The Future Information Infrastructure in Economics *

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Computers have already changed the lives of economists. The estimation of econometric models, the manipulation of data sets, word processing, and literature searches through EconLit are just a few examples of their impact. However, computers attached to networks may dramatically change our professional lives. The profession is now beginning to take full advantage of electronic mail and mailing lists, online access to card catalogs and U.S. government data. However, these changes may be only the beginning. Economists are now starting to participate in an online working paper culture, with more than 4,000 online working papers at last count; see *EconWPA* and *WoPEc*. Back issues of six economics journals (including the *American Economic Review* and the *Journal of Economic Perspectives*) are now available online (*JSTOR*), and a few other economics journals have current articles online (e.g., *Applied Economics*).

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

> Dr. Smith, reading an article in the latest JPE online with his PC in California, was surprised by a footnote that cited a recent article in the AER. He clicked 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 online archive for the paper's data set 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 online versions via a hypertext link (he was thankful those journals were online, 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 set. He then opened up a window to the AEA's index of data sets in economic publications (an outgrowth of EconLit). He soon found the data set online

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> at a journal archive in New Zealand. He contacted one of his graduate students in Virginia and they began an online 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.[1] In an hour, they had a new paper partially written.

In short, a fully networked world could offer much easier access to the working papers, articles, bibliographical information, and data that lies at the heart of much research and teaching. Indeed, some of this information is currently freely available at your desk through your computer (and it can be printed locally if desired). However, the path to the future is likely to be tumultuous. After all, technological change may not only alter existing practices, but may usher in entirely different institutional arrangements. In Scovill (1995), a report written by librarians, authors and publishers, three scenarios of the future are described including two where some publishers perish. The following scenarios are somewhat different given the different focus for this paper.

In one scenario, the technology of moving and storing information changes, but no fundamental change occurs in the relationships between librarians, publishers and readers. Although information will flow over networks, it will not be much more accessible. Instead, information will still be tucked away in distant libraries where you have no privileges, or at publishers' servers where you must purchase it. In this vision, libraries and publishers will play roughly traditional roles—publishers hold copyrights, libraries store information and journals, and they and users may pay fees for the electronic copies of material. In short, this future roughly maintains the status quo.

A second possibility is that scholarly material becomes freely available on the Internet, but is unorganized and all but impossible to find. This scenario could be labeled the "Field of Dreams Approach"—put it out there, and they will find it. This seems unlikely to us, since rational authors should quickly realize that readers will not find their work. At last count, there were tens of millions of web pages; one Internet search engine,*AltaVista*, recently found more than 1,000,000 documents containing the word "economic," and more than 5,000 with "Adam Smith." And in fact these publicly available web search engines only index a "only a small, flawed, arbitrary and not even random sample of what is on the web today... 31 million pages...out of as many as 150 million pages" (Pike, 1997).

Even if commercial search engines improve their abilities to sift the wheat from the chaff, it is doubtful that they will concentrate much on the academic arena. Authors who want their work to be read will need to post their papers to a working paper archive like *EconWPA*, or register the paper with an index like *WoPEc*.

We argue for a better future, in which information will be easily found and accessed. This paper offers a conceptual view of how computer networks should change the way we work. The guiding philosophical principle behind our discussion is that in academia, a primary goal is the growth, acquisition, and dissemination of knowledge, which is aided by the freest possible access to information produced by and for academics. Many academic practices illustrate this approach: publication of results, freely available material in libraries, conferences open to all, non-profit maximizing academic organizations, and free or inexpensive working papers. Throughout our discussion, it is important to keep this principle of greatest possible access to academic information at the lowest possible cost in mind. From this point of view, we examine the flow of information in the profession and how it might change with the arrival of computer networks. We begin

by discussing the impact of computer networks and the information technology on working papers, journals, libraries, data, and indices to information. Then, we will look at altogether new opportunities which may arise, and suggest a roadmap for moving to a networked world.

We hope that this paper will encourage debate in our profession about how to organize the flow of information that is critical to our professional lives. This paper also contains a brief overview of how networks will influence academia; more details and speculation 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*. Bailey (1996) contains a very extensive bibliography.

Journals

The impact of computer networking technology on journals is well explained by Kahin (1995): "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 that model, publishers and libraries formed a pipeline between authors and readers, and to some extent, publishers and libraries had a division of labor. But "in the networked environment," Kahin writes, "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."

