International Journal of Industrial Organization
19 (2001) 1085–1102

International Journal of Industrial Organization

www.elsevier.com/locate/econbase

The need for speed in emerging communications markets: upgrades to advanced technology at Internet Service Providers

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Abstract

How and why do young firms develop distinctive skills on the frontiers of technology in evolving technologies? As a window on these processes, this study analyzes the decisions by Internet Service Providers (ISPs) to upgrade the speed of communication. In 1997 this involved 56K modem technology and Integrated Services Digital Network (ISDN) technology. We investigate why an ISP chooses to offer neither, one or both high speed data transmission technologies. Our findings are consistent with the view that scale of investment, local infrastructure's quality and explicit costs shape investment decisions by young firms in emerging markets.

Keywords: Internet Service Providers; Emerging communications markets; Evolving technologies

1. Introduction

This study analyzes the decisions by 1846 U.S. Internet Service Providers (ISPs) to upgrade the speed of communication services in the spring and fall of 1997. This is a young and dynamic market, recently developed after the National Science Foundation helped commercialize the internet. In this study we examine the decision to offer two types of high speed transmission technologies — 56K modem technology and Integrated Services Digital Network (ISDN). Roughly

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0167-7187/01/$ – see front matter
PII: S0167-7187(01)00064-9

60% of the ISPs offer ISDN or 56K modem service. Why does an ISP choose to offer neither, one or both high speed transmission technologies? Why do some ISPs use frontier technology and others not?

Our analysis illustrates how and why young firms develop distinctive skills and assets in evolving technologies and evolving markets. In this case, the first business opportunity after the commercialization of the internet was the market for low cost dial-up access. In the internet's early commercial years most transmissions were character mode and, as such, speed was not particularly important. However, the development of the World Wide Web brought a much greater volume of graphics and data to many users. For this and other reasons, ISPs had incentives to start offering higher access speed. What influenced these incentives? We view this study as a detailed window on broader processes to adopt new technology.

There is a vast literature on the incentives to adopt new technologies in young markets. Broadly speaking, this literature examines how economic incentives shape the diffusion process (e.g., Rogers, 1995; Stoneman, 1983), as well as how this process alters and is shaped by a market's structure (e.g., Gort and Klepper, 1982; Klepper, 1996). This study resembles previous research that emphasizes heterogeneity in the incentives shaping the diffusion process at the microeconomic level in the short run. We distinguish between the different incentives arising from geographic territories (e.g., Griliches, 1957) and firm features (e.g., Demsetz, 1988; Nelson and Winter, 1982). Is diffusion shaped more by the dispersion of geographic factors (e.g., local competitiveness) or by the dispersion of firm-specific factors (e.g., firm size) which alter the incentives to bring new technology into use?

This study estimates a bi-variate probit model consisting of 56K and ISDN upgrade decision, where the 56K decision is given an ordered specification. We conclude that firm-specific factors and location-specific factors have roughly similar importance for both ISDN and 56K decisions. First, we find that variance in ISP's decisions are determined by variance in the size of ISPs. Second, the variance in the infrastructure of the markets in which ISPs operate also is important. Third, an ISP's behavior is not very sensitive to demographic make-up of the area, nor competitive conditions found in local markets. Both of these factors play a role, if at all, only in extreme circumstances. Finally, there is a geographic dimension to the important determinants of firm behavior, i.e. ISPs located in urban areas tend to be the ''type'' of ISP who adopt more quickly. We close by developing implications for long industry evolution.

2. The internet industry[2]

In the early years, e.g. 1994–96, it was possible to run a small ISP on a shoe-string in either an urban or rural area. These firms were devoted primarily to

[2] For more on the commercialization of the internet, see Greenstein (2000).

dial-up. At the time of this study broadband access was available only through T-1 and T-3 lines, primarily to large enterprises. Both ISDN and 56K were on the frontier of high speed access at the residential user level, each offering a substantial improvement over 28K modems, the widely used dial-up norm. In addition, ISDN was commonly being used by smaller businesses, requiring reasonably high speed access at manageable prices. From the ISPs point of view, these were two alternative means for users to achieve higher speeds. A user was likely to prefer only one of these, if at all, while an ISP could support one, both or neither.

2.1. Analog: 56K

Until early 1997, 33.6 Kbps was the fastest modem available that could be used with analog phone lines. V.34 modems are optimized for the situation where both ends connect by analog lines to the public switched telephone network (PSTN). Analog information must be transformed to binary digits in order to be sent over the PSTN, since analog waveforms are continuous and binary numbers are discrete, the digits that are sent across the PSTN and reconstructed at the other end approximate the original analog waveform. The difference between the original waveform and the reconstructed quantized waveform is called quantization noise, this limits modem speed to about 35 Kbps. Quantization noise affects only analog-to-digital conversion and not the other way.

