How Did Location Affect Adoption of the Commercial Internet? Global Village, Urban Leadership and Industry Composition

April 2004

Chris Forman, Avi Goldfarb and Shane Greenstein*

Abstract

We provide a framework and evidence to confront two contradictory yet common assertions: (1) new technology such as the Internet favors businesses in urban areas and (2) the Internet reduces the importance of distance for economic activity. Controlling for other factors, we show that participation in the Internet is more likely in rural areas than in urban areas. Use of frontier technologies also arises in rural areas for interfirm technologies, which are associated with ending economic isolation. Nevertheless, talk of the dissolution of cities is premature. Frontier Internet technologies for intrafirm communication and advanced computing appear more often at establishments in urban areas, even with industry controls. Major urban areas also contain many establishments from information technology-intensive industries, whose presence could reinforce the concentration of frontier Internet technologies in these areas. (JEL classification L63, L86, R0).

---

* Respectively at Carnegie Mellon University, University of Toronto and Northwestern University. We thank Ron Borzekowski, Tim Bresnahan, Karen Clay, Gilles Duranton, Steve Klepper, Roger Noll, Alicia Shems, Manuel Trajtenberg, Joel Waldfogel, seminar participants at the Center for Economic Studies, the University of British Columbia, the University of Illinois at Urbana-Champaign, Northwestern University, the University of Pennsylvania, the International Conference on Electronic Commerce, the International Industrial Organization Conference, and the ZEW Conference on Information and Communication Technologies, and especially Scott Stern for comments. We also thank Harte Hanks Market Intelligence for supplying data. We received funding from the Kellogg School of Management and the GM Strategy Center and seed funding from the National Science Foundation and Bureau of Economic Analysis. All opinions and errors are ours alone.

1. INTRODUCTION

The emergence of the commercial Internet had a large and readily apparent impact on firm investment during the booming 1990s. From 1995 to the end of 2000, stocks of information technology (IT) capital grew by 20% annually.[1] A large fraction of this investment was affiliated with business applications and infrastructure using Internet-related technology that became available to mainstream commercial users in the mid-1990s. In 2000, total business investment in IT goods and services was $466 billion, almost triple the level for personal expenditure on similar goods.[2] Considerable evidence suggests that this half-decade's worth of investment had a large impact on U.S. firm performance and productivity.

In this study, we examine two contradictory yet common assertions about how such investment shaped the geographic dispersion of economic outcomes. One stream of research argues that Internet technology requires infrastructure and support services, which are more readily available in urban settings. It forecasts that businesses in urban settings use Internet applications more frequently than do similar firms in rural settings. It also argues there was little that was exceptional about the economic impact of the Internet. Most of the productivity benefits from these investments accrued to urban businesses. A second stream of research about the "new economy" argues that Internet technology was exceptional, different from all the IT that came before it. According to this view, the Internet decreases coordination costs within firms and between firms, which reduces the importance of distance; and Internet technology dramatically reduces the costs of performing isolated economic activity, particularly in rural settings, even when deployment costs are high. This second view has been supported by an extensive case study literature, but thus far has seen little empirical verification.

The debate between these two views is ultimately about whether urban or rural business users faced lower or higher costs and benefits from the Internet. It is not a debate about what is *plausible*, since illustrative case studies and theoretical speculation support both outlooks. The open empirical question concerns what is *predominant*, whether illustrative cases are isolated examples or are representative of investment decisions across a variety of different locations.

Our study provides a modeling framework and empirical evidence for assessing what shaped most decision making. We analyze a cross-section of potential adopters of Internet technology in business. We analyze four business purposes for the Internet – *participation* and *enhancement* business computing applications, and within these, technologies designed for ***intra-*** and ***inter***firm communication. While controlling for other factors, we estimate the probability that an economic establishment adopts the Internet for each of these four purposes. Specifically, *participation* refers to adoption of simple

[1] This includes computer hardware, computer software, and communications hardware and instruments. See Price and McKittrick (2002) or Henry and Dalton (2002). The growth rates are even higher if communications hardware and instruments are excluded.
[2] For 2000, estimated personal consumption of IT goods and services was $165 billion. See Henry and Dalton (2002).

applications, a minimal requirement for coordinating geographically isolated locations. *Enhancement* refers to adoption of complex applications requiring technical support and third party servicing. Participation is less costly than enhancement and requires less sophisticated local support than enhancement. Furthermore, intrafirm technologies help coordinate activities within a firm, while interfirm technologies help coordinate geographically isolated activities between firms. All else being equal, interfirm activities – for either purposes of participation or enhancement – yield larger gross benefits to firms located in rural locations than to those in urban locations, whereas the benefits to intrafirm activities do not vary with location.

In our framework, contrasting assertions about geography and the Internet imply distinctly different forecasts about the marginal contribution of location to the probability of adopting different business applications. *Urban Leadership Theory* predicts that firms in dense locations adopt the Internet more quickly because such locations allow for the pooling of resources, which lowers the costs of adoption. This effect may be exaggerated because IT-friendly firms historically locate in cities in order to take advantage of these lower costs, though perhaps not in anticipation of the Internet specifically. In contrast, *Global Village Theory* predicts that firms in small cities and rural areas adopt the Internet more quickly than do urban firms because the marginal returns from the use of the communications capabilities of the Internet are higher in remote locations or in locations lacking economies of density. It is an empirical question whether the weight of evidence tends to favor one or the other.

Addressing our research goals requires detailed data about the largest investors in IT in the United States. Our estimates examine decision making at business establishments, and we use a sampling definition similar to Census surveys of businesses at specific addresses. Approximately two-thirds of the U.S. workforce is employed in the type of establishments studied. Specifically, we analyze Internet adoption at 86,879 establishments that have over 100 employees; this sample comprises roughly one-half of U.S. establishments of such size. It also consists of established firms rather than start-ups, which allows us to treat establishment location as exogenous. The data come from a survey updated to the end of 2000 and undertaken by Harte Hanks Market Intelligence (hereafter Harte Hanks), a commercial market research firm. The strength of this data is its breadth; we provide the first-ever census of Internet technology adoption. Its principal weakness is the absence of reliable estimates about the value of capital stocks.[3] This forces us to use discrete measures of Internet technology adoption rather than (the more ideal) dollar value-based units.

We utilize this research framework to examine two types of inquiries: (1) the role of location on the adoption of new technology; and (2) how the role of location varies across different technologies. Our research supports three central findings:

1. Urban Leadership Theory is not supported when the Internet is adopted for *participation* purposes. In other words, controlling for industry, participation does not increase with the size and density of a city. There is some evidence that the opposite holds–namely that participation rates support Global Village Theory.
2. We reach the opposite conclusion for *enhancement*. Even with industry controls, Global Village Theory is not supported and Urban Leadership Theory is, because the probability that an establishment will adopt enhancement applications increases with the population of a location. When this result is broken down into intra- and interfirm technologies, we find that Urban Leadership Theory is supported by intrafirm enhancement technologies only. The pattern of adoption for interfirm enhancement technologies is more consistent with Global Village Theory.
3. The type of industry found in major cities plays a key role in explaining the variance of adoption rates between cities. We label this *Industry Composition Theory.* More IT-intensive industries tend to cluster in urban areas. Urban Leadership Theory and Industry Composition Theory interact in a complementary way for enhancement applications. This interaction could exacerbate agglomeration in use.

Overall, our findings reconcile the two seemingly contradictory assertions found in the literature. We find considerable evidence consistent with the Internet's promise to reduce the importance of distance. This evidence pertains to all types of participation, where user investment is not expensive. It also pertains to interfirm enhancement, where the costs may be high, but the benefits to ending economic isolation are also strong. Furthermore, we find considerable evidence consistent with Urban Leadership for enhancement technology, especially intrafirm enhancement.

These findings also clarify the sense in which the productivity gain from investment in the Internet was exceptional. We are not asserting that dense urban areas do not provide locals with many advantages. Rather, evidence is consistent with the view that Internet technology had great appeal to businesses in less dense settings. There were heavy users in urban areas also, but adoption patterns for less urban areas were different from the patterns associated with urban users facing both lower costs and higher benefits.

Our findings show there was considerable variation in the benefits to Internet adoption across locations. Such variation may ultimately influence productivity differences across regions. In particular, we provide evidence suggesting that Internet technology helped reshape the long-run comparative advantage of regions and may have increased the net benefits of relocating business to rural areas.

Finally, while our evidence only covers the earliest period of use of this technology, we believe our empirical framework has relevance to future IT investment devoted to communications. As Internet

[3] Earlier versions of this database contained such information and have been used by researchers. This limitation

applications continue to grow, we believe that Global Village and Urban Leadership Theories will continue to influence the economic geography of the costs and benefits of IT investment.

1.1 Previous Literature

Two streams of research on the business use of the Internet are relevant to this study. First, there is literature on the productivity benefits affiliated with IT. Second, there are a few studies of the relationship between geography and communications investment.

Productivity Benefits of IT: There is considerable evidence that IT investment had a large impact on company behavior and productivity in the late 1990s, particularly in shaping the costs of coordination activities within a firm and between firms. For example, Oliner and Sichel (2000), Jorgenson and Stiroh (2000), and Baily and Lawrence (2001) credit IT with the rapid growth of the U.S. economy in the late 1990s. Stiroh (2002) argues that this productivity acceleration was broad-based and finds an increase in productivity related to IT use in nearly two-thirds of industries from 1995 to 2000. Although these studies focus on the role of IT investment generally, recent work has demonstrated a link between computer networking and acceleration in establishment-level productivity (Atrostic and Nguyen 2002).

Brynjolfsson and Hitt (2000) present and summarize large-sample empirical evidence that investment in IT lowers coordination costs, thereby resulting in increases in firm productivity. They emphasize how the technology changes employee decision making within firms. They also discuss how computer-based communications technologies have created new customer relationships (e.g., Dell and the Internet) and improved the efficiency of relations with suppliers (e.g., General Motors and electronic data interchange). They are not the only writers to make these arguments. For example, Porter (2001) discusses the role of the Internet in expanding market boundaries with specific reference to automotive retailing; Lucking-Reiley and Spulber (2001) discuss three different sources of productivity gains that result from Internet use: automation, new intermediaries, and vertical integration; and Autor (2001) and Stevenson (2003) emphasize the efficiency the Internet brings to filling job vacancies.

A number of case studies have documented the role of the Internet in lowering coordination costs within and between firms. Cisco uses Internet technology (1) to lower the intrafirm costs of distributing information to employees and of monitoring travel and supply requisitions and (2) to lower interfirm coordination costs by notifying suppliers of customer orders in real time (Nolan, Porter, and Akers 2001; Woerner 2001). Charles Schwab and other brokerage firms have used electronic trading to lower the costs of communicating with consumers (Mendelson and Dewan 2001), while industrial supplies firm W.W. Grainger has used the Internet to reach new business customers (Porter 2001; Lucas 2002).

A handful of studies explore the relationship between information technology and regional economic growth (Daveri & Mascotto 2002), or skilled labor demand (Bresnahan, Brynjolfsson and Hitt, 2002; Chun 2003; Doms, Dunne, and Troske 1997). These papers measure the local effects of

---

arose when ownership of the database changed hands and the new owners discontinued market value indicators.

information technology adoption, presuming that the benefits accrue to the firm making the investment or nearby neighbors. Participation and interfirm enhancement violate this assumption, yielding benefits to the business partners of the establishment in many disparate locations. In contrast to the standard specification, we thereby raise questions about non-localized benefits of IT investment.

Communications Investment and Geography: Although an extensive econometric and case study literature has examined the productivity-enhancing benefits of the Internet, there has been comparatively little work examining the geographic variation in Internet usage. We follow a long line of economic analysis (e.g., Griliches 1957) that employs geographic variance in the use of a well-defined innovation as a window into the factors shaping an innovation's costs and benefits. Our study builds on earlier findings (Forman, Goldfarb and Greenstein, 2002, 2003a) that the variance in geographic patterns of Internet adoption in business differs substantially from the variance uncovered in any existing research on early adopters in business, Internet adoption by households or infrastructure deployment. Nevertheless, *on average,* businesses located in urban areas employ Internet technology more than those in less dense locations. On the surface these patterns contradict the key predictions of Global Village Theory, namely the reduction in the importance of distance and the enabling of geographically isolated economic activity (see, e.g., Cairncross, 1997).[4]

In this study we decompose these adoption rates into their *marginal* determinants. Our reading of the theoretical literature on communications technology and geography is that it treats the direction of these margins as an empirical question. The open question is whether IT acts as a substitute or complement to the agglomeration of economic activity (e.g., Gaspar and Glaeser 1998). However, unlike some empirical studies in this vein, we do not consider the determinants of long-run equilibrium, that is, where firms relocate after technology markets develop (e.g., Beardsell and Henderson 1999; Kolko 2002; Charlot and Duranton 2003; Fitoussi 2003).[5] Rather, we follow the accounts of how this technology diffused and examine the short-run reaction of establishments to something new. In other words, we ask whether an otherwise similar establishment in a different location displays different adoption behavior.

The contrast with the literature on technology diffusion is informative. The existing literature presumes that urban areas have many advantages that lower the costs of using new technology. Because of their lower costs, theories of urban leadership forecast that after a new technology becomes available establishments in dense locations act first and establishments in rural locations act later, if at all. In contrast, we consider the possibility that the benefits of adopting new communications technologies may

[4] Cairncross (1997) was an early, though not the sole, proponent of Global Village Theory. She states, "The death of distance as a determinant of the cost of communicating will probably be the single most important force shaping society in the first half of the next century" (p. 1).
[5] These papers discuss how information technology influences the location decisions of firms. For a historical example which considers the impact of the Corliss steam engine, see Rosenberg and Trajtenberg (2001). All these

be greater for establishments located in geographically isolated areas. This possibility focuses on a new hypothesis --namely, establishments in less dense locations adopted Internet technology as rapidly as *or more rapidly than* their similar establishments in urban areas.

Kolko's (2000) study is the most similar to our empirical question of how location affects Internet practice. He uses domain name registrations in the context of a central city/periphery model to find that users in cities of medium size and above have registration patterns consistent with those areas benefiting disproportionately from the Internet. We examine businesses' adoption of certain processes in cities of varying size and location. Some of our results can also be interpreted in this central city/periphery framework rather than the urban/rural one that we emphasize. However, Kolko has only one measure of Internet activity, registrations, so he does not develop the implications for different types of communications and purposes, as we do here.

Forman (2003) also uses the Harte Hanks data to study the decision to adopt Internet technology among commercial establishments. He studies whether increases in the geographic dispersion of establishments in multi-establishment firms increase the likelihood of adopting basic Internet technologies. Our work is distinct from his because we examine a broader range of industries and locations across the United States, which enables us to identify the contribution of geographic location to Internet adoption decisions. Moreover, our later sample period enables us to focus on more complex margins of investment.

Similar in spirit, but more distant in its context, is Sinai and Waldfogel's (2001) study. While they examine household behavior for evidence that Internet content is either a substitute or a complement to content found locally, our focus is on adoption by business establishments. Moreover, our decomposition of the geographic variation of Internet use into industry- and location-specific factors enables us to test a different set of hypotheses.[6]

Prior research has examined how local network effects (e.g., Gowrisankaran and Stavins 2004) or spillovers that operate at a local geographic level (e.g., Goolsbee and Klenow 2002) can increase the likelihood of new technology adoption. The contrast with our study is informative. We view network effects and spillovers as two of several potential explanations for Urban Leadership Theory. Rather than testing these theories directly, we are instead interested in comparing the implications of Urban Leadership Theory to those of Global Village Theory. Previous research offers little guidance for our purpose because these papers do not examine the margin between urban areas and rural areas, as we do here. Moreover, if we find in favor of Global Village Theory it suggests the various explanations for Urban Leadership Theory are not the dominant explanations for adoption of the technology.

