The Death of Cities? The Death of Distance? Evidence from the Geography of Commercial Internet Usage

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Where is the internet? It is everywhere, as businesses and households even in the remotest parts of the world are discovering how internet technology revolutionizes communication. But it is also nowhere, with its nearly invisible infrastructure and its ephemeral content. Together, its apparent ubiquity and invisibility give its users a sense of placelessness, of freedom from the traditional constraints of physical distance. But this placelessness is an illusion. The internet is where its users are.

Those users are not everywhere equally: commercial internet domains are disproportionately concentrated in larger metropolitan areas. Firms are more likely to register internet domains, the larger the city in which they are located. This fact runs counter to the popular prediction that the internet should boost the fortunes of small cities and rural areas more than those of larger cities. The great advantage of cities, the popular argument goes, is that cities lower the costs of transporting goods and sharing ideas. Because the internet, too, lowers the costs of transportation (of documents, for instance) and of communication, the internet may replace some of the traditional functions of cities, allowing internet users to reap the advantages offered in cities without having to locate there. Gilder (1995) takes this argument to the extreme, claiming that the internet will cause the "death of cities."[1]

This paper uses data on the geographic diffusion of commercial internet usage to reconcile the fact that internet adoption is higher in larger cities with the widespread claim that the internet substitutes for the advantages of cities. Three hypotheses are considered. First is that the convention wisdom is just plain wrong, and the internet is

[1] Similar predictions have been expressed by Peter Drucker (1989) and Bill Gates (1995). The National Research Council (1998) puts it more soberly: "One can anticipate a shift of population away from the metropolitan areas to bucolic agricultural settings (rural Vermont, the California wine country, fishing villages), to resort areas (Aspen, Monterey, Sedona), and to the sunbelt and beachfront. Just as the automobile, superhighways, and trucking helped

actually a complement, rather than a substitute, for the face-to-face communication that cities facilitate. Second is that the internet is indeed a substitute for face-to-face communication, but cities offer other advantages, like skilled labor and better infrastructure, that facilitates internet usage. Third is that the internet is a substitute for longer-distance communication than the sort that cities facilitate, so that its main effect is benefiting remote cities (though not necessarily smaller cities). Rather than causing the "death of cities," the internet furthers the "death of distance." These three hypotheses are not mutually exclusive.

The empirical results support the first and third hypotheses. There is a positive relationship between city size and internet usage, as measured by commercial internet domain registration, even after controlling for a range of other factors that could explain this relationship. The proximity of a city to other cities, however, is negatively related to internet usage, supporting the hypothesis that the internet is a substitute for longer-distance communication. Similar analysis using a different data source -- individual-level computer usage data from the Current Population Survey – yields the same conclusions.

This paper has four sections. The first section presents the basic facts on the geography of commercial internet adoption. The second outlines the three hypotheses. The third describes the data and the empirical strategy. The fourth presents the results.

SECTION 1: THE BASIC FACTS

The most dramatic fact about the internet is its rapid growth. Over the period January 1994 to January 1998, the number of domains grew at over 11% per month,

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shift population out of the central city to the suburbs in the 1950's, the computer, the information superhighway, and modems will help shift population from the suburbs to more remote areas."

doubling every six or seven months.[2] This growth rate slowed from its peak rate of almost 16% per month in 1995, as internet domains became standard among larger companies in most sectors and among almost all companies in many sectors, including finance, publishing, entertainment, and, of course, computer hardware production and software services. In January 1998, there were over one million commercial domains registered in the United States. There were another 164,000 non-commercial domains registered, with the suffixes .edu (educational institutions), .org (non-profit organizations), and .net (network administration organizations). (See table 1.)

While these internet domains are everywhere – there are commercial domains registered in almost every county in the U.S. – they are not everywhere equally. The most domains, in absolute terms, are in the largest cities. (See table 2.) In 1998, New York, Los Angeles, and the San Francisco Bay Area had the most domains, each with over twice the number of the next area, Washington-Baltimore. But four years earlier, when commercial domains were still a novelty, domains were most concentrated in the San Francisco Bay Area and – at a distant second – Boston. These two areas have long been the centers of computer technology production in the United States, and their early concentrations of commercial internet use suggests the importance of local industry mix.

Looking at domain density, the ratio of domains to commercial establishments, offers a more meaningful comparison. Throughout the period, the Bay Area had the highest domain density. Again, this is in part due to industry mix, with Silicon Valley's computer industry and San Francisco city's multimedia industry. But larger cities

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[2] An internet domain is the address that identifies a computer that is connected to the internet. The domain name refers to the portion of the domain that includes the suffix and the character string immediately preceding it. Examples are amazon.com, schwab.com, and harvard.edu. The advantages of domain names as a measure of internet usage are discussed below.

dominate this list generally. In 1998, five MSA's on the list (San Francisco, San Diego, Los Angeles, Boston, Seattle) are among the largest 20 areas in the country.[3] Domain density is positively correlated with MSA size, and the relationship has grown steadily stronger between 1994 and 1998. (See table 5.) The regression analysis will show whether this positive, strengthening relationship is due to other factors correlated with both city size and internet usage (hypothesis two) or actually does reflect an inherent complementarity between the internet and cities (hypothesis one).

The rankings also offer support for hypothesis three, the "death of distance" argument. The domain density ranking is dominated by western cities, which tend to be more remote. In 1994, seven of the top ten areas were west of the Mississippi; in 1998, eight were. To measure a metropolitan area's remoteness, "isolation" is defined as the average distance between the MSA and the national population outside the MSA. A listing of the most and least isolated large metropolitan areas is in table 6. Isolation and domain density are positively correlated, and the positive relationship strengthens between 1994 and 1998. This is suggestive evidence that internet usage might substitute for longer-distance face-to-face and other non-electronic communication, as hypothesis three suggests.

SECTION TWO: THE THREE HYPOTHESES

This paper tests three different hypothesis that attempt to reconcile the popular prediction that the internet benefits smaller cities and rural areas with the fact that commercial internet usage is higher in larger cities.

