Commercialization of the Internet: The Interaction of Public Policy and Private Choices

or

Why Introducing the Market Worked so Well

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1. Motivation

The National Science Foundation (NSF) managed the Internet backbone after 1986 and commercialized it between 1992 and 1994. Consistent with its mandate, the NSF confined use of the growing data network exclusively to research activity in government funded laboratories and educational institutions such as universities. Commercialization involved selling the backbone, rescinding management responsibility for any public data exchange points, and privatizing domain name registration. This allowed private decision making to apply Internet technology to commercial purposes and develop the contours of network infrastructure further. While these private decisions were circumscribed by several legacy institutions inherited from both the research community and the regulated telephone industry, commercialization introduced heavy influence from market forces.

Sufficient time has passed to begin to evaluate how the market performed after commercialization. Such an evaluation is worth doing. Actual events have surpassed the forecasts of the most optimistic managers at NSF. Was this due to mere good fortune or something systematic whose lessons illuminate the market today? Other government managed technologies usually face vexing technical and commercial challenges that prevent the technology from diffusing quickly, if at all. Can we draw lessons from this episode for the commercialization of other government managed technologies?

In that spirit, this paper examines the Internet access market in detail and on one set of actors, Internet Service Provides (ISPs). ISPs provide Internet access for most of the households and business users in the country (NTIA, 1999), usually for a fee or, more recently, in exchange for advertising. Depending on the user facilities, whether it is a business or personal residence, access can involve dial-up to a local number or 1-800 number at different speeds, or direct access to the user's server employing one of several high-speed access technologies. The largest ISP in the United States today is America-On-Line, although there are many others with recognizable names, such as AT&T Worldnet, MCI WorldCom/UUNet, Mindspring/Earthlink, and PSINet.

The Internet access market is a good case to examine. Facilities for similar activity existed prior to commercialization, but there was reason to expect a problematic migration into commercial use. This activity appeared to possess idiosyncratic technical features and uneconomic operational procedures which made it unsuitable in other settings. The Internet's exclusive use by academics and researchers fostered the perception that unanticipated problems would abound.

In sharp contrast to expectations, however, the ISP market displayed three extraordinary features. For one, this market grew *rapidly*, attracting thousands of entrants and many users, quickly achieving mass-market status. Second, firms offering this service became *nearly geographically pervasive*, a diffusion pattern rarely found in new infrastructure markets. And third, firms *did not settle* on a standard menu of services to offer, indicative of new commercial opportunities and also a lack of consensus about the optimal business model for this new technology. Note that all three traits -- rapid growth, geographic pervasiveness and the absence of settlement -- rarely appear together in technology markets or new infrastructure markets, so explaining this market experience is also interesting in its own right.

What happened to make commercialization go so well? This paper's examination reveals three themes. First, commercializing Internet access did not give rise to many of the anticipated difficult or insolvable technical and operational challenges. Entrepreneurs quickly learned that the Internet access business was commercially feasible. This happened for a variety of economic reasons. ISPs began offering commercial service after making only incremental changes to familiar operating procedures borrowed from the academic setting. It was technically easy to collect revenue at what used to be the gateway functions of academic modem pools. Moreover, the academic model of Internet access migrated into commercial operation without any additional new equipment suppliers.

Second, privatizing Internet access fostered customizing Internet access technology to a wide variety of locations, circumstances and users. As it turned out, this predominant business model was feasible at small scale and, thus, at low levels of demand. This meant that the technology was commercially

viable at low densities of population, whether or not it was part of a national branded service or a local geographically concentrated service. Thus, privatization transferred the operation of the technology to a new set of decisions makers who had new ideas about what could be done with it. Since experimentation was not costly, this enabled attempts to adapt the technology in new uses, new locations, new market settings, new applications and in conjunction with other lines of business. While many of these attempts failed in the ISP market, a large number of them also succeeded. These successes went well beyond what anyone would have forecast by examining the limited uses for the technology by non-commercial users prior to 1992.

Third, and not trivially, the NSF was lucky. It commercialized the Internet access industry at a propitious moment, at the same time as the growth of an enormous new technological opportunity, the World Wide Web. This invention motivated further customization and experimentation to take advantage of the new opportunity. As it turned out, the Web thrived under decentralized and independent decision making. Indeed, it is impossible to imagine that government managed technical development could have done as well.

The paper first developing these themes. Then it describes recent experience. It ends by discussing how these themes continue to resonate today.

2. Challenges during technology transfer: an overview

Conventional approaches to technological development led most observers in 1992 to be cautious about the commercialization of the Internet. To understand how this approach went awry, it is important to understand its foundations.

Many studies of the commercialization of technology emphasize the situated nature of technological development. Technologies do not simply spring out of the ether; instead, learning processes and adaptation behavior shape them. Users and suppliers routinely tailor technologies to short term needs,

making decisions that reflect temporary prices schedule or idiosyncratic preferences, resulting in technological outcomes that can only be understood in terms of these unique circumstances and origins.[1] Such themes resonate throughout studies of technologies which develop under government management.[2]

Seen through this light, the most problematic feature of the Internet was its long exclusive use by military, government or academic users. Prior to 1992 it had developed into the operations found at an academic modem pool or research center. These were small scale operations, typically serving no more than several hundred users, involving a mix of frontier and routine hardware and software. A small operation required a server to monitor traffic and act as a gate-keeper, a router to direct traffic between the Internet and users at PCs within a local-area-network (LAN) or calling center, and a connection to the Internet backbone or data exchange point operated by the NSF. These were often run by a small staff, either students or information technology professionals.

Revenues were not regularly collected in these arrangements and budgetary constraints were not representative of what might arise with commercial operations and competitive pressures. Many small colleges had opened their Internet connections with NSF subsidies. The organizational arrangement within research computing centers also was idiosyncratic, usually with only loose ties, if any, to the professionally run administrative computing centers of a university or research organization. The array of services matched the needs of academic or research computing, which had only a partial overlap with the needs of commercial users.

Any student of technology transfer would have confidently predicted that the transition into

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[1] The literature on general purpose technologies (Bresnahan and Trajtenberg [1995], Helpman [1998]) also helps frame these themes by highlighting the role of co-invention, defined as the complementary inventions which make advances in general purpose technologies valuable for particular organizations in particular places at particular points in time.

[2] For example, see studies of the supersonic transport (Cohen and Noll [1990]), nuclear power (Cowan [1988]), air frames (Mowery and Rosenberg [1992]) and the early history of computing (Flamm [1989], Goody-Katz and Phillips [1982]), among many such examples.

commercial markets would give rise to challenges. Standing in 1992 and looking forward, it was uncertain whether these challenges would take a long time to solve and whether commercial user's needs would be difficult to address. In general, conventional analysis classifies anticipated problems as one of three challenges: *technical, commercial* and *structural challenges.*

Technical challenges often arise during commercialization. Government users, government procurement and government subsidies result in technology with many features mismatched to commercial needs. Products possessed features for which vendors or users have no need. Alternatively, commercial vendors and users do not need other features. Thus, as a technical or engineering matter, a technology which is mature for exclusive non-commercial uses -- such as a military application -- may appear primitive in civilian use. It may require complementary inventions or entrepreneurial imagination to become commercially viable. If these requirements are considerable, then commercialization may occur slowly.