In the last couple of years, ISPs have been converting from analog to digital circuits between their central site and the telephone company. This changed many assumptions upon which previous modem designs were based. 56K modems remove the analog-to-digital conversion between the server modem and the PSTN and are faster than the V.34 modems which run at 33.6 Kbps under optimal conditions. This new modem technology enabled data rates of up to 56 Kbps over standard analog phone lines. However, not all phone lines support 56K. Lines with more than one analog- to-digital conversion confine modem speeds to V.34 speeds.

When 56K first reached the market in 1997 there were two incompatible technologies; FLEX and X2. The lack of a standardized technology slowed the rate of adoption, revealing only the most eager early adopters. It also encouraged some users who would have adopted 56K to consider adopting ISDN instead (see Augereau, 1999, for more).

2.2. Digital: ISDN

Beginning in the 1960s, the telephone system gradually began converting its internal connections to a packet-based, digital switching system. Today, nearly all voice switching in the U.S. is digital within the telephone network. However, the final connection from the local central office to the customer equipment is largely an analog Plain-Old Telephone Service (POTS) line.

An ISDN line is a digital telephone service that allows for a combination of voice and data connections over a single high speed connection with throughput of up to 128 Kbps. Previously, it was necessary to have a phone line for each device you wished to use simultaneously. For example, one line each was required for a telephone, fax, computer, bridge/router, and live video conference system. ISDN allows multiple digital channels to be operated simultaneously through the same regular phone wiring. The same physical wiring can be used, but a digital signal, instead of an analog signal, is transmitted across the line. This scheme permits a much higher data transfer rate than analog lines.

ISDN first emerged in the middle 1980s and was available on a very limited basis at telephone companies. A competitive data transport industry began to make the service more widely available in the 1990s. In many locations its availability depended on the support of the local telephone company in specific locations, their conduct and policies regarding third party interconnection, and local regulations regarding interconnection with third parties, such as ISPs.

2.3. Adoption decisions

The costs of each technology differed. ISDN and 56K involved the adoption of new equipment and training, as well as the potential construction of arrangements with local telephone companies. Most of these costs were fixed costs and sunk once expended. Some of these costs were shared between ISDN and 56K and many were not.

The benefits of investing in each technology differed across ISPs. Users were unlikely to demand both technologies. ISPs also faced different degrees of competitive pressure. In the time period of the study, there was considerable commercial uncertainty over the ultimate value of these services to users. A related unknown was the speed with which the user community would adopt either technology, if at all.

We anticipate considerable heterogeneity in the behavior of ISPs, partly as a reflection of real differences in economic conditions and partly a reflection of different evaluations of similar, yet uncertain, economic circumstances. Beyond this general statement, theory does not provide specific guidance about which factors were likely to matter most to ISPs' decisions, nor are we comfortable imposing a specific model on the upgrade behavior. In addition, we will assemble coarse data about the upgrade decisions at a cross section of 1846 ISPs in a particular year. For all these reasons, we will favor use of general reduced-form econometric methods.

3. Data

3.1. Generating a sample

This study uses data from two different lists: one is maintained by *thedirectory*

Table 1
Distribution of ISDN and 56K

		56K			
		Early	Late	Not	Total
ISDN	Offers	256	445	335	1036
	Does not	76	185	549	810
	Total	332	630	884	1846

and the other by *Boardwatch*. *Thedirectory* lists the cities in which the ISPs operate. *Boardwatch* presents information on firm characteristics and adoption decisions.

The time period under study for adoption of ISDN and 56K modems is fall 1997. The data from Boardwatch is quite coarse (due to their periodic sampling and publication), so we are only able to break 56K adoption into three categories of intensity: early adoption, late adoption or none at all. Early is defined as March to August 1997 and late is September or October 1997. ISDN adoption did not differ much over the two sample periods. Hence, this variable is recorded as binary, recorded from the first period. Table 1 contains a summary of these data.

A market is defined as a county, as designated by the US Census. There are a total of 3115 counties (excluding Alaska), with less than a third represented by the sample.[3] Slicing US geography in this way has certain well-known drawbacks — county boundaries are political boundaries and do not directly correspond with meaningful economic market boundaries. Yet, these drawbacks are overwhelmed by the benefits of using US Census information to measure local conditions in which the ISPs compete (Downes and Greenstein, 1998).

