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The Internet and the rise of the new network cities, 1969 – 1999

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Abstract. The recent rapid growth of the Internet has avoided scrutiny from urban planners as little information is available from which to assess its impacts on cities and regions. As a result, explanations of the relationship between telecommunications and urban growth are overly simplistic, forecasting either the centralization of decisionmaking in so-called 'global' cities or wholesale urban dissolution. Based on two measurements of Internet geography—domain name registrations and backbone networks—this study finds that access to advanced communications technologies have broadly diffused across a wide group of medium-sized and large-sized metropolitan areas. Finally, the implications of these findings suggest a need to rethink global cities and a practical need to address the growing divide between network cities and the rest of the urban world.

Cities and space in the information age

Telecommunications networks are an essential component of urban infrastructure in the 1990s, enabling the coordination of increasingly complex, multilocation, and time-sensitive production systems as well as fractured social networks. However, despite the importance of this new information infrastructure to the economic and social prosperity of cities, relatively little effort has been devoted to systematic analysis of their structure, evolution, and future implications (Graham and Marvin, 1996).

Two perspectives dominate the discussion on how recent advances in information and communications technologies will affect urban development. The first, the global city concept, originated with Hall's (1966) seminal work on the urban geography of the "world cities". In subsequent research, others have developed this concept within ongoing debates on globalization and economic restructuring (Friedmann and Wolff, 1982). A second perspective forecasts wholesale urban dissolution as a result of the conquest of spatial constraints achieved through cheap and ubiquitous telecommunications systems. In this section, I contrast these two perspectives and propose a new framework to address their shortcomings. As I will demonstrate in this paper, the rapid diffusion of advanced telecommunications systems like the Internet across a wide range of urban areas challenges this traditional dichotomy of centralization or decentralization, pointing to the existence of a complex new network of networked cities.

The global city

Although earlier observers had identified the dominant role of a select group of 'global' cities in the rapid and fundamental structural changes in capitalism in the late 1960s and early 1970s, Friedmann and Wolff (1982) were the first systematically to articulate this concept and lay out a long-term research agenda. At the core of their argument was the observation that, for a small group of special cities, it had become impossible to disentangle or understand their internal dynamics without considering the much broader processes of global economic restructuring. In particular, they identified the rapid

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transformation of global city economies from manufacturing and goods processing into producer services and finance as a spatial manifestation of these global processes. They concluded that many local problems in cities like New York should be understood as impacts of these supranational processes, particularly the increasingly rapid and unregulated movement of capital across national borders.

Advances in information and telecommunications technology are universally identified as a major factor in the process of globalization and global city development. They provide the means for corporate control and coordination of far-flung production networks, as well as the distribution system for the information products of advanced service industries that dominate these cities: money, news, culture, and entertainment. Sassen (1995) argues that the globalization of economic activity has greatly increased the complexity of business transactions, fostering a centralization of corporate command and control functions concurrent with the concentration of the most advanced telecommunications technology in these cities. Castells also asserts the global city dominance of advanced telecommunications networks when describing "the empirical landscape" of global city development, stating:

> "[Megacities] are the connecting points to global networks of every kind. Internet cannot bypass megacities: it depends on the telecommunications and on the 'telecommunicators' located in these centers" (Castells, 1996).

However, neither Castells nor Sassen offer sufficient empirical evidence to support these claims. Although Moss (1986) illustrated the dominance of New York in the United States for overseas telephone traffic, this type of research is an exception to the rule and has not been repeated elsewhere. In general, the literature on global cities is long on speculation and short on specification when addressing the telecommunications issue.

Hall (1997) focuses attention on this gap, and proposes a set of measures that could be used to rank cities by their share of global flows of information, money, and power. He tentatively offers the usual triumvirate of New York, London, and Tokyo as the dominant urban centers by this measure, yet suggests the possibility that "changes in political, economic, and technological" frameworks might affect positions in such a hierarchy. In this paper it is argued that the rapid growth of the Internet since 1993 is an example of such a change in technological frameworks, and that it offers a unique opportunity to understand how new telecommunications systems are helping dramatically to reshape urban hierarchies within the global economy.

Urban dissolution

In opposition to the global cities concept, a long tradition of utopian thought has recently been resurrected to explain the spatial implications of telecommunications and information technology. Proponents of this 'urban dissolution' framework argue that the rapidly declining cost and expanding capability of telecommunications eliminates the need for the face-to-face communications that are the lifeblood of urban business districts. This view has gained widespread acceptance in academic, political, and media discourse as a result of its direct appeal to a long tradition of American antiurbanism and, as Campanella (1998) notes, its usefulness in marketing a wide variety of "liberating" communications products and services.

The urban dissolution fantasy is a fundamentally American idea with a long cultural history, yet its current form largely originated outside the urban planning profession. In the 1960s, as the power of television delivered graphic images of urban riots into new suburban tract homes, media scholar Marshall McLuhan "repeatedly announced the obsolescence of the built city in the electronically-mediated future" (Campanella, 1998). Gaining credence in the wake of the ascendant Republican conservatism of the 1980s, Toffler's (1980) bestseller *The Third Wave* predicted a future in which the telemediation of social and economic activities in the "electronic cottage", the advanced home of the future, would usher in a radical decentralization of population and production. Even respected urbanists have advocated this position in the past, arguing that telecommunications would bring the conveniences of metropolitan life to remote mountaintops (Webber, 1964).

Since the rapid growth of the Internet first became widely recognized in the popular press (around 1995) a new generation of technological evangelists has revived the language of urban dissolution. Arbitrarily, Gilder (1995) announced that cities are "leftover baggage from the industrial era". Similarly, Negroponte, director of the influential Media Lab at the Massachusetts Institute of Technology, states:

> "The post-information age will remove the limitations of geography. Digital living will include less and less dependence upon being in a specific place at a specific time, and the transmission of place itself will start to become possible" (Negroponte, 1995).

However, prophets like Negroponte often fail to see the irony in their statements. His own legacy, the MIT Media Lab, continues to demonstrate that research and development (the most glorified pursuit of the digital age) is still best done in very close quarters. Finally, although finding a future for cities as museum pieces or havens for bohemians, Cairncross (1997) resurrects Toffler's "electronic cottage", forecasting a drop in crime and a revitalization of bedroom communities as suburban homes emerge as the center of economic activity.

Similar to the global cities argument, however, proponents of the urban dissolution framework offer only anecdotal evidence to support their position. Although pervasive, this simplistic argument cannot explain even the modest evidence presented in this article, which suggests an overwhelmingly metropolitan dominance of Internet activity and infrastructure.