There are a number of different models for online journals[2] which have different implications for authors, libraries and publishers (Grycz, 1992; Harnad, 1995; Odlyzko, 1995). Among the most revolutionary is Harnad (1995), who presents a view of how the entire journal industry may be upended with the introduction of networks. Harnad first makes the distinction between the "trade" and "esoteric" author. The trade author expects to be paid for his work; journalists and writers of popular books are trade writers in Harnad's sense, and so are academics when they write textbooks. The esoteric author resides almost entirely in academia: the authors do not expect to be paid directly for their words; the market for a particular work is very small; and they sometimes even pay for their words to reach more readers (such as paying for and sending reprints). Their pay is tied to their recognition and status, which is indirectly gained from the words they write. Thus, esoteric authors want their words to be as freely accessible as possible. Harnad writes:

> 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 . . . been willing to make the "Faustian" bargain of trading the copyright for their words in exchange for having them published. ... 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).

Harnad then argues that "with the advent of electronic publication, the Faustian era for esoteric authors is now over. The per-page cost is so much lower for purely electronic publication than

for paper (if one reckons it properly) 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* and the online journal *Psycoloquy*, sponsored by the American Psychological Association (APA). There are two components to costs: distribution costs and "first copy" costs (all the costs up to distribution). Distribution costs for an online journal approach the trivial. Harnad argues that the savings for first copy costs of a totally electronic journal over a paper journal are on the order of 70-90%. Some find these cost reductions implausible (Scovill, 1995, p. 15), but others, such as Odlyzko (1995), are convinced.

A study by Jog (1995) of six academic journals shows that the average journal in the study costs $70,000 per year to produce. Typesetting (9%), printing (28%), and shipping (12%) costs account for almost 50% of the costs of the journal. Administrative costs were 25%, while editorial expenses were 23%. The paper-based costs of publication would disappear with an online journal. Some journal administration can also be automated and handled electronically (but that could also be done for a paper based journal). Editorial copy-editing expenses can be reduced. For example, if authors are required to submit the paper in a particular style format, then the journal's expenses of preparing a paper for the typesetter can be substantially reduced. Currently, authors with poorly copy-edited manuscripts are subsidized and efficiency would dictate that the authors rather than subscribers bear those costs. Springer-Verlag sometimes requires submission of LaTeX in a Springer style, and no copy-editing is done. Kluwer has its own LaTeX style files. Some math journals now reject any submission that is not in AMS-TeX and most psychology and education journals reject submissions that are not in APA format.

Editorial text-editing costs do not change much in the electronic world. The cost reduction debate may be mostly a question of how much editorial text-editing is done by a journal—some journals do little or none while others do a substantial amount. In any event, we believe that the costs of an online journal are easily 50% less than those of a hard copy based journal, and can be 100% less. One excellent example is the *Electronic Journal of Combinatorics* which is free and which has no direct costs. Editors, and referees serve for free, there is no copy or text editing, submissions are in TeX, and software produces the journal.

Pricing electronic journals, when there are first copy costs, brings up a number of interesting issues. The knowledge in journals represents a pure public good, as Arrow (1962) noted. Journals themselves 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 (Ordover and Willig, 1978). In Harnad's system, journals become a pure public good (in distribution) with the cost of providing this good borne by those who benefit the most from it: the authors and their sponsors. Although readers also benefit—not only from the content of the paper but also from the selection mechanism (editorial and referee process)—charging them reduces the readership which the esoteric author does not want. In addition, as pointed by Varian (1995), electronic journals, with relatively high first copy costs in comparison to distribution costs, face decreasing average costs, thus making it difficult to recover costs if goods are priced at marginal cost. But, with Harnad's system, journals are priced at zero and the costs (if any) are borne by those who benefit the most.

Harnad proposes that the costs of producing an online journal can be collected in several ways. Professional societies, universities, private foundations or the National Science Foundation might pay for the first-copy costs of an online journal. In effect, this means that the public good is purchased through some manner of collective decision. A second possibility is that journals would

be supported by a small page fee. This might be collected from either authors or their sponsors; for example, most science journals impose page charges. Or charges might be collected from those who make the information accessible to others, like libraries or universities. In any case, the works will then be freely accessible and available to readers.[3] This makes sense from the standpoint of "esoteric" authors, who would like to have their material broadly available. Also, since the marginal cost of distribution is close to zero, economic theory would seem to argue that distribution at close to zero cost would have desirable efficiency properties (if hard copy is desired, then the individual reader bears the cost when they print out a copy).