[3] There are 270 metropolitan areas, when the CMSA and NECMA definitions are used.

The first hypothesis is that the internet might complement, rather than substitute for, the face-to-face communications that cities facilitate. Gaspar and Glaeser (1996) present a model in which the internet and cities can be complements. Their model specifies two effects that electronic communication (over the internet) has on face-to-face communication (which cities facilitate). On one hand, any given interaction can take place either electronically or face-to-face, so the two forms of communication are substitutes. On the other hand, if some relationships involve both electronic and face-to-face communication, then a decrease in the cost of electronic communication due to the internet raises the overall level of relationships, a fraction of the new relationships will occur face-to-face. The overall impact of electronic communication on face-to-face communication – and, therefore, on the advantages of cities – depends on the relative magnitudes of these two effects. The popular "death of cities" argument focuses only on the first effect, the substitutability between electronic and face-to-face interaction. But, as Gaspar and Glaeser argue, both effects must be considered. The overall effect is ambiguous and must be resolved empirically.

If this first hypothesis is true, then the observed positive relationship should hold true even after controlling for other plausible reasons (outlined below) why internet usage might be higher in cities. Further, if there is a complementarity between the internet and cities, then internet usage should be highest in those cities where face-to-face communication is easiest: in the densest cities. The positive relationship between internet usage and city size should be explained, in large part, by the higher densities of large cities.

The second hypothesis is that the internet is a substitute for face-to-face communication, but internet usage is higher in larger cities for other reasons. Under this hypothesis, these other reasons are strong enough to result in a positive relationship between internet usage and city size, even though the substitutability between the internet and face-to-face communications alone raises relative internet usage in smaller cities and rural areas. Plausible other reasons[4] include:

1. Industry mix: High-tech industries are more likely to locate in larger cities than other industries are, and high-tech industries – particular computer manufacturing, research, and finance – have been quicker to adopt internet technology into their business processes.
2. Local consumer demand: Since residents of larger cities tend to be richer and more educated, and computer ownership and usage is directly correlated with education level and income,[5] local demand should result in higher commercial internet adoption in larger cities. While much of the communication on the internet is national or international in scope, some is local. Local businesses will adopt internet technology if their current and potential customers have access to computers and the knowledge to use them.
3. Technological leapfrogging: The age of a city might also affect its rate of technology adoption. If technologies involve localized learning, and if the learning involved with older technologies contributes little to adopting new technologies, then older cities can remain reliant on older technologies while newer cities adopt newer

[4] Graham and Marvin (1996) and Moss (1998) explore these, and other, reasons for complementarities.
[5] Graphic, Visualization, and Usability Center (1998); U.S. Department of Commerce (1998).

technologies.[6] If today's larger cities are newer, in the sense that their recent growth rates are higher, then technological leapfrogging might cause firms in larger cities to be more likely to adopt internet technology.

4. Skill level of local workforce: Skilled workers are in greater supply in larger cities, and the presence of skilled workers facilitates more rapid adoption of new technologies.[7] With the internet, programmers and other computer specialists often manage internet domains and offer advice on how to incorporate the internet into a firm's business process. And every business that uses the internet needs workers – not necessarily computer specialists – with the general skills necessary to use the internet day-to-day.
5. Physical infrastructure: Internet data travel along copper wires and fiber-optic cables, most of which are leased from or owned by local and long-distance telephone companies.[8] The quality of the local telephone infrastructure influences the quality of local internet service or, put another way, the cost of receiving a given level of internet service. Larger cities have more advanced telecommunications infrastructure;[9] this might help explain higher internet adoption rates in larger cities.
6. Spillovers from pre-commercial internet users: Before its commercialization in the 1990's, the internet linked together supercomputers at defense agencies and

[6] Brezis and Krugman (1997) develop a model of local technological leapfrogging. An example of this is the used- and rare-book industry. A New Yorker searching for a rare book will go door-to-door among the used bookstores off lower 5th Avenue, asking knowledgeable proprietors about their collections and those of their neighbors. The competing new technology is an on-line service like the one offered by Amazon.com, which searches a network of used-book collections until the book is found. Amazon's employees are doubtlessly less knowledgeable about rare books than the Manhattan bookstore owners, and the Manhattan bookstore owners less knowledgeable about computerized searching than Amazon's employees. Amazon is located not in New York but in Seattle, far from the center of the older book-searching technology.

[7] Doms, Dunne, and Troske (1997).

[8] Even dedicated data lines – that is, wires and cables that are operated by internet service providers and only carry internet traffic – are usually leased from telephone companies.

[9] Greenstein, Lizardo, and Spiller (1997).

universities. Since knowledge spillovers are localized,[10] one would expect to see commercial applications of the internet to arise first where the pre-commercial applications were adopted. The geographic distribution of defense activity and university research is highly uneven and might explain the higher rates of commercial internet adoption in larger cities.

7. Technology diffusion and learning: Innovations of all kinds tend to arise first and diffuse faster in larger cities. Because the cost of planned and spontaneous communications are lower in larger cities, the likelihood of learning about a new technology, or learning how to adapt a technology to a particular purpose, is higher in larger cities.[11]

The first six of the seven above reasons can all be assessed directly using explanatory variables – like local skill level or local infrastructure quality. After controlling for these other reasons, the remaining effect of city size (or density) on internet adoption is a cleaner indicator of the underlying substitutability or complementarity of the internet and face-to-face communication.

The seventh reason – technological diffusion occurring first and fastest in larger cities – is more difficult to identify empirically. The difficulty arises because the feature of cities that facilities rapid technology diffusion – the ease of face-to-face communications – is exactly the feature for which the internet might be a substitute.[12] One cannot separate the diffusion effect and the hypothesized substitution effect of city

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[10] Jaffe, Trajtenberg, and Henderson (1993).