The inadequacy of existing views

The conflict between these two visions of the future of cities remains sadly neglected by urban planners. Based on empirical evidence describing the geographic diffusion of Internet activity and infrastructure in the United States between 1969 and 1999, I argue that a more sophisticated theoretical framework is needed to understand the future coevolution of urban settlements and telecommunications networks.

First, the global cities concept is far too rigid to account for the potentially dramatic shifts in economic and cultural geographies made possible by telecommunications systems. As will be seen, although New York and Los Angeles represent the two largest clusters of Internet activity by the measure of domain names, they cannot compare to metropolitan areas like San Francisco or Washington, DC in terms of supporting infrastructure or depth and density of adoption. Furthermore, at least a dozen large metropolitan areas outpace these traditional global cities in the adoption of Internet technology.

Second, technological innovation is no longer a hallmark of global cities. Pred (1973) shows that in the US colonies and early years of nationhood, New York-based 'packet lines' were early innovators in accelerating the flow of communications between the United States and Europe. The early development of the telephone network was also dominated by intercity connections radiating from New York to Boston (1880), to Washington (1890), to Chicago (1892), to San Francisco (1914), and to Miami (1916) (Abler, 1977).

The Internet has emerged in a far different geography of innovation. Unlike the days of Bell and Edison, when research and development was largely concentrated in a few major industrial cities, the postwar US landscape is characterized by a dispersed system of university-based research networks and 'technopoles', such as Silicon Valley and the Route 128 corridor in Massachusetts (Saxenian, 1994). The invention of the personal computer is another classic example of tinkering in suburban garages that also typifies the geography of technological innovation in the United States today.

Thus, although the flow of information and related technologies remains vitally important to the economic well-being of global cities, they have become importers of technological innovation rather than producers. The Internet was developed in far-flung, specialized information cities and only adopted by global city institutions when its commercial usefulness had been established with the release of the graphical web browser Mosaic in 1993.

The urban dissolution framework is seriously flawed as well. First, as Thrift (1996) cogently argues, the financial districts of cities like London and New York persist precisely because highly skilled workers in close physical proximity provide the most efficient means of interpreting, in real time, the massive amounts of information generated by the international financial system. Advances in telecommunications and information technology actually increase the need for institutions, people, and districts that can extract meaningful knowledge from the rapidly increasing glut of undifferentiated information. This reasoning, although typically used to support the global hypothesis, however, is not limited only to the financial industry. It can also be applied to any emerging specialized industrial cluster, such as the technology firms surrounding Austin, Texas or the special effects industry in southern California.

Second, urban dissolution assumes that telecommunications and transportation are substitutes. The 'electronic cottage' obviates the need to travel to a central area for shopping, work, or entertainment. However, there is strong evidence of a complementary relationship between business travel and spending on telecommunications over the last twenty years (Glaeser and Gaspar, 1996).

Finally, prophecies of wholesale urban dissolution must be reconciled with the fact that cities are clearly prosperous in the digital economy. A mass exodus of firms and population from cities has simply not occurred and, in fact, most US cities are more vibrant than they have been in decades.

The network of networked cities

A new framework is needed for understanding the future of cities in an age of cheap and sophisticated telecommunications. Combining the salient aspects of these two frameworks: the importance of physical accessibility implied by the global cities view, and the decentralizing possibilities of new technologies from the urban dissolution view, I propose a new theoretical framework. A new network of networked metropolitan regions is emerging, capitalizing upon the continued importance of face-to-face contact in business and social life, yet increasingly using telecommunications systems to overcome traditional geographic barriers to: (1) access global information sources; (2) market and distribute highly specialized knowledge products on a global basis; and (3) support ever-sprawling urban forms.

The global city concept rests upon the assumption that these regions are in some way special and distinct because they play a particular and unique role in the global economy. However, the indicators of Internet infrastructure development and activity presented here do not indicate any particularly specialised or important role for global cities in the spatial organization of new telecommunications networks and the cyberspaces they enable.

Rather than the simple processes of centralization or decentralization predicted by the global city concept or the urban dissolution framework, the broad diffusion of

Internet technology has enabled many cities to become highly specialized global information producers. In this new urban network, a broad variety of local structures for supporting high-level information analysis and production can successfully market these services on a global scale. As Ernst (1997) has shown for the semiconductor industry in southeast Asia, production systems now span an unprecedented array of regions tightly networked in very complex chains. Rather than a handful of regions dominating global finance and culture, a constellation of highly specialized regions now interact in a globally telemediated economy.

This analysis is guided geographically by the primary organizing concept for the network city—the metropolitan area. In the United States, media markets (the Nielsen company's 'designated market areas'), Internet portals, and web-based city guides, cellular telephone networks, and Internet service providers organize the deployment and marketing of products by metropolitan areas. All-encompassing entertainment weeklies such as *TimeOut* market on a global scale, yet each local edition has a metropolitan orientation that is radically new among such publications. Technologically, the latest innovation in the delivery of high-capacity communications circuits will utilize high-altitude, aircraft-mounted antenna arrays to deliver services to an area 50–70 miles in diameter (*Wired News* 1998). Finally, as I will show, the spatial distribution of Internet activity and infrastructure defines a network of highly wired metropolitan regions connected to each other via high-capacity telecommunications links.

Cities and cybergeography: empirical investigations

The measurement and analysis of the geographic structure of earlier communications systems were difficult but feasible, because most communications systems were operated by tightly regulated monopolies. A lack of competition and vigorous public oversight meant that data on network development and message flows were more readily available. However, the underlying organizational structure of the Internet is deliberately decentralized, spread across a multitude of unregulated and highly competitive firms, individuals, and self-appointed steering committees.

Very little research has been conducted on the urban geography of the Internet. Moss and Townsend (1997a; 1997b; 1998) use the geographic distribution of Internet domain name registrations as a proxy for organizational use of Internet technology among businesses, universities, and government agencies. This technique uses billing addresses associated with domain names (such as cybergeography.org, or mit.edu) in order to localize the sites of Internet activity. Zook (2000) has broadly expanded and improved this technique, and finds that global cities like New York and Los Angeles represent the largest agglomerations of businesses using the Internet, but that university towns and corporate research and development clusters have the highest density of domain registrations.

These findings suggest that, although Internet use has diffused most widely in the localities where it was first adopted, commercial applications have moved the largest clusters of activity to major urban business centers. Accordingly, Moss and Townsend (1998) found that during the 1994–1997 period, it was major urban areas in the United States that drove the overall growth of Internet activity in the United States.

