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The Corporate Digital Divide: Determinants of Internet Adoption

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The diffusion of Internet technology among firms is widely considered to be one of the primary factors behind the rapid economic growth of the 1990s. However, little systematic study has examined the variation in firm decisions to adopt the Internet. I explore the sources of this variation by examining Internet adoption decisions in a very large sample of organizations in the finance and services sector in 1998.

I show how prior information technology (IT) investments and workplace organization decisions affect the returns to adopting simple and complex Internet technologies. I show that recent investments in client/server (C/S) networking applications have competing effects on the likelihood of Internet adoption. Such investments can slow adoption by acting as a short-run substitute or by creating "switching costs." Geographic dispersion of employees is complementary with Internet adoption, suggesting that Internet technology lowered internal coordination costs. Increases in organization size and external pressure also increase the likelihood of adoption.

Key words: adoption; Internet; discrete choice
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1. Introduction

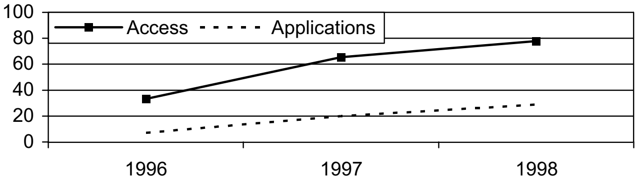
The diffusion of Internet technology is widely considered to be one of the primary factors behind the rapid economic growth of the late 1990s and responsible for transforming the way many firms now conduct business. In part because of the Internet's growth, industry spending on information technology (IT) rose from $142 billion in 1993 to $233 billion in 1998 (Margherio et al. 1998). Despite the importance of this technology, however, a surprising number of firms still had not adopted the Internet, even several years after its commercialization. According to my findings, 78% of organizations had adopted basic Internet access by 1998, and only 29% had adopted advanced applications such as e-commerce (Figure 1). What was responsible for this variation in firm decisions to adopt the Internet? Despite the wealth of research on the Internet, this question has not been widely explored.

Recent research in the information systems (IS) and economics literatures has emphasized how prior IT investments and new forms of workplace organization may be complementary with investments in new IT (e.g., Bresnahan et al. 2002). In this paper, I examine the importance of such complementarities in a particular environment: how prior IT investments and workplace organization decisions affected the returns to adopting simple and complex Internet technologies.

This research makes important contributions to two fields of research. First, it represents a contribution to the diffusion of innovations (DOI) literature (Rogers 1995) by developing and testing unique hypotheses. I explore the possibility that recent IT investment can reduce the returns to adopting new technology. Existing IS research has argued that recent IT investments would lower technical and organizational barriers to adopting new IT (e.g., Raymond and Paré 1992, Swanson 1994), thereby leading to a complementarity between recent IT investments and adoption of new technologies. However, such investments could also slow adoption by acting as a short-run substitute or by creating switching costs (Klemperer 1995) if the organization has made complementary technical or organizational investments that are specific to the old technology. Moreover, by observing the adoption patterns of geographically concentrated and dispersed firms, I examine whether the Internet helped firms to reduce communication and coordination costs created by geographic distance, a result that would suggest the presence of complementarity between geographic dispersion and Internet adoption.

Second, this work contributes to the literature on commercial Internet adoption. Prior research has studied commercial Internet adoption (e.g., Tan and Teo 1998, Zhu et al. 2002) and diffusion (e.g., Whinston et al. 2001). However, this study is unique in its use of detailed microdata in a sample of more than 6,000 organizations in the United States. This large, yet highly detailed, data set permits me to test hypotheses related to complementary organizational

Figure 1 **Percentage of Organizations Adopting Internet Technologies**



investments that have been unexplored by other authors. Moreover, unlike prior authors, I focus on adoption of simple Internet technologies such as basic access, which represent the bulk of Internet investments over my sample period.

To predict whether organizations adopt the Internet, I develop a set of hypotheses relating to the costs and benefits of adoption. To investigate the causes of variation of Internet adoption, I estimate a discrete choice model of organizational decisions to adopt simple and complex Internet technologies. I then use these results to determine whether the empirical evidence supports each hypothesis. I analyze a sample of more than 6,000 organizations that were surveyed by Harte Hanks Market Intelligence in 1998 and are concentrated primarily in the finance, insurance, real estate (FIRE), and services sectors.

Overall, I find that the net impact of recent IT investments on Internet adoption was mixed and depended on the complexity of the installed base of technologies. For many organizations with complex IT infrastructures, I show that recent client/server (C/S) investments reduced the likelihood of Internet adoption. Moreover, I provide evidence of complementarities between geographic dispersion and Internet adoption. Consistent with prior work in the DOI literature, I further show that Internet adoption was increasing in organization size and external pressure. Overall, I show that there was significant variation in the presence of complementary IT investments and workplace organization practices in the late 1990s. This variation, in turn, led to an uneven pattern of adoption across firms.

2. Framework and Hypotheses

As a general purpose technology (GPT) (Bresnahan and Trajtenberg 1995), Internet technology was applied in different ways across heterogeneous organizational contexts. I examine the simultaneous decision to adopt two types of Internet technologies: one simple and one complex. The simple technology, basic Internet access, was technologically mature and required little adaptation of business processes by organizations. The second type of technology, which included applications such as business-to-business and business-to-consumer e-commerce, was much more complex and technically difficult to implement. As such, it involved costly changes to existing business processes. Because this second type represented applications of Internet technology to commercial practices, I label this more complex technology "Internet applications."

As with other GPTs, organizations faced idiosyncratic short-run circumstances that affected their costs and benefits of adopting the new technology. These circumstances varied based on prior technological investments and workplace decisions. I observe a snapshot of adoption decisions as of 1998 and examine how variation in complementary organizational investments affected organizations' short-run demand for these two sets of technologies. Because most Internet investments during this period involved simple Internet access (Figure 1), I focus primarily on hypotheses that affect the returns to adopting access. Although other factors may have been important, prior network investments and the geographic spread of employees proved to be among the most important factors affecting adoption of a new communication technology. Because of data limitations, I am unable to observe how certain organizational factors—for example, managerial influences (e.g., Leonard-Barton and Deschamps 1988) or group norms (e.g., Webster and Travino 1995)—may have influenced adoption.

My statistical identification strategy relies on the fact that the proposed adoption hypotheses make different behavioral predictions for access than they do for applications. To test my hypotheses, I examine whether the observed adoption decisions conform to these behavioral predictions. Accordingly, in the following section, I state the various hypotheses in terms of their effect on both access and application adoption decisions. Because organizations had to adopt access in order to adopt applications, all applications hypotheses are expressed as conditional on the access decision.