It is also worth remembering that the cost of paper journals involves a number of opportunity costs that go beyond their production cost. Even if you have the journal in your office, you cannot search it electronically, but instead you must look through indices for individual years. The physical presence of a journal also takes up precious shelf space. If you want to read just one article, you must still carry the entire journal with you. Getting a journal from the library entails a round-trip of perhaps half an hour, assuming the journal is carried by the library and it is correctly shelved and no one else is using it including the bindery. If a local copy is not available, inter-library loan can take days or weeks. In the online world described above, any journal can be read with just a few clicks of a mouse. These costs must be balanced against online costs—equipment costs, learning to use electronic media, less portable media or local printing costs, etc. However, those online costs are shrinking daily due to advancing technology and general computer usage so that the balance is tipping (quickly) against hard copy.

There are a growing number of totally online journals, including *Psycoloquy*, the *Electronic Journal of Combinatorics*, the *Electronic Journal of Differential Equations*, and *Geometry and Topology*. All are freely available to readers, with first copy costs supported by others when there are any first copy costs. Hundreds of others are listed in Association of Research Libraries (1996).

Working Papers

Harnad's vision of completely free distribution of esoteric writing is reality in the field of high energy physics. In 1990, a group of high-energy physicists around the world were sending their research papers to each other through electronic mail by using a list of electronic mail addresses. Paul Ginsparg, a physicist at Los Alamos National Laboratories and a very competent programmer, created what is now known as the *E-Print Archive*, at Los Alamos National Laboratories. Submissions are made by authors, writing in TEX or LATEX. From the submission, software automatically creates PostScript and Acrobat PDF files (which are excellent electronic formats for technical papers as they readily display any graph or symbol). Readers access the system via the Internet by e-mail, ftp, and WWW browsers. E-mail notification lists notify subscribers each day of new submissions. Submissions are not only electronically 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*. Thus, each paper has its own built-in citation index (see Ginsparg, 1996).

This archive has been very successful. It is accessed about 70,000 times per day by over 35,000 users in 70 countries. The number of submissions to the most active area—high-energy physics-theory—is typically over 200 a month. Over 30,000 preprints are stored. Most if not all

high-energy physicists no longer consult hard copy journals, only the electronic archive, and some senior physicists are rumored to no longer bother with paper publications. There are many reasons for this success, not all of them applicable to the economics profession. The *E-Print Archive* began with a core of fewer than 100 researchers who used the archive; they all wrote using TEX; they were technologically adept at using e-mail; the peer review process for high energy physics is such that most papers are published within six months with very few revisions; hard copy preprints were very costly to some institutions requiring budgets of $20,000 or more; there was considerable international involvement, or at least collaboration; and research results were demanded on a timely basis (days rather than years).

One might think that with no peer review or selection process, the archive would be cluttered with junk, much like the Usenet physics newsgroups or the unmoderated economics newsgroup *sci.econ*.[4] However, in six years of operation, there is no junk (at least according to Ginsparg). The absence of junk may in part be due to the fact that with e-mail and Usenet, communications are nearly immediate, require far less effort than posting a paper, and are less formal than papers.

To get a handle on the possible cost savings from electronic publication we compare the cost of the *E-Print Archive* at the Los Alamos to the costs of the AER. The *E-Print Archive* was established with at most a couple of weeks of Paul Ginsparg's time writing the software that handles the archive's functions automatically, and originally was hosted on a machine which he also used for other purposes. The current cost for storage alone is less than six cents per paper, and less than sixty cents per paper per year including maintenance and depreciation.[5]

A much higher estimate of the cost can be made using the 1995 NSF grant to the archive. By unfairly attributing all of the $1,069,900 34 month grant to the archive's operating costs ($31,468 per month), and dividing by a typical month's submissions, 1,363 in February of 1997, we have $23.09 per paper. For 1995, Hinshaw (1996) reports the budgeted expenses of the AER were approximately $967,000, and in that year, the AER published 175 articles, including long and short articles, comments and proceedings, which is an average cost of $5,622 per article. Ashenfelter (1996) reports that printing and mailing costs were $447,709 (46% of total costs, in line with Jog's estimate), or $2,603 per article Thus, by either, average total costs ($5,622 to $23.09), or average distribution costs ($2,603 to sixty cents), there is a very substantial difference in costs.

Admittedly, this comparison—which is almost too sketchy even to qualify as back-of-the-envelope—has biases. The AER includes an editorial, referee and copy-editing process; in 1995, the AER processed 919 papers or $565 per submission ($519,291 for non-distribution costs divided by 919 submissions). The *E-Print Archive* publishes working papers (preprints) as they are. These comparisons also do not include shelf space, time, and search costs, etc. for hard copy, or equipment or learning costs on the electronic side. Nonetheless, the difference in cost is striking, and quite supportive of the notion that a fully online journal can bring dramatic reductions in cost.