Several studies have investigated the role of cities as hubs for Internet backbone networks. Moss and Townsend (2000) found that a group of seven metropolitan areas served as regional hubs for interurban backbone networks in 1997. Gorman (1998) used formal techniques for network analysis on similar data set and found that the coastal cities of the United States were more tightly linked to each other than the interior. Finally, global cities like New York rely heavily upon hubs in other domestic metropolitan areas as gateways for Internet connections to foreign countries (Townsend, 2001).

In this paper I expand upon my earlier work, utilizing both the domain name and the Internet backbone network as the units of analysis. In the following sections, a historical sketch of the growth of Internet backbones since the early 1970s is presented as well as a detailed picture of spatial patterns for both measured in early 1999.

The urban geography of Internet infrastructure

As the first part of this empirical investigation into the urban dimension of cybergeography, an historical overview of the geographic spread of national backbone networks in the United States is presented. In contrast to the distributed, redundant structure of its early predecessors such as ARPANET and NSFNET, the commercial Internet is characterized by a group of seven major regional hubs that serve as aggregation points for intermetropolitan connections and traffic. Despite the distributed nature of early network investment, private investment in backbone networks has created a highly stratified, hub-and-spoke decentralized network structure. Finally, although the metropolitan areas that housed a large share of ARPANET and NSFNET sites are well served by the commercial Internet, others that played little or no role in these early networks have become major hubs of the commercial Internet.

Phase I (1969 – 1987): ARPANET and the Pentagon

In response to Sputnik and other early feats of the Soviet technological prowess, the US Defense Department's Advanced Research Projects Administration (ARPA) commissioned a prototype packet-switched computer network in the early 1960s, which became known as ARPANET. In 1969, the first node was connected at the University of California, Los Angeles, and by 1976 there were 63 computers connected to the network.

The ARPANET was an experimental network that linked together defense researchers at a number of computing facilities throughout the United States, in order to test the viability of packet-switched computer networks. Although initially it connected just a handful of sites in a few metropolitan areas, ARPANET evolved throughout the 1970s into a highly deurbanized and decentralized communications network, linking remote centers and military bases throughout the United States.

The decentralization of network infrastructure and access sites was clearly a priority for a network that was, in some respects, a test bed for a nuclear-proof military communications grid (see Baran, 1964). In 1971, ARPANET primarily linked clusters of sites in the Boston, San Francisco, and Los Angeles metropolitan areas [figure 1(a)]. However, by 1980 the network had grown substantially and a fourth major metropolitan cluster in the Washington, DC area had emerged. Additional sites were located throughout the interior of the nation, often at universities and military installations far from urban cores [figure 1(b)].

In contrast, New York (the nation's largest city) had only a single node at New York University and there were no nodes in major cities such as Chicago, Houston, or Seattle. At the same time, dozens of other nodes had sprung up at universities and military bases throughout the country resulting in a fairly distributed network structure with at least four redundant transcontinental pathways.

As Winston (1998) notes, the connection between RAND [(1)] and the Pentagon's military interest in packet-switched networks and the subsequent evolution of ARPANET (largely under the nurture of the computer science community) is obscure. The geography of the early Internet was quite decentralized, as if to further ensure survivability in a nuclear strike. And although it is never explicitly stated in any documents of the period, it appears that the nodes of this network were deliberately placed outside major urban areas.

[(1)] RAND is a defense think tank based in California. The name is a contraction of 'research and development'.

(a)

(b)

Figure 1. Map of the ARPANET network in (a) 1971 and (b) 1980.

Phase II (1987 – 1995): NSFNET and the universities

In 1983 the Defense Communications Agency decided that ARPANET had grown large enough to raise serious security issues, and moved all nonclassified military traffic over to a separate network, MILNET. This marked the beginning of the end for ARPANET, and in 1987 it was replaced by NSFNET, an education and research network funded by the National Science Foundation (NSF).

The decentralized pattern of ARPANET was continued in the siting of NSFNET nodes, but the economics of building computer networks on an ever-increasing scale helped push the NSF to adopt a multitier service model that used a transcontinental backbone to provide interconnections among regional network consortia. Figure 2(a) (see over) shows the first 56 kilobits per second (kbps) NSFNET backbone that went into service in 1987. Figure 2(b) shows the same backbone, having been upgraded to T-1 capacity (1.5 Mbps), and the many regional networks, also funded partly by NSF, that were being connected to the national infrastructure by 1989.

The major nodes of the early NSFNET backbone are markedly different from both those of ARPANET and the subsequent commercial backbone of the 1990s. Of the fourteen metropolitan areas linked to NSFNET, only Houston and Pittsburgh had four links. In contrast, the 1980 maps of ARPANET show no sites in Houston and only one in Pittsburgh at Carnegie-Mellon University. In contrast to today's intermetropolitan backbones, all of the links had a uniform capacity.

By 1991, NSFNET was extremely congested as the number of nodes had grown rapidly. Throughout the NSFNET program, the NSF pursued an aggressive agenda, linking thousands of universities and colleges to the network between 1987 and 1995. The deployment of a new T-3 (45 Mbps) backbone, with thirty times the capacity of the older infrastructure, was a marked improvement. The geographic structure of the network, as shown in figure 2(b), shows the first signs of resemblance to today's network structure, with major hubs in Chicago, Los Angeles, and New York. San Francisco and