2.1. Complementarities with IT Investments

Compatibility and Technological Sophistication. Prior research in the DOI literature has shown that compatibility with existing practices, values, or norms can be a key factor in the decision to adopt new innovations (Tornatzky and Klein 1982). Internet technology represents an extension of C/S computing principles, so prior investments in C/S ought to increase the net benefits of adopting Internet technology (Bernard 1996). Furthermore, adoption of decentralized C/S involved significant investments in organizational change (e.g., Bresnahan and Saloner 1999), thereby reducing the incremental organizational learning (Attewell 1992) or co-invention (Bresnahan and Greenstein 1996) costs associated with Internet adoption.

Prior investments in C/S should also increase the technological sophistication of the organization.

Technological sophistication reflects the number and diversity of information technologies used by organizations, and is a key component of IT sophistication (Raymond and Paré 1992). Iacovou et al. (1995) note that organizations with high levels of IT sophistication are less likely to feel intimidated by technology and are more likely to have access to the technological and managerial resources necessary to adopt new technologies.

Compatibility with the legacy networking platform ought to be more important for access than for the conditional applications decision: once compatibility with Internet protocols is obtained by adopting access, the marginal effect of improvements in compatibility on the applications decision ought to be small. Similarly, increases in IT sophistication gained through investment in C/S are unlikely to affect an organization's technological readiness to adopt applications, which involve technological and organizational changes far beyond those of ordinary C/S technology. Thus, we have the following hypotheses.

Hypothesis 1a. *Prior investments in C/S will increase the likelihood of adopting basic access.*

Hypothesis 1b. *Conditional on the decision to adopt access, prior investments in C/S will have no effect on the decision to adopt applications.*

Competing Effects of Installed Base. Although, in general, investments in C/S make IT more compatible and are a signal of IT sophistication, certain C/S investments can reduce the net benefits to adoption if they are specific to a particular proprietary C/S platform. Some prior C/S software investments in network operating systems (NOS) and system/communication applications—such as file and print servers, directory services, and local area network (LAN) management, maintenance, and backup—were initially incompatible with Internet technologies (Orfali et al. 1999, p. 116). For example, Novell's NetWare, the leading NOS, was closely tied to its proprietary protocols and was slow to incorporate Internet features (McCarthy 1996).

Such "platform-specific" network investments (e.g., Bresnahan and Greenstein 1996) can reduce the returns to Internet adoption in two ways. To begin, they can act as a short-run substitute for Internet technology. In this instance, organizations with proprietary C/S investments revealed a preference for the backup, reliability, and security that was absent from networks based on the Internet's Transmission Control Protocol/Internet Protocol (TCP/IP), known as intranets (Korzeniowski 1996).[1] NOS vendors like NetWare were slow to integrate Internet protocols into the core features of their products. Many of their customers valued these features highly and, as a result, delayed their adoption of Internet technology (Gow 1996). Moreover, management information system departments may have preferred the more centralized control that proprietary C/S offers over intranets, where control of network functions was more dispersed to users (Baynton 1996). Investments in proprietary NOS may have indicated organizational differences that suggested a preference for traditional large-scale enterprise networking systems. Taken together, these effects may lead firms with prior investments in proprietary C/S technology to be less likely to adopt Internet technology.

Prior platform-specific network investments can reduce the net benefits of adopting basic access in another way. Incompatibilities between systems applications and Internet technology can create switching costs (e.g., Klemperer 1995) if organizations have made complementary technical and organizational investments that are incompatible with Internet technology. These switching costs may have reduced demand for the Internet by firms with certain types of prior IT investment.

As noted above, compatibility with the installed base will be very important for the adoption of basic networking technologies such as access. However, once access is adopted, the effect on the applications decision will be small. As a result, I expect platform-specific investments to affect access, but not applications, decisions.

Hypothesis 2a. *Investments in platform-specific network applications will reduce the likelihood of adopting basic access.*

Hypothesis 2b. *Conditional on the decision to adopt access, prior investments in platform-specific network applications will have no effect on the likelihood of adopting applications.*

2.2. Complementarities with Establishment Location

It has long been accepted that coordination costs increase with the geographic dispersion of organization establishments (e.g., Chandler 1962, Williamson 1975). Researchers on virtual teams have argued that by reducing these communications costs, Internet investments reduce the costs of having geographically dispersed employees (Boudreau et al. 1998, Saunders 2000).

The Internet offered potentially significant savings in communication costs between geographically dispersed establishments. Prior to the Internet, an organization had two alternatives for wide area networking (WAN). For one, an organization could set up point-to-point circuits, or leased lines, between establishments. Alternatively, it could run a leased line from

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[1] Thanks to an anonymous referee who suggested this interpretation.

its establishments to a telecommunications carrier's nearest access point. Under this second alternative, packets were carried over the public switched data network (PSDN), and the carrier handled all packet switching and maintenance. Both of these alternatives involved high fixed costs, long-distance charges, or both. Adopters of Internet technology gained the option of employing a virtual private network (VPN). VPNs allow communication among establishments over the Internet backbone, maintaining privacy through the use of tunneling protocols and security procedures (Panko 2001). VPNs offered organizations a WAN alternative that was cheaper than either leased lines or PSDN.

In brief, prior literature suggests that geographic dispersion is complementary to adoption of new communications technology like Internet access. In contrast, geographic dispersion should have little effect on applications adoption.

Hypothesis 3a. *Increases in geographic dispersion will increase the likelihood of access adoption.*

Hypothesis 3b. *Conditional on the decision to adopt access, increases in geographic dispersion will have no effect on the likelihood of applications adoption.*

2.3. Size

Prior research in the DOI literature has consistently shown a positive relationship between organization size and innovativeness (Rogers 1995). The most common reasons offered for this relationship are economies of scale (Kimberly and Evanisko 1981), slack resources (Eveland and Tornatzky 1990), access to outside resources (Attewell 1992), and ability to bear adoption risks (Hannan and McDowell 1984). I include variables on organization size as a control for these characteristics and to demonstrate consistency with prior DOI literature. Because adoption of applications involves high technical hurdles and complementary changes to business processes, I expect the importance of organization size in mitigating these barriers will be more important for applications adoption.

Hypothesis 4a. *Increases in organization size will increase the likelihood of access adoption.*

Hypothesis 4b. *Conditional on access adoption, increases in organization size will increase the likelihood of applications adoption.*

2.4. External Environment

Robertson and Gatignon (1986) describe several market characteristics that may affect the rate of new innovation diffusion across industries: heterogeneity of industry participants, industry concentration, and demand uncertainty. Although I am unable to measure these factors explicitly, I control for industry differences with industry (SIC) dummies. Organizations that are located in different locations also face heterogeneous markets for labor, third-party services, and complementary technological inputs (Tornatzky and Fleisher 1990, pp. 171–173). Forman et al. (2003) explore the sources of geographic variation in Internet use; in this paper, I control for differences in pooled resources through an urban/rural dummy.