[11] Glaeser and Mare (1994) offer empirical evidence that the wage premium in larger cities is due to faster learning (rather than lower goods transport costs, say).

[12] Jane Jacobs (1969) spotted this irony three decades ago, in the case of agricultural innovations. She argues that all inventions rely on cities for their development and dissemination, even if their greatest benefits are ultimately reaped in smaller cities or rural areas. Agricultural innovations were the example that inspired her observation.

size empirically with different explanatory factors, since it is the same force – the lower cost of face-to-face communication – that underlies both effects.

To distinguish these two effects of city size empirically, this paper uses internet adoption rates over time. The diffusion effect of city size on internet adoption should be strongest early in the technology's diffusion and then, as the technology diffuses more widely, should fade over time. In contrast, the inherent substitutability or complementarity of the internet and face-to-face communication is an effect that should endure.

More generally, one should expect factors affecting the supply of internet technology to matter most initially, while factors affecting the demand for internet technology to endure. This is the framework Griliches (1957) adopts in his classic study of hybrid corn adoption.[13] Of the seven reasons listed above why internet adoption might be higher in larger cities, the first three affect the demand for internet technology and the last four affect the supply (that is, the cost of acquiring and implementing) internet technology. Of the last four, three reasons – skill level, pre-commercial users, and physical infrastructure – can be measured directly. If the empirical section demonstrates that their influence on internet usage declines over time, then by extension the last reason should decline over time as well.[14]

To summarize: the second hypothesis is that the positive relationship between internet usage and city size is due to other reasons why cities raise internet usage and not due to an underlying complementarity between the internet and face-to-face interactions.

[13] Griliches (1957) analyzes the diffusion process of this agricultural innovation and related the diffusion process to spatial differences in supply and demand for the innovation. He associated variation in the initial adoption of hybrid corn with supply-side factors, and variations in the later rates of adoptions and predicted ultimate levels with demand-side factors. His identification rests on the assumption of long-run elasticity in the supply of seed (and other inputs) for hybrid corn. A similar framework can be used for the diffusion of internet technology.

The empirical implication is that, after controlling for the explanatory factors, the relationship between city size and density should either become negative or – if the diffusion effect matters greatly – possibly positive but certainly declining over time.

The third hypothesis is that information technology is primarily a substitute for longer-distance communication, either by personal travel or by non-electronic communication (like regular mail or other document delivery services). This differs from the popular argument that information technology is primarily a substitute for the daily planned and spontaneous face-to-face interactions that cities facilitate. The third hypothesis implies that the greatest beneficiaries of the internet would, in that case, be firms located in places – including large cities – that are relatively isolated.[15] Call this the "death of distance" argument, put forth in a recent eponymous book (an allusion to a 1966 history of Australia called the Tyranny of Distance).

DATA

This paper uses data on commercial internet domains to distinguish among these three hypotheses. An internet domain is the address that identifies a computer that is connected to the internet. Any company wishing to conduct electronic commerce, send product information, receive customer data, or transfer electronic information is likely to have registered a domain name. Each internet domain is registered to a company or person with a physical address, and this physical address is recorded when the internet domain is registered. Companies register domain names for a small fee with Network Solutions, under an exclusive U.S. government contract.

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[14] A model of supply, demand, and technological diffusion is given in Appendix One.

A domain name is a good, though imperfect, measure of internet usage. Companies are able to have e-mail without a domain name (through America On-Line, for instance), and the mere fact of a registered domain name does not imply that the internet is integrated into the daily business process. But even casual business users of the internet now have internet domains, and domain names are now a primary means of corporate identification and advertising. Television ads and billboards now include internet domain names (usually embedded in a World Wide Web address) as often as they include toll-free telephone numbers. Nearly every company with an internet presence has registered a domain name.

While a small fraction of companies lack an internet domain, another small fraction has multiple domains.[16] Some firms register a domain name for each product line, for instance. The domain gm.com is General Motors's corporate domain name, and General Motors also uses pontiac.com, chevrolet.com, and others. The number of domains registered to a company usually reflects the size of the company or the intensity of its internet usage. This affects the interpretation of domain data, without necessarily introducing bias.

This physical address is the location of the business to whom the domain refers, as opposed to the location of the internet service provider or the physical web server. For instance, spanishbookstore.com refers to the Spanish Language Bookstore in Chicago, whose domain name was registered by a consultant living in San Francisco, and the web

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[15] Not all remote places are small, even within the U.S. Many large cities, like Seattle and Denver, are far from other cities of similar size. A more extreme example is Sydney, Australia (where internet usage happens to be very high).

[16] A potential form of bias does exist, though: domain name speculators purchase hundreds or thousands of domain names for later resale. Luckily, the probable instances of speculation are rare and easy to identify in the data. See appendix for details on cleaning the domain data.

site sits on a server in Portland; this domain is assigned to the zip code of its location in Chicago.

The domain data in this paper are aggregate counts of new domains registered, by month and by zip code, from January 1994 to January 1998. The zip code associated with each domain is the location of the company referenced by the domain. The data include no other information about the individual firms or the intensity of internet usage. These domain data were compiled by Imperative!, an internet consulting firm, which downloaded the domain data from InterNIC, the branch of Network Solutions that registers domain names.

Only commercial domain names – those ending in ".com" – were included. Government, university, and non-profit domains are excluded from the data. The domain data were aggregated to the metropolitan area level, using the U.S. Postal Service's delivery type file and the official 1995 metropolitan area definitions.[17]

The empirical strategy with the domain data is to regress technology usage on several explanatory variables. The identical specification will be used for technology usage at five different points during the diffusion process: the month of January, from 1994 to 1998. The unit of observation is the metropolitan area, which facilitates matching to a range of explanatory variables. In all, the dependent variable is the log of ratio of <u>cumulative</u> registered commercial domains to commercial establishments; this ratio is referred to as "domain density." The main explanatory variables of interest are metropolitan area size and metropolitan area's isolation from other population centers.[18]

[17] New England County Metropolitan Areas (NECMA's) in New England, and Consolidated Metropolitan Statistical Areas (CMSA's) where relevant.
[18] Detailed variable definitions can be found in the data appendix.