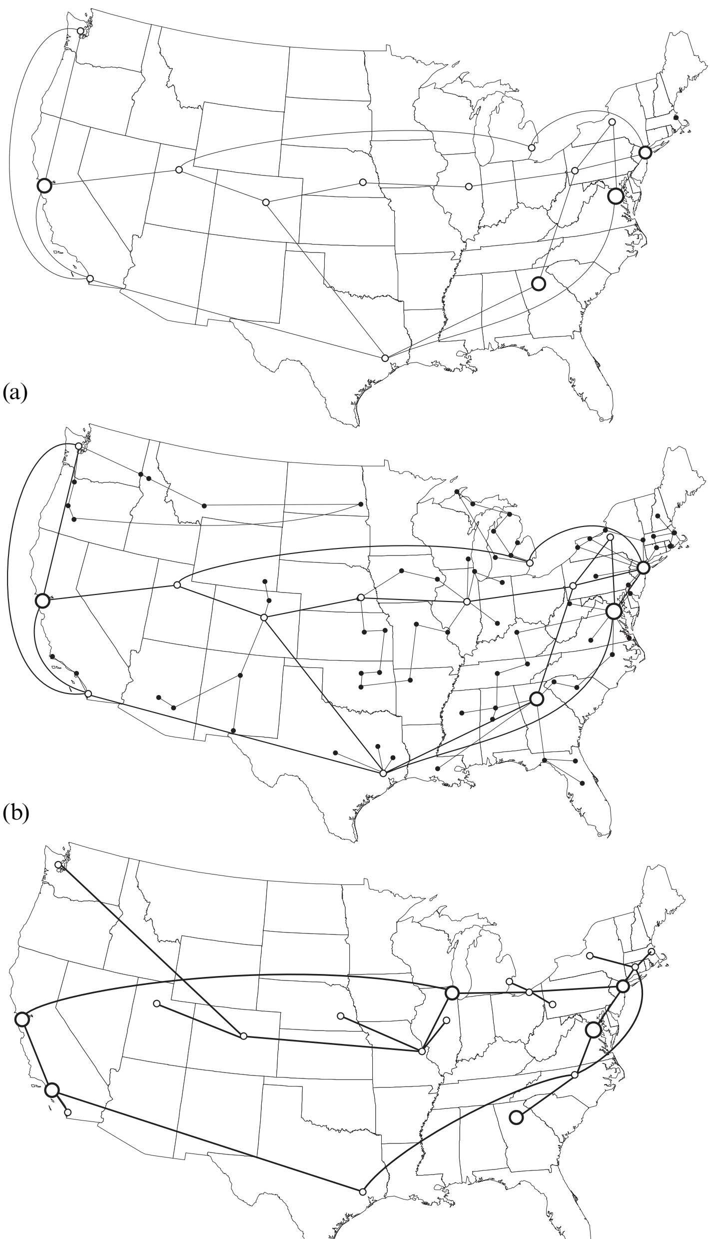


Figure 2. The NSFNET backbone in (a) 1987, the T-1 backbone; (b) 1989, including regional research networks; and (c) 1991, the T-3 backbone.

Atlanta, which are major hubs today, are only peripherally involved in this layout. Additionally, Denver and St Louis are secondary hubs; similar to the role they played in the commercial backbones of the late 1990s.

Phase III (1995 – 1999): the commercial backbone and the cities

The third major phase of growth in packet-switched networks in the United States followed the decommissioning of NSFNET in 1995. The introduction of visual tools like Mosaic for navigating the World Wide Web, and the push for telecommunications development by the Clinton – Gore administration led to the privatization of the national backbone network.

To facilitate the transition, NSF designated four regional aggregation points, called network access points (NAPs), where private carriers could interconnect their backbone networks to create a fully compatible nationwide data network. [Figure 3(a), see over]. In just four years, a flurry of construction by over two dozen companies has created a vast web of regional and national Internet backbone networks, primarily interconnected through the NAPs. By early 1999, key intermetropolitan routes such as New York – Washington and Los Angeles – San Francisco had over 5000 Mbps transmission capacity, over 100 times that of the last NSFNET backbone constructed in 1991.

Using network maps published in *Boardwatch Magazine* (1997; 1999) a trade publication for the Internet service providers' industry, it is possible to create a database of the endpoints and capacity of all intermetropolitan backbone networks. Figure 3(b) (see over) is a map of these data for the fall 1997 period, which displays 80% of total backbone capacity. The remaining 20% of capacity connects points that are not geographically adjacent and would render the map illegible. The seven metropolitan areas marked with large bold circles represent the seven largest hubs for Internet connections. The smallest hub among these seven metropolitan areas, Los - Angeles, still has nearly twice the total capacity of the next largest hub, Denver.

Between 1997 and 1999, the network continued to expand dramatically, as shown in figure 3(c). Figure 3(c) also shows only 80% of the Internet backbone, yet the nature of growth that occurred over this period has resulted in a much clearer geographic pattern. Unlike in 1997, by 1999 one set each of direct connections and indirect connections serve most routes between the major metropolitan hubs. For example, the Atlanta – Washington route is served (on aggregate) by a high-capacity direct connection as well as a secondary connection passing through intermediate locations in North Carolina and Virginia.

These figures illustrate the emergence of highly networked metropolitan regions such as Seattle, Austin, and Boston. These areas each have a number of backbone connections that far outpaces their population. Far more populous regions such as Philadelphia and Detroit lack a comparable number of backbone connections.

The metropolitan dominance of the commercial Internet backbone is clear. Backbone networks are used to link metropolitan areas to each other, not to remote and outlying areas. For example, despite the popularity of resorts such as Aspen, Colorado among a growing population of elite telecommuters, this much-publicized trend has yet to have any effect on the overall geography of the nation's information infrastructure.

Despite the constantly shifting centers of early networks, the aggregate commercial Internet backbone appears to have stabilized geographically around a core set of seven metropolitan areas. This consolidation is most clear in the relationship between the number of links and rank. In figure 4 (see over) the number of backbone links by metropolitan area on the vertical axis is plotted against the rank by number of backbone links on the horizontal axis. Compared with the fitted exponential regression line, the top seven metropolitan areas clearly form a separate group. Beyond this group, there is a fairly stable distribution of network nodes. More significantly, however, between 1997 and 1999, a period of intense deployment of new networks and capacity, the gap between the top seven metropolitan areas and the rest has remained. In 1997, Washington, DC had 3.17 times more links than the 8th ranked metropolitan area (Phoenix). By 1999, the Washington area still had 3.15 as many links as the 8th ranked metropolitan area (Seattle).

