WHICH INDUSTRIES USE THE INTERNET?

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ABSTRACT

Our study provides an industrial census of the dispersion of Internet technology to commercial establishments in the United States. We distinguish between participation, that is, use of the Internet because it is necessary for all business (e.g. email and browsing) and enhancement, that is, adoption of Internet technology to enhance computing processes for competitive advantage (e.g. electronic commerce).

We find that participation and enhancement display contrasting patterns of dispersion. In a majority of industries, participation has approached saturation levels, while enhancement occurs at lower rates with dispersion reflecting long standing industrial differences in use of computing. In general, lead adopters were drawn from a variety of industries, including many of the same industries that lead adoption of other generations of information technologies; however, the appearance of water transportation and warehousing as leading industries in Internet adoption shows that the Internet influenced establishments where logistical processes played a key role. We find large differences across industries and we caution against inferring too much from the experience in manufacturing despite the widespread availability of data in that sector.

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INTRODUCTION

The commercialization of the Internet in the 1990s brought about a complementary surge in hardware and software spending. Commercial firms undertook most of this investment. In 2000, for example, total business investment in IT goods and services was almost triple the level for personal consumption of similar goods.[1]

We view the diffusion of the Internet to business in the context of observations about technological convergence (Ames & Rosenberg, 1984), which is the increasing use of a small number of technological functions for many different purposes. Bresnahan and Trajtenberg (1995) develop this further in their discussion of General Purpose Technologies (GPTs), which they define as capabilities whose adaptation raises the marginal returns to inventive activity in a wide variety of circumstances. GPTs involve high fixed costs in invention and low marginal costs in reproduction. A GPT is adapted for any new use, and this adaptation takes time, additional expense and further invention. Following the literature, we label these as *co-invention expenses*. Studies have found that co-invention influences computing and Internet technology investments by business users (Bresnahan & Greenstein, 1997; Forman, 2002).

Almost by definition, GPTs have a big impact if and when they diffuse widely, that is, if they raise the marginal productivity of a disparate set of activities in the economy. As a practical matter, "disparate" means a great number of applications and industries, performed in a great number of locations. What stands in the way of achieving wide and disparate diffusion? Barriers arise as a result of users facing different economic circumstances, such as differences in local output market conditions, quality of local infrastructure, labor market talent levels, quality of firm assets or competitive conditions in output markets. Simply put, these barriers are different co-invention expenses.

By 2000, the level of investment flows associated with the Internet was immense and so was the variance across industries. In some industries, the Internet has been adopted across all facets of economic activity, while in other industries adoption has not been widespread. This variance offers valuable clues about where and how the Internet brings value.[2] In this study, we provide a census of commercial Internet use. We offer evidence about the dispersion of the Internet across industries and other factors that shape co-invention expenses at the industrial level. Moreover, we investigate whether industry-level adoption propensity affects regional variation in adoption.

Specifically, we investigate data from a private survey of 86,879 establishments with over 100 employees, updated to the end of 2000. These establishments undertake the vast majority of investment in information infrastructure in the U.S. Harte Hanks Market Intelligence, a commercial market research firm that tracks use of Internet technology in business, undertook the survey. We employ the County Business Patterns data from the Census and routine statistical methods to generalize our results to cover all medium and large commercial establishments in the United States, the type of location employing approximately two-thirds of the workforce.

We analyze the adoption of the Internet in two distinct layers. In one layer – hereafter termed *participation* – adoption of Internet technology enables participation in the Internet network. Participation is affiliated with basic communications, such as email use, browsing and passive document sharing. It also represents our measure of "table stakes," namely, the minimal Internet investment required to do business (Porter, 2001). In the second layer – hereafter termed *enhancement* – adoption of Internet technology enhances business processes. Enhancement uses Internet technologies to change existing internal operations or to implement new services. It represents our measure of investment aimed at competitive advantage.

The results can be summarized into three main points:

- First, our results emphasize the presence of widespread dispersion and considerable heterogeneity in the use of Internet technology across industries. In a majority of industries participation has approached saturation levels. Enhancement is similarly widespread, but at lower rates. We find large differences in behavior between establishments in different industries, particularly for enhancement. While industry adoption rates in each layer are correlated, the overall diffusion patterns are distinct. Therefore we caution against inferring too much from the experience in any given industry, such as manufacturing, where there happens to be widespread availability of data.
- Second, dispersion of enhancement reflects long standing industrial differences in use of computing. In general, lead adopters were drawn from a variety of industries, including many of the same industries that were on the technical frontier during the evolution of previous generations of information technologies. However, the appearance of new leading industries such as such as water transportation and warehousing shows that the Internet influenced establishments where logistical processes played a key role.
- Third, similarities between establishments from the same industry suggest the possibility that the pre-existing industrial composition of a region will explain regional variation in adoption propensities. In particular, our results raise the possibilities that the type of industry found in major cities plays a key role in explaining the variance of adoption rates between cities, or between cities and low-density regions.