---

papers stem from a broader literature that attempts to explain agglomeration of economic activity by examining the location decisions of firms (e.g., Holmes 2002).

Implicit in our hypotheses is the view of the Internet as a General Purpose Technology, or GPT (Bresnahan and Trajtenberg 1995). Although others have hypothesized that the Internet is a GPT (e.g., Harris 1998), we are the first to link this formulation to a statistical analysis of adoption behavior by commercial businesses. The GPT framework underscores our distinction between the geographic diffusion of participation and enhancement, both of which rely, to different degrees, on local market-based support.

Finally, our analysis and findings contrast strongly with the prevailing analysis inspired by literature on the digital divide (e.g., National Telecommunications Information Administration, 2000a). In particular, Urban Leadership Theory has received considerable exposure. For example, both Gorman (2002) and Zooks (2000a, b), summarizing the conclusions of many others as well as their own research, express this view quite strongly (see, also, Castells 2003).[7] They further argue that Internet technology is a complement to urban agglomeration. (For a full review of this literature, see Greenstein 2003). Even though, like previous studies, we find that some regions are leaders and some are laggards in the use of Internet technology, we do not conclude that use of the Internet is concentrated in a small number of places. Moreover, we emphasize the sharp differences between the diffusion processes shaping participation and enhancement, both of which support very different explanations about the factors shaping geographic variation in use.

2. Testable Hypotheses of a Technology Adoption Model

In this section we develop a model of Internet technology adoption. This model frames competing explanations for the observed geographic variance in Internet adoption. It also allows us to make predictions about how the sensitivity of adoption to variations in geographic location will differ across technologies. We posit that establishment *i* will adopt Internet technology by time *t* if

$$(1) \qquad NB(x_i,z_i,t) \equiv B(x_i,z_i,t) - C(x_i,z_i,t) > 0,$$

where *NB* is the net benefit of adoption, *B* is the gross benefit of adoption, and *C* is the cost of adoption. We let x_i describe geographic conditions, such as population size and density, [8] while z_i describes industry

---

[6] For other evidence on how Internet activity among households varies by region, see Goolsbee (2000), who examines the sensitivity of retail e-commerce spending to local taxation rates.
[7] This is a particularly prominent theme in the series of reports from the National Telecommunications and Information Administration (1995, 1998, 1999, 2000a, 2000b). See, also, Moss and Townsend (1997).
[8] From this point forward, Metropolitan Statistical Areas (MSAs) with populations greater than 1 million will be referred to as *large MSAs*, those with between 250,000 and 999,999 will be *medium MSAs,* those with less than 250,000 will be *small MSAs*, and non-MSA areas will be called *rural*. In addition, when two or more MSAs are part of the same urban environment, the Census combines them into CMSAs, or Consolidated Metropolitan Statistical Areas. For example the Dallas-Fort Worth CMSA contains both Dallas and Forth Worth.

characteristics that may affect a firm's decision to adopt Internet technology. Both features are fixed over time for establishments.

Our empirical work examines one cross-section at time *t*. Since adoption of the Internet is rarely reversed, we are comfortable with the data-driven requirement that we suppress the time dimension.[9] Under the standard "probit model" of diffusion (e.g., David 1969; Karshenas and Stoneman 1993), adoption costs decline over time for all potential adopters, so the timing of adoption coincides with intensity of demand. The difference between adoption and non-adoption reveals the threshold between those with high and low valuations from use.[10]

This simple model frames our predictions. We discuss different theories about $NB(x_i,z_i)$, each of which gives competing predictions about the role of location in the adoption of the Internet by commercial establishments. For reference, see Table 1, where we list each of the open questions addressed and the associated testable hypotheses.

2.1 Global Village Versus Urban Leadership

Urban Leadership Theory predicts that adoption of the Internet will be less common in rural areas than in urban areas, all other things being equal. There are multiple potential explanations for this pattern that emphasize the costs of adoption, such as (1) availability of complementary information technology infrastructure, such as broadband services, [11] (2) labor market thickness for complementary services or specialized skills, and (3) knowledge spillovers.[12] One other explanation emphasizes that the types of firms found in urban areas are not random. That is, historically IT-friendly establishments may have sorted into areas where costs have previously been low for precursors to Internet technology. It is not our goal to tease out the relative importance of these explanations. Rather, we aggregate them around their common prediction: Adoption increases as location size increases.

More precisely, Urban Leadership Theory argues that adoption costs increase as population size and density decrease (i.e., $dC/dx_i < 0$, where x_i is density) and that these costs increase faster than the benefits increase ($dC/dx_i > - dB/dx_i$ *for all* x_i). This relationship holds more strongly if IT-friendly firms

[9] This is data set is uniquely rich in detailing IT use in many diverse industries. Instead of using a Harte Hanks panel on a narrow group of industries as was done by Forman (2003), our goals in studying geographic dispersion are more conducive to the wide array of industries only available in a cross-section.

[10] Generally, see Rogers (1995). We allow the cost term *C* to include the opportunity cost of not adopting at some other time $s > t$, thus the net benefit condition above is both necessary and sufficient for the establishment to adopt by *t*. Another standard formulation would examine an establishment's decision to adopt at time *t*, and the equation above would be supplemented by an "arbitrage condition" (Ireland and Stoneman 1986) that it is less beneficial to adopt at any other time $s \neq t$.

[11] By this time almost all but the poorest and most remote geographic areas were serviced by dial-up Internet Service Providers (Downes and Greenstein 2002). Yet, broadband access was disproportionately an urban technology (U. S. Department of Agriculture 2001; Crandall and Alleman 2002)

[12] These are closely related to the three major reasons given for industrial agglomeration (e.g., Marshall 1920; Krugman 1991).

have presorted into urban areas.[13] Together, net benefits of adoption increase as population size and density increase ($dNB/dx_i > 0$). In other words, an establishment from the same industry is more likely to adopt the Internet if it is located in an urban area than if it were in a less dense area.

To our knowledge, the Global Village hypothesis has not been directly tested and has not had much empirical verification (Forman's (2003) study is an exception). Global Village Theory depends on three observations for contrasting predictions. First, while all business establishments benefit from an increase in capabilities, establishments in rural or small urban areas derive the most benefit from overcoming diseconomies of small local size. That is, Internet technology substitutes for the disadvantages associated with a remote location. There are several reasons why this may be true. For one, use of Internet technology may act as a substitute for face-to-face communications.[14] Common examples are email or instant messaging. Second, establishments in a rural area lack substitute data communication technologies for lowering communication costs, such as fixed private lines.

Third, advanced tools such as groupware, knowledge management, web meetings, and others also may effectively facilitate collaboration over distances.[15] Some tools enable simultaneous changes to electronic documents by users in multiple locations. Moreover, supply chain management software enables electronic communication of data that would be costly to transmit via phone or through the mail. For example, Cisco reduced design costs to new products by communicating design changes electronically to suppliers (Nolan, Porter, and Akers 2001).

More precisely, Global Village Theory argues that gross adoption benefits (1) increase as population size and density decrease (i.e., $dB/dx_i < 0$, where x_i is population size or density) and (2) increase more slowly than do costs ($dC/dx_i < - dB/dx_i$ *for all* x_i). Together, net benefits from adoption do not increase as population size and density increase ($dNB/dx_i \leq 0$). Global Village Theory predicts that adoption of the Internet will be more common among establishments in rural areas than in urban areas or will not be a function of density at all, all other things being equal.

Since most standard economic theory points towards the predictions of Urban Leadership Theory, it is our null hypothesis. Moreover, as we discuss below, our measurement framework stacks the deck in

---

[13] More formally, let net benefits be a function of u_i, an IT-friendliness index, with net benefits as $NB(x_i,z_i,u_i)$. If u_i is unobserved and positively correlated with x_i, then $dNB/dx_i > 0$. That is, unobserved presorting of "IT-friendly firms" and "friendly locations" gives observationally equivalent predictions. As the literature correctly observes, these explanations cannot be disentangled without detailed data on adoption over several generations of IT and relocation in response. This disentangling is not essential to our empirical goals.

[14] Other authors (e.g., Gaspar and Glaeser 1998) have argued that improvements in information technology may increase the demand for face-to-face communication. In other words, they argue that IT and face-to-face communication may be complements. The implication of this hypothesis is that commercial establishments relocate to urban areas in reaction to technical change in IT. However, in our data we observe short-run reactions by commercial establishments to the Internet, before they had the opportunity to relocate. As a result, we do not identify complementary relationships.

[15] Kontzer (2003) provides an overview of collaboration tools and provides examples of how they reduce the costs of remotely located employees.

favor of finding evidence consistent with Urban Leadership Theory. Hence, we assign the weak inequality to Global Village Theory, which aggregates all predictions that reject the null hypothesis under one label.

2.2 Predictions of Global Village and Urban Leadership

Our analysis will contrast two types of predictions. First, as was previously noted, each theory provides contrasting predictions about how density shapes adoption on the margin. Second, in the subsequent section we contrast differing predictions about the rate of sensitivity to location. In other words, the first prediction is about the direction of a derivative. The second prediction compares two derivatives to each other. These are summarized in the first four rows of Table 1.

Participation and Enhancement: In testing Global Village and Urban Leadership Theories, we contrast participation purposes for business use of the Internet with enhancement purposes.[16] Participation is affiliated with basic communications, such as email use, browsing, and passive document sharing. Enhancement, on the other hand, is affiliated with IT that either changes existing internal operations or implements new services. It is related to investment in frontier technologies linked to computing facilities, which are often known as "e-commerce" or "e-business," and it usually arrives as part of other intermediate goods, such as software, computing or networking equipment.[17]

The contrast between participation and enhancement is informative about local adaptation costs. Bresnahan and Trajtenberg (1995) argue that the invention of a GPT like the Internet involves high fixed costs to adapt the GPT to particular environments. Adoption involves a combination of (1) reproduction and (2) co-invention to meet idiosyncratic circumstances. Co-invention activity is not just R&D because it involves change to organizational processes.[18] As was explained by Urban Leadership Theory, co-invention costs vary by location.

We posit that these adaptation costs are relevant to the adoption decision for enhancement and negligible for participation. If the effect of changes in population density on adoption benefits (dB/dx_i) is similar for participation and enhancement, the rate of improvement in net benefits, with respect to density, rises faster for enhancement than for participation. This hypothesis predicts that enhancement is more sensitive to increases in density than participation is (i.e., dNB/dx_i *for enhancement* > dNB/dx_i *for participation*). This is a prediction about the *comparative* difference between the two types of

[16] In this choice, we follow Forman (2003), who found that investment clustered around a few key margins of behavior. For further motivation see the discussion in Forman, Goldfarb and Greenstein's (2002) study.
[17] Such applications often involve complementary organizational change to be used successfully. See, for example, Hitt and Brynjolfsson (1997), Hubbard (2000) and Bresnahan, Brynjolfsson and Hitt (2002).
[18] This is consistent with other research on IT, complexity and location. For example, in research that examines worker communication patterns using French data, Charlot and Duranton (2003) find that use of Internet technology for inter-organization communication is more likely in large cities. However, their discussion emphasizes the costs of deciding where to locate coordination activity, while ours emphasizes the costs of changing an establishment's processes as technology diffuses.

applications. For example, this forecast would hold if, as the population density increases, the probability of adopting the Internet for enhancement purposes increases more than that for participation.

Intrafirm and Interfirm: Within each application of participation and enhancement, we can compare geographic differences in Internet investments for inter- and intrafirm communication. Intrafirm investments involve use of the Internet's TCP/IP protocols for communication that remains within the boundaries of the firm. Interfirm technologies represent Internet investments that involve communication among firms within the value chain or between a firm and its end consumers.

Global Village Theory predicts that geographically isolated establishments will have higher gross benefits from communicating with external suppliers and customers. Gross benefits will vary by location for interfirm technologies but will vary negligibly for intrafirm technologies. As a result, changes in location size and density will primarily influence costs (and not benefits) for intrafirm technologies ($dNB/dx_i \approx dC/dx_i$). On the other hand, such changes will influence both costs and benefits of interfirm technology adoption ($dNB/dx_i = dB/dx_i + dC/dx_i$). Therefore the net benefits of adoption are increasing faster in location size for intrafirm than for interfirm (i.e., dNB/dx_i *intrafirm* > dNB/dx_i *for interfirm*). This suggests that any results supporting Global Village Theory will be especially strong for interfirm technologies and any results supporting Urban Leadership Theory will be especially strong for intrafirm technologies. This qualitative prediction will hold for both participation and enhancement. For example, this forecast would hold if the probability of adopting the Internet for enhancement of intrafirm communication increases as the density of location increases, while that for enhancement of interfirm communication does not.

2.3 Industry Composition

We also examine Industry Composition Theory, which provides a potential alternative hypothesis to Urban Leadership Theory. (See the last two rows of Table 1.) This theory argues that there is heterogeneous demand for Internet technology across industries and that establishments from the same industry tend to cluster together to take advantage of thicker industry-specific labor markets and other shared local resources. This implies two testable hypotheses: (1) the concentration of IT-intensive industries will explain geographic variation in use for both participation and enhancement and, in an extreme case, (2) location will have no marginal impact on adoption behavior beyond that explained by variation in industry composition. In other words, this version of the theory hypothesizes that $dNB/dz_i > 0$, corr(x_i, z_i) > 0 and $dNB/dx_i = 0$.

We also consider an alternative hypothesis. Here, industry composition plays a role, but so does location. This version hypothesizes that $dNB/dz_i > 0$ and $dNB/dx_i > 0$. We allow for two variants of this hypothesis, which make alternative predictions about the entry of complementary third-party services in response to demand from IT-intensive firms. These complementary services reduce adaptation costs, particularly for enhancement.

One variant argues that if new entry increases supply and lowers prices, despite increased demand from IT-intensive firms, then location and industry may be complementary for some applications. To summarize, $dNB/dz_i > 0$, $dNB/dx_i > 0$, and $d^2NB/dx_i dz_i > 0$. Alternatively, the other variant argues that it is possible for industry composition and urban agglomeration to be substitutes. Concentration of advanced industries leads to increased demand for limited resources. If new entry is insufficient to compensate for this resource competition, prices for local services will increase. In other words, $dNB/dz_i > 0$, $dNB/dx_i > 0$, and $d^2NB/dx_i dz_i < 0$. Thus, while cities will have more IT-intensive industries, the marginal benefit of being in a city decreases as the IT-intensity of the industry rises.

The first variant has received the most exposure in the literature on the digital divide.[19] The latter possibility has been discussed as a theoretical possibility (e.g., Gasper and Glaeser 1998) but has seen little empirical verification.[20] Prior research has indicated that entry of third-party Internet services in smaller markets was sometimes low (Greenstein 2000). Accordingly, this variant will be more likely in areas with low population than in those areas with high population.

3. Data and Method

The data we use for this study come from the Harte Hanks Market Intelligence CI Technology database (hereafter CI database).[21] The CI database contains establishment-level data on (1) establishment characteristics, such as number of employees, industry and location; (2) use of technology hardware and software, such as computers, networking equipment, printers and other office equipment; and (3) use of Internet applications and other networking services. Harte Hanks collects this information to resell as a tool for the marketing divisions at technology companies. Interview teams survey establishments throughout the calendar year; our sample contains the most current information as of December 2000.