As a comparison, a similar empirical analysis will be performed using the Current Population Survey (CPS) data. The CPS included detailed questions on computer usage in its 1989, 1993, and 1997 October education supplements. Specifically, respondents were asked whether they used a computer at work and, if so, for what purpose. Possible answers included electronic mail and communications. Since industry, location, and labor force characteristics are available in the CPS, it is possible to estimate the effect of location characteristics (like city size) on the likelihood of using a computer for communications at work. The CPS data differ from the domain data in two major ways. First, the data refer to individual employees' computer usage rather than a firm-level decision to register an internet domain. If location characteristics are correlated with the fraction of employees in a firm that use a computer for communications, the CPS results should differ from those using domain counts. Second, having a registered internet domain is not synonymous with using a computer for e-mail or communications. Intra-firm electronic-mail preceded internet domains in many companies; accordingly, the CPS data show some e-mail and communications usage long before the commercial registration of internet domains.

RESULTS

The regression analysis uses the data on domain density to test the validity of the three hypotheses. The dependent variable, domain density, is regressed on city size, city isolation, and other explanatory variables. A simple log-log regression of domain density on city size yields a coefficient of .29 – this means that a doubling of city size implies a

29% increase in domain density. (See table 7, column 1.) This positive relationship between domain density and city size is the basic fact that this research explores.

Before controlling for other factors, a correction is necessary. A domain is assigned to a firm's headquarters address, even though internet technology might affect business processes at all establishments in the firm. The data on domain density indicates only the location of the firm's headquarters, therefore understating the adoption of information technology in cities with few corporate headquarters. Since multi-establishment firms tend to locate their headquarters in larger cities, the relationship between city size and domain density (per commercial establishment) overstates the relationship between city size and internet usage. Starting with column 2 of table 7, the ratio of business headquarters to total establishments is included as a control. The tendency of business headquarters to be in larger cities accounts for one-third of the univariate effect of city size on domain density. The coefficient drops from .288 to .188.[19]

To begin testing the hypotheses for this positive relationship, several control variables are introduced into the regression. A key control variable in explaining domain density is local industry mix, as explained above. While the domain data do not identify the industries of individual firms, there is enough geographic variation in industry mix that correlations between industry shares and domain density are revealing. In 1994, the places with the highest domain density were those with considerable computer

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[19] A better method would be to define domain density as the ratio of domains to business headquarters. However, a complete count of business headquarters is unavailable publicly. The headquarters counts come from the One-Source Business Browser. One-Source is an incomplete list, including around 120,000 businesses. The headquarters counts for individual metropolitan areas were implausibly low, and using the headquarters counts as the denominator introduced gross irregularities into the domain density values. This problem is avoided by using establishments as the denominator for domain density, because the complete establishment counts are available in County Business Patterns. CBP does not identify which establishments are headquarter locations.

manufacturing, software, and data processing industries – unsurprising, since these are the industries that produce internet hardware, internet software, and related technology. The correlations between the presence of these industries and domain density peaked in 1995 and 1996, and then declined slightly. (See table 4.)

In contrast, the correlations between domain density and two other sectors, finance/insurance/real estate (FIRE) and professional business services,[20] started lower but rose consistently over the time period. Since 1996, the correlation between professional business services and domain density has been higher than the correlation between computer manufacturing and domain density. These relationships suggest a spread of internet technology from the sectors that produce the technology to those who are primarily consumers. They also show that the initial diffusion of internet technology differs from its later distribution, as previously lower-tech industries learn how to incorporate internet technology into daily business practices. This process continues: there are still other industries with low internet usage, like the legal profession, which have not yet incorporated the internet into daily business practices, but could benefit greatly from increased electronic information storage and communication.[21]

Columns 3 and 4 of table 7 introduce controls for industry mix and others factors.[22] Including the demand- and supply-side factors lowers the coefficient on city size to .139, and including industry controls lowers it further to .096. Thus, almost half of the univariate coefficient in column 2 can be explained with factors correlated with

[20] Professional business services include management consulting, public relations, accounting, engineering, and architectural services, among others.
[21] Reuters (1998).
[22] The industry-mix controls are the share of local establishments in each of the five industries shown in table 4; the share of local establishments in each of three one-digit SIC sectors (trade, manufacturing, and services); and the share in high-tech manufacturing (electronic equipment aside from computers, transportation equipment, and the instruments/photographic/medical equipment category).

both city size and domain density, but the basic relationship persists: city size is positively related to domain density, and significantly so.

The control variables generally have their expected effects. Average income and average education level are both strongly positive. While the education variables alone might reflect the importance of skilled labor or the importance of educated consumers, the income variable reflects the role of consumers specifically. The positive coefficients on both education and income suggest that both skilled labor and local demand matter. The importance on skilled labor is unsurprising, since even in the age of the internet labor market are still, for the most part, local. However, the importance of local demand is evidence that businesses use the internet, in part, for local transactions. Were consumers as likely to use the internet to reach distant businesses as local businesses, then average local income would not affect the demand for a business's electronic commerce and therefore not affect its likelihood of adopting internet technology. Thus, while the archetypal internet business is Amazon.com, serving customers across the country as easily as across Puget Sound, a more typical user might be the local florist taking orders over the web from local customers.

The results are also consistent with the theory of technological leapfrogging. The coefficient on population growth is positive and significant, suggesting that firms in cities less steeped in older technologies have greater demand for new technologies. This relationship holds even when industry controls are included (column 4), so the effect is not simply that growing cities have newer, more technologically advanced industries. The positive relationship, even with the inclusion of the fiber-optic cable variable, means that the technological-leapfrogging argument is not about physical infrastructure, but perhaps about some intangible process akin to the localized learning story in Brezis and Krugman.[23]

The last result to highlight from table 7 is the positive coefficient on university presence. It was argued, above, that since universities and the Defense Department were the main pre-commercial users of the internet, greater subsequent commercial usage in university and defense-research towns might be evidence of localized spillovers. This offers support for the university spillovers theory, because the main pre-commercial internet users were the elite research universities. However, the coefficient on the level of government procurement contracts per capita – the other main pre-commercial area of internet usage – is insignificant.

