6-1-1997

The Future Information Infrastructure in Economics

William L. Goffe
University of Southern Mississippi

Robert P. Parks
Washington University

Journal of Economic Perspectives—Volume 11, Number 3—Summer 1997—Pages 75–94

The Future Information Infrastructure in Economics

William L. Goffe and Robert P. Parks

Computers have already changed the lives of economists. A few examples of their impact include easier estimation of econometric models, the manipulation of data sets, word processing and literature searches through EconLit. However, computers attached to networks may change our professional lives even more dramatically. The profession is now beginning to take full advantage of electronic mail and mailing lists, and on-line access to card catalogs and U.S. government data—and these changes may be only the beginning. Economists are now starting to participate in an on-line working paper culture, with more than 4,000 on-line 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 on-line (through *JSTOR*), and a few other economics journals have current articles on-line (for example, *Applied Economics*).[1]

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

> Dr. Smith, reading an article in the latest *JEP* on-line with his personal computer in California, was surprised by a footnote that cited a recent article in

[1] All Internet sites referred to in this paper are italicized, and full addresses for them appear in the reference list; for the preceding paragraph, for example, these include listings for *EconWPA*, *WoPEc*, *JSTOR* and the site for *Applied Economics*. In addition, this paper itself can be found on the Internet, including PDF and HTML versions with active links to the Internet references given here, at ⟨http://econwpa.wustl.edu/eprints/mic/papers/9704/9704001.abs⟩.

■ *William L. Goffe is Associate Professor of Economics and International Business, University of Southern Mississippi, Hattiesburg, Mississippi. Robert P. Parks is Associate Professor of Economics, Washington University, St. Louis, Missouri. Their e-mail addresses are Bill.Goffe@usm.edu and bparks@wuecona.wustl.edu, respectively.*

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 on-line archive for the paper's data set in Tennessee and retrieved it. 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 set. He opened a window to the AEA's index of data sets in economic publications (an outgrowth of EconLit). He soon found the data set 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.[2] 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 among 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

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

labeled the "Field of Dreams Approach"—put it out there, and they will find it. This seems unlikely to us, since rational authors should realize quickly 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." In addition, these publicly available web search engines only index 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 another scenario, in which information will be easily found and accessed. This paper offers a conceptual view of how computer networks should change the way economists 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, nonprofit academic organizations, and free or inexpensive working papers. Throughout our discussion, it is important to keep in mind this principle of greatest possible access to academic information at the lowest possible cost. 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 that 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 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

Kahin (1995) explains well the impact of computer networking technology on journals: "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 on-line journals that have different implications for authors, libraries and publishers (Grycz, 1992; Harnad, 1995; Odlyzko, 1995).[3] 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 the "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 when they pay for 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 (1995) 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 journals' costs, where he speaks from experience—he edits both the paper journal *Behavioral and Brain Sciences* and the on-line journal *Psycoloquy*, sponsored by the American Psychological Association (APA). Costs can be divided into two components: distribution costs and "first copy" costs (all the costs up to distribution). Distribution costs for an on-line journal approach the trivial. Harnad argues that the savings for first copy costs of a totally electronic journal over a paper

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

journal are on the order of 70–90 percent. 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 percent), printing (28 percent) and shipping (12 percent) costs account for almost 50 percent of the costs of the journal. Administrative costs were 25 percent, while editorial expenses were 23 percent. The paper-based costs of publication would disappear with an on-line journal. Some journal administration can also be automated and handled electronically (although that could also be done for a paper-based journal). Editorial copyediting 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. Springer-Verlag sometimes requires submission of LaTeX in a Springer style, and no copyediting 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 on-line journal are easily 50 percent less than those of a hard-copy-based journal and can approach 100 percent less. One excellent example is the *Electronic Journal of Combinatorics*, which is distributed free and 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 personally, or go to the library and read a shared copy (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 readers will reduce the readership, which the esoteric author does not want. In addition, as pointed out 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 (if any) of producing an on-line 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 on-line 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 authors (for example, most science journals impose page charges), their sponsors, or 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.[4] 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 individual readers bear 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 costs. 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 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 is correctly shelved and no one else is using it, including the bindery. If a local copy is not available, interlibrary loan can take days or weeks. In the on-line world described above, any journal can be read with just a few clicks of a mouse. Of course, the on-line world has costs of its own: equipment costs, learning to use electronic media, less portable media or local printing costs, and so on. However, those on-line costs are shrinking daily due to advancing technology and general computer usage, and the balance is tipping (quickly) against hard copy.