Harte Hanks tracks over 300,000 establishments in the United States. Because we focus on commercial Internet use, we exclude government, military, and nonprofit establishments (mostly in higher education). We focus on this unit of analysis for three reasons. First, the actions of establishments will reflect local factors better than individual workers (who are mobile) or organizations (that are in multiple locations). Second, previous studies of the organizational use of IT demonstrate that most co-invention expenses are incurred at a level wider than an individual. Third, and related, productivity

[19] The discussions about the concentration of industrial demand tend to focus on a narrow array of industries, such as new media, dot-coms or electronic retailing. This also leads to a focus on Silicon Valley, Silicon Alley and the greater Boston area. In contrast, we focus on all industries and locations.
[20] One exception is Kolko (2002), who examines agglomeration in the location decisions of IT-intensive firms.
[21] This section provides an overview of our methodology. For a more detailed discussion, see Forman, Goldfarb and Greenstein (2002, 2003b).

advances occur across a wide array of interdependent processes at an establishment, even at those establishments where the Internet is not used widely.[22]

Our sample from the CI database contains all commercial establishments with over 100 employees, 115,671 establishments in all;[23] [24] and Harte Hanks provides one observation per establishment. We use the 86,879 clean observations with complete data generated between June 1998 and December 2000.[25] We adopt a strategy of utilizing as many observations as possible because we need many observations for thinly populated areas.[26] This necessitates routine adjustments of the data for the timing and type of the survey given by Harte Hanks. In Table A.1 in the Appendix, we compare the usable Harte Hanks data with the Census data. In general, the samples are close, so most adjustments are small.

3.1. Sample Construction and Statistical Method

Our endogenous variable will be y_j, the value to establishment *j* of adoption. The variable y_j is latent. We observe only discrete choices: whether or not the establishment chooses participation and whether or not it chooses enhancement. In either case, the observed decision takes on a value of either one or zero. We will define these endogenous variables more precisely below.

In our base specification we assume that the value to establishment *j* of adopting the Internet is

$$y_j = \sum_i \alpha_i d_{ij} + \sum_l \beta_l d_{lj} + \sum_t \gamma_t d_{tj} + \sum_{t>1995} \delta_t d_{tj} d_{pj} + \sum_m \phi x_{mj} + \sum_q \lambda w_{qj} + \varepsilon_j \quad , \tag{2}$$

where d_{ij} and d_{lj} are dummy variables indicating the industry and location of the establishment, respectively, d_{tj} indicates the month in which the establishment was surveyed, and d_{pj} indicates whether the establishment responded to the long survey.[27] The variables x_{mj} and w_{qj} denote other location-specific (e.g., population size and density) and establishment-specific variables (e.g., establishment size and dummies indicating single- or multi-establishment firm), respectively. In variations of the model, we may

---

[22] See, e.g., Hitt and Brynjolfsson (1997), Bresnahan, Brynjolfsson and Hitt (2002).

[23] Because average establishment size differs across urban and rural areas and because we only observe establishments with more than 100 employees, our sampling methodology may create some selection bias that could affect our interpretation of the marginal impact of location. However, we believe this bias will be minor. We have run regressions with and without size controls and the results remain qualitatively similar.

[24] Previous studies (Charles, Ives and Leduc 2002; Census 2002) have shown that Internet participation varies with business size and that very small establishments rarely make Internet investments for enhancement. Thus, our sampling methodology enables us to track the relevant margin in investments for enhancement, while our participation estimates may overstate participation relative to the population of all business establishments.

[25] We dropped establishments that did not indicate when they were surveyed and establishments that were not surveyed on information technology. There is a small bias in the dropped observations toward locations where Internet adoption is high. The weighting scheme controls for any location and industry bias in the sample.

[26] If we were only interested in the features of the most populated regions of the country, then we could rely solely on the most recent data from the latter half of 2000, about 40% of the sample. However, using only this data would result in a very small number of observations for most regions with a population of less than one million.

[27] Harte Hanks used two surveys. One asked for more details on IT use than the other. We interact the long survey dummy variable with time. See Forman, Goldfarb and Greenstein (2002) for more detail.

allow for interactions among these variables. If we assume the error term ε_j is i.i.d. normal, then the probability that establishment j participates can be estimated with a probit regression.

We use this model for two research purposes. Our first purpose is descriptive. We illustrate average tendencies for particular establishments in particular locations at a particular point in time. For the average estimates in Tables 2, 3, and 4, we calculate predicted probabilities of adoption for each establishment as if it were surveyed in the second half of 2000 and were given the long survey. We then weight observations using Census County Business Patterns data to obtain a representative sample. We do this to illustrate the extent of overall variation in average adoption propensity. This exercise is valuable because it represents the most comprehensive survey of commercial Internet use across manufacturing and service industries to date.[28] Moreover, it provides a means of benchmarking our results against those in the prevailing literature on the digital divide, which focuses on average rates of adoption across locations (e.g., National Telecommunications Information Administration 2000a, 2000b). The location-specific and establishment-specific variables, x_{mj} and w_{qj}, are not included in this specification.

Our second and core purpose is to test competing hypotheses. We analyze the marginal contribution of different locational factors that shape adoption decisions at the establishment, and compare how this marginal contribution varies across technologies. We report marginal effects from a variety of different specifications, where model in Equation 2 is our base case. The coefficients on α, β, and ϕ are weighted to give a representative sample. (We subsequently display these results in Tables 5 through 9 and Figures 1 through 4). Two econometric assumptions underlie the estimates of marginal effects, namely, exogenous location and no simultaneity bias.

Exogenous Location: We examine short-run marginal effects of industry and location variables on the decision to invest in Internet technology. To identify these effects, we assume that the location of an establishment is exogenous to the decision to adopt Internet technology. We argue that this assumption is supported by the (ex-ante) unexpected rapid diffusion of the Internet, as well as by a regression on a subset of the sample.

As noted in many contemporary accounts, the widespread diffusion of the Internet took most commercial establishments by surprise. Thus, firms did not make establishment-location decisions in anticipation of the Internet. In this study we observe short-run adoption decisions five years into the diffusion of the Internet, before medium and large establishments had time to relocate. That is to say, the technology was new and unexpected, so establishment location is exogenous with respect to Internet technology use. We partially test this assumption by comparing results between our entire sample of establishments and a special subsample of establishments that (we are certain) fixed their locations prior to 1995 when the commercial Internet became available to most businesses. Since we find that the key estimates do not differ between these two samples, we infer that the potential endogeneity of establishment locations is not likely to alter our inferences about the influence of location on adoption of Internet technology.

To be sure, Urban Leadership Theory allows for the possibility that technology-friendly, though not necessarily Internet-friendly, establishments located in urban areas prior to its diffusion. Because we control for many features of an establishment, this is a statement about an unobserved feature of an establishment correlated with a previous location choice. To put it another way, our econometric model may contain omitted variables that influence the benefits of Internet adoption and which are correlated with prior location choice. In our framework, all such unobservable previous choices favor the null hypothesis, stacking the deck in its favor. As a result, when we find in favor of the null, it clouds the interpretation—but not when we find against the null. We are comfortable with this asymmetric interpretive ambiguity, since it strengthens the surprise of finding against the null.

No Simultaneity Bias: Our base econometric specification assumes that the adoption decision of one establishment is independent of every other establishment's adoption decision. This assumption is questionable for multi-establishment firms in which a central executive decision maker (e.g., a CIO) possibly coordinates the choice to adopt or not adopt for each establishment under his domain. Depending on a wide variety of factors, adoption decisions at establishments from the same organization could be either substitutes or complements for one another in use. While understanding that this relationship is of independent interest, it lies outside the scope of this study. Here, we are concerned that simultaneity influences the relationship between location and adoption at each establishment.

We address these concerns directly by characterizing the decisions of related establishments at other locations in a reduced form, then measuring whether this alters the estimate of the coefficient on location, while instrumenting for decisions elsewhere. We find that our inferences about the influence of location on adoption of Internet technology are robust to introducing simultaneity into the estimation.

3.2. Identifying Margins of Investment

As a GPT, Internet technology is employed in many different uses and applications. Our data include at least twenty different types of Internet technology, from basic access to software for TCP/IP-based Enterprise Resource Planning (ERP). Moreover, there are considerable differences in the applications used across establishments.

Identifying participation was more straightforward than identifying enhancement. We define participation by an establishment that has basic Internet access or has made any type of frontier

[28] Census (2002) includes a larger sample of commercial Internet use, but is confined to manufacturing firms. See Forman, Goldfarb, and Greenstein (2003a) for further discussion on the geographic variation in average rates of Internet adoption.

investment.[29] The establishment survey provides plenty of information about these activities, so we identify participation with confidence.

In contrast, enhancement activity is less transparent in the survey. We look for indications that an establishment has made investments that involved frontier technologies or substantial co-invention. Most often, these technologies involved interfirm communication and/or substantial changes to business processes. We identify enhancement from the presence of substantial investments in e-commerce or e-business applications. The threshold for defining *substantial* is necessarily arbitrary within a range.[30] To be clear, the investments we consider go beyond the downstream interactions with consumers that are traditionally thought of as retail e-commerce. They often involve upstream communication with suppliers, and/or new methods for organizing production, procurement, and sales practices. We look for commitment to two or more of the following projects: Internet-based ERP or TCP/IP-based applications in customer service, education, extranet, publications, purchasing or technical support.[31]

We identified intra- and interfirm technologies for both participation and enhancement. Within participation, intrafirm investments involve activities most commonly associated with the term "intranet," such as internal web pages and TCP/IP-based networking. Intrafirm enhancement investment involves the use of Internet protocols in the input and output of data to and from business applications software. Examples include TCP/IP-based ERP, TCP/IP-based customer relationship management (CRM), or business software used in business functions such as production, manufacturing, and accounting.[32]

Interfirm participation technologies primarily involve basic access to the Internet, and enable activities such as passive web browsing or manual downloads of static data. Interfirm enhancement

[29] To be counted as participating in the Internet, an establishment must engage in two or more of the following activities: (1) have an Internet service provider; (2) indicate it has basic access; (3) use commerce, customer service, education, extranet, homepage, publications, purchasing or technical support; (4) use the Internet for research or have an intranet or email based on TCP/IP protocols; (5) indicate there are Internet users or Internet developers on site; or (6) outsource some Internet activities. We looked for two or more activities to guard against "false positives." This was a minor issue as the vast majority of positive responses involved use of more than one of these criteria.

[30] We tested slight variations on this threshold and did not find qualitatively different results.

[31] In brief, an establishment is counted as enhancing business processes when two or more hold: (1) the establishment uses two or more languages commonly used for web applications, such as Active-X, Java, CGI, Perl, VB Script, or XML; (2) the establishment has over five Internet developers; (3) the establishment has two or more e-business applications, such as customer service, education, extranet, publications, purchasing, or technical support; (4) the establishment reports LAN software that performs one of several functions: e-commerce, ERP, web development, or web server; (5) the establishment has an Internet server that is a UNIX workstation or server, mainframe, or minicomputer, or has five or more PC servers, or has Internet storage greater than twenty gigabytes; (6) the establishment answers three or more questions related to Internet server software, Internet/web software or intranet applications. For a more precise description of some exceptional cases, see the appendix to Forman, Goldfarb and Greenstein (2002).

[32] Intrafirm enhancement may indirectly facilitate communications beyond the boundaries of the firm by, for example, enabling electronic integration of supply chains. Our research design enables us to measure this secondary effect by identifying the associated interfirm software investment.

technologies involve advanced communications that permit, for example, commercial transactions between firms within the value chain, as well as between firms and end-consumers.

Our strategy for identifying differences in the marginal contribution of location for participation and enhancement is straightforward. By construction, every establishment that invests in enhancement also invests in participation, so differences in the adoption patterns across the two technologies are identified from establishments that invest in participation but not in enhancement. Our strategy for identifying differences in intrafirm and interfirm investment is somewhat less straightforward, as establishments can invest in either technology without the other. In practice however, the majority of establishments invest in either interfirm technologies or both intrafirm and interfirm, which means that that identification is obtained primarily from establishments that have interfirm but not intrafirm investments.[33]

3.3. Descriptive Statistics

To obtain a representative sample, we compared the number of establishments in our database to the number of establishments in the Census. We calculated the total number of establishments with more than 50 employees in the Census Bureau's 1999 County Business Patterns data and the number of establishments in our database for each two-digit NAICS code in each location.[34] We then calculated the total number in each location. This provides the basis for our weighting. The weight for a given NAICS in a given location is

$$\frac{Total\ \#\ of\ census\ establishments\ in\ location-NAICS}{Total\ \#\ of\ census\ establishments\ in\ location} \cdot \frac{Total\ \#\ of\ establishments\ in\ our\ data\ in\ location}{Total\ \#\ of\ establishments\ in\ our\ data\ in\ location-NAICS} \quad (3)$$

Each location-NAICS is given its weighting from its actual frequency in the Census. In other words, if our data undersamples a given two-digit NAICS at a location relative to the Census then each observation in that NAICS-location is given more importance. In Appendix Table A.1, we compare our sample to the Census data.

In Table 2, we present average rates for participation and enhancement for the United States. Participation by establishments within the sample is at 80.7% (see Unweighted Average in Table 2). The sample underrepresents adopters. Our estimate of the economy-wide distribution, using the true

[33] Among firms that invest in participation, 24.6% invest in interfirm alone, 75.2% in interfirm and intrafirm, and only 0.1% in intrafirm alone. Among firms who invest in enhancement, 67.8% invest in interfirm alone, 25.0% in interfirm and intrafirm, and 6.1% in intrafirm alone. Note that these totals do not sum exactly to 100% because some types of investments could not be reliably identified as intrafirm or interfirm.

[34] We use 50 employees because potential differences between different times for taking the survey mean that firms could grow after the Census and therefore be in the CI database. It was necessary to be inclusive for the weighting because some small rural areas had less than three firms in both the Census and the CI database; and therefore if one firm grew from the time of the Census to the time of the CI survey, the weightings would be difficult to interpret. The results are robust to weighting by firms with more than 100 employees in the Census and those with more than 25 employees. This is not surprising given the high correlation between these values.

distribution of establishments from the Census, is 88.6% (see Weighted Average in Table 2). Enhancement has been undertaken by 11.2% of our sample and 12.6% of the true distribution.

4. THE DISPERSION OF PARTICIPATION AND ENHANCEMENT

In this section, we argue that there is considerable variation across locations in the average propensity to adopt Internet technologies. Our results in Table 3 show participation and enhancement rates across Metropolitan Statistical Areas (MSAs) of varying size in the United States. Because there has been little prior work on variation in use of the Internet by business, these descriptive findings are not widely appreciated. In a previous work (Forman, Goldfarb and Greenstein 2003a, 2003c), we contrasted our findings with other studies of the geographic variation in household use of the Internet and infrastructure deployment. We reproduce it here because, on a broad level, this table motivates the present study. In Table 3, sizable differences in participation and enhancement adoption between large MSAs, medium MSAs, small MSAs and rural areas are presented. On the surface, this evidence supports either Urban Leadership Theory or Industry Composition Theory. We see that large MSAs have very high participation rates, averaging 90.4%. Participation rates in medium-sized MSAs and rural areas are lower at 84.9% and 85.1%, respectively. In small MSAs the participation rates are even lower, 75.5% on average.

The disparities in enhancement adoption rates are even greater (again, see Table 3). Large MSAs have relatively high adoption rates, with an average of 14.7%. In medium MSAs, adoption averages 11.2%. In small MSAs the rates are even lower, 9.9% on average. Average adoption rates in large MSAs are almost one-third greater than in medium MSAs. Once again, these averages suggest that Urban Leadership Theory or Industry Composition Theory may hold. Clearly there is considerable variation in adoption propensity by city size.

There is also variance in adoption propensity within the subset of large MSAs. In Table 4, we list the participation and enhancement estimates for MSAs with over one million people, in order of highest to lowest enhancement adoption rates.[35] As we do in all of our tables, we list the standard errors and number of observations to identify the degree of statistical confidence in the estimates.[36]

In Table 4, we show that participation is high in major urban locations. Virtually all establishments in the major urban areas are participating. Of the forty-nine MSAs, thirty-five are above 90%. All but five are within a 95% confidence interval of 90%. Nevertheless there are large differences between MSAs at the extremes.