For example, military users frequently require electronic components to meet specifications that make the component reliable under battle conditions. Extensive technical progress is needed to tailor a product design to meet these requirements. Yet, and this is difficult to anticipate, an *additional* amount of invention is often needed to bring such a product design and its manufacturing to a price/point with features that meet more cost-conscious or less technically stringent commercial requirements.

Commercial challenges arise when commercial markets require substantial adaptation of operation and business processes in order to put technologies into use. In other words, government users or users in a research environment often tolerate operational processes that do not translate profitably to commercial environments. After a technology transfers out of government sponsorship, it may not be clear how to balance costs and revenues for technologies that had developed under settings with substantial subsidies underwriting losses, and research goals justifying expenditures. Hence, many government managed technologies require considerable experimentation with business models before they begin to grow, if they grow at all.

For example, the supersonic transport actually met its engineering targets, but still failed to satisfy basic operational economics in most settings. Being technically sleek was insufficient to attract enough interest to generate the revenue which covered operating costs on any but a small set of routes. No amount of operational innovations and marketing campaigns were able to overcome these commercial problems.

New technologies are also vulnerable to *structural challenges* that impede pathways to commercialization. Commercial and structural challenges are not necessarily distinct, though the latter are typically more complex. Structural challenges are those which require change to the bundle of services offered, change to the boundary of the firms offering or using the new technology, or change to the operational structure of the service organization. These challenges arise because technologies developed under government auspices may presume implementation at a particular scale or with a set of technical standards, but require a different scale for commercial applications.

For example, while many firms successfully provided the technical advances necessary for scientific computing in academic settings during the 1950s, very few of these same firms migrated into supporting large customer bases among business users. As it turned out, the required changes which were too dramatic for many companies to make. The structure of the support and sales organization were very different, and so too were the product designs. Of course, the few who successfully made the transition to commercial users, such as IBM, did quite well, but doing so required overcoming considerable obstacles.

In summary, migrating Internet access into commercial use appeared to foster technical, commercial and structural challenges. Why did the migration proceed so different than expected?

3. The absence of challenge in the Internet Access industry

Internet access technology is not a single invention, diffusing across time and space without changing form. Instead, access technology is embedded in equipment which uses a suite of communication technologies, protocols and standards for networking between computers. This technology obtains

economic value in combination with complementary invention, investment and equipment.

ISPs provide access, maintain it for a fee and develop related applications as users require. While sometimes this is all they do, with business users they often do much more. Many end-users do not want to (and do not know how to) set up and maintain Internet access themselves, nor are many Internet end-users familiar with all the possible ways in which Internet access can change their operations.

ISPs are in a position to install, operate and maintain a variety of Internet related services and many other things related to what a user does with Internet access. ISPs may help customize Internet technologies to the unique needs of users and their organizations, solving problems as they arise and tailoring general solutions to idiosyncratic circumstances. Sometimes ISPs do simple things such as filtering. Sometimes it involves much more, such as managing and designing email accounts, data-bases and web pages. Some ISPs label this activity consulting and charge for it separately; others do not consider it distinct from the normal operation of the Internet access services.

On the surface the record of achievement for ISPs is quite remarkable. Most recent surveys show that no more than 10 percent of US households get their Internet access from university-sponsored Internet access providers, the predominant provider of such access prior to commercialization. Today almost all users go to a commercial providers (Clemente [1998], Ebring and Nie [2000]). As of 1997, this ISP industry was somewhere between a three and five billion dollar industry (Maloff [1997]), and it is projected to be much larger in a few years. This happened because technical and commercial challenges proved to be relatively insignificant. In contrast, the structural challenges have been significant, but have not slowed the diffusion of access very much.

3.1 Technical challenges did not get in the way

The Internet access market did suffer from some technical challenges, but not enough to prevent rapid diffusion. Commercialization induced considerable technical innovation in complementary inventive

activities. Much of this innovative activity became associated with developing new applications for existing users and new users.

It is often forgotten that when the electronic commerce first developed based on TCP/IP standards, it was relatively mature in some applications, such as e-mail and file transfers, which were the most popular applications (these programs continue to be the most popular today, NTIA [1999]). To be sure, TCP/IP based programs were weak in others areas, such as commercial data base and software applications for business use, but those uses did not necessarily have to come immediately. The invention of the World Wide Web in the early 1990s further stretched the possibilities for potential applications and highlighted these weaknesses.

More important for the initial diffusion, little technical invention was required for commercial vendors to put this technology into initial mainstream use. Academic modem pools and computing centers tended to use technologies similar to their civilian counterparts -- such as bulletin board operators -- while buying most equipment from commercial suppliers. Moving this activity into the mainstream commercial sector did not necessitate building a whole new Internet equipment industry; it was already there, supplying goods and services to the universities and to home PC users. Similarly, much of the software continued to be useful – i.e., Unix systems, the gate-keeping software, and the basic communication protocols. Indeed, every version of Unix software had been TPC/IP compatible for many years due to Department of Defense requirements. A simple commercial operation only needed to add a billing component to the gate-keeping software to turn an academic modem pool into a rudimentary commercial operation.

Technical information about these operations was easy to obtain if one had sufficient technical background; a BA in basic electrical engineering was far more than adequate. Many ISP entrepreneurs had used the technology as students or in related lines of business. Descriptions of some of the earliest access operations show that they did not employ any exotic hardware or rare technologies (Kalakota and Whinston [1996], Kolstad [1998]). Many Internet bulletin boards quickly developed and Boardwatch Magazine,

among others, expanded its focus from bulletin boards to ISPs as early as 1994, also spreading information about how to operate such ventures. In addition, the Commercial Internet Exchange (CIX), among many industry trade groups, came into existence quite quicky, acting as an information clearing house about policy issues, an area that might have seemed arcane to a technical entrepreneur.

Users with investments in networking technology, such as LANs or simple client/server architectures, also could adopt basic features with little further invention. Internet technologies associated with textual information had incubated for twenty years and were well past the necessary degree of technical maturity necessary for mainstream use. Telnet, FTP and the basic protocols for email were widely diffused and relatively easy to use. Some communication software already used TCP/IP and many of the common programs could easily adapt to it. There were already many similar technical activities taking place in commercial settings. TCP/IP compatibility was built into Windows 95, which further eased investments for users after 1995.

The basic commercial transaction for Internet access also did not raise prohibitive technical issues. Most often it involved repetitious and on-going transactions between vendor and user. A singular transaction arose when the vendor performed one activity, setting up Internet access or attaching Internet access to an existing computing network. If the ISP also operated the access for the user, then this on-going operation provided frequent contact between the user and vendor, and it provided frequent opportunity for the vendor to change the delivery of services in response to changes in technology and changes in user needs. This worked well because in many cases an ISP was better educated about the technological capabilities than the user. In effect, the ISP sold that general knowledge to the user in some form that customized it to the particular needs and requirements of the user. At its simplest level, this provided users with their first exposure to a new technological possibility while educating them about its potential.