External pressure to adopt Internet technology can come from the organization's environment in several ways. For one, competitive pressure arises when industry diffusion causes firms to adopt new innovations to maintain their competitive position (e.g., Iacovou et al. 1995). Moreover, industry diffusion may facilitate adoption through knowledge spillovers. Knowledge spillovers may be localized within industries (Irwin and Klenow 1994) or geographic regions (Goolsbee and Klenow 2002).[2]

I expect competitive pressure and knowledge spillovers to be more important for application technologies, which are more likely to be perceived as a source of competitive advantage (Porter 2001) and have higher knowledge barriers than will access technologies. Empirically identifying the role of competitive pressure or spillovers is inherently difficult, however, as constructs for these hypotheses may pick up unobserved heterogeneity across industries and regions. Thus, tests of these hypotheses should be considered preliminary and will await confirmation by future authors.

Hypothesis 5a. *Increases in intraindustry access diffusion will increase the likelihood of adopting access.*

Hypothesis 5b. *Conditional on access adoption, increases in intraindustry applications diffusion will increase the likelihood of adopting applications.*

Hypothesis 6a. *Increases in intraregion access diffusion will increase the likelihood of adopting access.*

Hypothesis 6b. *Conditional on access adoption, increases in intraregion applications diffusion will increase the likelihood of adopting applications.*

3. Empirical Model

I use discrete choice (e.g., McFadden 1981) to model an organization's joint decision to adopt access and

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[2] If competitors and suppliers are involved in business-to-business trading networks, organizations may also feel pressure from trading partners to adopt e-commerce systems. This mechanism has been studied recently in papers that examine adoption of interorganizational electronic data interchange systems (e.g., Iacovou et al. 1995, Chwelos et al. 2001), although it is probably less important to Internet adoption over this sample because of the slow diffusion of business-to-business e-commerce.

applications.[3] In this adoption model, I examine an organization's decision to invest in access or applications by a particular date, rather than looking at the change in investment status. Each organization, i, associates some utility, U_{ij}, with a choice, j, where $j=1$ denotes a decision not to adopt any form of the Internet, $j=2$ denotes a decision to adopt access only, and $j=3$ denotes a decision to adopt access plus applications. Utility takes the form of a random utility model, $U_{ij}=u_{ij}+\varepsilon_{ij}$. An organization's utility for a choice has two components: (1) a deterministic component, u_{ij}, that is a function of organizational characteristics and choice-specific attributes and (2) a random error term, ε_{ij}, that captures the effects of unmeasured variables.

Researchers commonly use the multinomial logit model in discrete choice analysis. However, the multinomial logit is unattractive in this setting because of the well-known independence of irrelevant alternatives property. This property imposes independence on the error terms of individual alternatives and places severe restrictions on the substitution patterns in the model.

To allow for correlation in the unobservables, I employ a nested logit model. I assume the tree shown in Figure 2 describes the adoption decision for an organization and assume that utility is additively separable into components that vary with the decision to adopt access and the decision to adopt applications

$$U_{ij}=V_{ik}+W_{ij}+\varepsilon_{ij}.$$

V_{ik} depends only on variables that affect the access decision, k, while W_{ij} depends only on variables that affect the application decision, j. Following the nested logit literature (e.g., McFadden 1981), I assume the error term, ε_{ij}, follows a generalized extreme value distribution. Under this distribution, errors within a nest are positively correlated and errors across nests are uncorrelated.

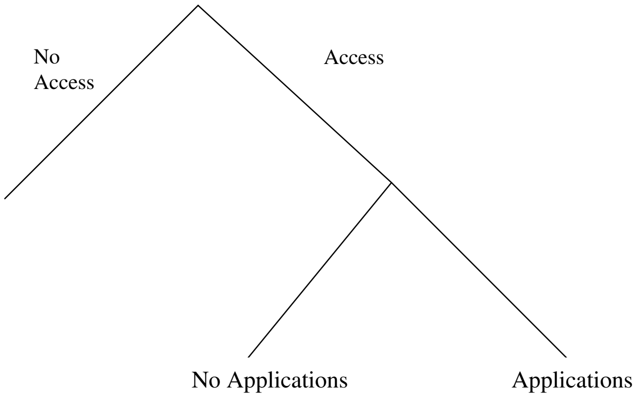
The joint probability of a choice j is $P_{ij}=P_{ik}P_{ij|k}$, where P_{ij} represents the joint probability of an access/applications decision, P_{ik} is the marginal probability of an access choice, and $P_{ij|k}$ is the probability of an applications choice conditional on an access decision.

The generalized extreme value distribution implies that the marginal and conditional probabilities can be written as

$$P_{ik}=\frac{\exp(V_{ik}+\lambda I_{ik})}{\sum_{l\in C}\exp(V_{il}+\lambda I_{il})} \quad \text{and}$$

$$P_{ij|k}=\frac{\exp(W_{ij})}{\sum_{h\in C_k}\exp(W_{ih})}, \tag{3.1}$$

Figure 2 Two-Level Nested Logit Tree for Internet Adoption Choice



where C_k denotes the set of choices available at node k in the tree and $I_{ik}=\log[\sum_{h\in C_k}\exp(W_{ih})]$ is the inclusive value, the expected aggregate value of choice k.[4] The coefficient on the inclusive value, λ, measures the dissimilarity of alternatives available to the buyer given different choices, k. I estimate the model using full information maximum likelihood.

The nested logit model imposes a very particular covariance structure on the error terms. One common alternative to the nested logit is the multinomial probit model. However, the multinomial probit presents identification problems for this study because the majority of my explanatory variables do not vary by choice. As shown by Keane (1992), identification in the multinomial probit model is tenuous in the absence of choice-specific variables. Movements in the coefficients mimic changes in the covariance parameters. I estimated a version of the multinomial probit model with and without the restriction that the error terms are i.i.d. $N(0,1)$, and a likelihood ratio test was unable to reject this constraint. Because of these concerns, I present only the nested logit estimates.

4. Data

4.1. Sample

I obtained data over the 1996–1998 period from the Harte Hanks Computer Intelligence (CI) Technology Database. 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 surveys establishments throughout the calendar year; my

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[3] I have also estimated panel data discrete choice models; the results are qualitatively the same.

[4] In practice, because I do not observe organizations adopting applications without access, I constrain the marginal probability of applications adoption conditional on no access to be equal to one.

sample of annual data contains the most current information as of December of each year.

To keep the analysis of manageable size, I obtained data from the CI database on SIC codes 60–67, 73, 87, and 27. These SIC codes correspond to the industrial groupings of Finance, Insurance, and Real Estate (60–67); Business Services (73); Engineering, Accounting, Research, Management, and Related Services (87); and Printing and Publishing (27). I selected these industries because they are heavy IT users. The sample contains data from the CI database on all establishments of over 100 employees in these industries. All establishments are from the United States.

The unit of observation in the CI database is an establishment-year. Roughly speaking, an establishment refers to a particular branch or location of a firm. Thus, I often observe data on multiple establishments from the same firm. The establishment is an inappropriate unit of observation in this setting, however, because the technology adoption decision for an establishment likely depends on observable and unobservable attributes of other establishments within the same organization. To avoid these problems, I aggregate across establishments and conduct all analyses at the organization level.