The top ten MSAs that adopted enhancement include a set of areas that partially overlaps with the top ten MSAs for participation. (Five of the top ten are also in the top ten for participation.) Again, the

[35] In Table 4, we present the CMSA results rather than the individual MSA results when an MSA is part of a CMSA.

differences between the lowest adopting areas and the highest adopting areas are substantial. The considerable variation in adoption propensity by city size and among cities of the same size illustrated in Table 3 and Tables 4 motivated this study. We next explore some potential causes for this variation.

5. THE MARGINAL IMPACT OF LOCATION ON INTERNET ADOPTION

In the subsequent two sections, we present the marginal effects of geographic location on Internet adoption. We further compare these marginal effects across participation/enhancement and intrafirm/interfirm technologies. We summarize the main findings of the paper in Table 10, which is organized around the key hypotheses listed in Table 1.

In this section, we estimate Equation 2, while focusing on testing between Global Village and Urban Leadership Theories. We weight observations by the inverse probability that an establishment will appear in our sample. To be precise, the weight for each observation is the total number of establishments in a state/(two-digit) NAICS in Census County Business Patterns data divided by the number of establishments in the state/NAICS in our sample multiplied by controls for sampling the same establishment twice.

In Table 5, we show the roles of population and density in the adoption decision. Part A presents the coefficients of the probit regressions. Part B presents the marginal effects. All probit regressions include dummy variables for three-digit NAICS, the month the data were collected, survey type, survey type interacted with month, and whether or not the establishment was part of a multi-establishment firm. Because prior studies suggest a correlation between establishment size and new technology adoption (e.g., Rose and Joskow 1990; Åstebro 2002), we included employment and employment squared as controls. Population was measured at the MSA level and density at the county level. For columns 1 and 5, we use rural areas for the base. For columns 2, 3, 6, and 7, we include a "rural area" dummy for rural areas, since no meaningful population figures exist for these areas. In Columns 4 and 8 we include population density for all urban and rural areas by using low-density areas as the base.

5.1 The Marginal Impact of Location

From Table 5, it is clear that for participation there is no support for the Urban Leadership Theory. Controlling for industry and firm characteristics, we show that location size and population density have little impact on the decision to adopt at the participation level. The effects of location size and density support Global Village Theory, but the impact of geography is of limited economic and statistical significance. In Column 1 we show that medium and large MSAs are 0.5% to 1.0% less likely to have adopted participation by the end of 2000. However, the effect is only significantly different

[36] These are computed using the delta method.

between rural areas and medium MSAs. Moreover, this effect is only of marginal economic significance, as participation rates average 88.6%.

In Column 2 we identify the effects of size through a variable that captures the effects of increases in population in urban areas. Increases in population size do not increase the probability of participation. While not statistically significant, the coefficient suggests a possible decrease in the probability of participation. In Column 3 we include a squared population term. In this formulation, the linear term remains statistically insignificant, while the squared term is significant, albeit very small. This model implies that the effects of population will turn negative once urban areas exceed 7.039 million, a threshold that is larger than all but the five largest urban areas. In Column 4 we include dummies for population density. This alternative specification provides very similar results. Variation in population density does not affect participation by more than 1%, and it is always statistically insignificant. [37]

In contrast to participation, the effects of population size and density on enhancement support Urban Leadership Theory. In Column 5, part B, we show that establishments in medium and large MSAs adopt enhancement at a rate 0.8% to 1.1% higher than do rural areas. In Column 8 we show that establishments in medium and large MSAs adopt enhancement at a rate 1.0% to 1.5% more than do rural areas. All of these effects are statistically significant. They are economically significant in light of the average enhancement rates of 12.6%. While the data in Column 6 suggest that a linear population term has little effect on enhancement, the data in Column 7 show that population will have a statistically and economically significant positive effect for all MSAs below 8.8 million in size (all but New York, Los Angeles, and Chicago).

Together these results support the key prediction of GPT theory about the comparative relationship between complexity of application and geographic variance in use. The probability that an establishment adopts the Internet for enhancement increases faster in denser locations than does the similar probability for participation. We interpret this as evidence that applications more dependent on third-party support and complementary services are most costly to deploy in less dense locations.[38]

Variance in the role of location varies by city size. In Figures 1 and 2 we graph the marginal effect of location in the baseline probit in Model 2 with MSA dummies rather than with population-size dummies to reinforce the results of Table 5.[39] We divide locations into four types: large MSAs, medium

[37] While population is measured at the MSA level, density is measured at the county level because it allows us to measure density in non-MSA areas. This consideration is not relevant for population.
[38] Although probit regressions are only identified up to scale, we can compare the marginal effects of location across participation and enhancement for two reasons. First, these are marginal effects not coefficients. Second, the difference in signs between the marginal effects of large minus small areas across the two technologies reinforces our interpretation of the sensitivity of adoption to location for the two technologies. We subsequently employ a similar strategy to identify the difference in differences in marginal effects between intrafirm and interfirm technologies.
[39] This probit is not depicted in any table. We identify the effects of population size and density directly through the location-specific dummy variables.

MSAs, small MSAs, and statewide rural (non-MSA) regions. We plot the kernel density estimates of the effects of location on participation and enhancement, respectively.[40] We use Epanachnikov kernels with "optimal" bandwidths.

In Figure 1 small MSAs and rural areas have a fatter right tail, while the density for large MSAs reaches its peak slightly below any of the three other classes of geographic area. Although the distributions of each MSA size are roughly centered in the same place, the plot shows that, comparatively, the large MSAs lave less variance in adoption of participation than the other MSAs, especial the small MSAs. In all, this figure provides further support for Global Village Theory: Increases in local population size and density do not increase the likelihood of participation adoption. If anything, they lower it.

In Figure 2, the density estimate for large MSAs stochastically dominates those for small MSAs, medium MSAs, and rural areas. The center peak of the large MSAs' distribution is obviously at a higher value than the others. However, it is also apparent that the variance of enhancement adoption within large MSAs and rural areas is less than that within small and medium MSAs. This figure provides a visual depiction of the results in Table 5 that Urban Leadership Theory better describes the geographic diffusion of enhancement than does Global Village Theory.

Despite these results it is important to keep in mind our previous discussion participation diffusion patterns in large MSAs (see Table 4), which shows that the variance of adoption rates within large MSAs is great. This is not immediately observable from Figures 1 and 2 because there is even more variance in the small MSAs, medium MSAs and rural areas.

In Table 6 we provide summary statistics on the marginal effects of the same regressions used for Figures 1 and 2. Again, the results show that establishments in larger MSAs are less likely to adopt participation and more likely to adopt enhancement.

We conducted a number of robustness checks on our results. As noted, we were concerned that establishment location decisions might not be independent of Internet use. To control for this potential source of endogeneity, we re-estimated the model using only establishments that had been added to the Harte Hanks database prior to 1995, the year in which Internet technology began to diffuse widely to businesses. Although this restricted the size of our sample substantially (to 23,436 observations), the basic results remain the same. The correlation coefficients between our baseline marginal effects and those using pre-1995 data are 0.829 for participation and 0.997 for enhancement. Qualitative results did not change.

We were also concerned potential simultaneity bias surrounding the existence of many multi-establishment firms in the data. Multi-establishment firms are more likely to adopt both participation and enhancement technologies. We extended our statistical model to include variables capturing the behavior

[40] The omitted MSA is San Jose, the top MSA for enhancement adoption.

of other establishments within the same firm. In particular, we added variables measuring the percentage and total of other establishments within the same firm adopting the dependent variable (i.e., participation or enhancement). Because these variables are likely to be correlated with unobserved factors affecting the decision to adopt participation and enhancement, we also used nonlinear instrumental variable techniques. For instruments, we used average population and density of other establishments in the same firm. These were correlated with adoption decisions at the firm's other establishments, but not at the establishment of interest.

The results in Appendix Table A.2 show the marginal effects of probit regressions that add other establishment adoption decisions to the models in Table 5. These regressions are performed with and without instrumental variables (IV).[41] These robustness checks make little difference to the estimated relationship between population density and Internet adoption; the results of our tests contrasting Global Village and Urban Leadership Theories remain unchanged. Part A of Table A.2 shows that variables capturing the percentage of establishments with participation and enhancement are positive and significant in weighted probit regressions, however their significance disappears once we instrument in Part B of Table A.2. We interpret the probit regressions without IV as picking up unobserved heterogeneity, which is ultimately eliminated in the IV probit regressions. The new variables have little effect on the population marginal effects. Moreover, statistical significance of our location variables is retained in the IV version of this model. See Forman, Goldfarb, and Greenstein's (2003b) study for more results regarding location and multi-establishment firms.

We tried a number of other robustness checks. To ensure our results were not driven by omitted variables, we experimented with a variety of different specifications, using different location variables (e.g., CMSA dummies), different firm controls (e.g., revenue, private/public), and alternative measures of population size and density. To ensure our results were not a function of the particular weighting scheme used, we tried weighting the probit regressions by three-digit NAICS/states and two-digit NAICS/MSAs, as well as not weighting at all. In all cases the results remained qualitatively the same; the correlation coefficients between our baseline coefficient estimates and the alternative specifications were between 0.88 and 0.95 for participation and 0.78 and 0.90 for enhancement.[42]

[41] IV regressions were calculated using Amemiya Generalized Least Squares estimators for probit regression with endogenous regressors. The endogenous regressors are treated as linear functions of the instruments and the other exogenous variables. Maddala (1983, p. 247-252) provides details.

[42] We also explored whether establishment differences across geographic locations drive our results. Though unobservable establishment differences could play a role, we were unable to uncover any pronounced observable establishment differences. Using weighted data, establishments in large MSAs are larger (12.8% of establishments have >500 employees versus 9.0% for small MSAs and 9.9% for rural areas) and more likely to be multi-establishment (48.7% multi-establishment versus 43.9% for small MSAs and 33.4% for rural areas). When using unweighted data much of the difference disappears (12.7% of establishments in large MSAs >500 employees versus 12.1% in small MSAs and 13.4% in rural areas; 46.3% of establishments in large MSAs are multi-establishment versus 46.8% in small MSAs and 40.8% in rural areas).

5.2 Intrafirm and Interfirm Investment

Because interfirm Internet technologies involve communication between an establishment and entities external to the firm, Global Village Theory implies that the gross benefits of adopting these technologies would increase more slowly as location size increases than would the benefits from intrafirm technologies. If variations in costs across the two sets of technologies are roughly the same magnitude, we expect that as city size increases the adoption of intrafirm technologies increases more quickly than the adoption of interfirm technologies. In this section, we explore the geographic variation in Internet adoption across these margins of investment.

We divided both participation and enhancement into intrafirm and interfirm communication,[43] and ran our baseline MSA-size regressions on the decision to adopt intra- and interfirm participation and enhancement. The results are included in Table 7. Because some of these narrowly defined margins of investment relied on information from the Harte Hanks long survey, our main results in Columns 1 and 5 of each table are estimated on the subsample that received the long survey.

Parts A and B of Table 7 identify the geographic variation in adoption for intrafirm and interfirm participation. Controlling for industry and establishment characteristics, we show in Column 1 that location has little effect on the decision to adopt intrafirm participation technologies. For interfirm technologies, the data in Column 5 show that increases in location size have a statistically significant, if economically small, negative impact on adoption. Large MSAs are 0.8% less likely than rural areas to have adopted participation by the end of 2000. The difference between the small MSA and large MSA dummies are statistically significant at the 5% level, however the effect is economically small when compared to interfirm participation rates of 80.6%.

Parts C and D of Table 7 further confirm that the role of location varies across inter- and intrafirm technologies. In Column 1 we show that establishments located in large MSAs are 3.5% more likely to adopt intrafirm enhancement than those in rural areas and 1.4% more likely to adopt than those located in small MSAs. Both these differences are significant at the 5% level. In contrast, for interfirm enhancement, establishments in large MSAs are only 1.1% more likely to adopt than rural establishments (10% significance) and 0.02% more likely to adopt than those in small MSAs (not significant).

We ran several robustness checks. First, to ensure that our reduced sample was not influencing our results through a selection problem, we reran the regressions using the complete sample. The results, in Columns 2 and 6 of Table 7, are qualitatively the same for both participation and enhancement. Second, one potential concern with our baseline results is that the gross benefits of adopting some

[43] Because we were splitting the original endogenous variable, we changed the threshold of adoption for these variables. An establishment adopted interfirm participation if it indicated that it had basic Internet access, and adopted intrafirm participation if it indicated that it had an intranet or intranet applications that involved basic communications. An establishment adopted interfirm enhancement if it indicated use of any type of Internet

intrafirm technologies may be increasing in location size for establishments from multi-establishment firms. In other words, Global Village Theory may apply to intrafirm technologies in multi-establishment firms. We examined whether our results were the same using only a sample of single-establishment firms. Again, the results, shown in Columns 3 and 7 of Table 7, are qualitatively similar. It is possible that very large establishments have different decision procedures that may skew the results. Columns 4 and 8 show that the main results do not change when we examine only small single-establishment firms.[44]

In summary, as MSA size increases, adoption of intrafirm technologies increases more quickly than adoption of interfirm technologies. For enhancement, Urban Leadership Theory is supported by intrafirm but not interfirm technology adoption. We interpret these results as either reflecting the role of Global Village Theory on interfirm technologies, or providing evidence that Urban Leadership Theory is not caused by self-selection of IT-intensive firms into urban areas. In contrast, as location size increases, adoption of participation decreases for interfirm but not intrafirm technologies. This pattern is consistent with Global Village Theory.

6. Industry Composition

The differences between the average adoption rates in Table 3 and the marginal effects in Table 5 show that much of the difference in adoption of participation and enhancement across locations is explained by establishment size, industry, and firm status. In Table 3, large MSAs have almost a 15% higher participation rate and 5% higher enhancement rate than small MSAs. In Table 5, locating in a large MSA rather than a rural area reduces the probability of participation by 0.6% and increases the probability of enhancement by 1.1%.

The large differences in adoption rates between large and small urban areas in Table 3 reflect differences in industry composition across locations. Industry composition explains much more of the variation in participation and enhancement rates than location does. Once industry is controlled for, the incremental contribution of location in the probit regressions is small. This is shown in Table 8. The pseudo-R^2 of a probit for participation including only location dummies is 0.1526, whereas the pseudo-R^2 of a probit with only industry dummies is 0.2251. Adding location dummies to a probit that includes industry dummies barely improves fit, from 0.2251 to 0.2339.

Enhancement displays a similar pattern. Location dummies explain only 0.0347 of the variation in enhancement, industry dummies explain 0.0591, and the combination of industry and location

commerce, or advanced applications such as customer service or technical support, and adopted intrafirm enhancement if it had TCP/IP-based business applications.

[44] The argument on intrafirm technologies implies that firms with many geographically dispersed establishments will get an especially large benefit from the technology. We find this to be the case. In a regression of multi-establishment corporate adoption on number of corporate employees, three-digit NAICS, and number of states in

dummies explains 0.0672. While there remains a great deal of unexplained variation in our results, we conclude that an establishment's industry explains more of the variation in Internet use than does geographic location.

6.1. What Does Industry Composition Explain?

Industry Composition Theory asserts that leading industries concentrate in large urban areas. To test this hypothesis, we separated establishments by MSA type and calculated the kernel density of industry marginal effects for each type of location. The underlying marginal effects are the same across all four types of locations. However, the densities of each marginal effect differ because of differences in industry composition across locations. We did this for both participation and enhancement.