Often access went beyond exposure to the Internet, especially with a business user, and included the installation, maintenance and training, as well as application development. These types of transfers of

knowledge typically involved a great deal of nuance, often escaped attention, and yet, were essential to developing infrastructure markets as an on-going and valuable economic activity. The technology lent itself to this small scale customization because it was easy to adapt to PC use or widely available LAN technology. The basic technical know-how did not differ greatly from routine knowledge found in the computing services sector prior to commercialization.

Finally, some NSF decisions and legacy regulatory decisions also aided. When the NSF took over stewardship of the Internet backbone, it invested in developing a scalable system of address tables and IP-address systems. Subsequent growth tested those investments and inventions; no surprise problems were found, nor did any engineering problems hinder growth. Domain name registration also remained a gentle monopoly until recently. Data exchange points remained organized around the cooperative engineering principles used within the NSF days. A competitive data communications industry was beginning to reach adolescence at about the same time as commercialization and provided additional access points for new firms, particularly in urban areas. So as a technical matter, interconnection with the public switch network did not pose any significant engineering challenges (Werbach [1997]).

3.2 Commercial challenges did not slow diffusion

Internet access was built in an extremely decentralized market environment. Aside from the loosely coordinated use of a few de facto standards (such as the World Wide Web consortium), government mandates after commercialization were fairly minimal. ISPs had little guidance or restrictions. They were therefore able to tailor their offerings to local market conditions and to follow entrepreneurial hunches about growing demand.

As a technical matter, there were few barriers to entry in the provision of dial-up access. As a result, commercial factors, and not the distribution of technical knowledge among providers, largely determined the patterns of development of the basic dial-up access market immediately after

commercialization. To the surprise of many, the operational procedures developed over two decades lent themselves to the early commercial implementations, fostering a foundation for commercial growth. As with many new markets which spawn in non-commercial environments (Ventresca, et al [1998]), many features were borrowed wholesale and without question. In effect, entrepreneurs borrowed the organization of the academic modem pool and tried to put a revenue generating function on top it. Billing software was added to the basic gateway component, and once this proved to be a feasible way to collected revenue, many entrepreneurs built on top of that commercial form.

Shortly after commercialization in 1994, only a few commercial enterprises offered national dial-up networks with Internet access, mostly targeting the major urban areas. Pricing was not standardized and varied widely (Boardwatch, 1994-1995). Most of these ISPs were devoted to recreating the type of network found in academic settings or modifying a commercial bulletin board with the addition of backbone connections, so interconnection among these firms did not raise insoluble contracting or governance problems. These ISPs were devoted primarily to dial-up; few ISPs attempted sophisticated data-transport over higher-speed lines, where the regulatory issues could be more complex and where competitive local exchange competitors were developing the nascent market.

Very quickly ISPs learned that low cost delivery required locating access facilities close to customers. This had to do with telephony pricing policies across the US. The U.S. telephone system has one pervasive feature; distance-sensitive pricing at the local level. In virtually every part of the country, phone calls over significant distances (i.e., more than thirty miles) engender per-minute expenses, but local calls are usually free. Hence, Internet access providers had a strong interest in reducing expenses to users by providing local coverage. Unmet local demand was a commercial opportunity for an entrepreneurial ISP.

As it turned out, access over dial-up lent itself to small scale commercial implementations. Several hundred customers could generate enough revenue to support physical facilities and a high-speed backbone

connection in one location, so scale economies were not very binding. The marginal costs of providing dial-up services were low and the marginal costs of expansion also fell quickly, as remote monitoring technology made it cheap to open remote facilities. The marginal costs to users of dial-up service were also low in response, involving only incremental changes for organizations that had experience with PC use or LAN technology. It was easy to generate revenue in subscription models, where a commercial firm withheld availability of access unless payment was made. Hence, the economic thresholds for commercial dial-up service turned out to be feasible on a very small scale, encouraging small firms and independent ISPs. To be sure, many firms also tried to implement access businesses on a large scale, but the economic advantage of large scale did not preclude the entry of small scale firms, at least not at first.

Finally, decades of debate in telephony had already clarified many regulatory rules for interconnection with the public switch network, eliminating some potential local delays in implementing this technology on a small scale. The FCC treated ISPs as an enhanced service, not passing on access charges to them as if they were competitive telephone companies, effectively making it cheaper and administratively easier to be an ISP. This decision did not receive much notice since most insiders did not anticipate the extent of the growth that would arise. As ISPs have grown and as they threaten to become competitive voice carriers, these interconnection regulations have come under more scrutiny (Sidek and Spulber [1999], Weinberg [1999]).[3]

In retrospect, two key events of 1995 set the stage for the commercial ISP market for the remainder of the decade. The first was the Netscape IPO in August 1995. The other was the entry of AT&T World Net.

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[3] If anything, regulatory decisions for reciprocal compensation of competitive location exchange providers (CLECs) encouraged CLEC entry, which also partly encouraged ISP entry through interconnection with CLECs. Though important to incumbent local exchange carriers, however, one should not exaggerate this too much. The scale of this phenomenon grew tremendously in the late 1990s, but ISP entry started well before then. Moreover, since CLEC entry was primarily concentrated in dense urban areas, much of this effect was felt in urban areas, which would have had a great deal of ISP entry even without this implicit subsidy to CLECs.

The World Wide Web was certainly known in the academic community in the early 1990s. It began to diffuse prior to commercialization and accelerated with Mosaic, an prototype browser developed at the University of Illinois. Many ISPs included Mosaic on their systems. Despite licensing the technology to many firms, the University of Illinois did not generate as much excitement as the Netscape IPO, which brought extensive publicity to the new technology (Cusumano and Yoffie, 1998). The subsequent browser wars further heightened this awareness.

The emergence of the web changed the commercial opportunities for ISPs. ISPs found themselves both providing a "traditional" service in demand, text-based applications such as e-mail, and trying to position themselves for a new service: web applications. This new opportunity provided strong incentives to grow and experiment with new business models. It also induced considerable new entry. While not all markets experienced the same type of competitive choices, nor did all ISPs see the same opportunities, many private firms found ways to develop opportunities quickly, seeding lessons which they then applied in other localities.

AT&T's entry had unanticipated consequences. AT&T developed a nationwide Internet access service, which was available in much of the country, opening with as large a geographic spread as any other contemporary national provider. It also grew quickly, acquiring one million customers with heavy publicity and marketing. This growth depended on the strength of its promise to be reliable, competitively priced and easy to use. It was deliberately aimed at households, and provided a mass-market service from a name brand.

AT&T's actions mattered because of what did not happen rather than what did. This was a branded, nation-wide, professionally operated subscription model of ISP service, opening with as large a geographic spread as any other contemporary national provider. Yet, it did not end the growth of others, such as AOL, nor did it stop new entry of small firms, such as Mindspring, nor did it initiate a trend towards consolidation around a few national branded ISP services. In other words, even with its deep

pockets AT&T did not dominate the offerings from all other firms, nor did it end the restructuring of the access business. This defied many predictions, further encouraging the decentralized growth and the emergence of independent ISPs.