I use 1998 adoption data to estimate the models described in §3. In the baseline model, I use prior year characteristics data as explanatory variables. As a result, each observation requires two consecutive years of data. Because establishments enter and exit the database, I define an organization as the set of establishments that has been in the database for both 1997 and 1998. I drop some establishments because of missing data. The establishment-level data originally obtained from the CI database contained 18,725 *establishments* in 1998; the final analysis sample contains 6,156 *organizations*.

4.2. Variables Measuring Internet Adoption

Establishments that have indicated use of an Internet service provider are counted as adopting Internet access. An establishment is counted as adopting applications if it responded positively to adopting any of the following: business-to-business e-commerce, business-to-consumer e-commerce, e-commerce, customer service, education, extranet, publishing, purchasing, or technical support. An organization is coded as adopting a technology if the technology was acquired by at least one establishment within that organization by 1998.

4.3. Exogenous Variables

Table 1 contains the names of the variables and their descriptive statistics. Descriptions of variables are organized by the hypotheses described in §2.

Table 1 Description of Variables

Variable	Mean	Standard deviation	Minimum	Maximum
PC-PER-EMPLOYEE	0.686	0.534	0	6.118
CLIENT	0.924	0.233	0	1.000
NO-APPLICATIONS	0.101	0.301	0	1.000
LAN-INTENSITY	0.351	0.256	0	1.000
MAINFRAME-INTENSITY	0.168	0.257	0	1.000
SYSTEM/COMM-APPS	0.327	0.469	0	1.000
NETWARE	0.616	0.486	0	1.000
INTRANETWARE	0.053	0.223	0	1.000
MICROSOFT-NT	0.374	0.484	0	1.000
NETWARE × LAN-INTENSITY	0.263	0.267	0	1.000
SYSTEM/COMM-APPS × LAN-INTENSITY	0.151	0.241	0	1.000
INTRANETWARE × LAN-INTENSITY	0.023	0.105	0	1.000
MICROSOFT-NT × LAN-INTENSITY	0.155	0.236	0	1.000
PCT-100-MILES	0.035	0.160	0	1.000
PCT-500-MILES	0.069	0.227	0	1.000
AVG-DISTANCE	0.777	2.134	−9.739	7.863
EMPLOYEE-CONCENTRATION	0.057	0.164	0	0.936
MULTIESTABLISHMENT	0.137	0.344	0	1.000
EMPLOYMENT(100–200)	0.166	0.237	0	0.693
EMPLOYMENT(201–500)	0.319	0.534	0	1.609
EMPLOYMENT(500 plus)	0.586	1.206	0	6.914
TOTAL-MIPS	2.132	2.352	0	11.381
IND-ACCESS-PRESSURE	0.551	0.135	0.083	1.000
IND-APPL-PRESSURE	0.175	0.078	0	0.530
REG-ACCESS-PRESSURE	0.433	0.161	0	1.000
REG-APPL-PRESSURE	0.090	0.078	0	1.000
NO-COUNTY-ESTABLISHMENTS	0.037	0.189	0	1.000
SIC 60	0.081	0.269	0	1.000
SIC 61	0.024	0.147	0	1.000
SIC 62	0.032	0.172	0	1.000
SIC 63	0.091	0.282	0	1.000
SIC 64	0.033	0.173	0	1.000
SIC 65	0.032	0.176	0	1.000
SIC 67	0.031	0.162	0	1.000
SIC 73	0.290	0.448	0	1.000
SIC 87	0.183	0.383	0	1.000
URBAN	0.940	0.229	0	1.000

Note. Number of observations is 6,156.

Compatibility and Technical Sophistication. The first set of variables captures the effects of compatibility and technical sophistication by measuring the intensity of investment in C/S technology. *Personal computers* (*PCs*) *per employee* is equal to total PCs divided by total employees. *Client* indicates the percentage of establishments that have installed Internet-ready clients. This includes Windows PCs, Macintoshes, and UNIX workstations, and it excludes PCs still running DOS.

Organizations with a high *LAN intensity* have adopted C/S heavily. This variable is equal to the percentage of customized applications accessed over the LAN. I calculate *LAN intensity* by dividing total LAN applications by total customized applications, which includes applications from mainframes, midrange systems, and workstations.[5] I code organizations without customized applications as zero. In contrast, *mainframe intensity* will indicate heavy investment in applications that are incompatible with the Internet. It is equal to the percentage of customized applications accessed over a mainframe or minicomputer and is calculated in a manner identical to the LAN intensity variable. As a control, I also include a variable, "*no applications*," that is one when an organization reports no software applications.

Several variables indicate whether an organization has made platform-specific investments in LAN operating systems (OS) or system/communication applications. Respondents to the Harte Hanks survey list only those applications they feel are most important, so a value of one for any of these variables represents heavy investments in C/S. However, because they are platform specific, their use may reduce the returns to other C/S investments. The variable *system/communication applications* is one if an organization reports the use of software for the management, maintenance, and backup of LANs. *NetWare* is a dummy that indicates whether an organization uses some version of Novell's NetWare. I use NetWare as my primary construct indicating platform-specific LAN OS investments for several reasons: ample evidence of incompatibilities between older NetWare versions and Internet protocols (e.g., McCarthy 1996); widespread use among large enterprise customers who may be predisposed toward centralized ISs (e.g., Orfali et al. 1999, p. 163); and a large installed base that enables statistical identification. As a robustness check, I include different vintages of NetWare and different types of LAN OS. *IntranetWare* indicates that an organization has invested in Novell's IntranetWare operating system, a more recent version of NetWare that was more compatible with Internet protocols and applications. *Microsoft NT* indicates that an organization uses NT, a recent network operating system developed by Microsoft.

Competing Effects of Installed Base. To identify whether *system/communication applications* or *NetWare* increase or decrease the returns to investing in C/S, I interact each with *LAN intensity*. A negative coefficient on these interaction terms indicates that the positive impact of C/S investments on Internet adoption is weakened if some C/S investments were directed toward technologies that are incompatible with Internet protocols. This negative impact will increase as system communication applications and NetWare are embedded in larger and more complicated networks. As a robustness check, I employ similar interactions using *IntranetWare* and *Microsoft NT*. Both operating systems are younger and more compatible with Internet protocols. In addition, they have IP protocols integrated into some of the core features of the OS (Orfali et al. 1999, pp. 115–118).

Complementarities with Establishment Location. To identify whether geographic dispersion increases the returns to adopting the Internet for multiestablishment organizations, I identify the distance between organization establishments. I use longitude, latitude, and the "great circle" formula to calculate the distance between each establishment in the organization. I then calculate the percentage of pairwise establishment combinations that are within 100 miles in distance, *percent within 100 miles*.