Other Issues of Online Distribution

Moving to an online world involves a number of issues for the profession. For example, how might electronic publication affect the quantity of economics papers and journals? Although technology has made it easier to write papers, especially joint authorship (using networks rather than hard copy systems), it still takes a substantial amount of time to write a paper and the underlying reasons for

writing one more paper have not changed. Our guess is that the quantity of output of economists is unlikely to substantially change. However, the number of journals could either rise or fall dramatically. With space limitations no longer a constraint, prominent journals could choose to expand in size, or perhaps once papers are be posted to a well-known archive, prominent economists will follow their physics brethren in not bothering with paper publication. These trends would reduce the number of journals. Conversely, it is possible that the low costs of electronic publication could cause a number of specialized journals to spring up.

Indeed, it seems plausible to us that electronic publication could be the savior of many journals that are either highly specialized, or appear at the middle or lower levels of journal rankings. Many libraries, under great budget pressure, are now canceling subscriptions to these journals. Without the opportunity to maintain broad availability at lower cost through online publication, many of these journals could fold, much as the scholarly monograph market has in other areas of academia.

A number of issues revolve around the question of how readers will find the material they are seeking in an networked world. Consider the *E-Print Archive* with some 16,000 submissions per year, all of which are available on your desktop computer. Economics certainly produces a similar number of working papers each year. Just because you don't receive all of them does not mean that you have an optimal selection method currently. At least with online distribution, we can eliminate one inefficient selection mechanism—the cost of hard copy distribution.

Journals will probably provide one important selection mechanism. After all, most of the value of a hard copy journal is in its refereeing and editorial process and this will not change; online journals will provide the same services. In addition, an online journal can assure the reader it has the most up-to-date or final version of an article, along with any comments on it. More importantly, current hard copy journals, due to publication lags, provide little selection for current (less than a year old) research. As online journals will least avoid publication lags and backlogs of the hard copy world, their selection services will be far more timely.

There are other means of search and selection than by journals. For example, notification lists can be sent by e-mail, either from a server or directly from the author. Electronic search mechanisms can easily be set up to search by JEL subject category or by a group of keywords. Electronic journals could count how often its papers are accessed, or how often they were cited in another paper. Another possibility would use the feedback from earlier readers as a guide for later ones. Readers could rate papers or articles, 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 (*Internet Movie Database*); more recently *WiseWire* (general web filtering) and *FireFly* (music) have appeared and more are under development (Varian, 1997) including one for academic articles (Varian, 1996).

While many hi-tech solutions have been proposed, it is interesting to note that on the *E-Print Archive* at Los Alamos, there are no such selection tools, in spite of more than 1,300 submissions in a month. Apparently, physicists have little trouble sorting through this number to find what is interesting and important. Finally, although navigating the online world is sure to have its frustrations, these should be placed in context. After all, current methods of finding material are messy as well; waiting for working papers or journals to arrive, talking with local and remote colleagues, checking the JEL, and visiting the library. Even an imperfect online world will likely be preferable to the present.

Yet another cluster of issues revolve around whether online journals will maintain certain levels of quality. Anyone can start an online journal, while hard copy journals require significant startup

effort. As with hard copy journals, authors will submit to and readers will read online journals that have high quality articles and they will ignore those that do not. The reputations of online journals, however, will depend more heavily on what they publish than who publishes them. Also, how will promotion, tenure, and annual review committees regard electronic publications? The United Kingdom has legislated that in review of grants, electronic publications must be weighted equally with hard copy publications. In the hard copy world, authors are willing to revise a number of times because without such revision, their paper does not receive wide distribution through a journal. But if wide distribution is possible without such revision, the pressure for honing an article may be reduced. While pressures for high quality and hence reputation will likely prevail, the transition may be bumpy.

For the short run, mixed paper and online journals are likely, with the online versions simply being an electronic version of the hard copy based journal.[6] Libraries and publishers tend to see the online future as simply adding another distribution method to their customers.[7] Librarians see one more demand on their budgets from paper journals who charge extra for the electronic version. However, we believe that in the long run something like Harnad's model of widespread online journals is both plausible and desirable. If that model comes to pass, then the current business model of libraries and publishers—which is based on paying for subscriptions—must change.

Finally, there is the obvious problem in the online world of making connections to the "installed base" of paper journals. The Mellon Foundation has funded some interesting work with *JSTOR* where they have taken back issues in a number of economics, ecology, political science and history journals and used optical character recognition (OCR) technology to create electronic versions. Details can be found in Varian's paper in this issue.