Table 7 established that the positive relationship between city size and domain density persists even after taking other factors and local industry mix into account. This is consistent with the hypothesis that electronic and face-to-face communication are complements, and inconsistent with the "death of cities" argument. But what remains to be discovered is whether the positive effect of city size is a short-run artifact of the initial diffusion process of commercial internet technology.

Table 8 presents the same regression model in each year of the period. The independent variables are held fixed across all years, to avoid endogeneity. The dependent variable is the cumulative domain density in January of the given year. The column for 1998 is identical to column (4) of table 7. The trends in the coefficient estimates for the clear demand-side and clear supply-side factors support the hypothesis outlined above. The clear demand-side factors, average income and population growth,

[23] Of course, an alternative interpretation is that fiber-optic cable does not measure the physical infrastructure most important for internet adoption. However, the tables below show that in earlier years, fiber-optic cable was highly

become more significant over the time period. The coefficient on average income is significantly different from zero starting in 1997, and its magnitude increases absolutely through 1997. The fall in 1998 is due, in part, to the declining variance of the dependent variable. The coefficient on population growth is significantly positive starting in 1997 and grows consistently over the period. In contrast, the clear supply-side factor, fiber-optic cable, has a positive and significant coefficient in 1994 and 1995, and becomes insignificant and increasingly negative starting in 1996. The decline in importance of physical infrastructure is not simply that the variable, which measures infrastructure quality in 1993, becomes a worse reflection of current local infrastructure. If a 1996 infrastructure measure is used in the 1997 and 1998 regressions, the coefficient remains negative and insignificant.

With some confidence in interpreting the trends in coefficients as shifting from supply-side to demand-side factors, attention can now turn to city size. The coefficient on city size jumps between 1995 and 1996, and remains at this higher level through 1998. This is more consistent with the demand-side explanation of city size rather than with the supply-side explanation of city-size. In other words, the positive effect on city size should be interpreted not as evidence that larger cities fostered rapid diffusion of commercial internet technology, but instead that there is a longer-term positive relationship between city size and domain density that reflects a complementarity between face-to-face and electronic communication. Again, this result is consistent with the complementarity hypothesis and inconsistent with the "death of cities" argument.

What about the "death of distance" argument? The coefficient on city isolation is positive and significantly different from zero in all years (see table 8). This relationship,

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related to domain density.

like the relationship between domain density and city size, strengthens over the time period, suggesting that the effect on isolated is not an artifact of the initial diffusion process. Thus, the data support the "death of distance" argument: electronic communication is a substitute for longer-range in-person and non-electronic communication.

Data from a separate source, the Current Population Survey, confirm these results. Table 9 presents individual-level regressions on computer-based communications technology usage at work. The dependent variable is whether the respondent uses a computer at work or electronic mail or other kinds of communication. The regressions include controls for individual characteristics and industry fixed effects. To make the sample consistent with the domain data, public-sector industries were excluded (public administration, education, postal service, and water and sewer utilities). This alternative approach to measuring commercial internet usage yields the same results on city size and isolation. In 1997, the coefficients on city size and city isolation are positive. Again, the effect of city size has grown more positive over time, so the positive relationship reflects longer-term complementarity rather than initial diffusion. Because the CPS data begin in 1989, five years before the domain data begin, they reveal what the domain data cannot: the relationship between city size and communications technology usage was initially negative. At that time, then, the "death of cities" argument would have found empirical support.[24]

Why, then, the shift from substitutability to complementarity between electronic and face-to-face communication? As has been argued, short-term supply side factors would imply that, if anything, the relationship would become less positive as diffusion advanced. For the relationship to become more positive over time, the relative demand for communications technology in larger cities must have increased. Without detailed firm-level data on technology usage, it is difficult to identify or explain this shift in demand, so speculation will have to do.

The reason for this shift might be changes in internet technology itself. The earliest application of internet technology was electronic mail, which is conceptually a direct replacement of existing point-to-point communication technologies like face-to-face contact, telephone calls, fax transmissions, and regular mail. The only metaphor used to describe electronic mail is simply "mail," with its inboxes, return addresses, and carbon copies. Newer internet applications, like the World Wide Web, have no direct counterpart in the non-electronic world. The Web combines the broadcasting functions of television, the reference function of libraries, and the spontaneous exchanges of city streets. The metaphors used to describe the Web are endless, ranging from virtual encyclopedia to virtual shopping mall to the virtual universe. For many firms, the Web represents a new way of doing new business, while electronic mail, by itself, was a new way of conducting old business. There are firms whose only public presence is on the World Wide Web; never was any firm's only public presence on electronic mail.

The early applications of the internet, then, might actually have been a direct substitute for some of the functions of cities. More recent applications of the internet no longer simply substitute for those functions, and seem, on balance, to complement what cities have to offer. Not coincidentally, the evolution of internet punditry has followed

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[24] The standard errors in table 9 are quite high. Using the CPS introduces some measurement error in the independent variables because the metropolitan area definitions are somewhat different. Therefore, the population estimates for

this shift. The "death of cities" argument was made primarily by earlier commentators, and true as it may have seemed at the time, the prediction was premature. The theories of potential or actual complementarity have emerged more recently and, for now, have the weight of empirical evidence behind them. Future applications of internet technology might well change this relationship again, and the internet might again become a clearer substitute for what cities have to offer. Until then, the city can quote Mark Twain: "the reports of my death are greatly exaggerated."