Growth and entry brought about extraordinary results. Downes and Greenstein [1998] have constructed maps that illustrate the density of location of ISPs at the county level for the fall of 1996 and 1998; Black and white versions of these are at the back of this paper.[4] For color versions see, respectively:

http://www.kellogg.nwu.edu/faculty/greenstein/images/htm/Research/Maps/mapsep1.pdf,
http://www.kellogg.nwu.edu/faculty/greenstein/images/htm/Research/Maps/mapoct98.pdf.

Colored areas are counties with providers. White areas have none. As the maps show, ISPs tend to locate in all the major population centers, but there are also plenty of providers in rural areas. The maps also illustrate the importance of changes over time. Many of the areas that had no coverage in the fall of 1996 were covered by the fall of 1998. Many of the areas that had competitive access markets in the early period were extraordinarily competitive in the latter period.

Downes and Greenstein [1998] show that more than 92 percent of the US population had access by a short local phone call to seven or more ISPs by 1998. No more than five percent did not have any access. Almost certainly the true percentage of the population without access to a competitive dial-up market is much lower than five percent. In other words, with the notable exception of some low-density areas, ISP service was quickly available everywhere. To put it simply, among the vast majority of the US population in urban and suburban areas lack of use was primarily due to demand factors, not the absence of supply.

[4] For further documentation of these methods, see Downes and Greenstein [1999] or Greenstein [1999]. The fall 1996 data covers over 14,000 phone numbers for over 3,200 ISPs. The fall 1998 data cover over 65,000 phone numbers for just under 6,000 ISPs.

An unexpected pattern accompanied this rapid growth in geographic coverage. First, the number of firms maintaining national and regional networks increased over the two years. In 1996, most of the national firms were recognizable; they were such firms as IBM, AT&T, and other established firms who entered the ISP business as a secondary part of their existing services, such as providing data services to large corporate clients. AOL, CompuServe and Prodigy all were in the process of converting their on-line service, previously run more like bulletin boards than ISPs, into Internet providers. By 1998, many entrepreneurial firms maintained national networks and few of these new firms were recognizable to anyone other than an industry expert.

There was also a clear dichotomy for growth paths of entrepreneurial firms who became national and regional firms. National firms grow geographically by starting with major cities across the country and then progressively moving to cities of smaller populations. Firms with a regional focus grow into geographically contiguous areas, seemingly irrespective of urban or rural features.[5]

Most of the coverage in rural areas comes from local firms. In 1996, the providers in rural counties with under 50,000 population were overwhelmingly local or regional. Only for populations of 50,000 or above, do national firms begin to appear. In fall of 1998, the equivalent figures were 30,000 or lower, indicating that some national firms had moved into slightly smaller areas and less dense geographic locations. In other words, Internet access in small rural towns is largely done by a local or regional providers, with national firms only slowly expanding into similar territory.

It appears as if it does not pay for many large national providers to provide dial-up service for the rural areas whereas many small local firms in other lines of business (e.g., local PC retailing) can afford to add Internet access to their existing business. It may also be the case that the local firm may have an easier

[5] Some ISPs have told me in interviews that this growth was initially in response to customer requests for local phone numbers for accessing networks (e-mail mostly at first) when these customers traveled outside their primary area. More recently, it is also common to have ISPs discuss the possibility of developing a large customer base for purposes of "selling the base" to a high bidder in some future industry consolidation.

time customizing the Internet access business to the unique needs of a set of users in a rural setting.

3.3. What structural challenges arose?

Commercialization of the Internet created an economic and business opportunity for providing access. The costs of entry into low quality dial-up access were low, and commercially-oriented firms filled voids in specific places. For any firm with national ambitions, coverage of the top fifty to one hundred cities in the US was a fleeting advantage and quickly become a necessity for doing business. For any local or regional firm in an urban market, many competitors arose.

Yet, not long after the Netscape IPO the ISP industry began to enter a second phase. Profitability and survival involved more than geographic expansion. It involved bringing ISP service to the households and businesses with PCs, but without access. Related, it also involved expanding into services which took advantage of new opportunities associated with the web.

Understanding this second phase requires an understanding of the services ISPs offer other than basic access and how those began to evolve. These new services include one of several activities: monitoring technical developments, distilling new information into components which are meaningful to unfamiliar users, and matching unique user needs to one of many new possible solutions enabled by advancing technical frontiers. Sometimes it includes heavy use of the technological frontier and sometimes not. In general, it depends on the users, their circumstances, their background, their capital investments, the costs of adjusting to new services, and other factors which influence the match between user needs and technological possibilities.

ISPs commercialized their adaptive role by offering new services, which can be grouped into five broad categories: networking, hosting, web page design, basic access and frontier access (see appendix of Greenstein [1999], for precise definitions.).

Networking involves activities associated with enabling Internet technology at a users' location. All

ISPs do a minimal amount of this as part of their basic service in establishing connectivity. However, an extensive array of these services, such as regular maintenance, assessment of facilities, emergency repair, and so on, are often essential to keeping and retaining business customers. Note, as well, that some of these services could have been in existence prior to the diffusion of Internet access.

Hosting is typically geared toward a business customer, especially those establishing virtual retailing sites. This requires the ISP to store and maintain information for its access customers on the ISP's servers. All ISPs do a minimal amount of hosting as part of basic service, even for residential customers (e.g., for email). However, some ISPs differentiate themselves by providing an extensive array of hosting services, including credit-card processing, site-analysis tools, and so on.

Web design may be geared toward either the home or business user. Again, many ISPs offer some passive assistance or help pages on web page design and access. However, some offer additional extensive consulting services, design custom sites for their users, and provide services associated with design tools and web development programs. Most charge fees for the additional services.

Basic access constitutes any service as slow as or slower than a T-1 line. Many of the technologies inherited from the pre-commercial days became standard parts of basic access and were not regarded as a new service. A number of other new functions, such as audio streaming, filtering and linking, also gradually became standard parts of most firm's offering. Frontier access includes any access faster than a T-1 line, which is becoming the norm for business access. It also includes ISPs that offer direct access for resale to other ISPs or data-carriers and ISPs that offer parts of their own "backbone" for resale to others.[6]

By 1998, different ISPs had chosen different approaches, offering distinct combinations of services and distinct geographic scopes. Table 1 shows the results of a survey of the business lines of 3816 Internet

[6] Speed is the sole dimension for differentiating between frontier and basic access. This is a practical choice. There are a number of other access technologies just now becoming viable which are slow but technically difficult, such as wireless access. Only a small number of firms in this data offer these services and these firms also offer high speed access.

service providers in the United States who advertise on *thelist*, an on-line directory of ISPs, in the summer of 1998 (see Appendix of Greenstein [1999]). Virtually every firm in the sample provides some amount of dial-up or direct access and basic functionality, such as e-mail accounts, shell accounts, IP addresses, new links, FTP and Telnet capabilities, but these 3,816 seem to under-represent both very small and quasi-public ISPs (e.g., rural telephone companies).