Databases, Access to Data, and Indices

There is a striking difference between the amount of external reviewing received by the typical journal article, and the amount received by the data sets and programs underlying the article. Many published papers are refereed by at least two reviewers, yet the foundation of many papers—the data sets and the programs that use the data sets—are very rarely reviewed. There is little reason not to require publishing data sets—journals certainly would not publish theorems without their proofs, so why publish empirical results without their evidence? It appears that the availability and quality of data and programs used in many publications are suspect. As described by Dewald, Thursby, and Anderson (1986) for the JMCB Project, only 35% of authors asked by the editor to supply programs and data after publication did so. Of the data sets collected, only 15% were judged to be complete. Replications were attempted with the data sets from nine papers, and only two articles could be replicated exactly and another two quite closely. Anderson and Dewald (1994) found generally similar results. But, if journals require authors to place their data sets online, clearly availability would improve, and likely quality as well, as the empirical work could be reviewed publicly.

A primary reason for the lack of access to data, of course, has been the previous technological difficulty of distributing data. However, it is now possible to archive data and programs. In fact, three economics journals, the *Journal of Business and Economic Statistics*, the *Journal of Applied Econometrics*, and the *Review (St. Louis Federal Reserve)* strongly request or require data sets to

be archived at their sites before the article is published. Anderson and Dewald (1994) reports the St. Louis Fed's experience of requesting data sets and programs *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." In addition, the JBES and JAE seem to have had little difficulty in obtaining data sets since the request is also made before publication.

Some argue that authors should restrict access to their data sets, but except for a very few cases involving proprietary or confidential data sets, the freest possible disclosure of information seems more appropriate. The NSF mandates public disclosure of data from studies they fund, and much of it is available online at the Inter-university Consortium for Political and Social Research. The *Publication Manual of the APA* 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, pp. 283, 298). NASA (1996) makes data from its newest series of space probes, the Discovery series, available when the data is collected. One suspects that these organizations have made an implicit cost-benefit calculation of their decisions, and have come out in favor of open access to data. Finally, closer to home, the official policy of the AER is to publish only papers with data that is "clearly and precisely documented and readily available." An online archive would implement this policy directly.

Online archives for data sets and programs are likely to change some professional incentives. As noted by Hare and Wyatt (1992) and countless other economists, those who generate data seldom receive much credit. Currently, the best way to receive a return from generating data is to use the data in a published article. But in the networked world, journals can archive data sets used in published articles and could even have sections *solely* devoted to publishing data sets. Someday perhaps a citation to an author's data will be a worthwhile addition to her vita.

Computer networks have already changed access to many types of data. For example, U.S. government agencies offer a substantial amount of data through 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 (Office of Management and Budget, 1996), and section 3506.d of the more recent Paperwork Reduction Act of 1995. Both state and local governments in the United States, and international agencies such as the IMF and OECD that receive U.S. funds, should be encouraged to follow the U.S. example in disclosure of data. After all, as this data is first produced for policy makers, the marginal cost of putting it online is quite low.

To find publications, working papers and data sets, directories or databases are essential. Without them, one is effectively in a library without a card catalog. Several indices for information for economists on the Internet already exist: *Resources for Economists on the Internet* and *WebEc* are two general indices; *BibEc* is a database of hard copy working papers; *WoPEc* is bibliographic database of online working papers; *EconWPA* is an automated archive of online working papers; *CodEc* and *Econometrics Laboratory Software Archive (ELSA)* are databases of programs in economics; and *Guide to Available Mathematical Software (GAMS)* lists 10,000 mathematical and statistical programs. 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 understandably skeptical about monopoly providers, a single database for each type of information may well be preferable to multiple, partially overlapping or disjoint indices. After all, single databases appear to work reasonably well for the phone system, most libraries and for Internet hosts (the Domain Name System, or DNS, which lies at the heart of the

Internet). We believe that just as the AEA has taken the lead in setting up JEL classification codes for indexing articles, it has a role to play in supporting and developing electronic databases for the benefit of its members.

Teaching

It is difficult to predict how the online world will affect teaching beyond providing articles, working papers, and data sets. Currently some publishers are supplementing principles texts with online sites that have both instructor aids and material for students, including biweekly current event exercises, news notification services, mailing lists, PowerPoint slides online, and lists of web sites. There are e-mail discussion lists for teaching[8] and many local lists for interaction between students and instructors. One of us requires that the book and the lectures be evaluated each week via e-mail. Many economists now post syllabi, previous tests, exercises, and exam results on web sites.