CONCLUSION

The geographic distribution of commercial internet domains is consistent with the view that the internet is a complement, not a substitute, for the advantages of cities. Domain density is higher in larger cities, even after controlling for a range of factors that might otherwise explain this relationship. The complementarity grew stronger over the period 1994-1998, so the relationship can not be attributed to a temporary lead that cities are hypothesized to have in the diffusion of new technologies. On the other hand, domain density is higher in more isolated cities, giving some credence to the "death of distance" argument. The internet to substitutes for longer-distance non-electronic communications. If current trends continue, then larger, relatively isolated cities, like Seattle, Denver, and Miami, will be the long-run "winners" from internet technology.

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individual MSA's are likely to contain more error than the regressions in tables 7 and 8.

Table 1: The Growth of Commercial Internet Usage

month	*".com" domains*	*monthly growth rate for previous twelve months*
January 1994	6,653	
January 1995	18,641	9.0%
January 1996	107,654	15.7%
January 1997	462,410	12.9%
January 1998	1,138,725	7.8%

Table 2: Centers of Commercial Internet Usage

Most Domains

1994		*1998*	
San Francisco Bay Area	1,446	New York	111,363
Boston	597	Los Angeles	109,582
New York	505	San Francisco Bay Area	89,458
Washington-Baltimore	429	Washington-Baltimore	44,598
Los Angeles	374	Boston	41,411
Denver	327	Chicago	38,288
Chicago	201	Miami-Ft. Lauderdale	27,802
Seattle	170	Philadelphia	26,929
San Diego	160	Dallas-Ft. Worth	26,445
Philadelphia	124	Seattle	25,065

Highest Domain Density (per thousand commercial establishments)

1994		*1998*	
San Francisco Bay Area	8.0	San Francisco Bay Area	480
Fort Collins-Loveland, CO	5.0	Provo-Orem, UT	454
Denver	4.8	San Diego	348
Colorado Springs	4.7	Austin	311
Boston	3.9	Los Angeles	309
Austin	3.4	Santa Barbara, CA	294
Santa Barbara, CA	2.8	Champaign- Urbana, IL	292
Huntsville, AL	2.7	Boston	267
Champaign- Urbana, IL	2.7	Reno	258
San Diego	2.7	Seattle	257

note: figures refer to metropolitan areas (CMSA's, NECMA's, and MSA's)

Table 3: Correlation of MSA Domain Density Over Time*

	1994	*1995*	*1996*	*1997*
1995	.9482			
1996	.8395	.9055		
1997	.7448	.8199	.9552	
1998	.6958	.7755	.9126	.9769

*figures represent simple correlations at the metropolitan-area level, n=270

Table 4: Correlations between Industry Mix and Domain Density*

	computer manufacturing (SIC 357)	*software and data processing (SIC 737)*	*communications (SIC 48)*	*finance, insurance, real estate (SIC 6)*	*professional business services (SIC 87)*
1994	.6640	.7096	-.0942	.2177	.5410
1995	.6783	.7362	-.1331	.2438	.6001
1996	.6485	.7923	-.1596	.3095	.6641
1997	.6146	.7856	-.1890	.3386	.7079
1998	.5965	.7782	-.2194	.3929	.7424

*figures represent simple correlation, at the metropolitan-area level, between the domains density each year and the fraction of the private-sector establishments in the given sector in 1995

Table 5: Correlations between MSA Size, MSA Isolation, and Domain Density*

	MSA size	*MSA isolation*
1994	.16	.34
1995	.18	.35
1996	.31	.46
1997	.46	.52
1998	.49	.56

note: the correlation between MSA size and MSA isolation is .22

*figures represent correlation at the metropolitan-area level, between the domain density each year and 1993 MSA size or average distance from an MSA resident to people outside the MSA; weighted by MSA size

Table 6: Isolation Ranking of Large MSA's*

Highest		***Lowest***	
Honolulu	4095	Indianapolis	786
Seattle	1824	Louisville	787
Portland	1802	Cincinnati	793
San Francisco Bay Area	1800	Dayton-Springfield, OH	795
Los Angeles	1718	Columbus	807
Stockton, CA	1713	St. Louis	808
Sacramento, CA	1712	Nashville	809
Fresno, CA	1664	Toledo, OH	814
Bakersfield, CA	1639	Knoxville, TN	826
San Diego	1632	Chicago	833

note: figures represent average distance from an MSA resident to people outside the MSA, in miles

Table 7: Determinants of Domain Density, 1998
dependent variable: log(domains / establishments) in 1998

	(1)	*(2)*	*(3)*	*(4)*
log population	.288	.188	.139	.096
	.025	.029	.019	.023
headquarters/establishment		26.239	17.823	8.422
		4.493	3.220	3.786
average distance between MSA resident and person outside MSA (miles/1000)			.200	.191
			.051	.049
log of average MSA income			.530	.397
			.157	.156
population growth, 1970-1990			.669	.577
			.065	.082
% residents with high school degree			1.896	1.768
			.332	.345
% residents with college degree			.745	.502
			.563	.626
% workers in programming occupations			6.098	3.024
			5.835	6.196
miles of fiber-optic telephone cable as fraction of miles of copper wires			.001	-.011
			.013	.013
university graduate students / population			16.079	14.592
			3.755	3.711
federal procurement contract awards per capita ($1000)			.018	.011
			.013	.013
industry controls?	no	no	no	yes
R-squared	.34	.41	.83	.85
N	269	269	269	269

notes:
standard errors under coefficient estimates

Table 8: Determinants of Domain Density, 1994-1998
dependent variable: log(domains / establishments) in given year