BACKGROUND

Our framework builds on micro-studies of Internet investment in commercial establishments and organizations.[3] It is motivated by the user-oriented emphasis in the literature on GPTs.[4]

General Purpose Technologies and the Commercialization of the Internet

There is no preset pattern for the dispersion of GPTs. They can diffuse in layers or waves (e.g. Lipsey, Becker & Carlaw, 1998). Below we argue that analysis of the dispersion of the Internet to commercial business requires analysis of distinct layers. We hypothesize that the co-invention costs of certain types of Internet investment were low, whereas other bottlenecks persistently produced high co-invention costs. When costs for some activities were low, adoption of these aspects of Internet technology became required to be in business. When the costs were higher and the benefits variable for other aspects, firms were more circumspect, investing only when it provided competitive advantage.

We ignore differences across applications and intensities of use within an establishment. We focus on two layers that vary across location and industry. We label these layers as *participation* and *enhancement*. Both layers of activity are important for economic advance, but each has distinct effects on industrial growth. We do not necessarily presume that the two are closely related, but intend to measure the correlation between them.

The first layer, participation, is a key policy variable. As noted, it represents a measure of "table stakes," the basic requirements for being at the table for medium and large businesses. By 2000, participation was regarded as a routine matter.[5]

The second layer, enhancement, is linked to the productive advance of firms and the economic growth of the regions in which these firms reside. It usually arrives as part of other intermediate goods, such as software, computing hardware, networking equipment or consulting services.[6]

Implementation of participation was rather straightforward by the late 1990s. It involved a PC, a modem, a contract with an Internet Service Provider and some appropriate software. Investment in enhancement, in contrast, was anything but routine during the latter half of the 1990s. Enhancement included technical challenges beyond the Internet's core technologies, such as security, privacy, and dynamic communication between browsers and servers. Organizational procedures usually also changed.[7] Benefits accrue to the business organization

employing enhancement through the addition of competitive advantage, but the co-invention costs and delays vary widely.

Why do Industries Differ?

Our thesis emphasizes the commonalities of investment behavior across industries, and how these differences between industries persist over time. It draws upon theories of general purpose technologies and co-invention, and is complemented by the work of computer industry historian, James Cortada (2003).

First, innovative IT rarely diffuses into an organization *tabula rasa*. Users face idiosyncratic co-invention costs based on variations in the installed base of hardware and software applications across firms and industries (Bresnahan & Greenstein, 1997). These variations shape the short run demand for innovative IT, as users rarely, if ever build IT infrastructure from scratch. Thus, adopters are incremental in their approach to investment, compromising between the benefits of frontier and the costs of keeping an existing process, picking and choosing among those new possibilities that make the most sense for their business. In particular, Forman (2002) showed that installed base of hardware and software applications played a major role in shaping organizations' early decisions to invest in the Internet.

Second, most innovative IT is directed toward automating functional activity or business processes within an organization, such as accounts receivable, inventory replenishment or point of sale tracking.[8] The activities that are essential for operating an organization have not changed over decades, even though the identities of firms have. In the language of economics, the list of functions that receive attention from one decade to the next is similar, whether or not the motive for adoption is "technology push" or "demand pull," and whether or not the same decision makers appear. Thus, if there is stability of the types of economic activity going on within organizations across different industries, then this stability shapes the demand for innovative IT, enhancing the same activities decade after decade.

Third, such investments have competitive consequences. Many models of diffusion and technology investment forecast there may be strong incentives to emulate rivals. This may be due either to competitive pressure (e.g. Porter, 2001), or knowledge spillovers within industries (e.g. Irwin & Klenow, 1994). Hence, most organizations examine other firms with functions similar to their own and enhance their own processes in similar manner. Both forms of benchmarking increase the incentives of lead firms to emulate other organizations in the same industry, either close competitors or those with similar supply chains.

This conceptual framing leads to two key implications. First, throughout several decades of change most investment is incremental. Both suppliers and vendors understand the conceptual problems and opportunities for augmentation in much the same terms. Each firm determines its priorities across activities, but firms in the same industry tend to come to similar conclusions about their priorities – because they employ the same processes, face the same range of costs, and because they compete with each other.