There are beginnings of online textbooks such as *Daniel* (an intermediate micro book) and *McCain* (a principles book). Whether these will replace, or just supplement current hard copy textbooks is uncertain. *Classroom Expernomics* is an online and hard copy journal with articles concerning the use of experiments in teaching economics. For example, the latest issue contains an experiment which demonstrates the effects on real aggregate output of anticipated versus unanticipated monetary policy. The *National Budget Simulation* is a simple but well done simulation to show trade offs in balancing the budget. The *Iowa Electronic Markets*, used in more than 70 classes in 30 universities, has actual money futures contracts which depend on economic and political events—participating in the market provides students with real incentives (a $5 to $500 investment is required to participate in the markets) to learn about markets and follow economic, financial and political news. The *Election Calculator* allows one to enter information about the state of the economy to forecast the winner of presidential elections, and the *FAIRMODEL*, developed by Ray C. Fair, can be used to forecast the economy, adjusting various policy or even structural components. Of course most government agencies have web pages so that, for example, the Federal Reserve and the US Treasury can be directly consulted in teaching about money. Thus, networks mean that resources invested in developing material for class can be made available for others at little cost. Hence, we can imagine selecting from multiple sources to compile a personalized online textbook, and certainly a personalized online collection of online articles, similar to what is done now in hard copy.

Further in the future, videos of lectures for students who miss class, or videos of lectures from the best people in the field can be distributed. Even Nobel lectures can be made available, as well as sessions from meetings. The technology for all of this now exits, only implementation and use remain.

New Opportunities

In the near future, computer networking is likely to change our profession's access to data, journals, and working papers. This section discusses changes that are further off. Some seem fairly certain; others are frankly speculative.

Currently, journals are constrained by the medium of paper. While paper is convenient and time tested, it also has limitations. For instance, color is quite costly to use and motion is impossible. With an online journal, color is as easy to display as black and white, and animation is straightforward. While animation sounds like a silly thing for an academic paper, consider how changes in the yield curve over time could be displayed with an animation where each second a new day's curve is shown—see *Holden* for an actual example. Another example is the animation of complicated graphs, as illustrated by *Daniel*, a complete interactive intermediate micro text. When graphs are animated with changes in key parameters, the underlying concepts are much easier to understand.

Another limitation of paper is that connections within and between papers, such as references, citations, and endnotes, range from distracting to difficult-to-use. With online journals and papers, a reference becomes a clickable entry, and notes can pop up rather than lurking at the bottom of the page or end of the paper. In a world of online journals, this change can be far-reaching. For example, not only can an article contain references to past works, but also a list of works which cite *it*. For example, the abstract page of *E-Print Archive* is Schoutens, Verlinde, and Verlinde (1993) offers "*refers to*" and "*cited by*" links, where "*refers to*" is a link to the usual sort of references within the paper, while "*cited by*" is a link to papers that cite *this* paper. There are 30 citations there, nine from papers written in 1996, and 29 available online. It takes only a moment to click backward and more importantly forward through the literature. In effect, the *Social Science Citation Index* is built into the article—automatically. This may even lead to new ways of valuing scholarship, where citations to a paper are more valued than the original place of publication. At an extreme, this can even lead to an unrefereed literature, which would be a literature where the quality evaluation is made by readers after publication rather than by referees beforehand.

Online journals also offer the possibility of linking present articles to future comments and references, and thus ushering in a new style of scholarly communication. For example, in the *Electronic Journal of Combinatorics*, Albert, Frieze, and Reed (1995) was accepted and put online in early May 1995. The authors posted a comment in late May 1995 and a mistake in a proof was noted in a comment on September 19, 1995. In the hard copy world, it might have been a year or two before the mistake was published. Even then, most readers of the original article would fail to see the mistake as it would appear in a separate issue, and the original paper issue cannot refer to a later publication. But in an electronic journal, present comments can refer back to a past article, and past articles can refer ahead to future comments. A more general version of this interaction is Harnad's (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...)." This sort of interaction is already occurring in *Psycoloquy*.

Communication patterns between referees and authors might shift considerably as a result of online journals. Consider a refereeing system based on an anonymous remailer; that is, an e-mail system which takes incoming mail, strips off all identifying information, and forwards it to the recipient. For example, say that an author posts a paper on *EconWPA*, and then submits the paper to a journal by filling out its online submission form. The form is processed by software at the journal site, which assigns a manuscript number and identifies a set of potential referees. The referee information and manuscript number are e-mailed to the journal editor, who selects two referees. The manuscript number is sent to both referees and the author, and the referees access

the paper on the archive. They use the manuscript number in reporting back to the journal, whose software archives their comments, forwards them to the editor who can then automatically forward the comments to the author. Now the referees and the author could communicate anonymously by sending e-mail to the journal site, which redistributes it anonymously. More importantly, the author and referees can discuss the problems in the paper, in-line rather than with such referencing as "at page 4 line 8, such and such..." Notice that this refereeing process involves little administrative expense at the journal; no secretary need be involved in transmitting the reports back and forth. In the future, anonymous "talk" and writing sessions could even be used, and even anonymous audio sessions where the voice is distorted to keep anonymity will be possible. Whether this improves and/or speeds the referee process remains to be seen. The point is that it is possible and involves little cost.