There are a growing number of totally on-line 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 (1995) vision of completely free distribution of esoteric writing is already 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 Labora-

[4] 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."

tories. 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 web 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 where this paper is cited. Thus, each paper has its own built-in citation index (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 bother no longer 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.[5] However, in six years of operation, this has not happened (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 are papers.

To get a handle on the possible cost savings from electronic publication, we compare the cost of the *E-Print Archive* at Los Alamos to the costs of the *American Economic Review*. The *E-Print Archive* was established with a few weeks of Paul Ginsparg's time writing the software that handles the archive's functions automatically and originally was hosted on a machine that he also used for other purposes. The current cost for storage alone is less than 6 cents per paper, and it is less than 60 cents per paper per year including maintenance and depreciation.[6]

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

[6] A nine-gigabyte disk drive, which costs $1,600, can easily store about 27,000 papers, which works out to 5.9 cents per paper. If the drive is replaced every four years, and we include a $3,400 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.

A higher estimate of the cost can be derived by referring to 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 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 percent of total costs, in line with Jog's (1995) estimate—or $2,603 per article. Thus, by either, average total costs ($5,622 to $23.09), or average distribution costs ($2,603 to 60 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 copyediting process; in 1995, the *AER* processed 919 papers, or $565 per submission ($519,291 for nondistribution 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, search costs, and so on for hard copy, or equipment or learning costs on the electronic side. Nonetheless, the difference in cost is surely striking enough to support the notion that a fully on-line journal can bring dramatic reductions in cost.

Other Issues of On-Line Distribution

Moving to an on-line 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 through joint authorship (using disks and 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 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 budget pressure, are now canceling subscriptions to these journals. Without the opportunity to maintain broad availability at lower cost through on-line 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 a 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 your current method of selection is optimal. At least with on-line distribution, we can eliminate one inefficient selection mechanism—the cost of hard-copy distribution.

Journals will probably continue to 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; on-line journals will provide the same services. In addition, an on-line 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 current (less than a year old) research. As on-line journals will reduce the 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 their papers are accessed, or how often the papers 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 on-line 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 on-line world will likely be preferable to the present.

Yet another cluster of issues revolves around whether on-line journals will maintain certain levels of quality. Anyone can start an on-line journal, while hard-copy journals require significant startup effort. As with hard-copy journals, authors will submit to and readers will read on-line journals that have high-quality articles, and they will ignore those that do not. The reputations of on-line journals, however, will depend more heavily on what they publish than on 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 papers do 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 on-line journals are likely, with the on-line versions simply being an electronic version of the hard-copy-based journal.[7] Libraries and publishers tend to see the on-line future as simply adding another distribution method to their customers.[8] 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 (1995) model of widespread on-line 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 on-line world of making connections to the "installed base" of paper journals. The Mellon Foundation has funded some interesting work; *JSTOR* has taken back issues in a number of economics, ecology, political science and history journals and used optical character recognition 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? Further, 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 percent of authors asked by the editor to supply programs and data after publication did so. Of the data sets collected, only 15 percent were judged to be complete. Replications were attempted with the data sets from nine papers, and

[7] 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 on-line.

[8] 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 who will make hundreds of their journals available on-line through U.K. libraries (Hitchcock, Carr and Hall, 1996).

