the E-Print Archive at Los Alamos, there are no such selection tools, in spite of more than 100 submissions a week to the archive. Apparently, physicists have little trouble sorting through this number, to find what is interesting and important.

Finally, there is the obvious problem of the "installed base" of paper journals. The Mellon Foundation has funded some interesting work in with the JSTOR (Journal Storage) Project <http://www.jstor.org/>, where they have taken back issues in seventeen economics, ecology, political science and history journals and used optical character recognition technology to create electronic versions. Details can be found in Varian (1997).

4 Databases, Access to Data, and Indices

The difference between the amount of external reviewing an article receives, and the data and programs underlying many articles, is striking. Many, if not most, published papers are refereed by at least two reviewers, and a substantial number are reviewed after resubmission. Next, an accepted paper is carefully copy-edited. Yet, the foundation of many papers—the data and the programs that use the data—are very rarely reviewed. In an ideal world, referees should review them as well—just as in theory papers the proofs are reviewed. A step in this direction now exists—the data and programs used in an article can be archived on-line. Three economics journals, the *Journal of Business and Economic Statistics* <ftp://ftp.duke.edu/jbes/>, the *Journal of Applied Econometrics* <http://qed.econ.queensu.ca/jae>, and the *Review* of the Federal Reserve Bank of St. Louis <http://www.stls.frb.org/research/reviewdata.html> request, if not require, data to be archived at their sites before the article is published.

Two studies on the availability and quality of data and programs are quite instructive. In the JMCB Project, (Dewald, Thursby, and Anderson (1986)), authors of papers accepted or submitted to the JMCB were asked to supply the data and programs used in their papers. Of those who were asked after the paper was published, only 35% did so (32% never even responded to the letter from the editor). However, 72% of those whose paper was still under review and 78% of those whose paper was accepted, but not yet published, were able to supply the data and programs. Unfortunately, of the datasets actually collected, only 15% were judged to be complete. Finally, replications were attempted with the data from nine papers. Only two articles could be replicated exactly and another two quite closely.

A follow-up study (Anderson and Dewald 1994) of the Federal Reserve Bank of St. Louis found generally similar results for papers given at one of their conferences—if data was requested after the fact, authors had trouble providing it. But, if the data was requested ahead of time, "Authors generally found it imposed little burden to submit data and programs with their manuscripts *so long as they were aware of the requirement in advance*, although the Bank's staff had to make some follow-up calls to clarify documentation."[31]

Thus, it appears that a researcher interested in obtaining someone else's data and programs will experience the same problems. This suggests that there may be substantial problems in our literature. But, at very little cost to the journals (running an archive site is relatively simple and low cost, particularly if it is centralized by an organization such as the AEA), and little cost to the

world to be a panacea.

[31] citeNAnderson, p. 83.

authors (if notified ahead of time), these problems can be ameliorated with an on-line archive. In short, the new technology of networks offers a real advance to the profession at low cost.

Some argue that authors should restrict access to their data,[32] but there are several arguments against this. A primary goal of academia is the freest possible exchange of information. For instance, the NSF mandates public disclosure of data from studies they fund (much of it is available on-line at the Inter-university Consortium for Political and Social Research <http://www.icpsr.umich.edu/>. The *Publication Manual of the American Psychological Association* tells its members to retain their data for a minimum of five years, and to make it available to all "competent professionals" as long as confidentiality and legal restrictions are upheld (American Psychological Association (1994), p. 283 & 298). Finally, NASA makes data from its newest series of space probes, the Discovery series, available when the data is collected (NASA (1996)). Surely the investigators who build and run these probes, a process that takes years, have more at stake than almost any economist in the data.