	1994	*1995*	*1996*	*1997*	*1998*
log population	.036	.033	.101	.093	.096
	.062	.068	.052	.031	.023
headquarters/establishment	8.015	15.380	13.461	13.140	8.422
	10.147	11.178	8.590	5.012	3.786
average distance between MSA resident	.284	.288	.376	.249	.191
and person outside MSA (miles/1000)	.132	.146	.112	.065	.049
log of average MSA income	.025	.375	.341	.569	.397
	.419	.461	.355	.207	.156
population growth, 1970-1990	-.481	-.052	.308	.555	.577
	.219	.241	.185	.108	.082
% residents with high school degree	2.422	2.370	2.995	1.584	1.768
	.926	1.020	.784	.457	.345
% residents with college degree	.739	2.025	2.698	1.629	.502
	1.678	1.849	1.421	.829	.626
% workers in programming occupations	2.841	16.656	-1.989	-.312	3.024
	16.607	18.295	14.059	8.202	6.196
miles of fiber-optic telephone cable as	.118	.102	.001	-.011	-.011
fraction of miles of copper wires	.035	.038	.030	.017	.013
university graduate students / population	17.138	12.658	15.608	14.935	14.592
	9.946	10.957	8.420	4.913	3.711
federal procurement contract awards per	.066	.041	.016	.016	.011
capita ($1000)	.036	.039	.030	.018	.013
industry controls?	yes	yes	yes	yes	yes
R-squared	.69	.69	.76	.81	.85
N	269	269	269	269	269

notes:
standard errors under coefficient estimates

Table 9: CPS Communications Technology Usage and Location
dependent variable is whether respondent uses computer at work for e-mail or communications

	1989	***1993***	***1997***
log MSA population	-.0042	-.0024	.0023
	.0017	.0020	.0027
isolation	.0133	.0105	.0114
	.0072	.0100	.0092
R-squared	.26	.29	.37
N	36896	34685	35619

notes:

- control variables are education, age, race, sex, part/full time status, general computer usage, and fixed effects for 3-digit industry
- standard errors under coefficient estimates

isolation is the average distance between an MSA resident and a person outside the MSA, divided by 1000

APPENDIX ONE: A MODEL OF DEMAND AND SUPPLY FACTORS AFFECTING INTERNET DIFFUSION

A simple model describes the decision to adopt internet technology by a representative firm in industry **i**, in city **m**, at time **t**.

- $D_{imt} = 1$ if $B(f_{it}, g_m) - C(h_m, k_t) > 0$
- D_{imt} is the decision to register a domain
- f_{it} is the time-varying benefit to firms in a given industry of commercial internet usage
- g_m and h_m are location-specific factors influencing benefits and costs, respectively, of internet usage
- k_t is a capital cost that is uniform across i and m; it is declining over time
- h_m and k_t are complements, such that $C_{hk} > 0$

The long-term geographic distribution of benefits, after controlling for industry mix, is represented by g_m. The form of the cost function is justified since the primary location-specific cost factors are the skill level of the local labor force and the quality of local telecommunications infrastructure. Both of these costs are complements with the costs represented by k_t, which includes the cost of network equipment, of commercial internet access, and the trivial cost of registering a domain name.[25] These latter costs vary little spatially, since network hardware is traded nationally (or internationally) and

[25] Brynjolfsson and Yang (1998) claim that investments in physical computer capital are accompanied by large training, consulting, and process re-engineering investments. Domain name registration costs $70 and is administrated by Network Solutions under a U.S. Government-granted monopoly.

national internet service providers (ISP's) tend to offer uniform pricing across their service areas. These costs – particularly hardware costs – are declining with rapid improvements in computer and networking technology. The complementarity between the locally-varying intangible costs and declining capital and access costs that means that local supply-side variations should fade over time in their influence over the decision to adopt internet technology. This implication is testable for factors that are exclusively supply-side, such as the quality of local telecommunications infrastructure and the skill level of the workforce; these factors should decline in importance over time. In turn, confidence in this framework will allow inferences to be drawn about the relative contributions of the supply-side effect of city size (faster diffusion and learning) and the demand-side effect of city size (longer-run complementarity or substitutability with electronic interaction).

APPENDIX TWO: DATA

This appendix gives summary statistics and detailed variable definitions.

SUMMARY STATISTICS

VARIABLE	*N*	*mean*	*st. dev.*	*min*	*max*
FOR TABLES 7 AND 8					
log of 1994 domain density	269	-7.11	.965	-9.21	-4.81
log of 1995 domain density	269	-6.12	.975	-9.21	-3.96
log of 1996 domain density	269	-4.25	.809	-9.21	-2.50
log of 1997 domain density	269	-2.69	.579	-5.01	-1.45
log of 1998 domain density	269	-1.78	.506	-3.53	.735
log population	269	14.56	1.46	10.94	16.71
headquarters/establishment	269	.021	.008	.0004	.042
average distance between MSA resident and person outside MSA (miles/1000)	269	1.14	.373	.780	4.10
log of average MSA income	269	10.38	.173	9.72	10.70
population growth, 1970-1990	269	.248	.246	-.155	1.40
% residents with high school degree	269	.768	.051	.466	.906
% residents with college degree	269	.222	.049	.095	.440
% workers in programming occupations	269	.006	.003	0	.033
miles of fiber-optic telephone cable as fraction of miles of telephone copper wires	269	2.59	1.38	.77	7.33
university graduate students / population	269	.003	.003	1	.041
federal procurement contract awards per capita ($1000)	269	.795	.815	.022	9.52
FOR TABLE 9					
CPS communications technology usage, 1989	36896	.123	.328	0	1
CPS communications technology usage, 1993	34685	.183	.387	0	1
CPS communications technology usage, 1997	35619	.247	.431	0	1
CPS: log population, 1989	36896	14.55	1.40	11.47	16.71
CPS: log population, 1993	34685	14.54	1.39	11.47	16.71
CPS: log population, 1997	35619	14.72	1.37	11.64	16.81
CPS: average distance between MSA resident and people outside MSA, 1989	36896	1.14	.374	.782	4.10
CPS: average distance between MSA resident and people outside MSA, 1993	34685	1.14	.392	.782	4.10
CPS: average distance between MSA resident and people outside MSA, 1997	35619	1.15	.378	.786	4.10

VARIABLE DEFINITIONS

domain counts and metropolitan aggregation

The domain counts are totals of the number of internet domains registered in a zip code during a given month. They were obtained from Imperative!, an internet consulting firm in Pittsburgh, who assembled the data based on InterNIC's database of registered domains.