We face two additional measurement difficulties. First, many large firms do not implement their upgrade decisions uniformly across locations. Second, it is difficult to identify the features of the geographic market which influence adoption decisions, and it becomes increasingly difficult as firms get larger. Our research strategy, as in Augereau (1999) and Greenstein (2000), is to favor a limited sample in order to gain more accurate measurement. We focus on ISPs who are not spread out, i.e. ISPs in five counties or less. This has one major cost, it restricts our sample to firms who target only a small number of markets. Note, however, it does not mean that our sample only contains small firms. Many large firms choose to concentrate on selected geographic areas, so we are not concerned that this selection biases our sample.[4]

[3] We excluded Alaska due to its unique geographic features.

[4] Since the national firms have a very high propensity to offer faster speeds, excluding them should bias us against finding any relationship between firm size and adoption of the frontier technology. However, below we find that firm size positively predicts adoption of higher speed equipment, suggesting that the relevant threshold is within the sample size we examine.

3.2. Exogenous variables

Table 2 contains variable definitions and descriptive statistics.

3.2.1. Firms-specific factors

BANDWIDTH is the capacity of a connection line to transmit data from one computer to another. A high bandwidth connection to the backbone is a good sign that an ISP intends to offer high speed service. PORTS provides a measure of overall capacity of the ISP. As with BANDWIDTH, it measures anticipated demand. Most ISPs maintain PORTS in rough proportion to the number of anticipated subscribers.[5]

EXPERIENCE is a dummy that takes on one if the ISP was listed in *thedirectory* in the fall of 1996. ISPs do not list their founding date. ONECOUNTY is a measure of geographic dispersion, it takes on the value one if the ISP maintains service in only one county, as indicated in *thedirectory*. Small geographic size indicates a focus on local customers. This may also indicate lack of access to financial capital to expand.

3.2.2. Location-specific factors

URBAN takes on a value between zero and one, where this number reflects the weighted average number of urban counties in which the ISP offers local dial-up service. A county is urban if it fits under the broadest definition for urban within the US Census. For most ISPs (1738 out of 1846) this number is either zero or one. THREENAT takes on one when there are more than three national firms in the same county as this ISP and zero otherwise. Since virtually all urban areas have national ISPs, this variable tends to strongly overlap with URBAN, but covers a smaller set of urban regions. THREELOCAL is a dummy that take on one when there are more than three local/regional ISPs in the same county as this ISP.[6] In practice, this variable captures the difference between counties with the thinnest demand in this data set and those with enough population to support at least a few ISPs.

RBOC and GTE are dummies which take on one if the ISP serves a county in which a regional Bell operating company or GTE is the dominant local telephone firm (see Greenstein et al., 1998, for sources). If the RBOC and GTE offer better backbone services than independent telephone companies, then it is easier for ISPs

[5] BANDWIDTH and PORTS are, arguably, endogenous from an econometric standpoint, as it is a decision that may have been made at the same time as the decision to experiment in high speed access. To test whether the estimates are sensitive to its inclusion, we tried specifications with and without it and found that the estimates did not dramatically change. Hence, we only show the estimates with this variables included.

[6] Note, by definition, every observation in the dataset arises in a county in which there is already one ISP — the ISP under observation. Thus, the presence of three local/regional ISPs indicates the presence of at least three competitors to the ISP under consideration.

Table 2
Descriptive statistics; 1846 observations

	Summary of definition	Mean	S.D.	Min	Max
Firm specific					
EXPERIENCE[a]	ISP is over a year old	0.45	0.50	0.00	1.00
BANDWIDTH[b]	Total backbone capacity at ISP	7.18	13.02	0.03	45.00
ONECOUNTY[a]	ISP is in only one county	0.81	0.39	0.00	1.00
PORTS[b]	Total number of computer connections at ISP	0.48	1.86	0.00	30.00
Location specific					
URBAN[c]	Percent counties designated as MSA	0.81	0.38	0.00	1.00
THREE NAT[d]	At least three national competitors in ISP service area	0.78	0.41	0.00	1.00
THREE LOCAL[d]	At least three local competitors in ISP service area	0.88	0.32	0.00	1.00
RBOC[e]	Regional Bell Operating Company provides service	0.72	0.43	0.00	1.00
GTE[e]	General Telephone & Electric provides service	0.10	0.29	0.00	1.00
FR22TO29[c]	Fraction population in ISP service area b/w 22 and 29	0.13	0.02	0.06	0.24
FR30TO39[c]	Fraction population in ISP service area b/w 39 and 39	0.17	0.02	0.11	0.28
FR40TO64[c]	Fraction population in ISP service area b/w 40 and 64	0.26	0.02	0.14	0.34
FR65OVER[c]	Fraction population in ISP service area over 65	0.12	0.04	0.03	0.34
WORKPCT[f]	Fraction of households who use a PC at work	0.29	0.12	0.00	1.00
HOMEPCT[f]	Fraction of households who use a PC at home	0.25	0.12	0.00	1.00
FRPROF[c]	Fraction of professional population in ISP service area	0.39	0.07	0.18	0.60
CSITE[e]	Large computer sites per population	5.65	4.02	0.00	27.23
UNIVERSITY1[d]	Research university, type 1, present in ISP service area	0.45	0.50	0.00	1.00
UNIVERSITY2[d]	Research university, type 2, present in ISP service area	0.60	0.49	0.00	1.00
UNIVERSITY3[d]	Research university, type 3, present in ISP service area	0.51	0.50	0.00	1.00