The role of geographic dispersion on access adoption is defined only for multiestablishment organizations. To control for type of organization, I include a variable that indicates whether there is more than one establishment in the organization, *multiestablishment*. The effects of geographic dispersion may capture, in part, the impact of employee dispersion across establishments, rather than geographic dispersion per se. For example, an organization with employees spread across two establishments may have higher returns to adopting the Internet either from (1) decreased communication costs across a long geographic distance or (2) increased benefits of networking employees in two locations. To control for employee dispersion, I calculate *employee concentration* by summing the squared shares of employees in each establishment across all establishments in the organization. A high value for this variable indicates that employees are concentrated within a small number of establishments, and this should lower the probability of adoption.

Size. To control for the effects of organization size on the probability of adoption, I include the natural logarithm of the total number of employees in the organization. Because I expect the marginal effect of increases in the number of employees to vary with number of employees, I allow this coefficient to vary between employment sizes of 100–200, 200–500, and 500 plus employees.

Another measure of size or slack resources is the magnitude of an organization's IT investments. To measure the scale of large-scale computing infrastructure within the organization, I calculate the *total MIPS* across an organization's mainframes, minicomputers, and servers. This variable may also capture the effects of IT sophistication.

External Environment. To capture the effects of external pressure or industry spillovers, I calculate *industry access pressure* and *industry applications pressure*, the percentage of competitors in the organization's three-digit SIC code that has adopted access and applications. In the case of multi-industry

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[5] All LAN applications are considered to be customized.

organizations, I calculate the average of the adoption rates across all of the organization's industries.

To capture the effects of geographic spillovers, I calculate *regional access pressure* and *regional applications pressure*, the percentage of establishments in the organization's county that has adopted access and applications. For multicounty organizations, I average across counties. My sample contains some counties that contain only one observation. In these cases, I normalize the regional pressure variables to equal zero and include a control indicating that there are no other establishments in the county.

To control for industry effects, SIC 60–SIC 87 indicate the percentage of an organization's establishments in SIC codes 60–67, 73, and 87. SIC 27 is the omitted category. Last, to control for urban/rural differences in the propensity to adopt Internet technology, I include a variable that indicates the percentage of establishments located in a metropolitan statistical area.

4.4. Data Limitations

The CI database offers one of the most comprehensive sources of data on microlevel commercial IT investment, however, it does have significant limitations. To begin, not all companies respond to the survey. Moreover, those that do may not respond every year. Though there is no way to quantify precisely the magnitude and impact of this nonresponse bias, other studies (e.g., Forman et al. 2002, p. 38) have compared the CI database to Census data and found the CI database to be fairly representative along major dimensions such as size, industry composition, and geographic composition.

The external pressure variables that capture industry and regional pressure are based on in-sample estimates. Because the adoption decisions from this sample may not be representative of the adoption decisions of establishments in an organization's industry or county, the estimates based on these variables should be interpreted with some caution.

As noted above, the CI database does not contain a complete census of hardware and software usage: establishments report only the hardware and software they feel is most important. To control for an extreme version of nonresponse in IT questions, I drop establishments that do not report any use of hardware or software.[6] Moreover, as noted above, I include control variables for establishments that did not report any software applications. There remains, however, a residual of establishments that responded to some but not all IT questions. Though this may create an upward bias on variables capturing the direct effects of compatibility or technical sophistication (establishments that consider C/S to be "important" will be more likely to consider Internet use important), there is no reason to believe, a priori, that it would create any systematic bias in the variables capturing organizational differences or lock-in.

Another potential weakness arises because I am able to observe only discrete adoption decisions. If the factors affecting technology acquisition are different from those affecting deployment, the analysis may not provide a complete picture of the factors affecting organization implementation of Internet technology. However, this "assimilation gap" (Fichman and Kemerer 1999) will be less of a factor for access adoption than for applications, which require substantial complementary change to business processes (Kalakota and Robinson 2001).

A last issue relates to the aggregation of data to the organization level. Because Harte Hanks does not survey all of the establishments in a firm, both the endogenous variable and constructs are measured with error. However, there is no reason to believe that these unobserved factors will be systematically correlated with any of the independent variables.[7]

5. Results

Figure 1 shows the adoption rates for access and applications over the 1996–1998 period. As noted earlier, the two technologies diffused at very different rates. In 1998, access achieved a penetration rate of 77.9%, while applications had been adopted by only 28.9% of organizations.[8] These results support my earlier hypothesis that the fixed costs for access were far lower than those for applications. What they fail to identify, however, are the particular forces driving heterogeneity in adoption behavior. Among firms with C/S and NetWare, 84.0% and 84.3% had adopted access in 1998. In unconditional statistics, these variables reflect differences in compatibility and technical sophistication. To separate the competing effects of platform-specific investments and to identify the factors driving adoption, I require an econometric framework. To this end, I estimate the model described above based on Equation (3.1). In this model, the utility for access decision k in organization i is

$$V_{ik} = \beta_{0k} + \beta_{1k} \mathit{PC\text{-}PER\text{-}EMPLOYEE}_i + \beta_{2k} \mathit{CLIENT}_i + \beta_{3k} \mathit{NO\text{-}APPLICATIONS}_i$$

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[6] However, all of the results are robust to their inclusion.

[7] Prior work has shown that measurement error in logit models can produce biased coefficient estimates. However, in cases where the measurement error is small and the sample size is large, the magnitude of this bias will be small and logit models will perform satisfactorily. See, for example, McFadden (1986) or Stefanski and Carroll (1985).

[8] This includes only establishments that were in the sample over the 1996–1998 period.

$$
\begin{aligned}
&+\beta_{4k}\mathit{LAN\text{-}INTENSITY}_i\\
&+\beta_{5k}\mathit{SYSTEM/COMM\text{-}APPS}_i+\beta_{6k}\mathit{NETWARE}_i\\
&+\beta_{7k}\mathit{INTRANETWARE}_i\\
&+\beta_{8k}\mathit{MAINFRAME\text{-}INTENSITY}_i\\
&+\beta_{9k}\mathit{NETWARE}_i\times \mathit{LAN\text{-}INTENSITY}_i\\
&+\beta_{10k}\mathit{INTRANETWARE}_i\times \mathit{LAN\text{-}INTENSITY}_i\\
&+\beta_{11k}\mathit{SYSTEM/COMM\text{-}APPS}_i\\
&\times \mathit{LAN\text{-}INTENSITY}_i\\
&+\beta_{12k}\mathit{MULTIESTABLISHMENT}_i\\
&+\beta_{13k}\mathit{EMPLOYEE\text{-}CONCENTRATION}_i\\
&+\beta_{14k}\mathit{PCT\text{-}100\text{-}MILES}_i\\
&+\sum_{m\in C_{sizeclass}}\beta^{m}_{15k}\mathit{EMPLOYMENT}(m)_i\\
&+\beta_{16}\mathit{TOTAL\text{-}MIPS}_i\\
&+\beta_{17}\mathit{NO\text{-}COUNTY\text{-}ESTABLISHMENTS}_i\\
&+\beta_{18}\mathit{REG\text{-}ACCESS\text{-}PRESSURE}_i\\
&+\beta_{19}\mathit{IND\text{-}ACCESS\text{-}PRESSURE}_i\\
&+\sum_{n\in C_{industries}}\beta^{n}_{20k}\mathit{SIC}_{in}+\beta_{21k}\mathit{URBAN}_i.
\end{aligned}
$$

This equation represents the utility from investing in access by the end of 1998. The utility for adopting access plus applications is similar, but it substitutes $\mathit{REG\text{-}APPL\text{-}PRESSURE}_i$ and $\mathit{IND\text{-}APPL\text{-}PRESSURE}_i$ for $\mathit{REG\text{-}ACCESS\text{-}PRESSURE}_i$ and $\mathit{IND\text{-}ACCESS\text{-}PRESSURE}_i$ as the variables proxying for external pressure. The models are estimated using full information maximum likelihood. Table 2 presents the results of the baseline model. To ease interpretation of the coefficients, Table 3 shows the marginal effects of a change from 0 to 1 in key dependent variables. These marginal effects are computed by averaging the marginal effects across all organizations in the sample. In the following discussion, I include these marginal effects in parentheses.