The economics of this issue are interesting. First, as noted by Hare and Wyatt (1992) and observed by countless economists, those that generate data seldom receive much credit.[33] This is partially due to the previous technological infeasibility of distributing data, which is no longer true. Currently the best way to receive a return from generating data is to use the data in publications. In the electronic world, journals cannot only archive data used in published articles, but can also have sections solely devoted to publishing data. Releasing the data in an article, in the current world, can reduce the incentive to generate it—an author may not have time to produce all the papers for which the data is a base before others write those papers. On the other hand, preparing data for release likely improves its quality and a citation to the data should be equally or more valuable than a citation to the article. Further, the organizations described above (NSF, APA, NASA, JAE, JBES) apparently have decided that reducing this incentive is worth the benefits it provides for generating more knowledge. Finally, given that "publication" of the data is possible in an electronic world, there is little reason not to require it—we certainly would not publish theorems without their proofs, so why publish empirical results without their proof?

Computer networks may change access to other sorts of data. Already, U.S. government agencies offer a very substantial amount of data over the Internet. With the exception of the Commerce Department's Bureau of Economic Analysis, data is freely available. This access is all but mandated by OMB Circular A-130, OMB () and section 3506.d of the more recent Paperwork Reduction Act of 1995 PRA () generally mandates public access to government data through "a diversity of public and private sources" at low cost. Interestingly, the resale of U.S. data is generally permitted. While the profession can hardly mandate that other governments follow the lead of the U.S. government, they should be encouraged—after all, their taxpayers paid for its collection. International agencies, such as the IMF and OECD, that receive U.S. funds should be encouraged to follow the U.S. lead as well.

To find publications, working papers and data, directories or databases are essential. Without them, one is effectively in a library without a card catalog. Already there are several in-

[32] Proprietary or confidential data raises some interesting replication issues. Should articles be accepted for publication which are based on data which no other researcher can access—ever? There are arguments on both sides of the issue.

[33] One significant exception is the Penn World Tables Summers and Heston (1991),<http://nber.harvard.edu/pwt56.html>.

dices for information for economists on the Internet: "Resources for Economists on the Internet" <http://econwpa.wustl.edu/EconFAQ/EconFAQ.html> and "WebEc" <http://www.helsinki.fi/~lsaarine/WebEc.html> are two of several general indices. "BibEc" <http://netec.mcc.ac.uk/BibEc.html> is a database of "hard copy" working papers, while "WoPEc" and "EconWPA" are databases of electronic working papers. Finally, "CodEc" <http://netec.mcc.ac.uk/CodEc.html>, "ELSA" <http://elsa.berkeley.edu/> are databases of programs in economics. and "GAMS" (Guide to Available Mathematical Software) at <http://gams.nist.gov/>[34] Finally, there are also many specialized databases that cover specific subfields, interests and topics (which are described in "Resources for Economists on the Internet" and WebEc).

While economists are skeptical about monopoly providers, a single database for each type of information may well be preferable to multiple, partially or non-overlapping indices. For instance, if each publisher had a separate database, only accessible to subscribers, and the information was not available elsewhere, networks would not provide much additional benefit to the profession in this area. Single databases appear to work reasonably well for the phone system, libraries,[35] and for Internet hosts (the Domain Name System, or DNS, which lies at the heart of the Internet). The trick, of course, is for the provider to face the correct incentives to operate in the best interests of the profession. Just as the AEA provides the *Journal of Economic Literature* to its members, it also needs to support and develop electronic databases for the benefit of its members.

5 New Opportunities

Previous sections examined how networking may change our profession's access to data, journals, and working papers in the near future. But, looking further ahead, other changes may occur in these or other areas, such as teaching. Some of the changes discussed in this section seem fairly certain, but others are frankly speculative.

Currently, journals are constrained by the medium they are distributed and stored on—paper. While it is a very convenient and time tested medium, it does possess limitations. For instance, color is quite costly to use. Connections within and between papers, such as endnotes and references, range from distracting to difficult to use in hard copy versions. With electronic journals and papers, a reference becomes a clickable entry, and notes can be pop-up items rather than something at the bottom of the page or end of the paper.