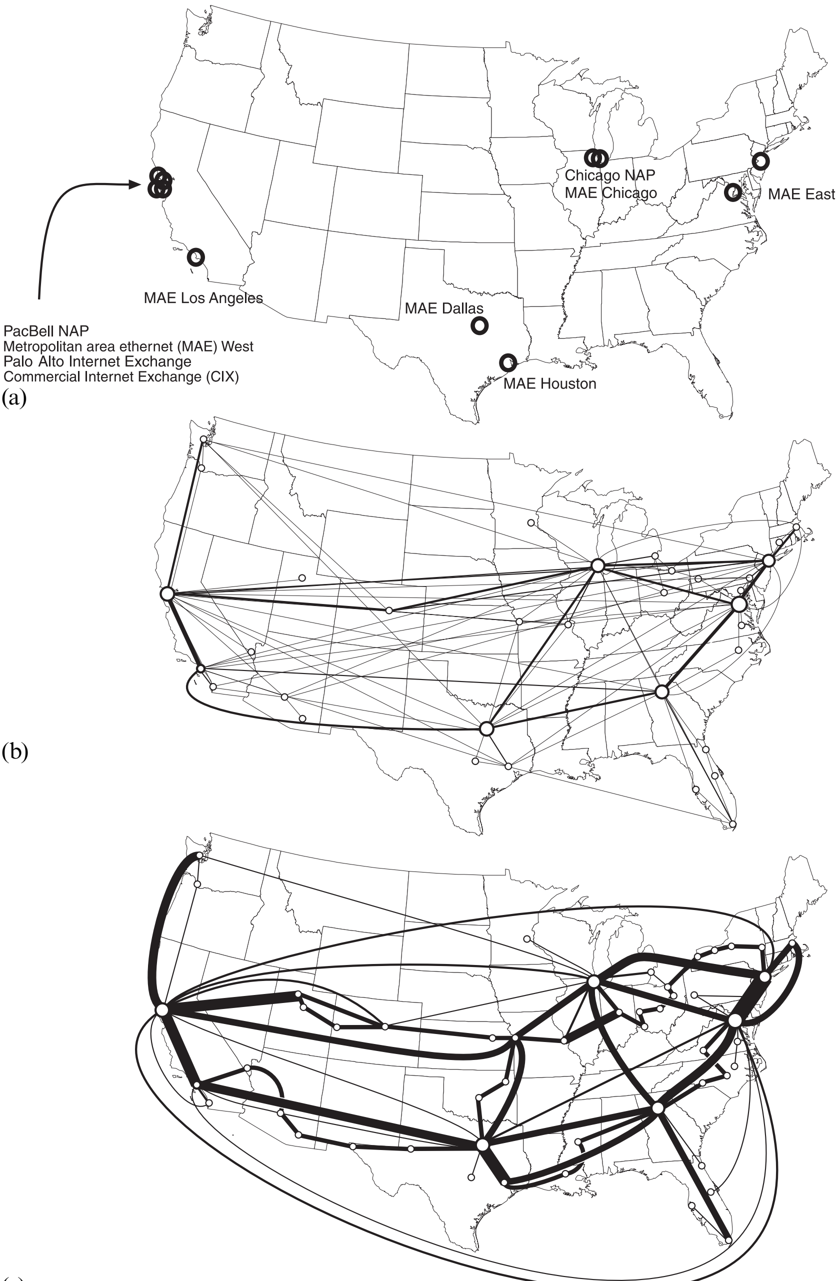


Figure 3. (a) Network access points (NAPs) and interconnection points; and the commercial Internet backbone in (b) 1997 and (c) 1999.

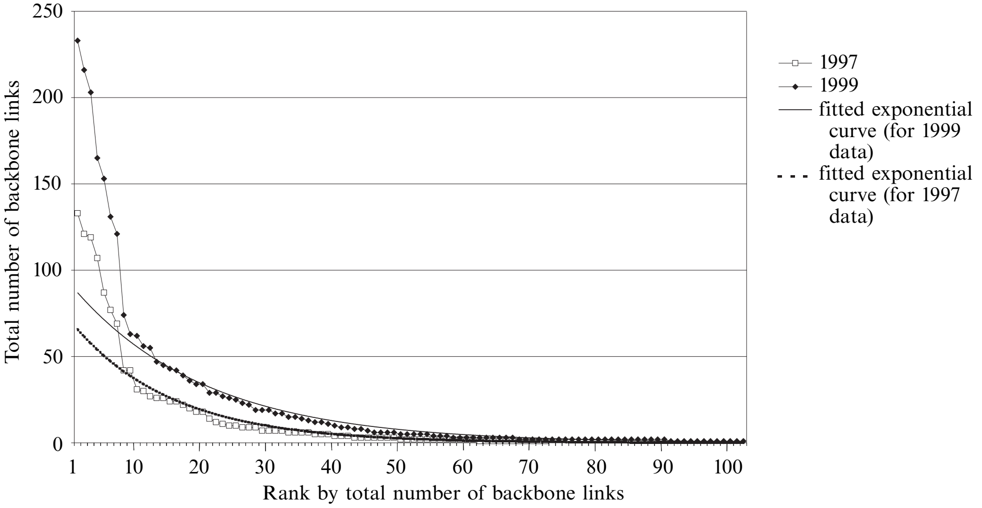


Figure 4. Rank – size relationship for backbone links by metropolitan area.

Finally, in table 1, the continued importance of this group of metropolitan areas as hubs for backbone networks despite the rapid growth of capacity over this period is summarized. By 1999, although network capacity grew five-fold over the study period, 58.8% of network links still originated in just ten metropolitan areas, down only slightly from 64.6% in 1997.

Table 1. Leading metropolitan areas for Internet backbone links in 1997 and 1999.

Year	Metropolitan area	Number of links to other metropolitan areas	Percentage share of all links in the USA
1997	Washington, DC	133	10.4
	San Francisco/San Jose	121	9.4
	Chicago	119	9.3
	New York	107	8.3
	Dallas	87	6.8
	Atlanta	77	6.0
	Los Angeles	69	5.4
	Phoenix	42	3.3
	Houston	42	3.3
	Seattle	31	2.4
	Total for these 10 metropolitan areas	828	64.6
1999	Washington, DC	233	9.6
	San Francisco/San Jose	216	8.9
	Chicago	203	8.4
	New York	165	6.8
	Dallas	153	6.3
	Atlanta	131	5.4
	Los Angeles	121	5.0
	Seattle	74	3.1
	Boston	63	2.6
	Houston	62	2.6
	Total for these 10 metropolitan areas	1421	58.8

The legacy of early networks

The aggregate structure of the commercial Internet backbone in the United States today is markedly different from the planned networks of the past (ARPANET and NSFNET). In general, the distributed structure that was somewhat realized by ARPANET has instead been replaced by the decentralized hub-and-spoke structure first put in place in 1987 for NSFNET. Considering that the share of backbone capacity in the top seven metropolitan areas remained constant at approximately 60% between 1997 and 1999, this pattern is established and persistent. Finally, as a reflection of the workings of a highly competitive market, it is reasonable to assume that this network structure reflects the level of information flow across the Internet between these regions.

It is clear that each phase of network development led to the rise of new locations as centers for activity. In general, those regions that have been involved with networking the longest have the highest level of penetration. ARPANET helped push the adoption of the technology very early on in the San Francisco and Boston areas, as well as Washington, DC and Los Angeles. NSFNET linked research universities to the network in many metropolitan areas that later became key nodes, such as Atlanta, Denver, and Seattle. Still others, like New York and Chicago, were not connected until the most recent phase of commercial development.

Finally, the location of the NAPs has done much to shape the geography of the commercial Internet. With the exception of Atlanta, every one of the seven major metropolitan backbone hubs was the site of a NAP following the privatization of NSFNET.

The urban geography of Internet activity

This section complements the preceding analysis of Internet infrastructure by analyzing the distribution of Internet activity in the United States as measured by the location of domain name registrations. High levels of activity are spread among a broad set of large and medium-sized metropolitan areas.