Table 2 Baseline Estimates from Two-Level Nested Logit Model

	Access	Applications
Compatibility and technical sophistication		
PC-PER-EMPLOYEE	0.4072**	0.1925**
	(0.0865)	(0.0707)
CLIENT	1.2487**	0.3427
	(0.1644)	(0.2316)
NO-APPLICATIONS	−0.6717**	−0.3338
	(0.1491)	(0.2005)
LAN-INTENSITY	1.3203**	0.3409
	(0.2670)	(0.2533)
SYSTEM/COMM-APPS	0.3372*	0.1346
	(0.1970)	(0.1721)
NETWARE	0.5133**	0.2099
	(0.1334)	(0.1332)
MAINFRAME-INTENSITY	−0.1537	−0.1707
	(0.1454)	(0.1586)
Competing effects of installed base		
NETWARE × LAN-INTENSITY	−1.1237**	−0.2937
	(0.3085)	(0.2975)
SYSTEM/COMM-APPS × LAN-INTENSITY	−0.7440*	−0.2042
	(0.3861)	(0.3485)
Complementarities with establishment location		
MULTIESTABLISHMENT	2.2427**	1.2554**
	(0.6353)	(0.2442)
EMPLOYEE-CONCENTRATION	−2.2057**	−1.8622**
	(1.0253)	(0.4290)
PCT-100-MILES	−0.5388*	−0.0694
	(0.2999)	(0.2312)
Size		
EMPLOYMENT(100–200)	−0.0307	0.1374
	(0.1791)	(0.1916)
EMPLOYMENT(201–500)	0.1260	0.4700**
	(0.1154)	(0.0820)
EMPLOYMENT(500 plus)	0.2275**	0.4006**
	(0.1036)	(0.0496)
TOTAL-MIPS	−0.0332	0.0948**
	(0.0287)	(0.0176)
External environment		
NO-COUNTY-ESTABLISHMENTS	0.2451	−0.0253
	(0.2417)	(0.1937)
REG-ACCESS-PRESSURE	0.4070*	—
	(0.2312)	—
IND-ACCESS-PRESSURE	0.5594*	—
	(0.3228)	—
REG-APPL-PRESSURE	—	1.1005**
	—	(0.4020)
IND-APPL-PRESSURE	—	0.8014
	—	(0.5465)
Inclusive Value	0.2128	
	(0.6360)	

Notes. Full information maximum likelihood estimates with asymptotic standard errors in parentheses. $N = 6{,}156$. Log likelihood $= -5{,}605.7506$. Includes controls for industry and urban/rural location. Variables grouped by hypothesis. *Indicates significance at 10% level. **Indicates significance at 5% level.

5.1. IT Complementarities

Compatibility and Technical Sophistication. Hypotheses 1a, b posited that prior investments in C/S technologies will increase the likelihood of adopting basic access, but will have little impact on the conditional applications decision. According to the results, increases in LAN intensity significantly increase the likelihood of access (+18.4%), as does the presence of system/communication or NetWare applications (+5.0% and +8.1%). The presence of Internet clients also has a significantly positive effect on access (+23.6%). In contrast, these C/S investments have no significant effect on the probability of applications adoption. Increases in PCs per employee have a significant effect on access adoption (+6.5%) and applications adoption (+3.6%), probably capturing the residual effects of technological sophistication.

Competing Effects of Installed Base. Hypotheses 2a, b suggested that prior investments in system/

Table 3 Marginal Effects in Baseline Model

	Marginal effect of change in RHS variable on probability of adoption		
	Access	Applications	Applications (conditional on access)
Compatibility and technological sophistication			
PC-PER-EMPLOYEE	0.065	0.046	0.036
CLIENT	0.236	0.105	0.062
NO-APPLICATIONS	−0.118	−0.077	0.044
LAN-INTENSITY	0.184	0.105	0.066
SYSTEM/COMM-APPS	0.050	0.035	0.026
NETWARE	0.081	0.054	0.040
MAINFRAME-INTENSITY	−0.025	−0.032	−0.032
Competing effects of installed base			
NETWARE × LAN-INTENSITY	−0.182	−0.090	−0.055
SYSTEM/COMM-APPS × LAN-INTENSITY	−0.124	−0.062	−0.038
Complementarities with establishment location			
MULTIESTABLISHMENT	0.217	0.316	0.272
EMPLOYEE-CONCENTRATION	−0.429	−0.234	−0.242
PCT-100-MILES	−0.089	−0.034	−0.013

Notes. Table presents marginal effect of change in variable on probability of outcome in column. Marginal effects are calculated by changing variables from 0 to 1. Effects are calculated for each organization, then averaged across organizations in the sample.

communication software and LAN operating systems might have competing effects on the likelihood of access adoption. The results support this assertion. Inspection of the interaction terms reveals that NetWare and system/communication software reduce the benefits to LAN intensity significantly (−18.2% and −12.4%).[9] In contrast to their significant effect on access, these interactions have no significant impact on applications adoption.

Overall, do investments in NetWare and system/communication applications have a positive or negative impact on access adoption? The answer depends on the complexity of the organization's C/S network. If the percentage of applications accessed over the LAN is small, then the positive effects of compatibility and technical sophistication outweigh the negative effects of organizational differences and lock-in. Investment in NetWare and system/communication applications is associated with an increase in the probability of access adoption. Conversely, if the installed base of LAN applications is very large, then these platform-specific investments lower the likelihood of adoption. These results suggest that, in most cases, the net effects of these investments are positive. In-sample simulations show that NetWare and system/communication software increase the probability of access adoption for 65.5% and 65.2% of organizations.[10]

Robustness Checks. The interaction of NetWare and LAN intensity may capture unobservable factors related to NetWare that lower the marginal benefit to LAN investment, but which are unrelated to lock-in or organizational differences. To investigate this possibility, I reestimated the model using different vintages of NetWare and different types of LAN operating systems. Table 4 presents a summary of the results.