[a] www.thedirectory.org.
[b] boardwatch.internet.com.
[c] US Census.
[d] Downes and Greenstein (1998).
[e] Greenstein et al. (1998).
[f] PNR Associates, as found in Kridel et al. (1997).

to experiment with frontier access. More likely, these companies serve as potential competitors for advanced data-transport services, which should motivate ISPs to get into frontier access. In practice, RBOC tends to strongly overlap with URBAN, but URBAN is broader. In practice, GTE tends to overlap with the areas for which URBAN is zero, but non-urban areas tend to be broader than GTE. We favored testing these hypotheses in a flexible way, so all were included.

Several variables describe the county (or counties) in which the ISP located.[7] Two fractions, PCHOME and PCWORK, describe the fraction of households who have adopted a PC at home and who use one regularly at work, as found by PNR Associates in a 1997 survey of over 30,000 households (see, e.g., Kridel et al., 1997). FRACPROF is a fraction between zero and one that describes the fraction of the population which works in white collar work (see Downes and Greenstein, 1998).[8] CSITE is the total number of respondents to a survey of large scale computer use in 1992 divided by population (see Greenstein, Lizardo and Spiller), which indicates the presence of many (presumably technically sophisticated) local information technology users. PCHOME, PCWORK, FRACPROF, and CSITE should be positive. Four fractions describe the demographic age of the population. One covers ages 22–29, another 30–39, another 40–64, and another over 65. These are controls and we make no prediction.

The last variables are UNIVERSE1, UNIVERSE2 and UNIVERSE3, all of which are dummies that measure the presence of at least one university in the county in which the ISP provides service.[9] UNIVERSE1 takes on one if there is at least one research university in the county which maintains a PhD and graduate program, according to the Carnegie rankings of universities. UNIVERSE2 takes on one if there is at least one university which maintains a graduate but not PhD program. UNIVERSE3 takes on one if there is at least one university which maintains an undergraduate program, but no graduate programs. Universities may act as demanders for internet services, as competitors for the delivery of some internet services, or as supplier of employees and new entrepreneurial talent in the internet business.

4. Specification

In our model, ISPs have three mutually exclusive ordered choices to make with

[7] The specification of these variables was inspired by micro-studies of household and business demand for computing, PCs and internet services. For example, Downes and Greenstein (1998), Clemente (1998) and Goolsbee and Klenow (1999).

[8] In practice, FRACPROF tends to correlate highly with education, income and some types of white collar work in a region, rendering many other potential economic measures redundant due to collinearity. We also experimented with several measures of the strength of the local financial, insurance and real estate markets, but did not find that any of them useful.

[9] Special thanks to Tom Downes for collecting this information and bringing these data to our attention.

regards to adoption of 56K modems and two choices for ISDN. We therefore observe two related discrete variables, as reported in Table 1. As both the adoption choice of 56K and ISDN represents an ISP's willingness to stay near the technological frontier, we expect unobserved characteristics in both equations to be positively correlated. We assume that underlying the adoption of ISDN and 56K there are related latent variables, ISDN* and 56K*, which are bivariate normally distributed. In the following specification X is a vector of observed characteristics for each ISP and ε is a random error term. The relation between ISDN and ISDN* may be written

$$\text{ISDN}^* = \beta_1' X_1 + \varepsilon_1.$$

$$\text{If ISDN}^* < 0, \text{ then ISDN} = 1,$$

$$\text{if ISDN}^* \geqslant 0, \text{ then ISDN} = 2,$$

where ISDN = 1 is no adoption, and 2 is adoption. As noted earlier, we model this as a bivariate because this is all the information we have on this decision. The probabilities take on the following form:

$$P(\text{ISDN} = 1) = P(\varepsilon_1 \leqslant -\beta_1' X_1) = P(\varepsilon_1 \leqslant -a_1),$$

$$P(\text{ISDN} = 2) = P(-\beta_1' X_1 \leqslant \varepsilon_1) = P(-a_1 \leqslant \varepsilon_1).$$