Domain names

Domain names are a basic part of the Internet's addressing scheme and are used to help map intuitive names (gis.mit.edu) to the arcane numeric addresses (18.89.1.209) that computers actually use to find each other on the network. Although there are many special cases, in general the publicly available billing address for the domain name can be used geographically to locate the owner of that name. A thorough discussion of the caveats of this measurement exists elsewhere and will not be repeated here (Moss and Townsend, 1997b).

The spatial distribution of domain name registrations is useful in uncovering geographic variations in Internet activity. As a direct artifact of the overlay of socially constructed divisions on the technological fabric of cyberspace, the domain name offers a unique link from cyberspace back to physical geography. In this study, the data on the number of domain name registrations were analyzed by postal code area (ZIP code) for January 1999 in the United States. Data were obtained from Domains On Disc (www.domainsondisc.com), which provides the addresses of firms with an Internet presence. In addition to identifying the regions with the largest clusters of Internet activity, the density of domain name registrations with respect to the local population is also used as a measure of intensity.

Differences among metropolitan areas

As indicated in table 2, at the highest level of aggregation (the metropolitan statistical area) the global cities of New York and Los Angeles clearly contain the largest clusters of Internet activity. However, the regions with the third and fourth largest

Table 2. Leading metropolitan areas by domain name registrations, January 1999.

Metropolitan area	Population (millions)	Number of domains (thousands)
New York*	19.8	156
Los Angeles*	15.7	154
San Francisco/San Jose*	6.6	106
Washington, DC*	7.2	77
Chicago*	8.5	64
Boston*	5.8	63
Dallas–Fort Worth*	4.5	44
Seattle*	3.4	42
Philadelphia*	6.0	42
Miami*	3.5	41
Houston*	4.2	38
Atlanta	3.5	34
San Diego	2.7	32
Minneapolis	2.8	30
Phoenix	2.5	28
Denver*	2.3	26
Detroit*	5.3	26
Portland, OR*	2.1	22
Austin	1.0	15
St Louis	2.5	14

*Denotes a 'consolidated' metropolitan area—a larger region designated for the more populous metropolitan areas.

number of domains are San Francisco and Washington, DC. Chicago, which is typically considered a global city in the academic literature (Abu-Lughod, 1999), ranks closer to Boston than to either New York or Los Angeles. Furthermore, there are a number of medium-sized metropolitan areas that top the list—including Boston, Seattle, Miami, and Atlanta.

By ranking regions in order of the density of Internet activity rather than magnitude, a significantly different list is generated. In table 3 (see over), all metropolitan areas are ranked by the number of domain name registrations per thousand persons, which is described as *domain name density*. Not surprisingly, the San Francisco/San Jose metropolitan area is still ranked highest, with 15.9 domains per thousand persons. However, a number of other large and medium-sized metropolitan areas have a strikingly high number of domain name registrations, including Seattle, San Diego, Miami, Denver, Phoenix, Minneapolis, Portland, and Atlanta. The larger metropolitan areas of Washington, DC, Los Angeles, Boston, Dallas, and Houston also rank in the top twenty. By contrast, Los Angeles is the only global city within the top twenty.

In general, medium-sized metropolitan areas dominate as centers for large and dense centers of Internet activity, and global cities appear to be competitive (if not dominant). However, small metropolitan areas—many of which are quite remote or geographically isolated and, presumably, could benefit greatly from the use of Internet technologies to overcome geographic and scale limitations to economic growth—show very low levels of Internet activity. Only two metropolitan areas under 1000 000 persons have a domain name density higher than nine domains per 1000 persons. But 83% (227 out of 273) of the metropolitan areas in this study have a population under 1000 000. This pattern coincides with the geographic distribution development of backbone networks in the previous section of this paper, which largely bypassed smaller metropolitan areas.

Table 3. Leading metropolitan areas by domain name density, January 1999.

Metropolitan area	Population (millions)	Number of domains per 1000 persons
San Francisco/San Jose*	6.6	15.9
Austin	1.0	14.9
Provo, UT	0.3	12.6
Seattle*	3.4	12.4
San Diego	2.7	12.1
Miami*	3.5	11.9
Denver*	2.3	11.5
Las Vegas	1.1	11.1
Phoenix	2.5	11.1
Minneapolis	2.8	11.0
Gainesville, FL	0.2	11.0
Boston*	5.8	10.9
West Palm Beach, FL	1.0	10.8
Washington, DC*	7.2	10.7
Portland, OR*	2.0	10.7
Orlando, FL	1.4	10.1
Los Angeles*	15.7	9.8
Dallas–Fort Worth*	4.5	9.7
Atlanta	3.5	9.7
Houston*	4.2	9.0

*Denotes a consolidated metropolitan area—a larger region designated for the more populous metropolitan areas.

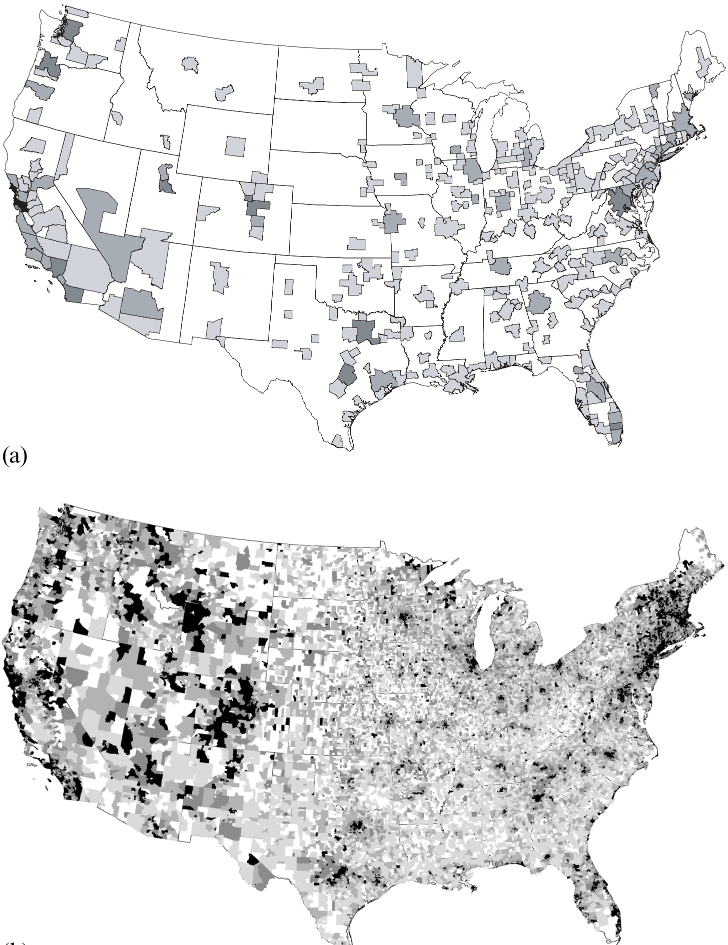
These patterns are more easily understood through maps. Figure 5(a) shows the domain name density in all metropolitan statistical areas in the United States. The major metropolitan areas of both coasts have high concentrations of domain names. In the interior, however, only Minneapolis, Denver, and the three Texan cities (Austin, Houston, and Dallas) show high concentrations of domain names. The Rust Belt and much of the South and Plains, already economically challenged areas, show an average concentration less than half of the other regions.