IntranetWare was a recent version of NetWare that incorporated common intranet features into NetWare. By itself, IntranetWare has an insignificant effect on access and applications decisions, and has little impact on the parameter estimates for NetWare. However, when IntranetWare is interacted with the LAN intensity variable, the coefficient is positive and significant, and completely removes the negative effects of the interaction of NetWare and LAN intensity. That is, investment in IntranetWare is associated with an increase in the likelihood of access adoption for all organizations.

I reestimated a version of the model that included Microsoft NT. Because the installed base of NT networks was, on average, younger than those of NetWare, the interaction of NT with LAN intensity should have little effect on adoption. This is the pattern that I observe. NT has a statistically significant positive effect on the probability of access adoption, while the interaction of NT with LAN intensity has no effect. Thus, if the interaction of NetWare and LAN intensity reflects the effects of unobserved factors or some spurious correlation, these unobservables would have to be specific to NetWare and, in particular, vintages prior to IntranetWare. Although the existence of such unobservables is possible, it is difficult to identify what they might be.

I reestimated the model using a greater number of industry effects, controls for metropolitan areas, and interaction of industry and geographic effects.[11] I estimated the model using only single-establishment firms to examine whether the behavior of "outlier" establishments was responsible for the organization-level results. I also estimated the model using a narrower applications definition that included only business-to-business and business-to-consumer e-commerce applications. The results are robust to all of these modifications.

I estimated the model using 1995 covariates as a robustness check against concerns of endogeneity or simultaneity. Because strong anecdotal evidence sug-

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[9] These are calculated assuming $PCTLAN = 1$.

[10] In-sample simulations were computed by examining the effect of a change in NetWare and system/communication software on access and applications, conditional on parameter estimates and other covariates for the organization.

[11] Complete results from these and other robustness checks are included in the online appendix available at mansci.pubs.informs.org/ecompanion.html.

Table 4 Robustness Tests of IT Complementarities

	Including IntraNetWare (access) (1)	Including IntraNetWare (application) (2)	Including Microsoft NT (access) (3)	Including Microsoft NT (application) (4)	Single estimate only (access) (5)	Single estimate only (application) (6)
LAN-INTENSITY	1.3371**	0.3433	1.0116**	0.4472	1.4988**	0.3439
	(0.2669)	(0.2540)	(0.2849)	(0.2816)	(0.3094)	(0.2730)
SYSTEM/COMM-APPS	0.3439*	0.1178	0.2445	0.0562	0.4755**	0.1896
	(0.1960)	(0.1727)	(0.1970)	(0.1761)	(0.2371)	(0.1888)
NETWARE	0.5354**	0.1761	0.5111**	0.2020	0.6676**	0.2597*
	(0.1332)	(0.1352)	(0.1330)	(0.1342)	(0.1672)	(0.1410)
INTRANETWARE	−0.3886	0.5732	—	—	—	—
	(0.4834)	(0.3621)	—	—	—	—
MICROSOFT-NT	—	—	0.4564**	0.3218**	—	—
	—	—	(0.1734)	(0.1449)	—	—
MAINFRAME-INTENSITY	−0.1581	−0.1694	−0.1144	−0.1433	−0.2636	−0.1329
	(0.1453)	(0.1591)	(0.1449)	(0.1601)	(0.1699)	(0.1693)
NETWARE × LAN-INTENSITY	−1.2078**	−0.2258	−0.8025**	−0.2501	−1.3256**	−0.3744
	(0.3090)	(0.3021)	(0.3099)	(0.3045)	(0.3631)	(0.3207)
INTRANETWARE × LAN-INTENSITY	1.8557*	−1.1681	—	—	—	—
	(1.1058)	(0.7670)	—	—	—	—
MICROSOFT-NT × LAN-INTENSITY	—	—	0.0759	−0.5010	—	—
	—	—	(0.3687)	(0.3140)	—	—
SYSTEM/COMM-APPS × LAN-INTEN	−0.7581**	−0.1761	−0.6150	−0.0629	−0.9901**	−0.2445
	(0.3847)	(0.3497)	(0.3875)	(0.3571)	(0.4511)	(0.3851)
Log likelihood	−5,601.2068		−5,586.4154		−4,965.6004	

Notes. Full information maximum likelihood estimates with asymptotic standard errors in parentheses. Based on the model in Table 2, with changes noted above. Standard errors in parentheses. *Indicates significance at 10% level. **Indicates significance at 5% level.

gests that the Internet took many firms by surprise in 1995, we can safely assume that 1995 covariates are exogenous with respect to the error terms. Unfortunately, because of entry and exit of organizations from the sample, this required me to discard more than 39% of observations. All results from this last model are qualitatively the same, however, the statistical significance of some of the coefficients is lost because of the smaller number of observations. I also reestimated the model using 1995 variables to explain 1996 adoption. Many of the networking variables have identical signs to the baseline model and have economically and statistically significant effects.

5.2. Complementarities with Establishment Location

Hypotheses 3a, b argue that geographic dispersion will be complementary with access adoption, but will have little effect on the decision to adopt applications. Controlling for organization size, multiestablishment status, and employment concentration, the effect of increases in the percentage of establishments within 100 miles is significant (−8.9%). However, geographic concentration has no significant effect on applications adoption.

The multiestablishment dummy and employee concentration variables have a statistically significant effect on both access and applications. The positive effects on applications may reflect the unobservable impact of organization size and slack resources.

Robustness Checks. One alternative hypothesis for the negative coefficient on *percent within 100 miles* is that geographic concentration is capturing unobservable effects of firm size. Although I control for organization size with variables describing employment, total MIPS, and multiestablishment dummies, there may remain some unobservable factors such as "network complexity" that are correlated with network size for which I am unable to control. I test this alternative hypothesis by examining the effects of alternative distance measures on the likelihood of adoption. Table 5 presents the results of these alternative models.

Hypothesis 3a argues that organizations operating in geographically dispersed areas will be more likely to adopt access because of the high cost of communications substitutes. The pricing of these communications substitutes is somewhat discontinuous because of long-distance charges, prices increase once communications must extended between (as opposed to within) metropolitan areas. I included the percent of establishments within 100 miles to capture precisely this phenomenon. Controlling for multiple establishments and employee dispersion, this variable captures the marginal effect of establishments being located within the same metropolitan area.