Second, innovation in IT is likely to lead to non-incremental change only when it involves "radical" change in products or production processes. In Cortada's view only three innovations have spurred such investments: the UPC code, EDI and the Internet. Cortada singles out the Internet because it altered the applications for many functions simultaneously, and consequently contained the possibility for dramatic re-coordination of multiple activities within an organization. He argued that this rearrangement of functions could lead to reorganization of supply chains in many specific markets.

More to the point, whether its effect is radical or incremental, pre-existing investment in IT should predict use of the Internet except where the Internet has devalued completely pre-existing activities. Firms that have invested in augmenting activities with IT in the past will continue to do so when the Internet becomes available. Large investors in the past will persist as large investors over time. Related, the emergence of lead users from industries that did not previously contain any lead users will also be indicative of radical departures from the past.

DATA AND METHOD

We will measure the dispersion of Internet technology across industries. Since there is no single way to measure dispersion, we will modify our analysis to the data available. Our research strategy involves identifying leaders and laggards, and comparing their features. Given that this study is the first to examine such data, our primary goal is to document and rank. Because we are interested in measuring the dispersion of Internet use across establishments from different industries rather than its evolution across time, an analysis of the cross-section data is sufficient for our purposes.

The data we use for this study come from the Harte Hanks Market Intelligence CI Technology database (hereafter CI database).[9] 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 Market Intelligence (hereafter HH) collects this information to resell as a tool for the marketing divisions at technology companies. Interview teams survey establishments throughout the calendar year; our sample contains the most current information as of December 2000.

HH tracks over 300,000 establishments in the United States. Since we focus on commercial Internet use, we exclude government establishments, military establishments and non-profit establishments, mostly in higher education. Our sample contains all commercial establishments from the CI database that contain over 100 employees, 115,671 establishments in all;[10] and HH provides one observation per establishment. We will use 86,879 of the observations with complete data generated between June 1998 and December 2000. We adopt a strategy of utilizing as many observations as possible, because we need many observations for thinly populated areas.[11] This necessitates routine adjustments of the data for the timing and type of the survey given by HH.

Data Description and Sample Construction

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

$$\frac{\text{Total \# of census establishments in location} - \text{NAICS}}{\text{Total \# of census establishments in location}} \times \frac{\text{Total \# of establishments in our data location}}{\text{Total \# of establishments in our data in location} - \text{NAICS}}$$

Therefore, each location-NAICS is given its weighting from its actual frequency in the census. In other words, if our data under-samples a given two-digit NAICS at a location relative to the census then each observation in that NAICS-location is given more importance.

Using two survey forms, HH surveyed establishments at different times. To adjust for differences in survey time and type, we econometrically estimate the relationship between an establishment's decision to participate or enhance as a function of its industry, location, timing of survey and form of survey. We then calculate predicted probabilities of adoption for each establishment *as if it were surveyed in the second half of 2000 and were given the long survey*. Once we weight by the true frequency of establishments in the population, we have information about establishments related to two-thirds of the U.S. workforce. The more observations we have for a given region or industry the more statistical confidence we have in the estimate.

Definitions of Behavior

Identifying participation was simple compared to identifying enhancement. We identify participation as behavior in which an establishment has basic Internet access or has made any type of frontier investment. Because the survey gives plenty of information on such activities, identifying participation was straightforward. In contrast, identifying the proper margin for complex enhancement activity was more difficult. We look for indications that an establishment must have made investments that involved frontier technologies or substantial co-invention. Thus, we identify enhancement from substantial investments in electronic commerce or "e-business" applications. We look for commitment to two or more of the following projects: Internet-based enterprise resource planning or TCP/IP-based applications in customer service, education, extranet, publications, purchasing or technical support.

In Table 1 we show the results of these definitions. Participation by establishments within the sample is at 80.7% (see Unweighted Average in Table 1). The sample under-represents adopters. Our estimate of the economy-wide distribution, using the true distribution of establishments from the Census, is 88.6% (see Weighted Average in Table 1). Enhancement has been undertaken by 11.2% of our sample and 12.6% of the true distribution. We also can estimate the rate of adoption by "experimenters," that is, those establishments with some indication of use, but not much. As one would expect for a technology still in the midst of diffusion, the proportion for experimenters (combined with enhancement) is considerably higher than for enhancement alone, reaching 18.1% for the unweighted average and 23.2% for the weighted average. We have explored this latter definition and

Table 1. National Internet Adoption Rates (In Percentages).