Some display technologies are simply impossible, such as movies or animation. While animations sound like a silly thing to use in an academic paper, think how changes in the yield curve over time could be displayed with an animation where each second a new day's curve is shown. With an electronic journal, all these technologies are possible and even easy—color is as easy to display as black and white, hyperlinks are a natural replacement for footnotes and references, and animation is quite common in multimedia.

Besides an electronic journal displaying dynamic material, the information in the journal it-

[34] Designed for numerical analysts, it lists roughly 10,000 useful programs. Besides being a nice database in and of itself, it is a very nice example of the utility of such databases.

[35] As a counterexample, the Duke University Library used to have two entirely separate card catalogs that varied depending upon the date of publication of the work.

self might become more dynamic. Other scholars could link their comments to a journal (perhaps only after the author prepared a response, with the author having the last word). Thus journals would more closely mirror the dynamic information they represent. As an example, Albert, Frieze, and Reed (1995), <http://ejc.math.gatech.edu:8080/journal/volume2/volume2.html\#R10> was submitted on April 25, 1995, and accepted in about two weeks. The authors posted a comment in late May, 1995 and a mistake in a proof was noted (in a fairly lengthy comment) in September 19, 1995. In the hard copy world, it might have been a year or two before the mistake was published and even then, most readers of the original article would fail to see the mistake as it would appear in a separate issue without any possibility that the original issue could forward reference the latter publication.

With links *to* papers, counting citations becomes integrated. That is, in an electronic journal, not only will an article contain references to other works, but links to that same paper also would be available instantly. This will make moving through the literature much easier—one could move forward just as easily as backward.[36] It might even lead to new ways of valuing scholarship, where citations are valued more highly than the placement of the paper. Indeed, it might even lead to an unrefereed literature. A more general version is Harnad's Harnad (1995) "scholarly skywriting," which he defines as "rapid electronic interaction," that "allows authors to interact directly with their peers at a tempo that keeps pace with the speed of thought (paper publication being hopelessly slow for it, and spontaneous speech, as in a live symposium, being perhaps too fast...)." It is already being used to good effect in *PSYCOLOQUY*. Thus, besides the usual journals and working papers, networks might usher in new forms of scholarly communication.

Poor communication between referees and authors seems to be a common complaint. Perhaps technology could offer a solution consistent with the academic tradition of blind reviewing—the anonymous remailer. Such e-mail systems take incoming mail, strip off all identifying information, and then forward it to the intended recipient. As an example, consider:

> An author posts her paper on EconWPA, and then fills out a web form for submission of the paper to a journal. The form is processed by software at the journal site, and it uses the information from the web form and a database of referees to select potential referees and to assign a manuscript number. The referee information and manuscript number are e-mailed to the editor, who then selects two referees. The manuscript number is sent to both referees and the author(s), and the referees access the paper on EconWPA. With some limits, the referees and author(s) use the manuscript number to send e-mail to the journal site which then redistributes it anonymously to the author(s) and referees jointly. It is archived so that the editor can view it at her leisure. The author(s) may 'prompt' the referees for a timely report from time to time, but more importantly, the author(s) and referees can 'discuss' the problems in the paper, inline rather than with such referencing as "at page 4 line 8, such and such..." Since all referees receive the same information, a joint decision can be reached, which is forwarded to the editor.

[36] For example, the paper hep-th/9304128, <http://xxx.lanl.gov/abs/hep-th/9304128> has thirty clickable citations to it. It takes only a moment to click forward and backward through the literature to discover a great deal of literature written about "Black Holes", the subject of this paper. The value of this paper is in part measured by its thirty citations.

With such a system, the refereeing process is faster and does not involve any administrative expense at the journal. It may even reduce the work of the editor since the referee and author can correspond directly if need be. No secretary need be involved in transmitting the reports back and forth. In addition, it would give referees an added incentive to be careful since the author could query them on their review. The pieces of this technology are in place now. In the future, anonymous "talk" and writing sessions could be used, and even anonymous audio sessions where the voice is distorted to keep anonymity will be possible. All of this will provide a faster and better review process.