If Hypotheses 3a, b are correct, other distance measures should have less power in explaining the variation in adoption decisions. As a robustness check, I reestimated the model using alternative distance measures: (1) the percent of establishments within

Table 5 Nested Logit Estimates, Robustness Checks of Location Complementarities

	PCT500 (access) (1)	PCT500 (application) (2)	AVG-DISTANCE (access) (3)	AVG-DISTANCE (application) (4)	1996 (access) (5)	1996 (application) (6)
MULTIESTABLISHMENT	2.1376**	1.2277**	1.6331**	1.5560**	2.7522**	1.2117**
	(0.6429)	(0.2555)	(0.7416)	(0.3765)	(0.3500)	(0.3641)
EMPLOYEE-CONCENTRATION	−2.2592**	−1.8943**	−2.1752**	−1.9857**	−2.8975**	−1.7740**
	(1.0220)	(0.4268)	(1.0422)	(0.4353)	(0.5669)	(0.6248)
PCT-100-MILES	—	—	—	—	−0.7431**	−0.3521
	—	—	—	—	(0.2312)	(0.4335)
PCT-500-MILES	−0.1204	0.0518	—	—	—	—
	(0.2975)	(0.2043)	—	—	—	—
AVG-DISTANCE	—	—	0.0791	−0.0472	—	—
	—	—	(0.0563)	(0.0440)	—	—
N	6,156		6,156		5,239	
Log likelihood	−5,607.3315		−5,605.9859		−3,912.3788	

Notes. Full information maximum likelihood estimates with asymptotic standard errors in parentheses. Based on the model in Table 2, with changes noted above. *Indicates significance at 10% level. **Indicates significance at 5% level.

500 miles in distance and (2) the average distance between establishments. Both are unsuccessful in explaining the variation in access adoption decisions.

Organization location decisions could also be endogenous with the cost of communications: the availability of low-cost Internet services may cause organizations to locate establishments farther apart. I explored this possibility by reestimating the model using 1996 adoption decisions and 1995 explanatory variables. Organization location decisions made in 1995 or before were made prior to the widespread diffusion of the Internet; these location decisions will be exogenous with respect to Internet adoption.[12] In this model, the effects of geographic location on access adoption are even stronger (+12.3%). Last, I estimated the model using the narrower "e-commerce" definition for applications. In this model, geographic dispersion continues to reduce the likelihood of adopting access, however, the results are significant only at the 23% level.

5.3. Size and External Pressure

Table 2 shows that employment has a significant impact on applications adoption but relatively little effect on access, supporting Hypotheses 4a, b. Among organizations of more than 500 employees, a one standard deviation increase in employment (equivalent to roughly 259 employees) increases the likelihood of access by 3.3% and applications by 7.7%. Total MIPS has no effect on access and a small but significant effect on applications. A one standard deviation increase in total MIPS increases the likelihood of applications adoption by 4.4%.

Table 2 indicates that, in general, the variables capturing external industry and regional pressure have a positive and statistically significant effect on access and applications adoption, supporting Hypotheses 5a, b and Hypotheses 6a, b. However, as mentioned above, these variables may also be proxying for unobserved heterogeneity in net benefits to adoption across industries and counties.

6. Discussion

What factors separated adopters of the Internet from nonadopters? These results suggest that the organizations that derived the greatest net benefits from the decreases in communications costs made possible by early Internet technologies were more likely to adopt the Internet. Organizations that had made complementary investments in information and communication technologies were more likely to adopt. Organizations that were geographically dispersed and benefited from reductions in communications costs engendered by the Internet were also likely adopters.

The results also suggest a common theme in the pattern of Internet adoption. Organizations first demanded basic Internet technologies that were relatively inexpensive to adopt. These early technologies lowered communication costs through applications such as e-mail and the World Wide Web, and were adopted first by organizations with the most to gain from reductions in communications costs. These technologies diffused rapidly. However, there remained some organizations for which these early technologies had little value; these organizations responded by delaying adoption.

How did recent IT investments influence adoption? Although prior investments in C/S software were

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[12] I have also estimated the model using 1998 adoption decisions and 1995 covariates. This model is estimated on a much smaller sample because of entry and exit of organizations from the database. In this specification, the signs of the coefficients are identical to those in the baseline model but statistical significance is generally lost.

complementary with Internet access, recent investments in system software or LAN operating systems were associated with a lower likelihood of adoption for some organizations. Moreover, the results suggest that the costs of platform-specific software were greatest among those organizations with the most complex network infrastructures. In other words, when organizations made platform-specific technical or organizational investments that were deeply embedded in the current IT infrastructure, these investments reduced the net benefits to adopting the Internet.

Prior DOI research has argued that organizations with recent IT investments or complex IT infrastructure are more likely to adopt new innovations (e.g., Swanson 1994, Raymond and Paré 1992). However, this prior research fails to discuss how IT comes bundled with complementary technical and organizational investments that may be incompatible with new technologies. This paper provides a unique way of disentangling the effects of IT sophistication and compatibility from those of organizational differences and lock-in.

Did the Internet help to break geographic boundaries? I focused on the relationship between geographic dispersion and adoption because of the early use of the Internet as a basic communications technology. Relatively few studies have examined how the geographic dispersion of the organization influences the adoption of new innovations. These results suggest that geographic dispersion was complementary with access adoption and that Internet technology helps to lower coordination costs arising from geographic dispersion. While prior research has shown how internal coordination costs can lead to greater IT expenditures (e.g., Hitt 1999), this paper is unique in showing how coordination costs may lead to more rapid adoption of a new technology.

6.1. Implications for Managers

In this paper, I examine organizations' short-run reactions to a new communications technology. As a general purpose technology (Bresnahan and Trajtenberg 1995), Internet technology diffused unevenly across organizations based on exogenous factors often unrelated to skill or IT sophistication. That is, organizations' short-run success in implementing Internet technology for competitive advantage depended, in part, on conditions that may be largely uncorrelated with their past IT successes.

This study suggests that early investment decisions can have long-term consequences. Many organizations in the sample made recent investments in C/S technologies that were incompatible with TCP/IP. These investments appeared to decrease the net benefits to early Internet adoption and temporarily locked these organizations into their earlier investments. The analysis reinforces the point that managers investing in new IT need to consider how these investments will fit with planned acquisitions of future generations of technologies.

The evidence suggests that Internet technology helped to break down coordination costs related to geographic dispersion. Recent work (Forman et al. 2003) has shown that basic Internet technology is complementary with rural location, possibly reducing external coordination costs with suppliers and customers. This suggests that Internet technology does help to break down geographic barriers that raise coordination costs. It remains for future work to show whether firms modify their location decisions in response to these lower coordination costs.

6.2. Conclusions

Overall, these results suggest that the organizations that benefited most from the decreases in communications costs made possible by early Internet technologies were more likely to adopt Internet technologies. I find that recent IT investments may sometimes have unintended consequences for the adoption of new technologies. Moreover, these results suggest that Internet technology helps to break down coordination costs related to geographic dispersion. The results confirm prior findings that size and external pressure influence adoption of new IT.

This study raises many new questions for future research. For one, future work should examine how competition and knowledge spillovers affect Internet adoption, particularly for frontier technologies such as e-commerce, where this is likely to be most important. Moreover, additional work is needed to understand how Internet technology affects the long-run relationship between advances in IT and the geographic agglomeration of economic activity. Forman et al. (2003) is a step in this direction. In all, this paper has taken a first look at understanding the forces driving investment in early Internet technologies. Much work remains to be done in understanding how these technologies have been implemented, and the impact of their usage.

An online appendix to this paper is available at http://mansci.pubs.informs.org/ecompanion.html.

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