	Weighted Average (%)	Unweighted Average (%)	Northeast (%)	Midwest (%)	South (%)	West (%)
Participation	88.6	80.7	88.0	88.7	89.0	85.7
Enhancement	12.6	11.2	12.7	12.7	12.4	12.5
Enhancement & experimenting with enhancement	23.2	18.1	24.0	23.1	22.7	23.3

found that it tracks the enhancement definition we use below, so it provides no additional insight about the dispersion of use. We do not analyze it further.

LEADING INDUSTRIES

In Tables 2 and 3 we list the estimates for participation and enhancement organized by two-digit NAICS industry; we list industries in the order of highest to lowest adoption rates. We first show the results for all two-digit NAICS industries in the left half columns, and then break them into their three-digit NAICS industries in the right half columns. We identify leading and laggard industries. We also list the standard errors and number of observations.

Participation

Our first finding is quite apparent in Table 2 – participation is high in every industry, reaching over 92% – near saturation – in a majority of them. Of course, this is not a surprise after Table 1, since the average rate of participation was 88%. The striking feature in Table 2 is the skew of these results. Establishments in all but four two-digit NAICS industries are at 90% or higher. With rare exception, the Internet reaches everywhere. Participation clearly represents a low cost "table stakes."

The two major low outliers are the two components of retail trade, each at 80% adoption rates. Looking more closely at the NAICS three-digit industries in retail trade, we see there are a few outliers. These are (more narrowly) NAICS 452, general merchandising stores (69%); NAICS 447, gasoline stations (75%); NAICS 444, building materials and garden equipment and supply dealers (73.7%); and NAICS 445, food and beverage stores (72.1%), all of which contribute many observations to their respective NAICS two-digit category. NAICS 452 has some apparent non-response bias, so we believe these estimates are a lower bound.[12]

We conclude that participation is virtually ubiquitous in all establishments excepting – at worst – a few industries. This dispersion is consistent with the popular perception that: (1) adoption costs were low; (2) the Internet was available almost everywhere; (3) nearly every business experienced some benefit from adoption; (4) this diffusion saturated potential adopters sometime before the decline in Internet technology spending in 2001; and (5) the Internet became a necessity for U.S. business by the end of the millennium.

This is remarkable for a technology that is less than a decade old. To our knowledge, no major historical technology diffused this fast to such a disparate set of industries right after introduction – not electricity, telephony, the steam

Table 2. Participation by Industry.