The choice with regards to 56K, in contrast, has three categories: adopt early, adopt late or do not adopt at all. The relation between 56K and 56K* may be written

$$56\text{K}^* = \beta_2' X_2 + \varepsilon_2.$$

$$\text{If } 56\text{K}^* < 0, \text{ then } 56\text{K} = 1,$$

$$\text{if } 0 < 56\text{K}^* \leqslant \mu, \text{ then } 56\text{K} = 2,$$

$$\mu \leqslant 56\text{K}^*, \text{ then } 56\text{K} = 3,$$

where 56K = 1 is no adoption, 2 is late adoption and 3 is early adoption. The probabilities take on the following form:

$$P(56\text{K} = 1) = P(\varepsilon_2 \leqslant -\beta_2' X_2) = P(\varepsilon_2 \leqslant -b_1),$$

$$P(56\text{K} = 2) = P(-\beta_2' X_2 < \varepsilon_2 \leqslant \mu - \beta_2' X_2) = P(b_1 < \varepsilon_2 \leqslant b_2),$$

$$P(56\text{K} = 3) = P(\mu - \beta_2' X_2 < \varepsilon_2) = P(b_2 < \varepsilon_2),$$

where a_i and b_j denote thresholds, $a_0 = b_0 = -\infty$ and $a_3 = b_4 = +\infty$. The data consists of observed frequencies n_{ij}: $i = 1,2$; $j = 1,2,3$. If we denote by π_{ij} the probability that ISDN $= i$ and 56K $= j$ then the likelihood of the sample is

$$L = \prod_{i}^{2} \prod_{j}^{3} \pi_{ij}^{n_{ij}}.$$

The thresholds for ISDN are denoted by a_i, $i = 0, \ldots, 3$, and for 56K by b_j, $j = 0, \ldots, 4$. It follows that

$$\pi_{ij} = \Phi_2(a_i, b_j) - \Phi_2(a_{i-1}, b_j) - \Phi_2(a_i, b_{j-1}) + \Phi_2(a_{i-1}, b_{j-1}),$$

where Φ_2 is the bivariate normal distribution function with correlation ρ. In effect, we estimate a bivariate probit with a typical probit in one equation and an ordered probit with three potential choices in the other. For estimation we follow the procedures outlined in Olsson (1979).

The coarseness of the endogenous variable makes the use of any specification with more parameters no better than what we propose above. This specification sacrifices information on the sequence of modem adoption and its relationship to ISDN adoption. However, we gain precision from imposing an ordered probit on the 56K decision and from relating the errors in the 56K and ISDN decisions through a single unknown parameter, ρ. In theory, we could have used a specification with more parameters and an explicit sequence of actions, but found in exploratory work that such specifications used up degree of freedom with no benefit.[10]

5. Results

Parameter estimates and asymptotic standard errors for the model of technology adoption are presented in Table 3. The first column gives the estimated coefficients for adoption of ISDN and the second for 56K. Table 4 includes estimates of the economic importance of selected variables. It shows the change in ISDN* and 56K* which results from turning a dummy on and off. It also shows the change which results from increasing a continuous variable by one standard deviation. These results give a normalized sense of which variables move an ISP toward or away from thresholds to the greatest degree.[11]

The estimate of ρ is significant at the 1% level and yields a correlation coefficient of 0.47. This confirms that it was essential to estimate a model which

[10] We experimented with one probit for the early decision and the other probit for the latter decision, conditional on not adopting in the early period. The estimated coefficients did not statistically differ because the number of early decisions is a small fraction of the sample and the coefficients on this decision were imprecisely estimated. Hence, we gain precision from estimating an ordered probit. This specification saves on estimating additional parameters for the error structure on the 56K equation. In addition, it simplifies the error structure between 56K and ISDN decisions.

[11] The influence on the probability of adoption depends on the value of the other variables. For example, a change of 0.2 in ISDN* alters the probability of adopting ISDN by approximately 8% for most actual sample values.

Table 3
Estimates (standard errors in parentheses)