In Figure 3 we show the kernel density estimates of the marginal effects of industry by geographic area for participation.[45] Lead-user industries tend to be concentrated in large geographic areas. The average of the marginal effects of industry in rural and small MSAs is –18.7% and –20.2%, respectively, while the average of the marginal effects for medium and large MSAs are –18.8% and –16.9%, respectively. Except when comparing rural and medium MSAs, these averages are significantly different from one another at the 99% level. Large MSAs tend to have more lead-user industries, even for participation.

In Figure 4 we show that lead users of enhancement are even more skewed toward large MSAs. Rural areas and small MSAs have the highest densities along the left tail of the distribution, whereas large and medium MSAs have higher densities along the right tail. The average marginal effect of industry on enhancement adoption increases as location size increases: –8.0% in rural, –7.8% in small MSAs, –7.7% in medium MSAs, and –7.4% in large MSAs. Again, these averages are all significantly different from one another at the 1% level. The bulk of the variation in Table 3 reflects differences in industry composition between small and large MSAs, rather than other location-specific benefits of locating in large urban areas.

We conclude that large urban areas are comprised of establishments with a disproportionate tendency to be information intensive. To be concrete, within large MSAs, 27.5% of establishments are in industries that are part of the top quartile of adopters, compared to 19.0% of establishments in small MSAs. The industries in the upper quartile are traditionally information intensive, such as utilities, finance and insurance, company headquarters, professional and scientific services, electronics

which the firm operates, we found that each additional state increases the probability of adopting intrafirm participation by 1.5% and intrafirm enhancement by 4.2%.

[45] All industry results are unweighted. The omitted industry is information and data processing (NAICS 514). We use Epanachnikov kernels with bandwidth of 0.05 for participation and 0.005 for enhancement. These are wider than "optimal" bandwidths. Optimal bandwidths fail in this case because there are thousands of observations but only eighty-one possible values as there are eighty-one relevant three-digit NAICS levels. Therefore the optimal bandwidth does almost no smoothing.

manufacturing, and wholesale trade.[46] The geographic dispersion of establishments from these industries favored large urban areas prior to the diffusion of the Internet and largely contributed to higher rates of participation and enhancement in large urban areas.

Two conclusions emerge. First, this supports the importance of controlling for industry composition when testing between Global Village and Urban Leadership Theories. Second, inferences about the role of location are fraught with omitted variable biases in the absence of such controls.[47] We note that this factor is missing from all existing analyses about the geography of Internet use.

6.2. Are Industry and Location Complements or Substitutes?

The results in Table 8 and Figures 3 and 4 suggest that Industry Composition Theory explains a major part of the geographic patterns in establishment decisions to adopt Internet technology. However, more analysis is needed to determine whether industry and location effects are complements or substitutes. To identify between these alternatives, we reran the probit regressions in Table 5 with additional variables controlling for (1) whether the establishment is in a lead-user industry and (2) interactions of this lead user dummy with MSA-size dummies. We define lead-user industries in one of two ways: (1) the top quartile of participation or enhancement adopters among three-digit NAICS industries in our study or (2) the United States Department of Commerce's (2002) top fifteen IT-using industries as reported by Daveri and Mascotto (2002). Both measures of IT intensity have strengths and weaknesses. The measure based on the top quartile selects on the basis of the dependent variable; the measure from Daveri and Mascotto's study is based on a more general measure of IT intensity than the Internet.

Consequently, these are not final tests. We present these results as descriptive evidence that may support either a complement or substitute relationship between industry and location effects. To further supplement our analysis, we later examine whether establishments in lead-user industries (defined by high marginal effects) also tend to be located in favorable locations (locations with high marginal effects). In other words, we examine whether "good" industries are located in "good" locations.

Using the data on lead Internet adopters, Part A of Table 9 shows that there is little evidence of a complementary relationship between industry and location in participation; if anything, they are substitutes. An establishment in a top quartile NAICS and a large MSA is 2.6% more likely to adopt participation than an otherwise equivalent top quartile establishment in a rural area. However, large MSAs are 2.8% less likely to adopt participation than are small MSAs, though the difference is not statistically significant. The NAICS-level controls likely explain the lack of significance of the IT-intensive industry dummy (under both definitions). Perhaps because they are based on the Department of

[46] For more detail, see Forman, Goldfarb and Greenstein (2003a, 2003c).

[47] We cannot control for differences in IT-friendly firms within industries. We subsume this concept into Urban Leadership Theory.

Commerce's (2002) more general measure of IT use, the industry-location interactions in Part B of Table 9 are less significant than in Part A. However, they tell exactly the same story. An establishment in a lead-user Standard Industrial Classification and large MSA is no more likely to adopt participation than an otherwise equivalent establishment in a small MSA.

In contrast to participation, the results for enhancement in Table 9 show a strong complementary relationship between industry and location. Part A shows that an establishment in a top quartile NAICS and a large MSA is 20.0% more likely to adopt enhancement than an otherwise equivalent top quartile establishment in a rural area. The difference between small MSAs and large MSAs is even larger. Large and medium MSA establishments are equally likely to adopt enhancement. The results based on the Department of Commerce's (2002) more general measure of IT-intensity again are weaker, but again tell the same general story: An establishment in a lead-user industry and a large MSA is more likely to adopt enhancement than an otherwise equivalent establishment in a small MSA. Moreover, the positive coefficient on the interaction of lead-user industry and large MSA is the only statistically significant interaction in the regression. In summary, as was suggested by our industry-density complementarity hypothesis, industry and location are complements for complex applications.

As an alternative way of examining whether industry and location effects tend to complement or substitute one another, we compare median industries by IT use across cities. This is not an explicit test for complementarities, but rather another way of showing whether establishments in IT-intensive industries tend also to be located in favorable locations.

We calculate correlations between the marginal effects of the median industry within each urban area with those of the urban areas themselves. The results are consistent with our findings in Table 9. For participation, the marginal contribution of the median industry in a location is uncorrelated with the marginal contribution of the location itself ($\rho = -0.0214$). However, this result disguises a large difference between large and medium MSAs on the one hand and small MSAs and rural areas on the other. The correlation between the marginal contribution of median industry and location is significantly positive ($\rho = 0.307$) for large and medium MSAs but significantly negative ($\rho = -0.211$) for small MSAs and rural areas. For larger population locations, good cities do have good industries for participation; yet for smaller areas the opposite is true. Cities with high marginal adoption rates have industries with low marginal adoption rates.

For enhancement, there do seem to be complementarities between cities and locations ($\rho = 0.161$). These complementarities do not vary much by city size. Regardless of size, good industries are in good cities and good cities are dominated by good industries. Cities and IT-intensity appear to be complements for enhancement, but not for participation, especially in low population areas.

This is consistent with our hypothesis on industry-density complementarity, which emphasizes complementarity for complex applications. We interpret this complementarity as a likely result of spillover effects in using frontier technologies, or through the entry of complementary third-party services. Such complementary may exacerbate agglomeration in use, however we note that Tables 3 and 4 show that use of frontier technologies remain widespread. Moreover, such agglomeration in the use of complex applications is understandable as an economic matter. Co-invention theory suggests that adaptation of complex new technologies will be most sensitive to the presence of spillovers and complementary third-party services. This is exactly what we observe.

The exception in this section is as interesting as the more general finding. In low population areas, favorable locations likely only help adoption in firms without in-house expertise. In that case, location and industry become substitutes. This result is potentially consistent with our theory that emphasizes substitution between industry and agglomeration, which is most relevant for small urban areas.

7. Conclusions

We explore how geographic location affected adoption of the commercial Internet. Has use of the Internet been greater in urban areas--following the geographic diffusion pattern of previous computing technologies and exacerbating local differences in the potential for economic growth? Or, as a communications technology, has the diffusion of the Internet been different from other IT and realized its promise of reducing the importance of location to economic activity? In this paper, we test competing views by examining hard data about the short-run decisions of firms to invest in the Internet. Summaries of our questions and findings are listed in Table 10.

By 2000, participation activities such as email and web browsing had diffused almost everywhere. For these simple technologies, there is no evidence to support Urban Leadership Theory. Once industry composition was controlled for, we found that the variation across locations is best explained by Global Village Theory. This was particularly true for technologies that lowered interfirm coordination costs.

For complex enhancement technologies, adoption behavior is best explained by Urban Leadership Theory. We show that these overall results were driven by intrafirm enhancement technologies that played little role in reducing coordination costs with other firms. Adoption of interfirm enhancement technologies, in fact, is more consistent with Global Village Theory than with Urban Leadership Theory.

Geographic variation in use was consistent with GPT theory: enhancement costs decrease more quickly as population density increases than do participation costs. Adopters of participation faced low technical hurdles to implementation, whereas adopters of enhancement faced high ones. Establishments overcame these costs because they had experience with overcoming technical and co-invention costs, had access to rich complementary resources through local markets, or both.

We show that industry composition played a major role in explaining the geographic variance in average rates of Internet adoption. This supported our focus on the marginal contribution of location, in contrast to prior studies. We found evidence of complementarities between industry and location effects in the adoption of enhancement: IT-intensive firms found greater benefits than other firms from pooled resources in large cities. Nevertheless, our research shows that Internet participation did not exacerbate geographic inequalities by diffusing primarily to urban areas with complementary technical and knowledge resources. In terms of the basic technology, the Internet diffused at least as rapidly to isolated areas as to large cities.

Of more relevance to economic growth, the geographic pattern of adoption for enhancement may increase an urban/rural divide in productivity. The value and co-invention costs of an application may vary with local conditions; in particular, urban areas may possess pooled resources that lower co-invention costs. In smaller MSAs and rural areas, thin technical labor markets alone could drive up costs of operating facilities employing frontier Internet technology. Such urban/rural divides may be exacerbated if technology-friendly establishments choose to locate in urban areas. However, such regional differences may be lessened if high participation rates in rural areas permit resource sharing across regions. With the right investments in interfirm technologies, establishments in rural areas may be able to access services located in urban areas.

Our findings provide several questions for further research. First, our conclusions apply only to medium to large establishments. We defer to future research the examination of small establishments and newly founded firms, which may face a different array of benefits and may have diminished access to internal resources for idiosyncratic adaptation costs. It is already apparent from existing papers that participation is lower on average in small firms,[48] so we speculate that smaller firms will be more sensitive to geographic variation in local complementary resources than found here.

Second, our findings suggest broadly that variations in co-invention costs across technologies and locations shaped the diffusion of Internet technology. Research on the role of co-invention costs on Internet diffusion has been hampered by the binary nature of the adoption decision considered in many studies, including this one. Future work should analyze variations in firm co-invention costs, emphasizing in particular the impact of variation in labor market conditions, spillovers, and markets for technical support.

Third, our findings suggest there was considerable variation in the benefits of Internet investments across locations and industries. Such variation has implications for how Internet investment shaped regional productivity and, by implication, comparative advantage. Consequently, it may affect the long-run location decisions of firms and the agglomeration of economic activity. For example, inexpensive communications may mean that establishments relocate from high-cost–high-density areas to low-cost—low-density areas. These remain open questions, however. Further work should compare the location decisions in industries where interfirm Internet technologies are prevalent with those in other industries. This will help complete the picture of how the Internet affects geographic variance in productivity and employment.

Fourth, our findings have implications for variation in the dollar value of investment across location and industries and the net returns from those investments. The diffusion model of adoption used in this study implies that magnitudes of investment should follow patterns similar to the patterns for the binary adoption decision. Hence, we speculate that the flow of investment dollars will correlate positively with the rankings of location and industries uncovered in this study. We know from our earlier research that this correlation is present for investment measured at the level of the industry, at least for manufacturing (Forman, Goldfarb and Greenstein 2003c). Furthermore, if this model is correct, the investment dollars affiliated with the commercialization of the Internet were widely dispersed throughout locations and industries in the United States. This speculation awaits confirmation with data about investment behavior beyond adoption.

References

Åstebro, Thomas. 2002. "Noncapital investment costs and the adoption of CAD and CNC in U.S. metalworking industries" *RAND Journal of Economics* 33(4): 672-688.

Atrostic, Barbara, K., and John Gates. 2001. "U.S. Productivity and electronic business processes in manufacturing." Working Paper #01-11, Center for Economic Studies, U.S. Census Bureau.

Atrostic, Barbara K. and Sang V. Nguyen. 2002. "Computer networks and U.S. manufacturing plant productivity: New evidence from the CNUS Data." Working Paper #02-01, Center for Economic Studies, U.S. Census Bureau.

Autor, David H. 2001. "Wiring the labor market." *Journal of Economic Perspectives* 15(1), 25-40.

Baily, Martin Heil and Lawrence, Robert Z. 2001. "Do we have a new e-conomy?" *American Economic Review* 91(2):. 308-12

Beardsell, Mark and Vernon Henderson. 1999. "Spatial evolution of the computer industry in the USA." *European Economic Review*, 43(2): 431-56.

Bitler, Marianne P. 2002. "Computer adoption by small businesses: Who adopts?" Mimeo, Rand Corporation, Santa Monica, CA.

Bresnahan, Timothy, and Manuel Trajtenberg. 1995. "General Purpose Technologies: 'Engines of growth'?" *Journal of Econometrics.* 65 (1): 83-108.

[48] For the beginnings of such research, see Atrostic and Gates (2001) on manufacturing establishments, and Buckley and Montes (2002) and Bitler (2002) for analysis of small-business computer use.

Bresnahan, Timothy, Erik Brynjolfsson, and Lorin Hitt. 2002. "Information technology, work Organization, and the demand for skilled labor: Firm-level evidence." *Quarterly Journal of Economics* 117 (February): 339-76.

Brynjolfsson, Erik and Lorin Hitt. 2000. "Beyond computation: Information technology, organizational transformation and business performance." *Journal of Economic Perspectives* 14(4), 23-48.

Buckley, Patricia and Sabrina Montes. 2002. *Main Street in the digital age: How small and medium-sized business are using the tools of the new economy,* Department of Commerce, Economics and Statistics Administration (February 2002). http://www.esa.doc.gov/reports.cfm.

Cairncross, Frances, 1997. *The death of distance.* Cambridge, MA: Harvard University Press.

Castells, Manuel, 2003. *The internet galaxy, reflections on the internet, business and society*. Oxford: Oxford University Press.

Charles, Sandra, Matthew Ivis and André Leduc. 2002. "Embracing e-business: Does size matter?" Research Report, Statistics Canada.

Charlot, Sylvie and Gilles Duranton. 2003. "Cities and workplace communication: Some French evidence." Mimeo, London School of Economics.

Chun, Hyunbae. 2003. "Information Technology and The Demand for Educated Workers: Disentangling the Impact of Adoption Versus Use." *Review of Economics and Statistics* 85(1): 1-8.

Crandall, Robert and Alleman, James H. 2002. *Broadband: Should we regulate high speed internet access?* Washington DC: AEI-Brookings Joint Center for Regulatory Studies, Brookings Institution Press.

Daveri, Francesco and Andrea Mascotto. 2002. "The IT revolution across U.S. states." Mimeo, IGIER.

David, Paul A. 1969. "A contribution to the theory of diffusion," Memorandum No. 71, Stanford Center for Research in Economic Growth. Stanford University.

Doms, Mark, Timothy Dunne, and Kenneth R. Troske. 1997. "Workers, Wages, and Technology." *Quarterly Journal of Economics* 112(1): 253-290.

Downes, Tom and Shane Greenstein. 2002, "Universal access and local internet markets in the U.S." *Research Policy* 31: 1035-1052.

Fitoussi, David. 2003. "So close and yet so far: Information technology and the spatial distribution of customer service." In *Proceedings of the Twenty-Fourth International Conference on Information Systems*, eds. Joseph Valacich and Leonard Jessup. Available on CD, Associate for Information Systems, Atlanta.

Forman, Chris. 2003. "The Corporate Digital Divide: Determinants of Internet Adoption." Mimeo, Carnegie Mellon University.