Correcting for domain-name speculation was done by observing unusually high registrations for a zipcode-month cell. One-time spikes in domain registrations were smoothed; occasionally, such spikes can arise from changes in zipcode definitions. Assuming that non-commercial users are unlikely to hoard domain names or, at least, unlikely to hoard them in exactly the same month, the .com counts were adjusted to the non-commercial registrations (.edu, .org, .net) for each zipcode-month.

To aggregate these counts to the metropolitan level, two correspondences were used. First is the U.S. Postal Service's delivery-type file, which associates every zip code with a county. The delivery-type file is available on-line at <http://ribbs.usps.gov/files/addressing/DELVTYPE.TXT>. A few zip codes had to be coded by hand; most of these were in Orange County, CA, and in central Florida. The second correspondence is the metropolitan area definitions. These came from the Census's geographic correspondence engine, on-line at <http://www.census.gov/plue/>. The 1995 New England County Metropolitan Areas (NECMA's) were used for New England in order to match county-level variables easily. Consolidated Metropolitan Statistical Areas (CMSA's) were used where they existed. A total of 270 metropolitan areas were included.

commercial establishments

Commercial establishment counts, by county, come from the 1995 County Business Patterns (CBP), the latest available at the time of the analysis. CBP reports exact establishment counts, by county and by industry. Only employment data – which were not used in this research – are sometimes withheld to prevent confidential infringement. In calculating domain density for each year, the number of commercial establishments was scaled according to changes in population relative to 1995 population. The ratio of commercial establishments to population in each metropolitan area was assumed to remain constant over the period 1994-1998. This rescaling avoids the bias that would arise if 1995 establishment counts were used as the denominator for domain density in all years.

domain density

Domain density is the ratio of commercial internet domains to commercial establishments. In the regression analysis, the dependent variable is the log of domain density. In order to include areas with no domains, the value .0001 was added to all domain densities before taking the logarithm.

local industry composition
Local industry composition variables are the fraction of establishments in the given industry relative to all establishments in the county. Data are from 1995 County Business Patterns. The nine industry controls are:

- computer manufacturing (SIC 357);
- software and data processing (SIC 737);
- communications (SIC 48);
- finance, insurance, and real estate (SIC 6);
- professional business services (SIC 87);
- high-tech manufacturing (SIC 36, SIC 37, and SIC 38);
- trade, generally (SIC 5);
- manufacturing, generally (SIC 2 and SIC 3); and
- services, generally (SIC 7 and SIC 8).

population
The population variable refers to 1993 metropolitan area population. The population is the July 1 Census estimate for counties, aggregated using the 1995 MSA definitions.

isolation
Isolation is the average distance between an MSA resident and a person outside the MSA. The revised 1990 Census population figures were used. Centroids and the algorithm to calculate distances were provided by Jake Vigdor.

business headquarters
Business headquarters data are from the Global Business Browser, a list of companies maintained by One-Source, a consulting firm. A headquarters was defined as the chief address of a parent company, subsidiary, or major division. A list of headquarters addresses was downloaded, and these counts were aggregated by zip code to counties and metropolitan areas.

average income
The income variable is the log of median household income in 1990. County-level median income comes from the Census's 1990 Summary Tape File 3C. County-level median income was aggregated to 1995 metropolitan areas.

education
The education variables are the fraction of the 25-and-over population that has the given degree (high school, college, or graduate). These data come from the Census's 1990 Summary Tape File 3C.

population growth
The population growth variable is the log of the ratio of 1990 population to 1970 population, using constant 1995 metropolitan area definitions. Population data for 1970, 1980, and 1990 are the revised April 1 Census populations.

fiber-optic telephone cables
The fiber-optic variable comes from the Federal Communications Commission's *Statistics of Common Carriers 1993*, Table 2.2. It is the total fiber kilometers deployed (lit and dark), divided by sheath kilometers of copper wiring. The data are only available for states; metropolitan-area estimates were generated by averaging the data for states that each metropolitan area covers, weighted by the fraction of MSA population in that state.

workers in programming occupations
The programming data is the fraction of employed workers in computer programming occupations. These occupations include Census occupation codes 64, 65, and 229. Data are from the 1990 PUMS.

university graduate students / population
The university variable reported is the number of graduate students in universities as a fraction of total metropolitan area population. Data come from the Institutional Characteristics file of the Integrated Postsecondary Education Data System, available on-line at <http://nces.ed.gov/Ipeds/ic.html>. Quality rankings were provided by Bridget Terry.

establishment size
Establishment size is the log of the average number of employees per establishment across all commercial establishments in a metropolitan area. Employee and establishment counts come from 1995 County Business Patterns.

neighborhood domain density
A neighborhood was defined as the set of counties whose centroids are within 200 miles of the centroid of the county being considered. Neighborhood domain density is the log of the ratio of the weighted sum of neighborhood domains and the weighted sum of neighborhood establishments, weighted by (201-distance). Centroids and the algorithm to calculate distances were provided by Jake Vigdor.

metropolitan area definitions in Current Population Survey
The Current Population Survey identifies most metropolitan areas. A few small metropolitan areas (population under 100,000) are left unidentified. Only respondents in identified metropolitan areas were included. The 1989 and 1993 CPS used the official 1983 metropolitan area definitions; the 1997 CPS used the official 1993 metropolitan area definitions. Population figures for the contemporaneous metropolitan definitions were used. For the 1989 and 1993 CPS, the 1990 metropolitan area populations were used, available on-line at <http://www.census.gov/population/censusdata/90den_ma.txt>. For the 1997 CPS, the 1996 metropolitan area populations were used, available on-line at <http://www.census.gov/population/estimates/metro-city/ma96-05.txt>.

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