	ISDN		56K	
Log likelihood:	2905.68			
Firm specific				
EXPERIENCE	0.20	***	0.14	***
	(0.06)		(0.05)	
BANDWIDTH	0.01	***	0.00	**
	(0.00)		(0.00)	
ONECOUNTY	−0.09		−0.15	**
	(0.08)		(0.08)	
PORTS	0.09	***	0.06	***
	(0.02)		(0.01)	
Location specific				
URBAN	0.38	***	−0.08	
	(0.12)		(0.10)	
THREE NAT	0.17	*	−0.06	
	(0.11)		(0.09)	
THREE LOCAL	0.13		0.21	**
	(0.13)		(0.11)	
RBOC	0.33	***	0.14	*
	(0.10)		(0.09)	
GTE	0.32	***	0.21	**
	(0.13)		(0.12)	
FR22TO29	4.94	**	3.00	
	(2.81)		(2.40)	
FR30TO39	−3.87		−5.14	**
	(3.09)		(2.54)	
FR40TO64	2.38		0.25	
	(1.96)		(1.62)	
FR65OVER	−1.45		−1.37	
	(1.40)		(1.21)	
PCWORK	0.65	**	−0.20	
	(0.29)		(0.23)	
PCHOME	−0.10		−0.16	
	(0.34)		(0.25)	
FRACPROF	0.41		0.70	
	(0.79)		(0.69)	
CSITE	0.00		0.02	**
	(0.01)		(0.01)	
UNIVERSITY1	−0.18	**	−0.12	**
	(0.08)		(0.07)	
UNIVERSITY2	0.11	*	−0.01	
	(0.08)		(0.07)	
UNIVERSITY3	0.07		−0.08	
	(0.07)		(0.06)	
Other				
RHO	0.47	***		
	(0.03)			
CONST1	−1.57	**	0.28	
	(0.83)		(0.66)	
CONST2, 56K			0.99	***
			(0.03)	

Statistical significance at ***1%, **5%, *10%.

Table 4
Measures of economic importance for selected variables[a]

	ISDN	56K
EXPERIENCE	0.20 A	0.14 A
BANDWIDTH	0.13 B	0.09 B
ONECOUNTY		−0.15 B
PORTS	0.17 B	0.14 B
URBAN	0.38 A	
THREE NAT	0.17 A	
THREE LOCAL		0.21 A
RBOC	0.33 A	0.14 A
GTE	0.32 A	0.21 A
FR22TO29	0.10 B	
FR30TO39		−0.10 B
PCWORK	0.07 B	
CSITE		0.08 B
UNIVERSITY1	−0.18 A	−0.12 A
UNIVERSITY2	0.11 A	

[a] (A) Change in 56K* and ISDN* from change in dummy variable (from 0 to 1). (B) Change in 56K* and ISDN* from one standard deviation increase in variable.

allows for correlation between adoption of 56K and ISDN. This is strong evidence of similarities between the two decisions (after controlling for other determinants), as well as strong evidence that strong unobservable factors influence the decision. We cannot say whether this is unmeasured supply or demand (e.g., is it due to a more technically adept staff at the ISP or a more technically demanding set of users for the ISP's services?). In addition, the estimates lead to an easy rejection of $B_{56K} = B_{ISDN}$ in the bivariate probit, suggesting that 56K and ISDN are determined by different processes.

5.1. Firm-specific factors

EXPERIENCE is positive and significant for both ISDN and 56K. In other words, if an ISP has been in business for a year it is more likely to have the resources and capabilities necessary to offer high speed access. Both coefficients indicate that experience has moderate importance for each decision. It contributes 0.2 to the ISDN* threshold and 0.14 to the 56K* threshold.

The two measures of capacity, BANDWIDTH and PORTS, are both positive and significant, as expected. The positive influence of BANDWIDTH indicates that investment in a costly high speed connection to the backbone encourages the ISP to offer high speed access to its customers. A one standard deviation increase in bandwidth contributes 0.13 to the ISDN* threshold and 0.09 to the 56K* threshold. This means variance in BANDWIDTH is of relatively moderate importance except between extreme maximum values, when it matters a great deal. PORTS is positive and significant for both decisions, indicating that larger size encourages ISPs to offer either type of high speed access. At 0.17 for ISDN* and 0.14 for 56K*, variance in PORTS is also of only moderate importance except at extreme maximum values.

Size is an important determinant of adoption behavior for about a quarter of the ISPs in the sample. The correlation of BANDWIDTH and PORTS is only 0.11. Both are highly skewed. The medians of BANDWIDTH and PORTS are well below their mean. The median of BANDWIDTH is 1.5 and the upper quartile is 3.08, both below the mean of 7.18. The median of PORTS is 0.14 and the upper quartile is 0.35, both below the mean of 0.47. This means that the firms who were large in either of these dimensions were very likely to offer both ISDN and 56K. However, in both variables, the meaning of ‘‘large’’ is ambiguous. Firms with values higher than the mean involved between no more than 20% of the sample, with only a little overlap. That is, approximately a quarter of the sample is ‘‘large’’ with respect to BANDWIDTH or PORTS.

In contrast, ONECOUNTY is negative in both equations and significant for 56K. This shows that, geographically, small firms are less likely to offer higher speeds. However, the variable is of only moderate importance in the 56K* threshold, reducing the index by −0.15.