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 on-line, availability clearly 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 of the 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 on-line 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. 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 on-line archive would implement this policy directly.

On-line 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 already produced for policymakers, the marginal cost of putting it on-line 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 on-line working papers; *EconWPA* is an automated archive of on-line 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 on-line world will affect teaching beyond providing articles, working papers and data sets. Currently some publishers are supplementing principles texts with on-line sites that have both instructor aids and material for students, including biweekly current event exercises, news notification services, mailing lists, PowerPoint slides and lists of web sites. There are e-mail discussion lists for teaching[9] and many local lists for interaction between students and instructors. One of us requires that the book and the lectures be evaluated by students each week via e-mail. Many economists now post syllabi, previous tests, exercises and exam results on web sites.

There are beginnings of on-line 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 on-line and hard-copy journal with articles concerning the use of experiments in teaching economics. For example, the latest issue contains an experiment that 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 tradeoffs in balancing the budget. The *Iowa Electronic Markets*, used in more

[9] 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.

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 U.S. 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 on-line textbook and certainly a personalized on-line collection of on-line articles, similar to what is done now in hard copy.

Further in the future, lectures given earlier can be made readily available: everything from lectures for students who miss class to sessions from the AEA annual meetings to the Nobel lectures can be made available. The technology for this exists now: only implementation and use remain.

New Opportunities

Computer networking is likely to change our profession's access to data, journals and working papers in the near future. 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 on-line journal, color is as easy to display as black and white, and animation is straightforward. While animation may sound like a silly thing for an academic paper, consider how changes in the yield curve over time could be displayed with 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 on-line journals and papers, a reference becomes a clickable entry, and notes can pop up rather than lurking at the bottom of the page or at end of the paper. In a world of on-line 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 that cite it. For example, the abstract page of an article in the *E-Print Archive* by 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 and "cited by"

is a link to papers that cite this paper. There are 30 citations there, nine from papers written in 1996, and 29 are available on-line. 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, it could 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.

On-line 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 on-line 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 on-line journals. Consider a refereeing system based on an anonymous remailer; that is, an e-mail system that 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 on-line 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 it 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—on-line 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 on-line papers, note that with current technology, plagiarism from hard-copy works is quite easy today.

Moving to an On-Line 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 on-line possibilities.

For a journal thinking about going on-line, 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 on-line distribution, it would be wise to use standard Internet tools such as web browsers, HTML and Adobe's Acrobat (PDF) format.[10] 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

[10] Many of these tools are freely available. While this provision without charge 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). 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.

any sort of table or mathematical expression, along with color, movies, sound, links within and to external web sites, and indexes; 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 on-line; 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 on-line 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 copyediting in SGML. From the SGML, both hard-copy and on-line 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 could also play an active role. It 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 on-line (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 on-line, 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 on-line archives (*EconWPA* has a section for data sets) and to consider beginning its own data and program archive for the three AEA journals.

There are a number of additional relatively minor steps 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 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 on-line journal. The AEA program could be put on-line rather than taking up valuable journal space in the September issue of the *AER*, and the entire ASSA Program could be put on-line before the meeting. The Econometric Society did that for their program this year (see *Econometric Society Program*).

The AEA could also take an emphatic step toward electronic journals by pub-

lishing the *Papers and Proceedings* on-line. Currently, only about one quarter of the AEA sessions are published, and those papers that are published are almost all text, severely limited in size, and with few tables or graphs. The papers are not refereed, nor is there much editing of the manuscripts. The printing cost alone is high—over $100,000 for the 1995 issue (Ashenfelter, 1996). Although the *Papers and Proceedings* does appear in May, five months after the January meetings is a substantial lag given the unrefereed and unedited nature of the papers. With a requirement that authors make electronic submissions in an AEA-approved style and format, the *Papers and Proceedings* could appear much sooner. The electronic medium would impose no limitations on length, nor on graphs or tables (although such limits might be imposed for editorial reasons). The cost savings and experience gained would help provide a basis for putting the other AEA publications on-line. As one model, the *Journal of Finance* has had great success in putting accepted papers on-line.