To unambiguously date their work, academics could adopt "digital time stamps." This technology could reduce the sometimes fracas debates over when ideas were developed and would even be a weapon against plagiarism. See Haber and Storentta (1992), Surety Technologies <http://www.surety.com/> and PGP (Pretty Good Privacy, <http://www.itconsult.co.uk/stamper.htm>). However, the greatest deterrent to plagiarism is notoriety—electronic working paper archives with notification and search technologies provide the easiest means to greater notoriety, and hence the greatest deterrent to plagiarism.

Besides communication within the profession, networks could aid communication with our students. Networks facilitate interaction, between students and teachers, both intra- and inter-class. Initial experiments have been encouraging (Manning (1996)). In addition, networks provide a convenient forum for smaller papers and ideas for teaching.

6 Roadmap to the Future

It seems fairly clear that many changes will occur in the information flow of the profession. One important lesson comes from the development model of the Internet itself. Rather than designing a grand system with every possible feature, the Internet has been developed in an incremental fashion with repeated and frequent testing.[37] In addition, rather than adding every possible feature, stress is put upon getting a useful version working. The general idea is well expressed by the "Internet Credo:"

> We reject kings, presidents, and voting.
> We believe in rough consensus and running code.[38]

In addition, it would be wise to use standard Internet tools, such as web browsers and Adobe's Acrobat (PDF) format, as much as possible. These tools are rich enough to support almost anything economists might wish to do. When new tools must be developed, it should be done in an open manner. For example, a group of chemists have developed a standard way of exchanging viewable images of molecules that is freely available to all (MIME ()).

Such freely available standards and software has a long history on the Internet and likely stems in part from the Internet's genesis as a research and educational network. For instance, the math and physics professions use the TEX system and it variants, such as LATEX, for their word processing. They are freely available to all. While this system of freely available software may seem

[37] In fact, work has begun on replacing one of the key components of the Internet, the Internet Protocol (IP), which transfers packets from one host to another. Test code is already being run using the new IP version 6.

[38] *The Internet Society*, Internet Standards, <http://ftp.isoc.org/standards/>.

odd at first brush to economists, the non-pecuniary returns to the developers are substantial, and the indirect pecuniary returns can be quite substantial indeed, as these projects advertise skills to potential employers. But, something more than returns are at stake—for some these projects simply are enjoyable. Rather than building a model train set in the basement, some build Web pages, others write software, and some maintain archives, all as a hobby—but as a hobby that can be seen by millions. Larry Wall, the author of one of the most widely used, but freely available programming languages `Perl`, simply states "Just a personal note: I want you to know that I create nice things like this because it pleases the Author of my story. If this bothers you, then your notion of Authorship needs some revision. But you can use perl anyway. `:-)`"

With these concepts in mind, consider the development of electronic journals. Most are accessed using either html or Adobe Acrobat to display text and figures, and are accessed through the web. This combination offers the features needed for an electronic journal[39].

These tools cover the "back end" of the process—how to put a journal on-line given an electronic version of the paper. Another part of the process is the front end—how papers are processed before publication. The costs savings are likely to be considerable if this process (submission, copyediting, reviewing, etc.) is entirely electronic. Complete automation requires standard word processing tools—for example TEX. Needless to say, it seems extremely unlikely that economists will move to a common word processing system. However, a journal could insist on electronic submission in one of a few popular formats (say Word, WordPerfect, and TEXor LATEX) that cover the vast majority of economists.[40] Furthermore, with the sophisticated "style sheets" of these word processing systems, all authors would submit papers in the "look and style" of the journal.[41] In other words, typesetting could be entirely eliminated with the resultant cost savings.