Forman, Chris, Avi Goldfarb, and Shane Greenstein. 2002. "Digital dispersion: An industrial and geographic census of commercial internet use." NBER Working Paper #9287.

——,. 2003a. "The geographic dispersion of commercial internet use," In *Rethinking Rights and Regulations: Institutional Responses to New Communications Technologies*, eds. Lorrie Faith Cranor and Steven S. Wildman. Cambridge: MIT Press.

——, 2003b. "How did location affect adoption of the commercial Internet? Global village, urban density and industry composition." NBER Working Paper #9979.

——, 2003c. "Which industries use the Internet?" In *Organizing the New Industrial Economy*, ed. Michael R. Baye. Chapter 2. Amsterdam: Elsevier.

Gaspar, Jess and Glaeser, Edward. 1998. "Information technology and the future of cities." *Journal of Urban Economics*. 43(1): 136-56.

Goolsbee, Austan. 2000. "In a world without borders: The impact of taxes on electronic commerce." *Quarterly Journal of Economics* 115(2): 561-576.

Goolsbee, Austan and Peter Klenow. 2002. "Evidence on Learning and Network Externalities in the Diffusion of Home Computers." *Journal of Law and Economics* 45(2): 317-344.

Gorman, Sean P. 2002, "Where are the Web factories: the urban bias of e-business location." Mimeo, Neoteric Media Inc., Arlington VA.

Gowrisankaran, Gautam and Stavins, Joanna. 2004. "Network externalities and technology adoption: lessons from electronic payments." Forthcoming, *RAND Journal of Economics.*

Greenstein, Shane. 2000. "Building and developing the virtual world: the commercial internet access market." *Journal of Industrial Economics* 48(4): 391-411.

——. 2003. "The Economic geography of Internet infrastructure in the United States," In *The Handbook of Telecommunications Economics.* Vol. II, eds. M. Caves, S. Majumdar and I. Vogelsang, Amsterdam: Elsevier.

Griliches, Zvi. 1957. "Hybrid corn: An exploration in the economics of technological change." *Econometrica* 25(4), 501-22.

Harris, Richard. 1998. "The Internet as a GPT: Factor market implications," In *General Purpose Technologies and Economic Growth*. ed. E. Helpman, 145-166. Cambridge, MA: MIT Press.

Henry, David and Donald Dalton. 2002. "Information technology industries in the new economy," in *Digital Economy 2002*, Chapter III. Washington DC: Department of Commerce, http://www.esa.doc.gov/reports.cfm.

Hitt, Lorin and Erik Brynjolfsson. 1997. "Information technology and internal firm organization: An exploratory analysis." *Journal of Management Information Systems* 14 (Summer): 1-101.

Holmes, Thomas. 2002. "The Role of Cities: Evidence from the Placement of Sales Offices." Federal Reserve Bank of Minneapolis Research Department Staff Report 298.

Hubbard, Tom. 2000. "The demand for monitoring technologies: The case of trucking." *Quarterly Journal of Economics* 116 (May): 533-60.

Ireland, Norman and Paul Stoneman. 1986. "Technological diffusion, expectations and welfare." *Oxford Economic Papers* 38: 283-304.

Jorgenson, Dale and Kevin Stiroh. 2000. "Raising the speed limit: U.S. economic growth in the Information Age" *Brookings Papers on Economic Activity* 2000(1): 125-211.

Karshenas, Massoud and Paul Stoneman. 1993. "Rank, Stock, order, and epidemic effects in the diffusion of new process technologies: An empirical model" *RAND Journal of Economics* 24(4): 503-28.

Kolko, Jed. 2000. "The death of cities? The death of distance? Evidence from the geography of commercial Internet usage," In *The Internet Upheaval*. eds. Ingo Vogelsang and Benjamin M. Compaine, 73-98. Cambridge, MA: MIT Press.

——. 2002. "Silicon mountains, silicon molehills, geographic concentration and convergence of Internet industries in the US." *Information Economics and Policy* 14(2): 211-32.

Krugman, Paul. 1991. *Geography and trade*. Cambridge: MIT Press.

Lucas, Henry C. 2002. *Strategies for electronic commerce and the Internet*. Cambridge, MA: MIT Press.

Lucking-Reiley, David and Daniel F. Spulber. 2001. "Business-to-business electronic commerce" *Journal of Economic Perspectives* 15(1): 55-68.

Maddala, G. S. 1983. *Limited-dependent and qualitative variables in econometrics*. Cambridge, England: Cambridge University Press.

Marshall, Alfred. 1920. *Principles of economics*. 8th ed. New York: Porcupine Press.

Mendelson, Haim and Sanjeev Dewan. 2001. "Schwab.com." Stanford Business School Case #EC18. Stanford Business School.

Moss, Mitchell L. and Anthony M. Townsend, 1997. "Tracking the net: using domain names to measure the growth of the Internet in US cities." *Journal of Urban Technology* 4(3): 47-60.

National Telecommunications and Information Administration. 1995. "Falling Through the Net: A Survey of the 'Have Nots' in Rural and Urban America." http://www.ntia.doc.gov/reports.html.
.

——.1998. "Falling through the net II: New data on the digital divide." http://www.ntia.doc.gov/reports.html.

——.1999. "Falling through the net: Defining the digital divide." http://www.ntia.doc.gov/reports.html.

——.2000a. "Falling through the net: Toward digital inclusion." http://www.ntia.doc.gov/reports.html.

——. 2000b. "Advanced telecommunications in rural America, the challenge of bringing broadband service to all Americans." http://www.ntia.doc.gov/reports.html

Nolan, Richard L., Kelley Porter and Christina Akers, 2001. "Cisco Systems: Web-enablement." Harvard Business School Case #9-301-056. Harvard University.

Oliner, Stephen D. and Daniel E. Sichel. 2000. "The resurgence of growth in the late 1990s: Is information technology the story?" *Journal of Economic Perspectives* 14(4 Fall): 3-22.

Porter, Michael E. 2001. "Strategy & the Internet". *Harvard Business Review*. 79 (March): 62-78.

Price, Lee and George McKittrick. 2002. "Setting the stage: The new economy endures despite reduced IT investment." In *Digital Economy 2002*, Chapter I. Washington DC: Department of Commerce, http://www.esa.doc.gov/reports.cfm.

Rogers, Everett. 1995. *The diffusion of innovations.* Fourth ed. New York: Free Press.

Rose, Nancy L. and Paul L. Joskow. 1990. "The diffusion of new technologies: Evidence from the electric utility industry." *RAND Journal of Economics* 21(3): 354-73.

Rosenberg, Nathan and Manuel Trajtenberg. 2001. "A general purpose technology at work: The Corliss steam engine in the late 19th century US." NBER Working Paper 8485.

Sinai, Todd and Joel Waldfogel. 2001. "Geography and the Internet: Is the Internet a substitute or a complement for cities?" Mimeo. Wharton School of Business, University of Pennsylvania at Philadelphia, PA.

Stevenson, Betsy. 2003. "The Internet, job search, and worker mobility." Mimeo. Stanford University.

Stiroh, Kevin. 2002. "Information technology and the U.S. productivity revival: What do the industry data say?" *American Economic Review* 92(5): 1559-76.

U.S. Bureau of the Census. 1999. *County Business Patterns 1999.* http://www.census.gov/epcd/cbp/view/cbpview.html.

U.S. Bureau of the Census. 2002. "Detailing tabulations of manufacturing e-business process use in 2000." Survey Release. United States Department of Commerce, http://www.census.gov/epcd/www/ebusiness.htm.

U.S. Department of Agriculture. 2001. "Farm computer usage and ownership report, 07.30.01." http://usda.mannlib.cornell.edu/reports/nassr/other/computer/

U.S. Department of Commerce. 2002. "A nation online: How Americans are expanding their use of the Internet," Joint Report from the National Telecommunications and Information Administration and the Economics and Statistics Administration. Washington DC.

Woerner, Stephanie. 2001. "Networked at Cisco" Teaching Case #1. Center for E-Business at Massachusetts Institute of Technology, Cambridge, MA.

Zooks, Matthew. 2000a. "Internet metrics: Using hosts and domain counts to map the Internet globally." *Telecommunications Policy,* 24: 6-7.

——.2000b. "The Web of Production: the Economic Geography of Commercial Internet Content Production in the United States." *Environment and Planning* 32: 411-26.

Table 1
Open Questions

Open Question	Prediction	Testable Hypotheses
Global Village & Urban Leadership, Participation and Enhancement		
Is investment in participation and enhancement consistent with Global Village (Urban Leadership) Theory?	$dNB/dx_i \leq 0$ $(dNB/dx_i > 0)$	Coefficient on rural areas ≥ small MSA ≥ medium MSA ≥ large MSA (Coefficient on rural areas< small MSA < medium MSA < large MSA)
Does enhancement increase faster than participation as location size increases-- consistent with GPT theory?	dNB/dx_i *for enhancement* > dNB/dx_i *for participation*	Is the difference between the coefficient for large and rural or small MSAs for enhancement *greater* than the difference between the coefficient on large and rural or small MSA for participation?
Global Village & Urban Leadership, Intra- and Interfirm Communication		
Is investment in **intra-** and **inter**firm communications consistent with Global Village (Urban Leadership) Theory?	$dNB/dx_i \leq 0$ $(dNB/dx_i > 0)$	Coefficient on rural ≥ small MSA ≥ medium MSA ≥ large MSA (Coefficient on rural < small MSA < medium MSA < large MSA)
Does **intra**firm investment increase faster than **inter**firm investment as location size increases-- consistent with Global Village Theory?	dNB/dx_i *for **intra**firm* > dNB/dx_i *for **inter**firm*	Is the difference between the coefficient on large and rural or small MSAs for **intra**firm *greater* than the difference between the coefficient on large and rural or small MSA for **inter**firm?
Industry Composition		
Does Industry Composition Theory explain everything?	$dNB/dz_i > 0$; $corr(x_i, z_i) > 0$, $dNB/dx_i = 0$	Industry Composition Theory explains all adoption behavior and IT-intensive industries are concentrated in larger areas
Are industry and density complements (substitutes)?	$dNB/dz_i > 0$, $dNB/dx_i > 0$, and $d^2NB/ dx_i dz_i > 0$ $(d^2NB/ dx_i dz_i < 0)$	Industry Composition Theory and Urban Leadership Theory both explain a part of adoption and the effect of IT-intensity is increasing (decreasing) as MSA size increases.

Notes :
$NB(x_i,z_i) \equiv B(x_i,z_i) - C(x_i,z_i)$
x_i describes geographic conditions such as population size and density.
z_i describes the IT-intensity of an industry.
Testable implications describe manifestation of each theory in probit models of decision to adopt participation and enhancement.

Table 2
National Internet Adoption Rates (in percentages)

	Weighted Average	**Unweighted Average**
Participation	88.6%	80.7%
Enhancement	12.6%	11.2%

Notes:
Source: Authors' calculations using the CI database and Census data.
Definitions for participation and enhancement are given in the text. See also Forman, Goldfarb, and Greenstein (2002) for further documentation.
Unweighted average uses only CI database sample.
Weights are defined by Equation 3, as given in the text.

Table 3
Average Adoption by Size of Metropolitan Statistical Area (MSA)

Population	Average Participation	Standard Error	Average Enhancement	Standard Error	Number of Areas
Rural Area	85.1%	0.1%	10.6%	0.2%	49
Small MSA: < 250,000	75.5%	0.2%	9.9%	0.3%	143
Medium MSA: 250,000–1 million	84.9%	0.2%	11.2%	0.3%	116
Large MSA > 1 million	90.4%	0.1%	14.7%	0.2%	57

Notes:
Source: Authors' calculations using CI database and census data.
Definitions for participation and enhancement are given in the text. See also Forman, Goldfarb, and Greenstein (2002) for further documentation.
All calculations use weighted averages, where weights are defined by Equation 2, as given in the text. Standard errors are computed using the delta method.

Table 4: Metropolitan Statistical Areas with Over One Million People

CITY	Enhancement			Participation			Obs.	Population
	Rank	Rate	Std Err	Rank	Rate	Std Err		
Denver--Boulder--Greeley, CO	1	18.3%	1.3%	2	95.9%	0.7%	940	2,581,506
San Francisco--Oakland--San Jose, CA	2	17.0%	0.9%	1	96.4%	0.4%	2135	7,039,362
Salt Lake City--Ogden, UT	3	16.7%	1.7%	5	93.5%	0.8%	535	1,333,914
Minneapolis--St. Paul, MN--WI	4	15.9%	1.0%	9	92.7%	0.5%	1411	2,968,806
Houston--Galveston--Brazoria, TX	5	15.7%	1.0%	15	91.7%	0.6%	1413	4,669,571
Atlanta, GA	6	15.4%	1.0%	24	90.9%	0.6%	1426	4,112,198
Oklahoma City, OK	7	15.4%	2.0%	34	90.2%	1.1%	339	1,083,346
Dallas--Fort Worth, TX	8	15.3%	0.9%	13	92.1%	0.5%	1720	5,221,801
San Antonio, TX	9	15.3%	1.9%	6	93.3%	0.8%	395	1,592,383
Portland--Salem, OR--WA	10	15.1%	1.3%	14	92.1%	0.6%	776	2,265,223
Providence--Fall River--Warwick, RI--MA	11	14.9%	2.2%	7	93.0%	1.2%	290	1,188,613
Austin--San Marcos, TX	12	14.7%	1.9%	12	92.1%	0.7%	344	1,249,763
Cleveland--Akron, OH	13	14.7%	1.2%	3	94.8%	0.6%	1099	2,945,831
Tampa--St. Petersburg--Clearwater, FL	14	14.6%	1.3%	41	88.4%	0.9%	812	2,395,997
Memphis, TN--AR--MS	15	14.5%	1.8%	35	90.0%	1.0%	437	1,135,614
Seattle--Tacoma--Bremerton, WA	16	14.5%	1.2%	4	93.9%	0.5%	1012	3,554,760
Hartford, CT	17	14.4%	1.6%	33	90.2%	0.9%	500	1,183,110
San Diego, CA	18	14.3%	1.3%	20	91.5%	0.7%	738	2,813,833
Cincinnati--Hamilton, OH--KY—IN	19	14.2%	1.3%	37	89.7%	0.8%	772	1,979,202
Washington--Baltimore, DC--MD—VA--WV	20	14.2%	0.8%	30	90.4%	0.5%	2222	7,608,070
Chicago--Gary--Kenosha, IL--IN—WI	21	14.1%	0.7%	28	90.5%	0.4%	3431	9,157,540
Rochester, NY	22	14.1%	1.9%	32	90.3%	1.0%	373	1,098,201
Boston—Worcester--Lawrence, MA--NH--ME--CT	23	13.9%	0.8%	27	90.6%	0.5%	2231	5,819,100
Detroit—Ann Arbor--Flint, MI	24	13.8%	0.9%	21	91.4%	0.6%	1621	5,456,428
Kansas City, MO--KS	25	13.7%	1.3%	11	92.2%	0.6%	753	1,776,062
Raleigh--Durham--Chapel Hill, NC	26	13.7%	1.7%	17	91.6%	0.9%	398	1,187,941
Pittsburgh, PA	27	13.6%	1.3%	39	89.1%	0.8%	727	2,358,695
Indianapolis, IN	28	13.6%	1.4%	22	91.3%	0.8%	646	1,607,486
Charlotte--Gastonia--Rock Hill, NC—SC	29	13.6%	1.5%	26	90.7%	0.9%	618	1,499,293
West Palm Beach--Boca Raton, FL	30	13.6%	2.0%	47	85.9%	1.2%	299	1,131,184
Los Angeles--Riverside--Orange County, CA	31	13.5%	0.6%	10	92.5%	0.4%	4099	16,373,645
Miami--Fort Lauderdale, FL	32	13.5%	1.1%	25	90.9%	0.7%	1010	3,876,380
New York—Northern NJ--Long Island, NY--NJ--CT--PA	33	13.5%	0.6%	29	90.5%	0.4%	4775	21,199,865
Philadelphia-Wilm.-Atlantic City, PA—NJ--DE--MD	34	13.3%	0.9%	31	90.3%	0.5%	1745	6,188,463
St. Louis, MO--IL	35	13.2%	1.2%	38	89.7%	0.7%	936	2,603,607
Louisville, KY--IN	36	13.2%	1.6%	36	89.9%	1.0%	448	1,025,598
Columbus, OH	37	13.0%	1.5%	18	91.5%	0.9%	574	1,540,157
Buffalo--Niagara Falls, NY	38	12.9%	1.7%	40	88.5%	1.1%	393	1,170,111
Phoenix--Mesa, AZ	39	12.4%	1.1%	16	91.6%	0.7%	988	3,251,876
Greensboro--Winston-Salem--High Point, NC	40	12.2%	1.4%	23	91.1%	0.9%	570	1,251,509
Grand Rapids--Muskegon--Holland, MI	41	12.0%	1.5%	8	93.0%	0.7%	503	1,088,514
New Orleans, LA	42	11.9%	1.7%	46	86.0%	1.1%	386	1,337,726
Milwaukee--Racine, WI	43	11.7%	1.2%	19	91.5%	0.7%	855	1,689,572
Nashville, TN	44	11.7%	1.5%	49	84.6%	1.1%	466	1,231,311
Jacksonville, FL	45	11.3%	1.7%	42	87.6%	1.3%	373	1,100,491
Sacramento--Yolo, CA	46	11.8%	1.6%	44	87.0%	1.2%	427	1,796,857
Norfolk--Virginia Beach--Newport News, VA--NC	47	10.8%	1.7%	45	86.9%	1.2%	374	1,569,541
Orlando, FL	48	10.5%	1.3%	48	85.5%	1.0%	622	1,644,561
Las Vegas, NV--AZ	49	9.0%	1.4%	43	87.2%	1.2%	417	1,563,282
Standard Deviation		1.7%			2.5%			