The AEA's costs could be lowered with networks through 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. Some costs are transferred to journals in this system. But with a sufficient number of journals doing this, the fall in costs could be so substantial that EconLit could become freely available, which would benefit all journals by making their results more available. Ultimately, journals that do not participate would be excluded from the *JEL* and EconLit. This database would become even more useful to members if it were integrated with on-line 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 freely available on-line 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 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, we expect that 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 economists 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.

■ *We are in great debt to Timothy Taylor and the other editors for extensive comments and suggestions on previous drafts. We would also like to thank, without implicating, Mark Dickie, James T. Lindley, Frank Mixon and participants at the Second International Conference on "Computing in Economics and Finance" at Geneva in June 1996 for helpful comments.*

References

AEA Web Site, ⟨http://www.vanderbilt.edu/AEA/⟩.

Albert, M., A. Frieze, and B. Reed, "Multicolored Hamiltonian Cycles," *Electronic Journal of Combinatorics,* 1995, 2:10,⟨http://ejc.math.gatech.edu:8080/Journal/Volume-Z/volume2.html#R10⟩.

AltaVista, ⟨http://www.altavista.com/⟩.

American Psychological Association, *Publication Manual of the American Psychological Association.* 4th ed., Washington, D.C.: American Psychological Association, 1994.

Anderson, R. G., and W. G. Dewald, "Replication and Scientific Standards in Applied Economics a Decade After the *Journal of Money, Credit and Banking* Project," *Review, Federal Reserve Bank of St. Louis,* November/December 1994, *76*:6, 79–83.

Applied Economics, ⟨http://www.thomson.com:8866/ae/default.html⟩.

Arrow, K. J., "Economic Welfare and the Allocation of Resources for Invention." In the *Rate and Direction of Inventive Activity: Economic and Social Factors.* NBER Report, 1962.

Ashenfelter, O., "Report of the Editor," *American Economic Review,* 1996, *86*:2, 481–90.

Association of Research Libraries, *Directory of Electronic Journals and Newsletters.* ⟨http://arl.cni.org/scomm/edir/⟩, 1996.

Astrophysical Journal Electronic Edition, ⟨http://www.journals.uchicago.edu/ApJ/⟩.

Astrophysics Data System, ⟨http://adsabs.harvard.edu/⟩.

Bailey, C. W., "Network-Based Electronic Publishing of Scholarly Works: A Selective Bibliography," ⟨http://info.lib.uh.edu/sepb/sepb.html⟩, 1996.

BibEc, ⟨http://netec.mcc.ac.uk/BibEc.html⟩, Fethy Mili, ed.

Boyce, P. B., "Building a Peer-Reviewed Scientific Journal on the Internet," *Computers in Physics,* 1996, *10*:3, 216–21.

Chapman-Hall, ⟨http://www.chapmanhall.com⟩.

Classroom Expernomics, ⟨http://www.marietta.edu/~delemeeg/expernom.html⟩.

CodEc, ⟨http://netec.mcc.ac.uk/CodEc.html⟩, Dirk Eddelbuttel, ed.

Daniel, J. I., oo..Micro!, ⟨http://medusa.be.udel.edu/WWW_Sites/oo_Micro.html⟩.

Dewald, W. G., J. G. Thursby, and R. G. Anderson, "Replication in Empirical Economics: The *Journal of Money, Credit and Banking* Project," *American Economic Review,* 1986, *76*:4, 587–603.

E-Print Archive, ⟨http://xxx.lanl.gov⟩.

Econometric Society Program, ⟨http://gemini.econ.yale.edu/em97/sessions.html⟩.

Econometrics Laboratory Software Archive (ELSA), ⟨http://elsa.berkeley.edu/⟩.