Table 1
Product lines of ISPs

Category definition	Most common phrases in category	Original Sample
Providing and servicing access though different channels	28.8, 56k, isdn, web TV, wireless access, T1, T3, DSL, frame relay, e-mail, domain registration, new groups, real audio, ftp, quake server, IRC, chat, video conferencing, cybersitter TM.	3,816 (100%)
Networking Service and Maintenance	Networking, intranet development, WAN, co-location server, network design, LAN equipment, network support, network service, disaster recovery, backup, database services, novell netware, SQL server	789 (20.6%)
Web Site Hosting	Web hosting, secure hosting, commercial site hosting, virtual ftp server, personal web space, web statistics, BBS access, catalog hosting	792 (20.7%)
Web Page Development and Servicing	Web consulting, active server, web design, java, perl, vrml, front page, secure server, firewalls, web business solutions, cybercash, shopping cart, Internet marketing, online marketing, electronic billing, database integration	1,385 (36.3%)
High Speed Access	T3, DSL, xDSL, OC3, OC12, Access rate > 1056k	1,059 (27.8%)

Of the 3,816 ISPs, 2,295 (60.1%) have at least one line of business other than basic dial-up or direct Internet access. Table 1 shows that 1,059 provide high speed access,789 networking, 792 web hosting, and 1,385 web page design. There is some overlap: 1,869 do at least one of either networking, hosting or web design; 984 do only one of these three; 105 do all three as well as frontier access. This reveals many different ways to combine non-access services with the access business.[7]

3.4 The contours of response to structural challenges

[7] One of the most difficult phrases to classify was general "consulting." The vast majority of consulting activity is accounted for by the present classification methods as one of these three complementary activities, networking, hosting and web-design.

Structural issues did not become resolved quickly and have not disappeared as of this writing. This occurred because these activities contain much more complexity and nuance than Table 1can display.

ISPs customize Internet technologies to the unique needs of users and their organizations, solving problems as they arise, and tailoring general solutions to idiosyncratic circumstances and their particular commercial strengths. Sometimes ISPs call this activity consulting, and charge for it separately; sometimes it is included as a normal business practice. In either case, it involves the translation of general knowledge about Internet technologies into specific applications which yield economic benefits to end-users.

What factors influenced vendors' attempts to construct viable and on-going economic entities using new technology in an evolving market place? Is it possible to classify and analyze the determinants of co-invention? Why did some regions play host to ISP growth and others did not? There are many explanations, but these aggregate into two classes, one which emphasizes firm-specific factors and another which emphasizes location-specific factors:

Firm-specific factors: Firm-specific factors shape the incentives to bring new technology into use (See, e.g., Demsetz [1988] or Nelson and Winter [1977] for a summary). ISPs came to the new opportunities with different skills, experiences or commercial focus. In the face of considerable firm-specific commercial uncertainty, ISPs purchased and installed their own capital equipment, publicized brand and service agreements, and made other long-lasting investments. Many of these investments could commit the ISP to particular services, even before market demand was realized or new commercial opportunities were recognized.

Strategies pursued by national firms can be viewed in this light. Most national ISPs covered the same geographic territories, so their strategies reflected either unique assets at the firm level, a firm's vision for where their service should fall relative to competitors, or some other firm-specific feature. A more detailed look at each of IBM, AT&T, AOL, Earthlink/Mindspring and PSINet will illustrate the variety of strategies each pursued.

IBM had been an early entrant in the ISP market, focusing primarily on business customers and secondarily on home users. Their service grew rapidly nationwide and globally, complimenting their considerable other computer services. Yet, in a few years the firm decided to divest itself of its ISP backbone and facilities, eventually selling to the highest bidder, AT&T. The firm concluded that joint provision of access and other computer services was not a strategic advantage, and therefore focused its attention on computer operations in many firms. The full benefits from this refocusing will only be manifest in time.

AT&T entered into consideration in another way. As already noted, it added a dial-up service soon into commercialization. In 1998 it purchased TCI/@home, a cable company and Excite, a web portal. These acquisitions position them for providing data service to the home with some content. With the recent agreement to purchase Media One, which was pending at the FCC as of this writing, AT&T became the largest cable provider in the country. The benefits from this are somewhat speculative, as the revenue stream justifying these purchases has not been realized. If voice telephony, streaming media or any other host of new broadband services become viable over cable lines, AT&T is well positioned to provide them. Subscription fees for high speed access could also justify these purchases, if that technology becomes widely adopted.

AOL took a different approach. First, it grew its home user base through aggressive marketing to more technical users. In response to the proliferation of ISPs in the late 1990s, it ended its tiered subscription model and introduced a flat-rate pricing model which mimics these other ISPs. Next it bought CompuServe, a failed competitor with a loyal customer base, and currently operates it as a separate branded entity. It also sold off its access facilities to Uunet, a sub-division of MCI/Worldcom, announcing concentration on the development of content. It has since pursued its "walled-garden" strategy of making AOL proprietary content attractive and the primary focus of AOL users. The purchase of ICQ, an instant messaging service, and Time/Warner, among others, are consistent with this strategic approach. It is still

an ISP, but a unique one, providing access to the Internet that its customer base infrequently uses. The full benefits of this approach are speculative as of this writing, as the revenues from it have not been fully realized.

Earthlink and Mindspring illustrate the issues facing new entrants on a national level. They market a low-cost reliable service which is also easy to use, successfully competing against AT&T with much the same appeal but a different branding. These firms also specialize in making the Internet easy to use for the non-AOL user, the web-surfer who wants some but not too much help. Eventually these firms merged, partly to consolidate their resources for competition against AOL, and partly to compete more strongly in the non-AOL customer space. As one of the largest dial-up services in the country, there is a big question whether they can survive in their niche in the face of competitive substitutes from all sides.

Finally, PSINet illustrates the feasibility of embarking on a strategy of emphasizing infrastructure. They started as a consumer Internet service, but got out of that business in 1996. They had built out their own backbone, investing in high speed facilities across the country, focused on becoming a carrier's carrier for other ISPs and for business. Part of their strategy involves heavy investments in complimentary services, such as hosting services corporate software services, which can offer high speed service when located just next to fast Internet backbone lines. They also focus on offering infrastructure services to business, developing services such as VPNs, which take advantage of their technical capabilities and nationwide coverage. Once again, the full benefits of this approach are speculative, depending on realizing demand in the future.

There are, of course, many other national firms. As with the above examples, their strategies mix different elements of speculative investment, restructuring of organizations and entrepreneurial guesses about future demand. In all cases, these experiments involve executives making investments under technical and commercial uncertainty, restructuring production and distribution assets on a grade scale, trying to bring new services to market, and only finding out if they meet market demand years after those

investments.

It is also important to recognize the variance associated with local and regional ISPs, another and particularly interesting subset of ISPs, who provide service for approximately between a fifth and a quarter Internet users in the US. These firms locate in many different parts of the country; hence their firm-specific strategies are also influenced by factors associated with their locations.

Location specific factors: A well-known line of economic research, dating at least to Griliches [1957], has emphasized the geographic dispersion of incentives to adopt new technology. In this instance, while basic dial-up access is widely available in all urban areas and many rural areas (Downes and Greenstein [1998]), there is great variance in market structure on a local level. Some areas contain many suppliers from a wide variety of backgrounds, while others contain few suppliers. From the standpoint of an ISP, many of these structural features of markets are exogenous, and shape the competitive pressures on the ISP. In addition, ISPs customize frontier technology to the needs of enterprises doing business at a specific time in a specific place. The costs of this may vary by region because infrastructure differs by region. The demand for higher speed service should also differ across regions if the users who find speed valuable are unevenly distributed across geographic regions -- e.g., someone from San Francisco may be more willing to pay for speed than people from Poughkeepsie.