Figure 5(b) offers a much richer picture, indicating domain density by ZIP code and including nonmetropolitan areas as well. While the high-density patterns in and around a handful of key metropolitan areas are still apparent, it is clear that there are large rural areas in New England and the Mountain West with very high levels of penetration. These regions are sparsely populated, however, and although the high rate of adoption in these areas is a legitimate subject of interest, the large and dense metropolitan domain clusters are much more prevalent.

Differences within metropolitan areas

If one assumes that the Internet and electronic commerce will have a major impact on economic activity, the metropolitan areas indicated in table 2 and table 3 are best poised to capture the growth associated with these changes. The potential for the firms and the individuals in these metropolitan areas to exert their influence in global markets and culture represents a challenge to the established order as formulated by the global cities concept.

However, Internet activity is not evenly distributed inside metropolitan areas. Global cities in particular are fraught by a number of social polarizations that have characterized their development in the past and are reflected in the diffusion of Internet technologies within these regions. In comparison, in the medium-sized metropolitan



(a)

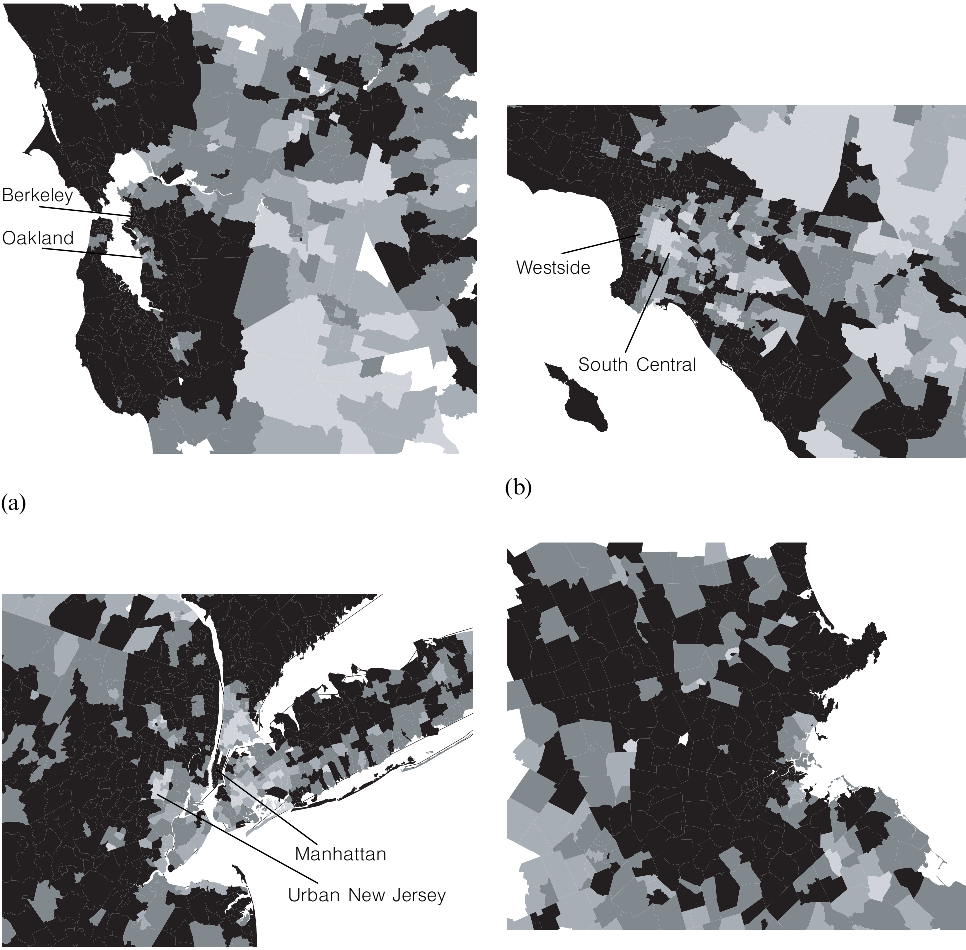
(b)

Figure 5. Domain name densities in January 1999 by (a) metropolitan area, and (b) postal code. The darker the shading, the higher the density.

areas that have high domain density—the new network cities—variations are much smaller.

Figure 6 (see over) shows four maps comparing domain name density in global cities with that in the new network cities. In California, the San Francisco area clearly has a much more even distribution of domain names than Los Angeles, where immigrant and minority neighborhoods show little Internet activity. Within the San Francisco area, the difference in domain name density between academic Berkeley and poor, ethnic Oakland is hardly on the scale that separates South Central Los Angeles from the affluent Westside. On the east coast, Manhattan's Silicon Alley agglomeration of web-design firms is surrounded on all sides by a ring of largely disconnected communities in the outer boroughs of New York City as well as urban New Jersey. In contrast, most communities in the Boston region enjoy a high level of Internet activity.

These spatial patterns further illustrate the social and economic dimension of these new network cities. As discussed earlier, Boston and San Francisco have had many years for technology to permeate throughout their population. In both regions, computer technology has been a major component of the economy for at least twenty years, and both regions have a highly educated population.



(c) (d)

Figure 6. Domain name densities in global cities and network cities: (a) San Francisco; (b) Los Angeles; (c) New York; and (d) Boston.

These cases highlight the emergence of a new breed of global city. In contrast to the traditional global city, the *network city* is typically a medium-sized metropolitan area with excellent access to high-capacity Internet backbone networks and possessing a broad-based diffusion of Internet activity throughout its highly educated population. Other examples in the United States include Washington, DC, Seattle, San Diego, and Minneapolis.

Discussion

The rise of the new network cities

The preceding analysis of high-capacity Internet backbone networks, and the metropolitan activity nodes they connect, illustrates the rise of a new urban system in the United States. In this section, I synthesize the backbone and domain name measurements to compare the newly emerging hubs of Internet activity with the global cities as identified by the academic literature: New York, Chicago, and Los Angeles. The list of cities is not intended to be comprehensive nor exact, but rather to illustrate the broad extent to which access to advanced telecommunications technologies has diffused throughout the US metropolitan system. Finally, it is intended to stimulate a reevaluation of how urbanists define what makes one city 'global' and another not.