EconWPA, Economics Working Paper Archive, ⟨http://econwpa.wustl.edu⟩, Robert P. Parks, coordinator.

Election Calculator, ⟨http://www.mit.edu/people/irons/myjava/ecalc.html⟩.

Electronic Journal of Combinatorics, ⟨http://ejc.math.gatech.edu:8080/journal⟩.

Electronic Journal of Differential Equations, ⟨http://ejde.math.swt.edu/⟩.

FAIRMODEL, ⟨http://fairmodel.econ.yale.edu/⟩.

FireFly, ⟨http://www.firefly.com/⟩.

Geometry and Topology, ⟨http://www.maths.warwick.ac.uk/gt/⟩.

Ginsparg, P., "Winners and Losers in the Global Research Village," ⟨http://xxx.lanl.gov/blurb/pg96unesco.html⟩, 1996.

GNU, "GNU General Public License," ⟨ftp://prep.ai.mit.edu/pub/gnu/COPYING⟩, 1991.

Grycz, C. J., "Economic Models for Networked Information," *Serials Review,* 1992, *18*:1-2, 11–18.

Guide to Available Mathematical Software (GAMS), ⟨http://gams.nist.gov/⟩.

Haber, S., and W. S. Storentta, "A Stamp of Authority," *Bellcore Exchange,* 1992, *8*:6, 15–20.

Hare, P., and G. Wyatt, "Economics of Academic Research and its Implications for Higher Education," *Oxford Review of Economic Policy,* 1992, *8*:2, 48–66.

Harnad, S., "The Postgutenberg Galaxy: How to Get There from Here," *Times Higher Education Supplement,* ⟨http://cogsci.soton.ac.uk/~harnad/THES/thes.html⟩, 1995.

Hinshaw, C. E., "Report of the Treasurer for the Year Ending December 31, 1995," *American Economic Review,* 1996, *86*:2, 479–80.

Hitchcock, S., S. L. Carr, and W. Hall, "A Survey of STM Online Journals 1990–95: The Calm Before the Storm," ⟨http://journals.ecs.soton.ac.uk/survey/survey.html⟩, 1996.

Holden, C. W., Excel-Based Interactive Software, ⟨http://www.bus.indiana.edu/finweb/holden.htm⟩.

IDEAL, ⟨http://www.apnet.com/www/ap/whatsnew.htm⟩.

Internet Movie Database, ⟨http://us.imdb.com/⟩.

Iowa Electronic Markets, ⟨http://www.biz.uiowa.edu/iem/index.html⟩.

Job Openings for Economists, ⟨gopher://vuinfo.vanderbilt.edu:70/11/employment/joe⟩.

Jog, V., "Cost and Revenue Structure of Academic Journals: Paper-based versus E-Journals," ⟨http://www.schoolnet.ca/biz/economics/vijayjog.html⟩, June 1995.

Journal of Applied Econometrics, ⟨http://qed.econ.queensu.ca/jae/⟩.

Journal of Business and Economic Statistics, ⟨ftp://ftp.duke.edu/jbes/⟩.

Journal of Economic Literature, ⟨http://www.econlit.org/⟩.

Journal of Electronic Publishing, ⟨http://www.press.umich.edu/jep/JEPtitle.html⟩.

Journal of Finance, ⟨http://www.cob.ohiostate.edu/~fin/journal/abstract.htm⟩.

JSTOR, ⟨http://jstor.umdl.umich.edu/jstor/⟩.

Kahin, B., "Institutional and Policy Issues in the Development of the Digital Library," *Journal of Electronic Publishing,* ⟨http://www.press.umich.edu/jep/works/kahin.dl.html⟩, 1995.

McCain, R. A. "Essential Principles of Economics: A Hypermedia Text," ⟨http://william-king.www.drexel.edu/top/prin/txt/Ecotoc.html⟩.

MUSE, Project Muse at Johns Hopkins University Press, ⟨http://muse.jhu.edu/⟩.