Even the largest journals can be put on-line; a good example, with many valuable lessons, is the *Astrophysical Journal Electronic Edition* **AJEE**,<`http://www.journals.uchicago.edu/ApJ/`> is described by Boyce Boyce (1996). The *Astrophysical Journal* publishes approximately 25,000 pages per year. One of the chief design goals was to handle this amount of material with as little human intervention as possible. AJEE determined that they could not go partly electronic, and that it was ineffective to take the paper version of the journal and deliver it electronically. Each party to the publication had to participate to make the electronic journal work. The authors have to submit in AASTEX(a version of LATEX) to provide the structure of the document - title, author, abstract, sections, and references. Only with this structure can the submitted article be automatically transcribed into Standardized General Markup Language (SGML), wherein the database of references to the extant literature can be automatically linked and checked. The typesetter had to

[39]html stands for "hypertext markup language." Web pages are written in it, so it describes their elements: text, graphics, and links to other web pages and various media. Unfortunately, it is not the ideal method of displaying technical material since html does not natively support many mathematical symbols. PDF (portable document format), invented by Adobe Corporation as part of their "Acrobat" product line, is designed as "digital paper." Thus, it can accurately replicate any sort of table or mathematical expression, and even supports color, movies, and sound; it is ideal for technical papers. Adobe gives away "readers" for PDF that work closely with web browsers (they generate revenue from Acrobat by selling products that create PDF files). The programs that generate PDF files are quite flexible and work with many different programs.

[40]And they could charge whatever the additional cost is for other word processing formats. Authors who insist on using their own should bear that cost.

[41]The Student Economic Review, <`http://www.bess.tcd.ie/ser.htm`> requires its student authors to write and submit with Microsoft Word using its own style files. The on-line and print versions then require little copyediting.

do their copy-editing markup in SGML. From the SGML, both paper and electronic versions are created.

The benefits to a journal of this system are clear: more visibility for its editors and authors (and thus more citations). Further, in the near future, as journals transition to an electronic world, there will doubtless be opportunities for journals that aggressively move to this model—with much easier access, their use and status will rise. In the rapidly moving world of high technology, the field is littered with failed organizations that didn't adapt to changes in their environment.

Clearly, a substantial amount of work on the part of many will be required. Editors and others working with journals will need to become more familiar with the Internet and the different tools that produce electronic documents. In addition, indices will need to be further developed. Economists will have to get used to supplying information for these databases. Simply putting a working paper or dataset on a local web site without entering the information in a database is analogous to libraries putting books on their shelves without entering it in their on-line catalog.

The AEA sponsors a number of programs that support the profession beyond journals: their directories of economists, JOE, and the indexing of the JEL and EconLit. Already, the directory, and JOE are on-line (as is a home page with information about the association). The AEA could help with many network initiatives. Some would be in the nature of "infrastructure," such as developing "style sheets" for Word, WordPerfect, and LaTeX, so that papers produced by these word processing systems would have an identical look when placed in an on-line journal (thus, no typesetting would be required, dramatically reducing costs). Sessions at the AEA annual meeting on the nuts and bolts of electronic publishing would rapidly increase economists' human capital in this important area. To encourage other journals to establish on-line archives of data and programs, the AEA should establish an archive for the association's journals.[42] The archive might even be used for non-AEA journals. Another program would be to sponsor a freely available on-line journal to demonstrate the model described above, much like how the APA sponsors *PSYCOLOQUY*, or how the AMS cooperates with the *EJC*. Finally, the AEA should encourage its members it register their working papers and on-line data in databases so that other researchers can find them.

7 Conclusion

This paper is a first stab at how the information infrastructure for economists might change dramatically with the introduction of extensive computer networks. Rather than simply a new method of storing and moving information, networks might usher in a new era with radically easier access to publications, working papers, and data, which will benefit the profession as a whole. The most revolutionary change is Harnad's view of freely available journals. He first recognizes that an electronic journal will have much lower production costs. From that, he proposes that the costs of journals be borne by those who benefit from journals: the authors and their sponsors. As a result, journals become freely available and much more accessible. Similar, changes will occur in other parts of academic exchange: working papers and data. In addition, the medium open up a number of new possibilities. Finally, to make sure all these parts function smoothly, good indices of these materials are essential.

[42] After all, the AER states that its policy is to only publish papers with data that is "clearly and precisely documented and readily available." Putting data on-line would simply implement this policy.

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