The contrast between firm-specific and location-specific questions are examined in Augereau and Greenstein [1999], who looked at small ISP's investments in upgrades, and Greenstein [1999], who examined small ISP's propensity to offer services other than routine service associated with basic access. Both studies identify the importance of geographic factors by taking advantage of variation between the locations of small ISPs.

These studies are motivated by two observations. First, as noted in Downes and Greenstein [1998], most large firms located in the same (or largely overlapping) set of major cities. Hence, for the importance of location to be understood, the cause of variation between the small firms needs to be identified. Second,

Greenstein [1999] and Strover et al [1999] document that ISPs in rural locations tend to provide fewer high quality services than those found in urban locations. Was this due to differences in infrastructure between urban and rural areas, differences in the type of customer found there, or differences in the type of entrepreneur who locate in different regions?

These studies both found that firm size, capacity and financial strength were important determinants of behavior. There was also some evidence in Augereau and Greenstein [1999] that local infrastructure quality influenced investment behavior. Generally, variation in local demographic conditions or competitive conditions did not influence behavior. Both studies find much unmeasured variance in behavior, consistent with the presence of unmeasured location-specific or firm-specific determinants. Moreover, the factors which lead ISPs to offer new services, such as size, previous investments and strategic focus, are disproportionately found in national firms and in local firms in urban areas.

These findings are consistent with the view that the scale of investment, the local infrastructure's quality, and the explicit costs shape investment decisions by young ISPs in emerging markets. It is also consistent with the view that there is too much commercial uncertainty in this market for firms to tailor the technical vintages of their capital stocks too closely to geographically local demand or competitive conditions. Finally, it is consistent with the view that most young firms with ambitious expansion plans initially locate in urban areas instead of rural areas, growing their base markets and expanding outward, if at all.

4. Past lessons and future challenges

As public discussion of electronic commerce has grown, a loose coalition of prophets for the new economy has come to dominate popular discussion. They write for such publications as *The Industry Standard, Business 2.0, Wired, Red Herring, Fast Company,* and more "Web-zines" than anyone can list. It is only a slight exaggeration to say that all popular portrayals of the Internet contain two principal

features. First, the prophets declare a business revolution in all information-intensive activities -- such as broadcasting, entertainment, retail marketing, supply-chain management, other coordinative activity and research. Second, and this is related, these same prophets proclaim that this technology's novelty dilutes standard lessons from the past. In other words, because this technology contains so many unique features, it is ushering a new commercial era which operates according to new rules.

To be sure, there is probably a grain of truth to these declarations. However, momentary euphoria does not, nor should it, justify too simplistic a retrospective view of what actually happened, nor what is about to happen. Indeed, this paper showed that a traditional economic perspective does provide considerable insight into this new industry. In that spirit, we return to the questions which motivated the study and recap the findings:

4.1 Lessons for commercialization of technology

! **Why did the Internet access business grow quickly?** Stated simply, exclusive use did not lead to isolated technical and operational developments. Hence, commercializing Internet access did not give rise to any difficult or insolvable technical and operational challenges. This was due in no small part to the way in which the defense department and the NSF incubated the technology. It grew among researchers and academics without being isolated from commercial suppliers. That is, the technology grew without generating a set of suppliers whose sole business activity involved the supply of uniquely designed goods for military or government users. Related to this was the fact that the basic needs of researchers and academics were not so different from early commercial users. Hence, simple applications of the Internet invented for academic users -- such as e-mail and file transfer using phone lines -- migrated to commercial uses without much technical modification.

! **Why did geographic ubiquity arise?** To summarize, the Internet access business was commercially feasible at a small scale and, thus, at low levels of demand. This meant that the technology

was commercially viable at low densities of population, whether or not it was part of a national branded service or a local geographically concentrated service. Again, this partly mimicked the academic experience, where the operations were also feasible on a small scale, but that statement alone does not capture all the factors at work. Internet access was feasible in a wide variety of organizational forms, either large and small. Small scale business opportunities thrive with the help of entrepreneurial initiative, which tend to be widespread throughout the US -- including many low density and isolated cities in otherwise rural areas, which were largely not being served by national firms. Small scale implementation also depended on the presence of high quality complementary local infrastructure, such as digital telephony, and interconnection to existing communications infrastructure. These too were available throughout most of the US due to national and local initiatives to keep the communications infrastructure modern.

! **Why did the Internet access business not settle into a common pattern?** Market forces did not impose uniformity in the use nor in the supply of access technology. Part of this was due to the absence of technical and commercial challenges, which allowed low cost experimentation of the technology in new uses, new locations, new market settings, new applications and in conjunction with other lines of business. More generally, the technology was quite malleable as an economic unit. It could stand alone or become part of a wider and integrated set of functions under one organizational umbrella. Such malleability motivated experiments with new organizational forms for the delivery of access services, experiments which continue today. Finally, and unique to this example, the invention of the World Wide Web brought new promise to the technology. Not only did new business models arise to explore and develop its primitive capabilities and expand them into new uses, but it motivated firms to experiment with Internet access along side new business lines.

! **Why did market forces lead to such extensive growth?** This case illustrates how market forces can customize new technologies to users and implement new ways of delivering technologies. These activities have immense social value when there is uncertainty about technical opportunities and complex

issues associated with implementation. In addition, as the literature on general purpose technology would put it, co-invention problems are best situated with those who face them. In this case, those actors were ISPs who knew about the unique features of the user, the location or the application. More generally, commercialization transferred development into an arena where decentralized and unregulated decision-making took over. This was precisely what was needed to customize Internet access technology to a wide variety of locations, circumstances and users. Removing the Internet from the exclusive domain of NSF administrators and employees at research computing centers brought in a large number of potential users and suppliers, all pursuing their own vision and apply it to unique circumstances. In addition, it allowed private firms to try new business models, employing primitive web technologies in ways that nobody at the NSF could have imagined.

! **In what sense did the NSF get lucky?** As it turned out, the NSF commercialized the Internet access industry at a propitious moment, during the growth of an enormous new technological opportunity, the World Wide Web. Competitive forces sorted through new uses of this opportunity in particular places, enabling some businesses to grow and unsentimentally allowing unsuccessful implementations to fade. To be sure, some of these developments were heavily constrained by non-profit institutions, such as the World Wide Web Consortium or the Engineering Internet Task Force, but profit motives still played a prominent role. Said another way, one shudders to imagine what would not have happened had NSF stewardship over the Internet continued. There would have been some experimentation at computing centers found at universities and government laboratories, but it would not have been possible to replicate all the exploratory activity that did arise in commercial markets. If anything, this leads one to wonder why the NSF did not commercialize the Internet sooner.