NASA, "Science Requirements (of Discovery Missions),"⟨http://mercury.hq.nasa.gov/office/discovery/scirequire⟩, 1996.

National Budget Simulation, ⟨http://garnet.berkeley.edu:3333/budget/budget.html⟩.

NSF, "NSF Announces Awards for Digital Libraries Research," ⟨http://walrus.stanford.edu/diglib/pub/nsf.announce.html⟩, 1994.

Odlyzko, A. M., "Tragic Loss or Good Riddance? The Impending Demise of Traditional Scholarly Journals." In Okerson, A., ed., *Scholarly Journals at the Crossroads: A Subversive Proposal for Electronic Publishing; An Internet Discussion about Scientific and Scholarly Journals and Their Future.* Washington D.C.: Association of Research Libraries, 1995, pp. 63–73.

Office of Management and Budget, "Circular A-130 (revised)," http://www.whitehouse.gov/WH/EOP/OMB/html/circulars/a130/a130.html⟩, 1996.

Okerson, A. S., and J. J. O'Donnell, *Scholarly Journals at the Crossroads: A Subversive Proposal for Electronic Publishing; An Internet Discussion about Scientific and Scholarly Journals and Their Future.* Washington D.C.: Association of Research Libraries, 1995.

Ordover, J. A., and R. D. Willig, "On the Optimal Provision of Journals qua Sometimes Shared Goods," *American Economic Review,* 1978, *68*:3, 324–38.

Peek, R. P., and G. B. Newby, eds., *Scholarly Publishing: The Electronic Frontier.* Cambridge Mass.: Massachusetts Institute of Technology Press, 1996.

PGP Digital Timestamping Service, ⟨http://www.itconsult.co.uk/stamper.htm⟩.

Pica, Dutch Centre for Library Automation, ⟨http://www.pica.nl/⟩.

Pike, J., "Flawed AltaVista Internet Search Engine," ⟨http://www.utopia.com/mailings/rre/

Flawed.AltaVista.Internet.Search.Engine.html⟩, March 1997.

Psycoloquy, ⟨http://www.cogsci.soton.ac.uk/psycoloquy/⟩.

Resources for Economists on the Internet, ⟨http://econwpa.wustl.edu/EconFAQ/EconFAQ.html⟩, William L. Goffe, ed.

Review (St. Louis Federal Reserve), ⟨http://www.stls.frb.org/research/reviewdat.html⟩.

Schoutens, K., E. Verlinde, and H. Verlinde, "Quantum Black Hole Evaporation," ⟨http://xxx.lanl.gov/abs/hep-th/9304128⟩, April 1993.

Scovill, L., *Librarians and Publishers in the Scholarly Information Process: Transition in the Electronic Age.* Washington, D.C.: Council on Library Resources, 1995, ⟨http://arl.cni. org/clr/Frontmatter.html⟩.

Stanford Linear Accelerator Center's Library Databases and Documents, ⟨http://www-spires.slac.stanford.edu/find/spires.html⟩.

TULIP, The University LIcensing Project. ⟨http://tulipsrvr.engin.umich.edu/tulip/⟩.

Varian, Hal R., "Pricing Information Goods," ⟨ftp://alfred.sims.berkeley.edu/pub/Papers/price-info-goods.pdf⟩, June 1995.

Varian, Hal R., "Papers in Informational Economics," ⟨http://alfred.sims.berkeley.edu/pages/PIE.html⟩, 1996.

Varian, Hal R., "Collaborative Filtering," ⟨http://www.sims.berkeley.edu/resources/collab/⟩, 1997.

WebEc, ⟨http://netec.wustl.edu/WebEc.html⟩, Lauri Saarinen, ed.

WiseWire, ⟨http://www.empirical.com/emc/wisewire.html⟩.

WoPEc, ⟨http://netec.wustl.edu/WoPEc.html⟩, managed by Jose Manuel Barrueco Cruz and moderated by Thomas Krichel.