Table 4 summarizes and compares the two indicators discussed above to begin laying out a broad typology for cities in the digital economy. To identify these new network cities, the first consideration is domain name density, so that only regions with a high level of activity are selected. Second, backbone capacity and total number of domains must be sufficiently large. Third, the list is split based upon the population of the metropolitan area. This results in a three-tiered list, with each tier sharing a number of characteristics. These metropolitan areas are compared with the established global cities on all three criteria, and population figures are used to show how similar-sized metros show similar characteristics. Finally, several examples of metropolitan areas that are not participating in this new urban network are given. The results of this exercise raise a number of questions.

Table 4. Comparison of Internet measures for new network cities, established global cities, and information blackholes.

Metropolitan area	Number of domains per 1000 persons	Number of domains (thousands)	Backbone capacity (Mbps)	Population (millions)
The new network cities				
Tier 1				
San Francisco/San Jose	15.9	106	28 297	6.6
Washington, DC	10.7	77	28 370	7.2
Tier 2				
Dallas	9.7	44	25 343	4.5
Houston	9.0	38	11 522	4.2
Atlanta	9.7	34	23 861	3.5
Boston	10.9	63	8 001	5.8
Seattle	12.4	42	7 288	3.4
Tier 3				
Miami	11.9	41	4 478	3.5
Minneapolis	11.0	30	1 545	2.8
San Diego	12.1	32	2 160	2.7
Phoenix	11.1	28	6 701	2.5
Denver	11.5	26	8 674	2.3
Las Vegas	11.1	13	4 791	1.1
Established global cities				
New York	7.9	156	22 232	19.8
Los Angeles	9.8	154	14 868	15.7
Chicago	7.5	64	23 340	8.5
Information blackholes				
Detroit	4.9	26	2 245	5.3
Philadelphia	6.9	42	4 280	6.0
Cleveland	4.2	12	6 201	2.9
St Louis	5.7	14	10 342	2.4

Mbps, megabits per second.

Rethinking global cities

Rather than being completely centralized in a small group of global cities, nodes for Internet activity are distributed among a far broader group of information-producing regions in the United States than predicted by the global city hypothesis. It is therefore clear that current concepts of the definition, role, and functioning of global cities that rely upon a supposed superiority in telecommunications services are seriously flawed.

For example, San Francisco has only been identified as a global city in four of nine major identification efforts (Jo, 1992). Washington, DC has only been so named once, yet it is the leading hub for backbone networks in the United States. Furthermore, at least a dozen metropolitan areas outpace Chicago in Internet activity, and even Dallas has greater backbone capacity. Nonetheless, Chicago continues to be considered a global city by urban scholars.

Classification schemes for cities that fail to take into account the availability and usage of telecommunications systems will inevitably fail. But more importantly, the findings of this study must lead to a more fundamental question. Is this merely a matter of measurement and definition, or must these emerging regions now be considered effectively 'global'? In other words, are we witnessing an explosion in the variety of regions that actively participate in global flows of capital and information, facilitated by the dramatically different spatial economics of packet-switched telecommunications networks? It is the interpretation of this analysis that the new networked system shown in this analysis reflects a fundamentally new spatial pattern. In the past, urban hierarchies evolved into the centralized or decentralized networks that characterize industrial nations, structures which sought to minimize the cost of transport and secure control over branch plants and offices. The network city, however, operates in an economy where the transport costs of the highest value products—information and knowledge—are fairly insensitive to distance. Furthermore, the widespread proliferation of sophisticated information technology has undermined the need to coordinate operations in a central headquarters. Both trends, as well as emerging patterns in air transportation, point towards a continuation of this distributed pattern of urbanization in the future—a structure of urban activity nodes connected by many redundant pathways. Such a form exists directly in subversion to the traditional gatekeeping role of global cities.

Practical planning concerns

Apart from questioning a purely academic determination of what constitutes a global city, the results of this analysis raise a number of practical concerns for urban planners and policymakers which should be addressed through future research.

First, a cursory examination of the cities identified as emerging Internet nodes reveals that this might also be a list of the most economically prosperous metropolitan areas in the United States. High-technology firms have driven the expansion of the US economy in the 1990s, and they are highly concentrated in these regions. These regional economies have developed into enormously effective feedback loops in which growth and wealth feed new technological innovation and Internet development, which in turn drives new growth.

The danger and concern arise when turning attention to those regions that cannot achieve the critical mass necessary for development to 'take off'. Thus, in some ways, problems of regional development within a country might begin to resemble those that have plagued international development for decades. This is likely happening inside the United States, with the network cities described in this paper pulling away from smaller cities and interior regions. This also appears in the United Kingdom in the once again growing fracture between the prosperous South and the economically stagnant North.

A second concern, and corollary of the first, is the direction of causality between the development of Internet infrastructure and the level of productive activity in cyberspace within a geographic region. It is tempting to gravitate towards the popular 'information superhighway' metaphor and address the problem of cyberspatial underdevelopment as merely a shortage of adequate physical infrastructure. Yet any number of cases around the world, most recently Singapore's troubles with underutilization of its new national data networks, indicate that the real challenge to information development is not physical or financial capital, but human capital.

As a result, what at first appears to be a challenge for physical planners becomes a highly complex problem. For example, the Washington, DC metropolitan area has both the highest per capita income and the highest proportion of college graduates in the United States. What is most disconcerting is that a lack of these human assets can take many years, or even decades to alleviate. As there already exists a critical and growing shortage of skilled high-technology workers in the United States and Europe, regions attempting to bootstrap their economy into a growth cycle will not be able to attract the necessary labor force. Places that already have a large skilled labor force will become even more special and attractive to footloose firms. Quick-fix policies that try to use physical infrastructure as an incentive will fail without substantial commitments to develop the skilled labor force which is necessary to make these facilities a valuable asset.

In conclusion, it is increasingly clear that a new type of global city, the network city, is emerging in the United States and possibly elsewhere in the world. These highly prosperous regions are attracting the skilled workers and the investment in infrastructure that is needed to sustain their growth, often at the cost of lost opportunities for other regions, and they are being organized into an exclusive and highly codependent economic system. Although the Internet is the increasingly visible vehicle for this transformation, it must be made clear and explicit that societies create technologies, not vice versa. In fact, this transformation is in many ways favoring those regions with firms and individuals that are most able to create and shape these new technologies. Without the capacity to use these new tools, struggling regions will always fall behind.

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