We now compare these findings with Augereau (1999) and Greenstein (2000). In Augereau, size also was an important factor in firm decision making, though that work examined standards choice, a very different type of decision. In Greenstein, firm-specific factors mattered but size was not measured as it is here. Moreover, in the previous study, the important firm-specific factors tended to be found disproportionately at ISPs located in urban areas. Here, while the measures of firm traits differ, the econometric pattern is similar. Here, firms in urban areas do have higher PORTS and BANDWIDTH than those in non-urban areas. For those entirely in urban areas the mean value of PORTS is 0.52 (S.D. 1.95) and for BANDWIDTH it is 8.02 (S.D. 13.85), while for those entirely in rural areas the mean values are 0.19 (S.D. 0.57) and 3.77 (S.D. 8.51).[12] More firms in urban areas have EXPERIENCE (0.46 versus 0.37), but there was no meaningful difference in number of counties. We will return to this theme below.

These estimates indicate the importance of investment and size primarily, with experience and geographic coverage secondarily. Upgrades are most likely done by ISPs who are older, have more capital equipment, and wider geographic reach. These type of firms tend to be found more often in urban areas than rural areas. This is consistent with the presence of some scale and scope economies between high speed access technologies, with the scope arising through technical training of personnel, investment costs or budgets for capital expenditures.

[12] MSA varies between zero and one. There are 1406 ISPs who only offer service in urban counties, 332 who only offer service in non-urban counties and 108 who are in multiple counties with a mix of urban/rural settings.

5.2. Location-specific factors

An URBAN environment is a good predictor of offering ISDN but not 56K, where it has no statistical significance. It is relatively large in the ISDN, reaching levels of 0.38. This arises either because competition is greater in urban areas or access to digital infrastructure is much easier in urban areas or particular types of users are found in urban areas. The asymmetric importance of URBAN (between ISDN and 56K) tends to reduce the plausibility of a simple demand or competition story. But why would high speed users want ISDN more than 56K? Similarly, why does more competition, if that is what exists in urban areas, induce adoption of ISDN more than 56K? It seems more plausible that this coefficient signals something else about the urban areas that differentially influences the supply of ISDN, but not the supply of 56K. Access to digital lines, digital switches and other digital infrastructure is one such explanation, since the infrastructure for ISDN and 56K differs. Dense urban areas tends to have a newer and more accessible telephony infrastructure, sometimes due to local and federal regulatory mandates.

RBOC and GTE are positive and significant predictors of both ISDN and 56K. The variables are relatively important in ISDN* with values of 0.33 and 0.32 and moderately important in 56K* with values of 0.21 and 0.14. Again, this probably is an indicator of competition (e.g., from either an RBOC or GTE) or infrastructure quality in the regions serviced by these large telephone firms (e.g., more digital switches and lines).

Interestingly, RBOC and GTE are distinctly different than the other measures of location. ISPs in RBOC regions tend to be urban and more competitive (i.e., MSA, THREENAT and THREELOCAL are all higher), while GTE regions are less so. Note, however, that GTE captures something that resembles RBOC in influence, which is distinct from MSA, THREENAT or THREELOCAL. Our findings are consistent with the view that the RBOCs and GTE offer better backbone services than independent telephone companies, making it easier for ISPs to experiment with high speed access.

Beyond the above, the other measures of competitiveness are inconsistent. THREENAT is positive and significant in the ISDN equation, signifying that the presence of national competition encourages ISPs to offer ISDN. THREELOCAL is positive and significant for 56K. Neither is more than moderately important and none of the other competitiveness measures matter. In other words, local competitiveness does not influence upgrade decisions.

The individual coefficients for the demographic variables of age vary significantly across particular categories of variables. FR22TO29 is a positive indication of offering ISDN and is the only age group which is significant in this equation. In the 56K equation, FR30TO39 is negative, a somewhat puzzling finding. Neither has much importance except at extremely high values. None of the other demographic factors matter, including the other age groups, nor the fraction of professionals.

Other measures of local demand also offer inconsistent findings. The fraction of households which use a PC regularly at work is a good predictor of an ISP adopting ISDN, but has no significance for 56K. As we expect to see the majority of ISDN use in the workplace this is in line with expectations. In contrast, the per capita use of large scale computers predicts 56K adoption, not ISDN, which does not have a ready interpretation. In both cases, the coefficients are not large enough to matter except in extremely high situations. Use of a PC in the home predicts nothing.

Universities have some effects on adoption behavior, but it is limited. UNIVERSITY1 is negative in both equations, so the presence of a research university deters an ISP's adoption of high speed technologies. This may be because students and faculty at these universities have access to high speed at work and do not need to pay for the same service at home. UNIVERSITY2 is positive for ISDN. In all cases, none of the coefficients are especially large.