To date their work unambiguously, academics could adopt "digital time stamps" to reduce the debates over when ideas were developed and could even be a weapon against plagiarism. For discussions of some possibilities, see Haber and Storentta (1992) and PGP Digital Timestamping Service. However, the greatest deterrent to plagiarism is notoriety—online working paper archives with notification and search technologies provide the easiest means to greater notoriety, and hence the greatest deterrent to plagiarism. While some worry about plagiarism of their online papers, note that with current technology (scanners and OCR software), plagiarism from hard-copy works is quite easy today.

Moving to an Online World

For existing economics journals, and potential journals of the future, the benefits of electronic publication are clear: a combination of lower cost, potentially higher visibility for editors and authors, and easier access to information for readers. In a rapidly moving technological world, some journals will ride their electronic versions to a greater prominence; and other journals will diminish in status by a failure to adapt to the online possibilities.

For a journal thinking about going online, perhaps the first step is to consider the front end—how papers are processed before publication. The costs savings are likely to be considerable if the processes of submission, copyediting, reviewing, and so on can be as fully electronic as possible. Although it seems extremely unlikely that economists will move to a common word processing system, a journal could insist on electronic submission in one of a few popular formats—say Word, WordPerfect, and TEX or LATEX—that cover the vast majority of economists. Authors who insist on using other formats will then bear the costs of that decision, as they should. Using the sophisticated "style sheets" of these word processing systems, all authors would submit papers in the "look and style" of the journal.

For a journal considering the back end problem of online distribution, it would be wise to use standard Internet tools[9] such as web browsers, HTML and Adobe's Acrobat (PDF) format. 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. Acrobat PDF (portable document format, invented by Adobe Corporation) is designed as "digital paper." Thus, it can accurately replicate any sort of table or mathematical

expression, and even supports color, movies, sound, links within and to external web sites, and can be fully indexed; it is ideal for technical papers. Adobe gives away "readers" for PDF that work closely with web browsers. The programs that generate PDF files are quite flexible. These tools are rich enough to support almost anything economists might wish to do.

Even the largest journals can be put online; one vivid example is the *Astrophysical Journal Electronic Edition*, as described by Boyce (1996). The AJEE publishes approximately 25,000 pages per year. A chief online design goal was to handle this material with as little human intervention as possible. To achieve this, each party to the publication process had to participate. The authors must submit in AASTEX (a version of LATEX), with the papers structured by title, author, abstract, sections, and references. Using this structure, the submitted article is automatically transcribed into Standardized General Markup Language (SGML), and the database of references to the extant literature is automatically linked and checked. The typesetter does their copy-editing in SGML. From the SGML, both hard copy and online versions are created.

Clearly, a substantial amount of work on the part of many in our profession 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. Indices will need to be further developed, and economists will have to get used to supplying information for these databases.

The AEA already sponsors a number of programs that support the profession, in addition to its three journals: a directory of economists, *Job Openings for Economists* (JOE), and the indexing of the JEL and EconLit. The directory and JOE are online (as is a home page with information about the association; see the *AEA Web Site*) and the JEL is distributed on CD-ROM in Acrobat format. We believe that the AEA could help its members with additional network initiatives. At a minimum, the AEA should encourage its members to put their papers online, in archives such as *EconWPA*, or at least register their working papers in indices such as *WoPEc* so that other researchers can find them. It should also encourage authors to place their data sets in online archives (*EconWPA* has a section for data sets) and begin their own data and program archive for their three journals.

There are a number of relatively minor programs the AEA could undertake. For instance, sessions at the AEA annual meeting on the nuts and bolts of electronic publishing could increase economists' human capital in this important area. Another step would be for the AEA to promote development of "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 online journal. In a "baby-step" toward electronic publishing, the AEA program could be put online rather than taking up valuable journal space in the September issue of the AER, and even the entire ASSA Program could be put online before the meeting. The Econometric Society did that for their program this year (see *Econometric Society Program*).