Table 5
Effect of Population Size and Density on Adoption of Participation and Enhancement
(Standard errors in parentheses)

		Participation				Enhancement			
		(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
A. Coefficients from (Weighted) Probit Regressions	Small MSA	0.0095				0.0198			
		(0.0285)				(0.0350)			
	Medium MSA	-0.0491				0.0449			
		(0.0227)*				(0.0265)+			
	Large MSA	-0.0262				0.0632			
		(0.0201)				(0.0228)**			
	MSA Population		-3.95e-09	1.36e-08			-8.80e-10	2.10e-08	
			(3.80e-09)	(1.02e-08)			(3.24e-09)	(1.15e-08)+	
	MSA Population Squared			-1.94e-15				-2.39e-15	
				(1.13e-15)+				(1.24e-15)+	
	Medium-Low Density				-0.0170				0.0275
					(0.0194)				(0.0224)
	Medium-High Density				-0.0282				0.0860
					(0.0200)				(0.0244)**
	High Density				-0.0177				0.0577
					(0.0224)				(0.0224)*
	Log Likelihood	-33470.6	-33472.1	-33469.3	-33473.5	-28694.7	-28696.9	-28693.1	-28688.2
	Pseudo R^2	0.2252	0.2252	0.2252	0.2251	0.0593	0.0592	0.0593	0.0595

		Participation				Enhancement			
		(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
B. Marginal Effects from (Weighted) Probit Regressions	Small MSA	0.0021				0.0035			
		(0.0064)				(0.0062)			
	Medium MSA	-0.011				0.008			
		(0.0052)*				(0.0048)+			
	Large MSA	-0.0058				0.0110			
		(0.0045)				(0.0039)**			
	MSA Population		-8.89e-10	3.06e-09			-1.54e-10	3.67e-09	
			(8.56e-10)	(2.30e-09)			(5.67e-10)	(2.02e-09)+	
	MSA Population Squared			-4.37e-16				-4.18e-16	
				(2.55e-16)+				(2.17e-16)+	
	Medium-Low Density				-0.00385				0.00485
					(0.00440)				(0.00399)
	Medium-High Density				-0.00639				0.0154
					(0.00456)				(0.00450)**
	High Density				-0.00400				0.0103
					(0.00508)				(0.00406)*

Notes:
All regressions include dummy variables for three-digits NAICS, month that data was collected, survey type, and whether it was a multi-establishment firm. Employment and Employment squared were also included as controls. Population was measured at the MSA level. Standard errors are in parentheses.
(1) & (5) Non-MSA is the base for these regressions.
(2), (3), (6), & (7) Since no meaningful population data was available for non-MSA areas, we include a “rural area” dummy variable in each of these regressions. The population and density variables were interacted with (1-RURAL). Therefore the coefficients on the population variables do not include non-MSA areas.
(4) & (8) Low density is the base for these regressions. One-quarter of the observations fit into each density type.
+significant at 90% confidence level
*significant at 95% confidence level
**significant at 99% confidence level

Table 6
Average and Median Location Effects, by Type of Location

Type	N	Median Participation Marginal Effect	Average Participation Marginal Effect	Standard Deviation Participation Marginal Effect	Median Enhancement Marginal Effect	Average Enhancement Marginal Effect	Standard Deviation Enhancement Marginal Effect
Rural	49	-0.0290	-0.0292	0.0486	-0.020	-0.0135	0.0274
Small MSA	130*	-0.0225	-0.0271	0.0772	-0.018	-0.00708	0.0495
Medium MSA	95	-0.0460	-0.0535	0.0579	-0.012	-0.0111	0.0313
Large MSA	48	-0.0445	-0.0397	0.0324	-0.008	-0.00652	0.0150

Notes:
Authors' calculation using estimates from probit models shown in Figures 1 and 2.
*N = 127 for enhancement because three small MSAs perfectly predicted non-adoption.

Table 7
Effect of Population Size and Density on Adoption of Intra-Firm and Inter-Firm Adoption
(Standard errors in parentheses)

		Participation							
		***Intra*firm**				***Inter*firm**			
		(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
A. Coefficients from (Weighted) Probit Regressions	Small MSA	-0.000307	-0.00472	0.0318	0.0765	0.019097	0.0209	0.0334	0.0360
		(0.0252)	(0.0188)	(0.0328)	(0.0491)	(0.0342)	(0.0224)	(0.0451)	(0.0649)
	Medium MSA	0.0138	0.00497	0.0303	0.0444	-0.0356	-0.0294	-0.0244	-0.00809
		(0.0198)	(0.0150)	(0.0257)	(0.0387)	(0.0264)	(0.0178)+	(0.0348)	(0.0506)
	Large MSA	-0.00678	-0.00747	-0.0013	0.0378	-0.0492	-0.0208	-0.0572	0.00101
		(0.0171)	(0.0130)	(0.0220)	(0.0333)	(0.0229)*	(0.0155)	(0.0298)+	(0.0434)
	Log Likelihood	-30431.8	-52357.1	-17680.6	-8411.4	-15356.3	-34342.7	-8625.6	-4231.0
	Observations	53231	86879	30260	13822	53231	86879	30119	13735
B. Marginal Effects from (Weighted) Probit Regressions		***Intra*firm**				***Inter*firm**			
		(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
	Small MSA	-0.000102	-0.00181	0.0107	0.0269	0.00280	0.00489	0.0048	0.00559
		(0.00837)	(0.00718)	(0.0109)	(0.0169)	(0.00497)	(0.00518)	(0.0064)	(0.00987)
	Medium MSA	0.00457	0.00190	0.0102	0.0157	-0.00536	-0.007	-0.0036	-0.00129
		(0.00653)	(0.00572)	(0.0086)	(0.0136)	(0.00404)	(0.00428)	(0.0052)	(0.00808)
	Large MSA	-0.00225	-0.00285	-0.0004	0.0135	-0.00727	-0.0049	-0.0084	0.00016
		(0.00568)	(0.00495)	(0.0075)	(0.0119)	(0.0033)*	(0.00364)	(0.0043)+	(0.00689)

		Enhancement							
		***Intra*firm**				***Inter*firm**			
		(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
C. Coefficients from (Weighted) Probit Regressions	Small MSA	0.0801	0.0724	0.114	0.115	0.0330	0.0379	0.0183	0.0404
		(0.0285)**	(0.0265)**	(0.0390)**	(0.0647)+	(0.0257)	(0.0199)+	(0.0340)	(0.0535)
	Medium MSA	0.0841	0.0931	0.0992	0.130	0.0462	0.0172	0.0370	0.0421
		(0.0226)**	(0.0210)**	(0.0311)**	(0.0518)*	(0.0202)*	(0.0159)	(0.0267)	(0.0424)
	Large MSA	0.130	0.147	0.125	0.169	0.033368	0.00703	0.0013	0.0519
		(0.0197)**	(0.0183)**	(0.0270)**	(0.0455)**	(0.0176)+	(0.0138)	(0.0231)	(0.0368)
	Log Likelihood	-24608.8	-27269.8	-12499.4	-5011.7	-29910.4	-46272.2	-16510.5	-7170.9
	Observations	53227	86872	30260	13788	53227	86872	30265	13821
D. Marginal Effects from (Weighted) Probit Regressions		***Intra*firm**				***Inter*firm**			
		(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
	Small MSA	0.0217	0.0116	0.0274	0.0237	0.01081	0.0117	0.0057	0.0121
		(0.00795)**	(0.0044)**	(0.0098)**	(0.0141)+	(0.00851)	(0.00622)+	(0.0108)	(0.0162)
	Medium MSA	0.0226	0.0148	0.0235	0.0267	0.0151	0.00530	0.0116	0.0125
		(0.00620)**	(0.00348)**	(0.0076)**	(0.0111)*	(0.00668)*	(0.00491)	(0.0085)	(0.0127)
	Large MSA	0.0340	0.0224	0.0285	0.0326	0.0108	0.00215	0.0004	0.0153
		(0.00510)**	(0.00277)**	(0.0061)**	(0.00864)**	(0.00570)+	(0.00422)	(0.0072)	(0.0108)

Notes:
All regressions include dummy variables for three-digits NAICS, whether it was a multi-establishment firm, employment and employment squared as controls. Standard errors are in parentheses. Non-MSA is the base for these regressions.
(1) & (5) include only establishments that received the supplementary Harte Hanks survey.
(2) & (6) include entire sample.
(3) & (7) include only establishments from single-establishment firms who received the supplementary Harte Hanks survey.
(4) & (8) include only establishments from single-establishment firms with less than 200 who received the supplementary Harte Hanks survey.
+ significant at 90% confidence level
* significant at 95% confidence level
**significant at 99% confidence level

Table 8
Contribution of Industry and Location to Explaining Adoption Decisions

	Participation		**Enhancement**	
	Pseudo R^2	**Log Likelihood**	**Pseudo R^2**	**Log Likelihood**
Full model	0.2339	-33093.4	0.0672	-28443.4
No MSA dummies	0.2251	-33475.0	0.0591	-28701.4
No NAICS dummies	0.1526	-36604.2	0.0347	-29434.6

Notes:
Source: Authors' calculation. Pseudo-R^2 from full model shown in Figures 1 and 2, and from subsets of coefficients controlling for industry and location effects.
Cities defined by CMSA.

Table 9
Interaction of Industry and Location Effects

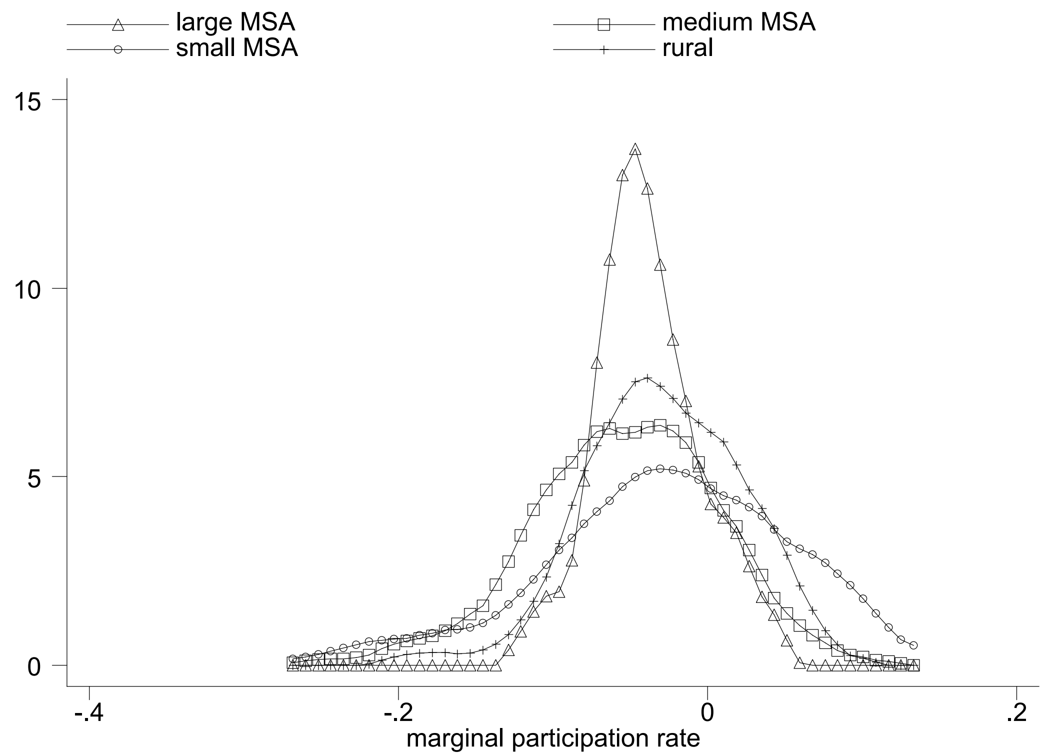
	A. Leading Internet Adopters (NAICS)				B. Top IT-Using Industries (SIC)			
	Participation		Enhancement		Participation		Enhancement	
	Coefficient	Marginal Effect	Coefficient	Marginal Effect	Coefficient	Marginal Effect	Coefficient	Marginal Effect
Small MSA	-0.0127	-0.0029	0.0085	0.0476	-0.0175	-0.00397	-0.00153	-0.000267
	(0.0302)	(0.0069)	(0.0062)	(0.0338)	(0.029)	(-0.0130)	(0.0405)	(0.00707)
Medium MSA	-0.0640	-0.0147	0.0013	0.0073	-0.0569	-0.0130	0.0279	0.00494
	(0.0241)**	(0.0056)**	(0.0047)	(0.0269)	(0.0237)*	(0.00554)*	(0.0291)	(0.00521)
Large MSA	-0.0372	-0.0083	0.0042	0.0243	-0.0409	-0.00917	0.0371	0.00646
	(0.0214)+	(0.0048)+	(0.0040)	(0.0228)	(0.0210)+	(0.00470)+	(0.0247)	(0.00430)
Top quartile NAICS3	0.8869	0.1512	0.0390	0.2072				
	(0.7270)	(0.0906)	(0.0908)	(0.4489)				
Small MSA*	0.2791	0.0539	-0.0121	-0.0727				
Top quartile NAICS3	(0.0864)**	(0.0140)**	(0.0169)	(0.1062)				
Medium MSA*	0.1618	0.0335	0.0397	0.2020				
Top quartile NAICS3	(0.0692)*	(0.0131)*	(0.0181)*	(0.0831)*				
Large MSA*	0.1205	0.0259	0.0382	0.1998				
Top quartile NAICS3	(0.0582)**	(0.0119)**	(0.0155)*	(0.0744)**				
IT intense SIC					-0.0739	-0.0169	-0.0672	-0.0115
					(0.0702)	(0.0163)	(0.0662)	(0.0112)
Small MSA*					0.1761	0.0361	0.0917	0.0170
IT intense SIC					(0.0927)+	(0.0171)+	(0.0833)	(0.0163)
Medium MSA*					0.0683	0.0149	0.0773	0.0141
IT intense SIC					(0.0707)	(0.0149)	(0.0677)	(0.0129)
Large MSA*					0.0996	0.0217	0.1022	0.0187
IT intense SIC					(0.0620)	(0.0130)	(0.0595)+	(0.0113)+
Log Likelihood	-33464.7	-33464.7	-28674.1	-28674.1	-33465.9	-33465.9	-28691.3	-28691.3
Pseudo R^2	0.2253	0.2253	0.0600	0.0600	0.2253	0.2253	0.0594	0.0594