4.2 Lesson and challenges for the near future

The diffusion of broad-band access, the widely forecast future for this industry, seems to be taking

on a more typical pattern for new technology, where technical and commercial constraints shape the pattern of diffusion. It is unclear what the lowest cost method for the delivery of broadband services will be. It is also unclear what type of services will motivate mass adoption of costly high speed access to the home. There are technical limitations to retrofitting old cable systems and with developing DSL technology over long distances. It is unclear how many people will be willing to pay for such high-speed services. These uncertainties cloud all forecasts. However, unlike the past, there will not be two decades of incubation of broadband technology by only government sponsored researchers. Hence, there is no reason to anticipate anything like the speed of diffusion found in the dial-up market, nor take for granted that ubiquity will arise as easily (for more, see, e.g., Weinberg, 1999, or Werbach, 1997).

This observation would seem, at first blush, to suggest that this history sheds little light on the future -- that past and future challenges are too unique to their time for comparison. However, that conclusion is a bit hasty. Looking forward in the ISP industry, it is possible to identify some technical, commercial and structural challenges which resemble those of the past and which will alter the contours of behavior and outcomes. I will discuss some of these, cognizant that restructuring is still taking place and changing sufficiently fast, so that any discussion runs the risk of becoming obsolete as soon as it is written.

Lesson 1: The past does offer guidance for understanding patterns of restructuring. The names of the firms may change and so too may the specifics of the strategies, but the absence of uniformity in the development of Internet access business models should persist into the future. New applications for Web technology are still under development because the technology has potential beyond its present implementations. Not all local markets will experience the same type of competitive choices in access, nor should they. Not all vendors will see the same opportunities and these differences arise for sound economic reasons. User with more experience still adopt applications closer to the frontier, while users with less experience still demand more refined applications. Web technology enables these differences to manifest in new directions and it is not obvious which implementation will succeed with either type of user. In other

words, most of the economic fundamentals leading to structure challenges have not disappeared; hence, experimentation with new business models will probably continue.

Lesson 2: The subscription model of Internet access will continue to change. Commercial markets inherited an organizational form from their academic ancestors, modifying it slightly for initial use. There is no reason to presume that it will maintain the same operational structure under competitive pressure. Indeed, it is presently under competition from a variety of alternate business models which use dial-up access to subsidize another activity. There are already hints of these potential changes as some ISPs charge very little for access and make up for the lost revenue with other services, such as networking, hosting or web design. AOL has successfully combined access with its "walled garden" of content and AT&T appears intent on pursuing a unique approach to combining content and access. Other recent innovative firms include Netzero.com, which is the most successful to date of many firms who have tried to provide access for free and garner revenue through sales of advertising. There are also many other such experiments altering the explicit definition of basic service, embedding it with more than e-mail, but also with games, streaming, linking and so on, which has the effect of changing the pricing structure too. It is not crazy to predict that access, by itself, could become absorbed into a bundle of many other complementary commercial services, slowly fading as a stand-alone service, as it existed in the academic domain.

Lesson 3: The economics of Internet diffusion lie behind much of the digital divide. Internet access diffused more easily to some users and in some locations. The margin between adoption and non-adoption has become popularly known as the "digital divide." If some of these outcomes are understood as temporary results of a young diffusion process, then many of the differences between those with virtual experience and those without can be framed as the by-product of the economic factors shaping this diffusion episode. Within business the important factors influencing adoption are the density of the location of the business, the availability of basic computer support services nearby, and a firm's previous investment

in IT. At the home the important determinants are availability (which is influenced by density) as well as the same factors behind the diffusion of PCs: age, education and income especially, and also race for some income levels. It follows, therefore, that policies aimed at digital divide issues, such as the E-rate program, should not address those factors which are only temporary and will resolve themselves independently. Instead, it should target factors which are likely to be more durable over time and which lead to division in adoption behavior; such as density of location, income, education and race**.**

Lesson 4: Geographic pervasiveness introduces new economic considerations. There is one additional reason to expect the typical business model to remain unsettled. Geographic pervasiveness has entered into calculations today and it was not a relevant consideration at the outset of commercialization. The pervasiveness of the Internet across the country (and the developed world) changes the economic incentives to build applications on top of the backbone, and alters the learning process associated with its commercial development. All ISPs now depend on each other on a daily level in terms of their network security, reliability and some dimensions of performance. Many new applications -- e.g., virtual private networking, voice telephony over long distances, multi-user conferencing, some forms of instant messaging, and gaming -- require coordinating quality of services across providers. It is still unclear whether new business models are needed to take advantage of applications which presume geographic pervasiveness. If so, it will provide a commercial advantage to the firms with national backbones and assets. Pervasiveness also changes the activities below the backbone in the vertical chain. It has altered the scale of the market for supplying goods and services to the access industry, altering the incentives of upstream suppliers, equipment manufacturers or middle-ware software providers, to bring out new services and inventive designs for the entire network. This factor was also not present in the academic network and it is unclear how it will influence the structure of the industry moving forward.

Lesson 5: Is there a need for new communications policy for the new millennium? Until recently, the pace of technical change in most communications services was presumed to be slow and easily

monitored from centralized administrative agencies at the state and federal level. It is well known that such a presumption is dated, but it is unclear what conceptual paradigm should replace it. This paper illustrated how vexing the scope of the problem will be. In this instance, ISPs addressed a variety of commercial and structural challenges with little government interference, but under considerable technical and commercial uncertainty. This occurred because many legacy regulatory decisions had previously specified how commercial firms transact with the regulated public switch network. These legacy institutions acted in society's interest in this instance, fostering experimentation in technically intensive activities, enabling decentralized decision-making to shape commercial restructuring in specific place and time periods. To put it simply, it was in society's interest to enhance the variety of approaches to new commercial opportunities and existing set of regulations did just that. However, going forward it is unclear whether these legacy institutions are still appropriate for other basic staples of communications policies, such as whether a merger is in the public interest, whether incumbent cable firms should be mandated to provide open access, whether communications infrastructure should be subsidized in under-served areas, and whether Internet services should be classified as a special exemption, immune from taxation and other fiscal expenses. Hence, we live in an era where market events and unceasing restructuring will place considerable tension on long-standing legal foundations and slow regulatory rule making procedures.

References

Augeareau, Angelique, and Shane Greenstein [1999]. "The Need for Speed in Emerging Communications Markets: Upgrades to Advanced Technology at Internet Service Providers." http://www.kellogg.nwu.edu/faculty/greenstein/images/research.html

Boardwatch Magazine, *Directory of Internet Service Providers*, Littleton, CO.

Bresnahan, Timothy, and Shane Greenstein [1999]. "Technological Competition and the Structure of the Computing Industry," *Journal of Industrial Economics*, 47, 1-40.

Bresnahan, Timothy, and Manuel Trajtenberg [1995]. "General Purpose Technologies: Engines of Growth?" *Journal of Econometrics*, 65, 83-108.

Clemente, Peter C. [1998]. *The State of the Net: The New Frontier*, New York: McGraw-Hill.

Cohen, Linda, and Roger Noll [1990]. *The Technology Pork Barrel*, Brookings.

Cowan, Robin [1988]. *Nuclear Power Reactors: A Study in Technological Lock-in*, Working Paper 88-33, C.V. Starr Center for Applied Economics, New York University.