In summary, urban biases in the geographic factors induce upgrades, especially to ISDN. ISPs in urban areas are more likely to face RBOC competition than those in rural areas (mean value for ISPs entirely in urban areas is 0.81 versus 0.34 for those entirely in rural areas). The difference in facing GTE is smaller and less relevant for most of the sample (0.09 versus 0.15). Measures of competition, THREENAT and THREE LOCAL — the former matters in ISDN and the latter in 56K — are also much higher in urban areas (respectively, 0.90 versus 0.23, and 0.96 versus 0.51). And, interestingly, the presence of universities, which is only of moderate importance and works mostly against diffusion, also favors urban areas. The means of UNIVERSITY1 are 0.53 for ISPs in urban areas and 0.08 for ISPs in rural areas (0.70 versus 0.14 for UNIVERSITY2 which is positive in ISDN).

6. Interpretation

This study investigated upgrade behavior at ISPs in 1997. The findings provide a window on the factors influencing the decisions to upgrade to the technological frontier. That said, it is a young market undergoing considerable technical change. We do not view the upgrade behavior in this study as the end of the evolution of this industry; rather, it is one episode of several technical episodes occurring at this time. It is also one of several which will occur over time as ISPs face new technical opportunities.

This industry tends to pride itself on the presence of many small firms and shoe-string operations, though it is widely recognized that the majority of customers go to several score larger firms (Maloff Group International, 1997). In that light, these results are provocative. The ISPs with the highest propensity to upgrade are the firms with more capital equipment and the firms with propitious locations. These factors do not influence the upgrade decisions of both 56K and ISDN to the same degree, but generally these do work in the same direction.

Infrastructure in a local area tends to encourage ISPs to adopt high speed access, but ISDN adoption is more sensitive to these factors than 56K adoption. That said, competitive conditions and other demographic factors have only limited importance and only in extreme circumstances for both adoption decisions.

These findings indicate that small operations upgrade less frequently than their larger and more widely used competitors. If these quality differences lead to severe competitive advantages, then this difference in upgrade behavior may foreshadow consolidation of provision or widespread exit of small firms sometime in the future. It may also foreshadow an inequality in the quality of supply between ISPs in high density and low density areas. In the extreme, such forces could result in bifurcation in size distribution of firms — large firms serve high density areas and small ISPs serve low density areas, if any serve those areas at all.

Overall, there are forces which may mitigate against such an extreme outcome. For example, we cannot conclude that firm-specific factors matter more than location-specific factors for both ISDN and 56K decisions. That is, though size and experience matter, an urban location with local competitive pressure and a major telephone company can have as much economic importance. Moreover, the firm-specific factors which favor upgrades tend to disproportionately influence ISPs located in urban areas. This suggests a pattern of initial development of these services in urban settings before their diffusion to non-urban settings. However, these findings also raise the question of why firms with particular traits tend to locate in urban areas in the first place. The open question is whether similar economic motives will arise later in non-urban areas. If so, then the geographic differences are temporary and non-urban areas will eventually ‘‘catch up.’’

This leads to one other interpretative challenge. Our findings show only a minor role for the local economic factors we associate with ‘‘demand,’’ such as the local demographics of business and households. These findings are consistent with two explanations. One is that we simply mis-measure demand, that its determinants are not manifest in county statistics. The other explanation is that cross-geographic heterogeneity in demanders actually does not matter much for upgrade behavior, i.e. that heterogeneity in a supplier’s economic incentives and outlook is more important. This latter interpretation is consistent with evolutionary approaches to understanding firm behavior in young industries where technical and commercial uncertainty cloud investment decisions (Nelson and Winter, 1982). In these models, decisions are initially determined by inherited business processes and other institutional constraints; i.e., some ISPs are simply more aggressive than others and possess a predilection towards such behavior. In these models the association of investment behavior with a cluster of other firms’ features, as we have found here, would not be so surprising.

These findings and interpretation also suggest further areas for investigation as this industry grows. It will be important to re-examine the micro-economic incentives for changing technical capabilities at an ISP. As of this writing, the next generation of broad-band technology, DSL and cable modems, has an unknown underlying economic determinant at the firm level, but it is presumably different than the logic for 56K and ISDN (e.g., Bailey, 2000). There are also wireless data technologies coming on line that may alter the comparative incentives to upgrade to new delivery systems at ISPs in low and high areas. How these new technologies alter the industry's structure, if at all, depends on how they shape the economic incentives to adopt at many locations at many ISPs.

Acknowledgements

We thank Oded Bizan, Tom Downes, Chris Forman, Neil Gandal, Paul Geroski, Jose Mata, and an anonymous referee for comments and suggestions. We thank the Kellogg Graduate School for research funding and Holly Gill for research assistance. All remaining errors are our own.

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