Notes:
All regressions include dummy variables for three-digits NAICS, month that data was collected, and whether it was a multi-establishment firm. Employment and Employment squared were also included as controls. Standard errors are in parentheses. Non-MSA is the base for these regressions
+significant at 90% confidence level
*significant at 95% confidence level
**significant at 99% confidence level

Table 10
Main Findings

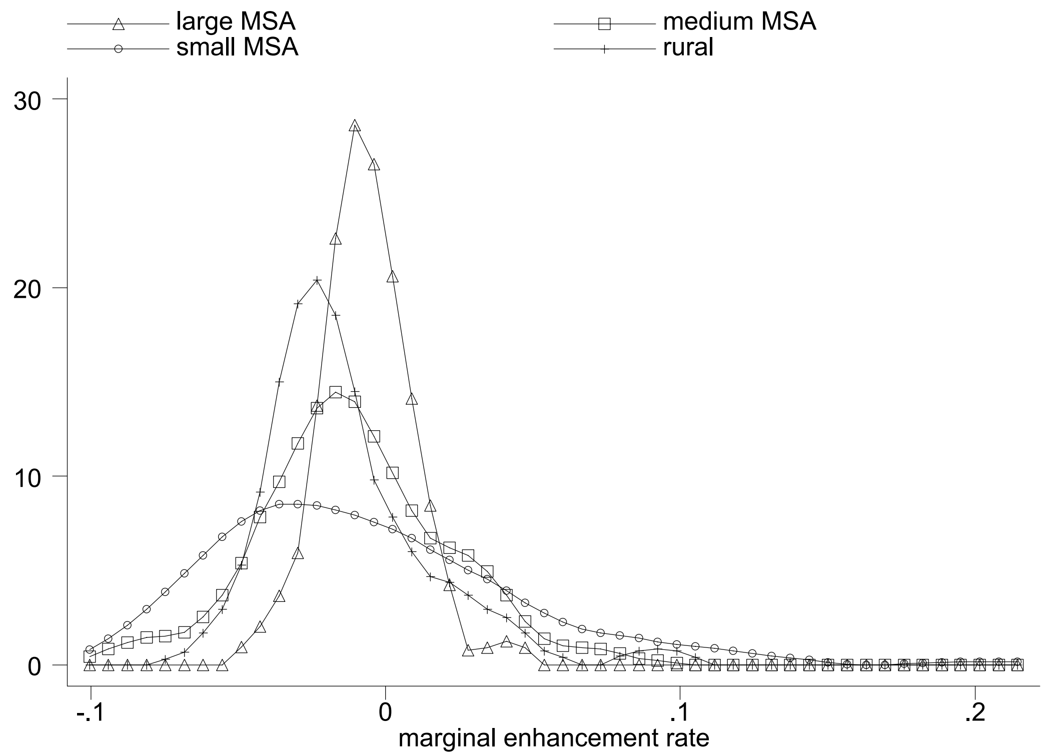
Open Question	Summary of findings	Source
Global Village & Urban Leadership, Participation and Enhancement		
Is investment in participation and enhancement consistent with Global Village (Urban Leadership) Theory?	Overall, participation is consistent with predictions of Global Village Theory. Overall, enhancement is consistent with predictions of Urban Leadership Theory.	Section 5.1 Tables 5, 6 Figures 1, 2
Does enhancement increase faster than participation as location size increases?	Yes, and this is consistent with GPT theory.	
Global Village & Urban Leadership, Intra- and Inter-firm Communication		
Is investment in **intra-** and **inter**firm communications consistent with Global Village (Urban Leadership) Theory?	Only **intra**firm enhancement is consistent with predictions of Urban Leadership Theory. All inter-firm investment and **intra**firm participation is consistent with predictions of Global Village Theory.	Section 5.2 Table 7
Does **intra**firm investment increase faster than **inter**firm investment as location size increases--consistent with Global Village Theory?	**Inter**firm investment is more sensitive **than** **intra**firm investment to increases in location size, which is consistent with the predictions of Global Village Theory.	
Industry Composition		
Does Industry Composition Theory explain everything?	IT-intensive industries tend to be in urban areas. Industry Composition Theory explains a high fraction of the variance in participation and enhancement, but not all of it.	Section 6.1 Tables 8, 9 Figures 3,4
Are industry and density complements (substitutes)?	Overall, findings are consistent with industry and density being complements for investments in enhancement in urban areas.	Section 6.2 Tables 8, 9

Figure 1
Comparison by City Size of Location Marginal Effects for Participation



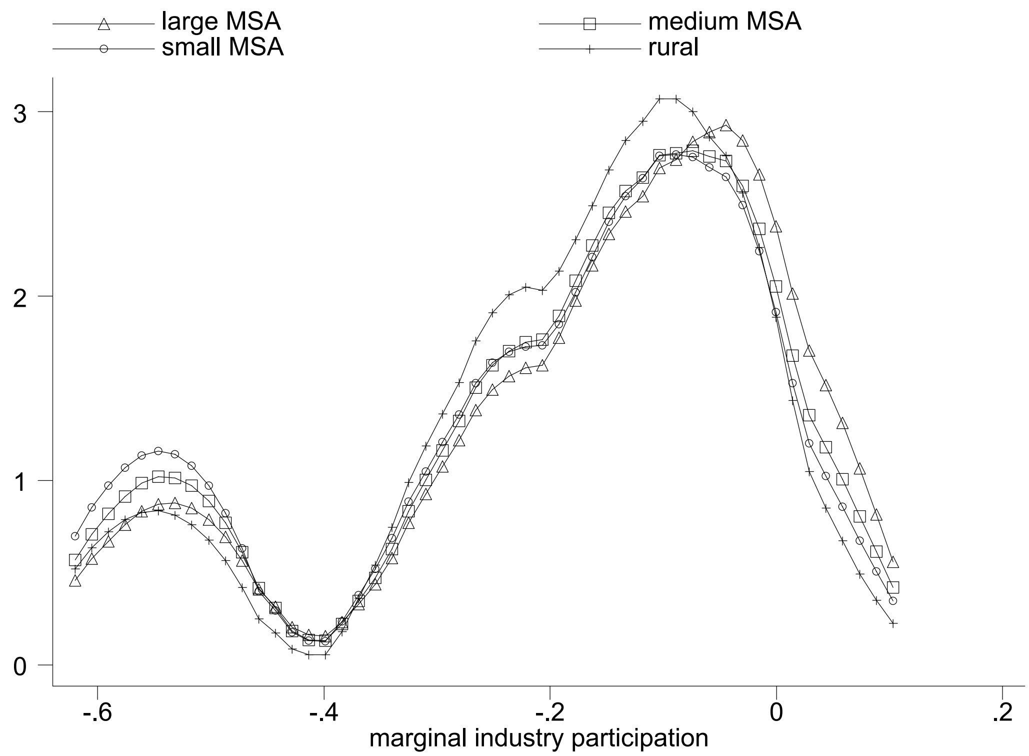
Notes:
Source: Authors' calculation.
Figure shows Epanachnikov kernel density estimates of the marginal effect of location on participation, by city size.
Uses baseline probit in the model in Equation 2.

Figure 2
Comparison by City Size of Location Marginal Effects for Enhancement



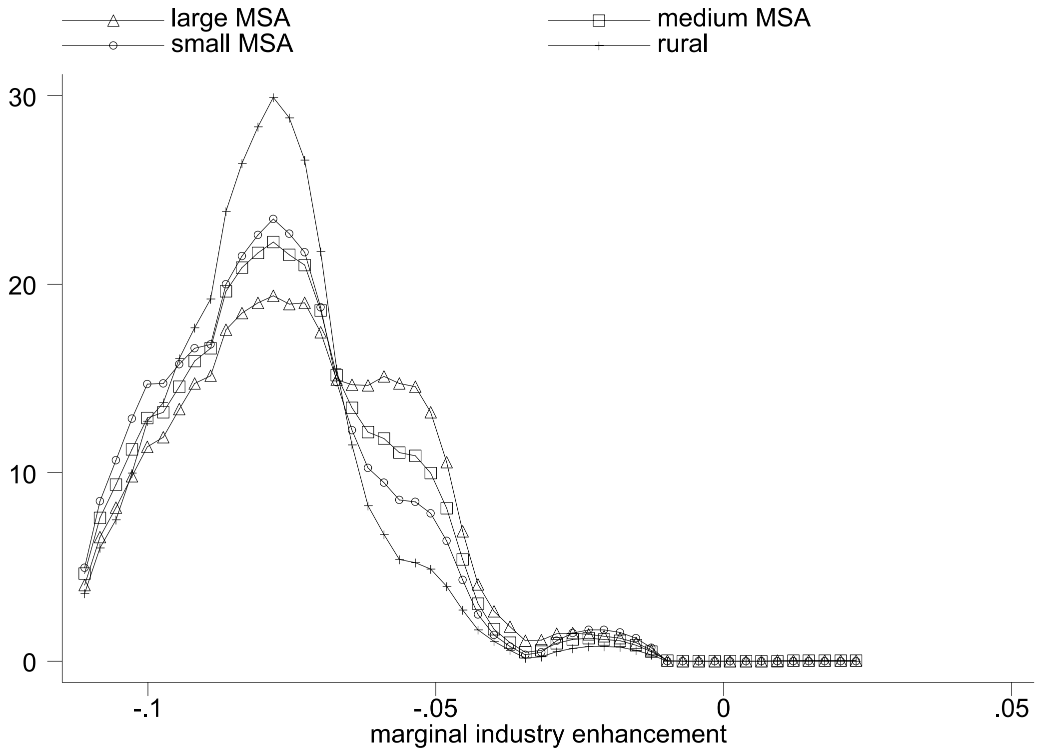
Notes:
Source: Authors' calculation.
Figure shows Epanachnikov kernel density estimates of the marginal effect of location on enhancement, by city size.
Uses baseline probit the model in Equation 2.

Figure 3
Industry Marginal Effects for Participation by City Size



Notes:
Source: Authors' calculation.
Figure shows Epanachnikov kernel density estimates of the marginal effect of industry on participation, by city size.
Uses baseline probit in the model in Equation 2..

Figure 4
Differences in Industry Marginal Effects for Enhancement



Notes:
Source: Authors' calculation.
Figure shows Epanachnikov kernel density estimates of the marginal effect of industry on enhancement, by city size.
Uses baseline probit in the model in Equation 2.

Table A.1: Harte Hanks Sample Versus the Census of Business Establishments

	Sample	Census
Number of Establishments with over 100 Employees	86,879	168,372
% MSA	82.5%	86.7%
% CMSA	37.2%	42.5%
% >500 Employees Given Have 100 Employees	12.7%	10.6%
% Northeast	17.7%	19.6%
% Midwest	27.9%	25.5%
% South	34.8%	34.0%
% West	19.6%	21.0%
% Agriculture, Forestry, Fishing and Hunting (NAICS = 11)	0.2%	0.1%
% Mining (NAICS = 21)	0.6%	0.5%
% Utilities (NAICS = 22)	0.8%	0.8%
% Construction (NAICS = 23)	2.9%	4.1%
% manufacturing (NAICS = 31, 32, 33)	27.9%	20.8%
% Wholesale Trade (NAICS = 42)	6.0%	4.8%
% Retail Trade (NAICS = 44, 45)	17.1%	14.7%
% Transportation and Warehousing (NAICS = 48, 49)	2.9%	3.1%
% Media, Telecommunications and Data Processing (NAICS = 51)	3.7%	3.7%
% Finance and Insurance (NAICS = 52)	4.5%	4.6%
% Real Estate and Rental and Leasing (NAICS = 53)	0.5%	1.0%
% Professional, Scientific and Technical Services (NAICS =54)	5.2%	5.0%
% Management of Companies and Enterprises (NAICS =55)	0.3%	3.2%
% Administrative and Support and Waste Management and Remediation Services (NAICS = 56)	2.7%	10.2%
% Educational Services (NAICS = 61)	0.01%	1.2%
% Health Care and Social Assistance (NAICS =62)	16.7%	12.8%
% Arts, Entertainment and Recreation (NAICS = 71)	1.6%	1.5%
% Accommodation and Food Services (NAICS = 72)	5.5%	5.1%
% Other Services (except Public Administration) (NAICS = 81)	0.9%	2.2%

Source: Authors' calculation using the CI database and Census data.

Table A.2
Population Variable Marginal Effects from Probit Regressions in Table 5, Includes Percent Participation and Enhancement Adopters within Firm

	Model	Variable	Old	New Result
A. Weighted probits without IV	Add percentage of other establishments adopting participation to Column 1	Small MSA	0.0021	0.0021
		Medium MSA	-0.0110*	-0.0112*
		Large MSA	-0.0058	-0.0063
		Pct. shallow	N/A	0.2401**
	Add percentage of other establishments adopting enhancement to Column 5	Small MSA	0.0035	0.0038
		Medium MSA	0.0080+	0.0081+
		Large MSA	0.0110**	0.0108**
		Pct. deep	N/A	0.1026**
	Add percentage of other establishments adopting participation to Column 4	Medium-Low Density	-0.0039	-0.0039
		Medium-High Density	-0.0064	-0.0069
		High Density	-0.0040	-0.0052
		Pct. shallow	N/A	0.1637**
	Add percentage of other establishments adopting enhancement to Column 8	Medium-Low Density	0.0049	0.0049
		Medium-High Density	0.0154**	0.0152**
		High Density	0.0103*	0.0099*
		Pct. deep	N/A	0.1024**
B. Unweighted probits with IV#	Add percentage of other establishments adopting participation to Column 1 (instrument using average population)	Small MSA	0.0032	0.0025
		Medium MSA	-0.0072+	-0.0075+
		Large MSA	-0.0045	-0.0051
		Pct. shallow	N/A	0.0193
	Add percentage of other establishments adopting enhancement to Column 5 (instrument using average population)	Small MSA	0.0095*	0.0097*
		Medium MSA	0.0077*	0.0078*
		Large MSA	0.0129**	0.0128**
		Pct. shallow	N/A	0.0336
	Add percentage of other establishments adopting participation to Column 4 (instrument using average density)	Medium-Low Density	-0.0019	-0.0013
		Medium-High Density	-0.0012	-0.0010
		High Density	-0.0027	-0.0028
		Pct. shallow	N/A	0.1538**
	Add percentage of other establishments adopting enhancement to Column 8 (instrument using average density)	Medium-Low Density	0.0044	0.0042
		Medium-High Density	0.0167**	0.0171**
		High Density	0.0110**	0.0114**
		Pct. shallow	N/A	-0.1604

Notes:
Table compares results of probit regressions with and without variables measuring behavior of other establishments within the same firm.
"Old" coefficients are different because probits are unweighted. Instruments are average population or density of locations of other establishments in same firm
+significant at 90% confidence level
*significant at 95% confidence level
**significant at 99% confidence level