Cusumano, Michael and David Yoffie [1998]. *Competing on Internet Time, Lessons from Netscape and It Battle With Microsoft*, New York: The Free Press.

Demsetz, Harold [1988]. "The Theory of the Firm Revisited," *Journal of Law, Economics, and Organization*, **4**, 159-178.

Downes, Tom, and Greenstein, Shane [1998]. "Do Commercial ISPs Provide Universal Access?" in (Ed) Sharon Gillett and Ingo Vogelsang, *Competition, Regulation and Convergence: Selected Papers from the 1998 Telecommunications Policy Research Conference*, Lawrence Erlbaum Associates.

Norman Nie and Ebring, Lutz [2000]. *Internet and Society: A Preliminary Report*, Stanford Institute for the Quantitative Study of Society, Stanford University.

Flamm, Kenneth [1989]. *Targeting the Computer, Government Support and International Competition, Brookings Institute*, Washington, D.C.

Greenstein, Shane [1999]. "Building and Developing the Virtual World: The Commercial Internet Access Market," http://skew2.kellogg.nwu.edu/~greenste/research.html

Griliches, Zvi [1957]. "Hybrid corn: An exploration in the economics of technological change," *Econometrica*, 25, 501-522.

Helpman, Elhanan [1998]. *General Purpose Technologies and Economic Growth*, The MIT Press.

Kalakota, Ravi and Andrew Whinston [1996]. *Frontiers of Electronic Commerce*, Addison-Wesley, Reading, MA.

Katz, Barbara, and Almiran Phillips [1982]. "The Computer Industry," in Richard Nelson R (Ed.) *Government and Technical Progress: A Cross-Industry Analysis*, New York: Pergamon Press, pp. 162-232.

Kolstad, Rob [1998]. "Becoming an ISP," *www.bsdi.com.* January.

Maloff Group International, Inc.[1997]. "1996-1997 Internet Access Providers Marketplace Analysis," Dexter, MO, October.

Mowery, David and Nathan Rosenberg [1992]. *Technology and the Pursuit of Economic Growth*, Cambridge University Press.

National Telecommunication and Information Administration [1999]. *Falling Through the Net: Defining the Digital Divide*. US Department of Commerce, July.

Nelson, Richard, and Sidney Winter [1977]. *An Evolutionary Theory of Economic Change*, Cambridge, MA: Belknap Press.

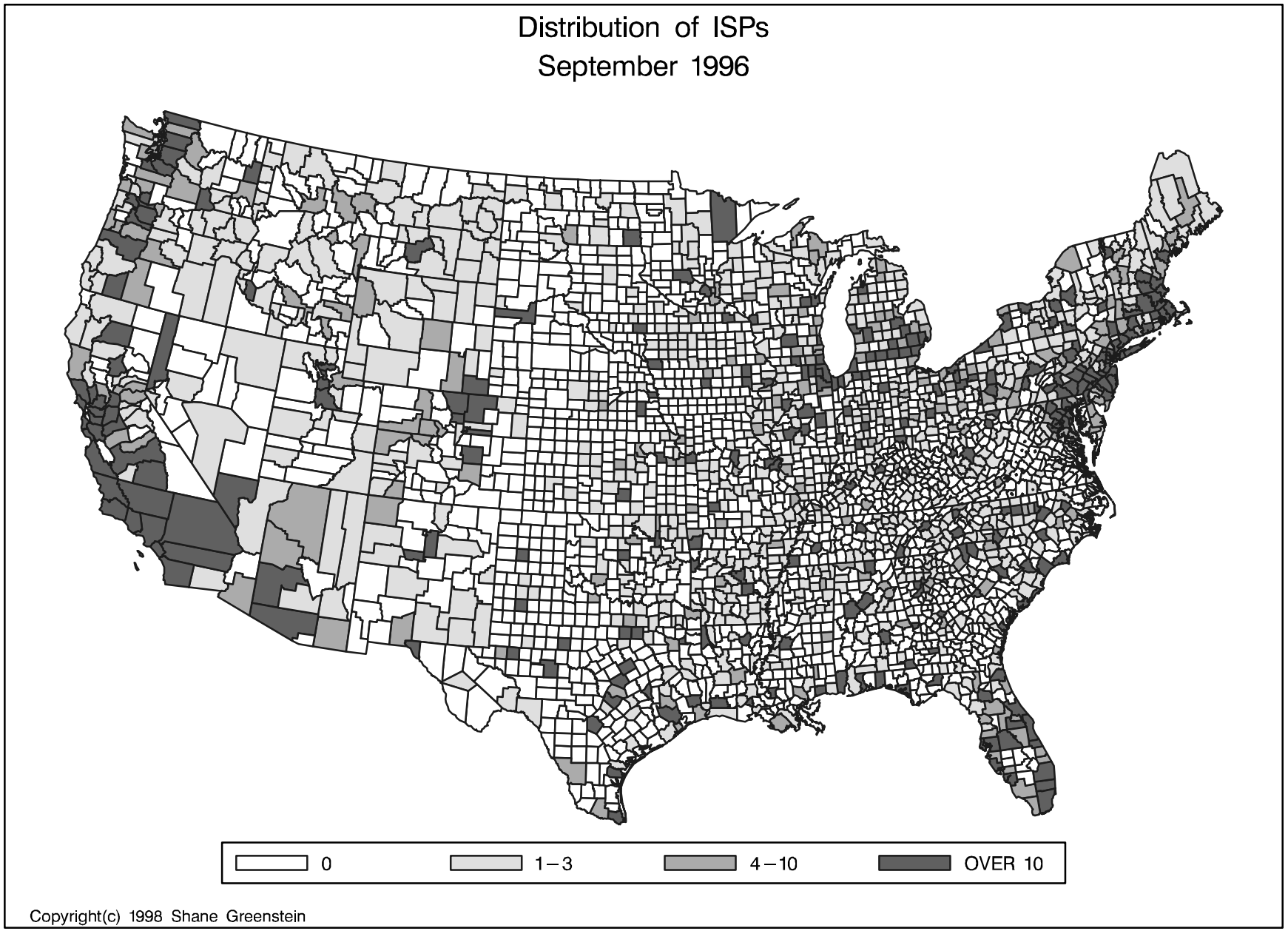
Sidek, Greg and Dan Spulber [1998]. "Cyberjam: The Law and Economics of Internet Congestion of the Telephone Network." *Harvard Journal of Law and Public Policy*, 21, 2.

Strover, Sharon [1999]. "Rural Internet Connectivity." Working Paper, University of Texas at Austin.

Ventresca, Mark, Rodney Lacey, Michael Lounsbury, and Dara Szyliowicz [1998]. "Industries as Organizational Fields: Infrastructure and Formative Dynamics in U.S. Online Database Services." A Working Paper in the "Business and Government" Series of the Institute for Policy Research, Northwestern University.

Weinberg, Jonathan [1999]. "The Internet and Telecommunications Services, Access Charges, Universal Service Mechanisms, and Other Flotsam of the Regulatory System." *Yale Journal of Regulation*, Spring.

Werbach, Kevin [1997]. *A Digital Tornado: The Internet and Telecommunications Policy.* FCC, Office of Planning and Policy Working Paper 29, March.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