The AEA should take a real step towards electronic journals by publishing the *Papers and Proceedings* online. Currently, only about one quarter of the AEA seesions are published and those papers that are published are severly limited in size. The papers are not refereed nor is there much editing of the manuscripts. They are mostly limited to text with few tables or graphs. The printing cost alone is high ($109,457 for the 1995 issue, Ashenfelter 1996). Although the *Papers and Proceedings* appear in May, five months is a substantial lag given the nature of the papers (presentations, unrefereed and unedited). We believe that with electronic submissions (requiring authors or their secretaries to submit in an AEA style and format), the *Papers and Proceedings*

could appear by the first of March, or it could appear in May but with more refereeing and editing. There would be no limitations on size nor on graphs or tables. The cost savings and experience gained would provide a basis for putting the other AEA publications online. Along with publishing the *Papers and Proceedings* online, the AEA should put accepted papers online similar to what the *Journal of Finance* does. It has had enormous success.

Another example of how the AEA's costs could be lowered with networks is by electronic collection of the bibliographical material for the JEL and EconLit. Currently, much of this material is typed in. Instead, journals could submit the material electronically (many already have it from their production process), and the JEL would process this input for inclusion into its database. With a sufficient number of journals doing this, the fall in costs would be so substantial that EconLit could become freely available. While some costs are transferred to journals, they also benefit with greater notoriety of their results. Ultimately, journals that do not participate would be excluded from the the JEL and EconLit. This database would become more useful to members if it were integrated with online material. For example, the *Astrophysical Journal Electronic Edition* uses the *Astrophysics Data System* in its citations and bibliographies, and the *E-Print Archive* uses the *Stanford Linear Accelerator Center's Library Databases and Documents* physics database.

Finally, the AEA might consider sponsoring a complete freely available online journal, similar to the way that the APA sponsors *Psycoloquy*, or the American Mathematical Society cooperates with the *Electronic Journal of Combinatorics*. By providing a template for how this could be done, an electronic AEA journal would surely help the establishment of electronic journals across the profession.

Conclusion

Steven Harnad (in Okerson and O'Donnell, 1995, p. 90) observed: "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."

This paper is a first look at how the information infrastructure for economists will change with the Internet. Since the birth of our profession, most of our interaction has taken place through the exchange of paper, but that era is ending. While some changes to an electronic world might be long in coming, and while there may be some confusion along the way, the ultimate outcome will be exciting and generate many benefits. From working papers to journals to teaching to data, the ultimate changes will be profound—a new era of easy and open access to the information that lies at the heart of what we do. As a guiding light, it will be wise to keep the key academic principle of the freest possible access to information in mind. During this period of technological change, there will be many opportunities for innovative and enterprising individuals and institutions—all that remains is for them to grab the brass ring.

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Notes

[1]The final draft of this paper was edited this way with Microsoft NetMeeting, and the increased productivity was striking.

[2]We distinguish online journals from electronic journals. The JEL is available electronically on CD-ROM but not via the Internet.

[3]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 (1991) "copyleft"—copying is permitted, and the program can even be resold, but resellers cannot restrict further copying. Linux, claimed to be the world's second most popular version of Unix and authored by thousands of volunteers around the world, is "copylefted."

[4]Usenet is an electronic discussion system, sometimes known as news or netnews. It is similar to e-mail disucssion lists, but the messages are distributed with different technology. Some of the 20,000 or so newsgroups suffer from junk, while others do not.

[5]27,000 papers can easily be stored on a 9 gigabyte disk drive which costs $1600 or 5.9 cents per paper. If the drive is replaced every four years, and we include a $3400 computer every four years, and 100 hours per year maintenance of a $25 per hour system administrator, the total costs for four years is $11,600 or 55.5 cents per year per paper.

[6]There are many mixed journal projects: Johns Hopkins Press along with its collaborators have *MUSE*; Elsevier and nine U.S. universities have *TULIP*; Academic Press has *IDEAL*; and Kluwer and Dutch libraries have *Pica*. Chapman-Hall has a number of its print journals available online.

[7]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, 1994); perhaps the largest move is a number of British publishers will make hundreds of their journals available online through U.K. libraries (Hitchcock, Carr, and Hall (1996)).

[8]The largest seems to be TCH-ECON. To subscribe, send e-mail to <majordomo@majordomo.elon.edu> with *subscribe tch-econ* in the body of the message.

[9]Many of these tools are freely available. While this may seem odd to economists, it partly stems from the Internet's genesis as a research and educational network. Some is done as a hobby by extremely skilled individuals (perhaps one of the few hobbies whose benefits can be enjoyed by millions), and for others the indirect pecuniary returns can be very substantial as these projects advertise skills to potential employers. Finally, note that the math and physics professions depend upon TEX and LATEX for their word processing; these are freely available and are developed by volunteers.

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