Two-Digit NAICS	Two-Digit NAICS Adoption Rate (%)	Standard Error (%)	Two-Digit # Obs.	Three-Digit NAICS	Three-Digit NAICS Adoption Rate (%)	Standard Error (%)	Three-Digit # Obs.
51- Media, Telecommunications, & data processing	99.1	0.1	3181	511-Publishing industries	99.3	0.2	1475
				512-Motion picture & sound recording industries	90.3	1.0	129
				513-Broadcasting & telecommunications	99.2	0.2	1076
				514-Information & data processing services	98.0	0.4	501
22-Utilities	99.0	0.2	680	221-Utilities	99.0	0.2	680
54- Professional, scientific, & technical services	98.9	0.1	4556	541-Professional, scientific & technical services	98.9	0.1	4556
52- Finance & insurance	97.8	0.2	3933	522-Credit intermediation & related activities	96.9	0.4	1369
				523-Security, commodity contracts, etc.	96.3	0.4	503
				524-Insurance carriers & related activities	98.4	0.2	1707
				525-Funds, trusts, & other financial vehicles	86.1	0.6	74
33- Manuf. 3: metals, machinery, computers & electronics, appliances, transportation equipment, furniture, & other manufacturing	97.8	0.1	12679	331-Primary metal mfg	96.7	0.4	1019
				332-Fabricated metal product mfg	97.2	0.3	2257
				333-Machinery mfg	98.4	0.2	2575
				334-Computer & electronic product mfg	99.0	0.2	2026
				335-Electrical equip, appliance & component mfg	97.4	0.4	962
				336-Transportation equipment mfg	97.8	0.3	1825
				337-Furniture & related product mfg	94.3	0.6	912
				339-Miscellaneous mfg	97.8	0.3	1103
55- Mngmt of companies & enterprises	97.2	0.5	291	551-Management of companies & enterprises	97.2	0.5	291
32- Manuf. 2: wood, paper, printing, petroleum, chemical, plastics & rubber, non-metallic minerals	97.0	0.2	7161	321-Wood product mfg	94.6	0.5	964
				322-Paper mfg	96.5	0.4	1243
				323-Printing & related support activities	97.6	0.3	1030
				324-Petroleum & coal products mfg	92.7	0.8	213
				325-Chemical mfg	98.1	0.3	1440
				326-Plastics & rubber products mfg	97.0	0.3	1513
				327-Nonmetallic mineral product mfg	94.8	0.6	758
23-Construction	95.9	0.3	2518	233-Building, developing & general contracting	95.8	0.6	703
				234-Heavy construction	96.2	0.5	652
				235-Special trade contractors	94.7	0.5	1163
42- Wholesale trade	95.8	0.3	5197	421-Wholesale trade, durable goods	96.7	0.3	2814
				422-Wholesale trade, non-durable goods	94.7	0.4	2383
21-Mining	95.6	0.6	529	211-Oil & gas extraction	88.6	0.7	63
				212-Mining (except oil & gas)	92.7	1.0	269
				213-Mining support activities	96.5	0.9	197
62- Health care & social assistance	94.1	0.3	14506	621-Ambulatory health care services	96.5	0.3	2129
				622-Hospitals	97.5	0.2	4406
				623-Nursing & residential care facilities	91.1	0.4	6516
				624-Social assistance	93.7	0.5	1455
49- Transportation & warehousing2: couriers & warehousing	93.6	1.0	283	492-Couriers & messengers	92.9	1.2	127
				493-Warehousing & storage	94.0	1.3	156
71- Arts, entertainment, & recreation	93.6	0.5	1363	711-Performing arts, spectator sports, etc.	95.8	0.7	260
				713-Amusement, gambling & recreation industries	92.6	0.6	1103
56- Administrative & support & waste management & remediation services	92.9	0.5	2303	561-Administrative & support services	93.0	0.5	2078
				562-Waste management & remediation services	91.1	1.3	225
31- Manufacturing 1: food & textiles	92.7	0.4	4400	311-Food mfg	92.6	0.5	1983
				312-Beverage & tobacco product mfg	93.7	0.9	415
				313-Textile mills	91.6	0.8	612
				314-Textile product mills	93.8	0.8	368
				315-Apparel manufacturing	90.8	0.8	873
				316-Leather & allied product mfg	85.3	1.8	149
53- Real estate & rental & leasing	92.3	1.0	467	531-Real estate	94.8	0.7	480
				532-Rental & leasing services	86.1	1.3	256
				533-Lessors of other non-financial intangible assets	47.4	3.2	11
48- Transportation & warehousing1: transportation	92.0	0.5	2273	481-Air transportation	90.5	1.0	152
				482-Rail transportation	88.6	2.2	137
				483-Water transportation	76.8	1.1	40
				484-Truck transportation	90.2	0.9	856
				485-Transit & ground passenger transportation	86.7	1.2	509

Table 2. (*Continued*)

Two-Digit NAICS	Two-Digit NAICS Adoption Rate (%)	Standard Error (%)	Two-Digit # Obs.	Three-Digit NAICS	Three-Digit NAICS Adoption Rate (%)	Standard Error (%)	Three-Digit # Obs.
				486-Pipeline transportation	81.4	2.0	40
				487-Scenic & sightseeing transportation	75.8	0.6	28
				488-Transportation support activities	94.7	0.7	511
81- Other services (except public administration)	90.5	0.8	791	811-Repair & maintenance	92.3	0.9	321
				812-Personal & laundry services	87.3	1.2	470
72- Accommodation & food services	90.4	0.5	4775	721-Accommodation	97.0	0.2	3066
				722-Food services & drinking places	79.4	1.1	1709
44- Retail trade1: durables	80.1	0.7	9069	441-Motor vehicle & parts dealers	96.5	0.3	1892
				442-Furniture & home furnishing stores	88.6	1.5	184
				443-Electronics & appliance stores	96.0	0.6	421
				444-Bldg material & garden equip & supp dealers	73.7	1.7	675
				445-Food & beverage stores	72.1	0.9	5319
				446-Health & personal care stores	86.1	2.0	140
				447-Gasoline stations	75.0	3.3	109
				448-Clothing & clothing accessories stores	90.1	1.2	329
11-Agriculture, forestry, fishing & hunting	80.0	1.5	145	113-Forestry & logging	68.5	1.4	22
				114-Fishing, hunting & trapping	55.3	3.5	7
				115-Agriculture & forestry support activities	80.4	1.8	116
45- Retail trade2: non-durables	72.1	0.9	5767	451-Sporting goods, hobby, book & music stores	84.6	1.2	172
				452-General merchandise stores	69.0	1.0	5083
				453-Miscellaneous store retailers	90.0	1.2	278
				454-Nonstore retailers	88.9	1.1	234
61- Educational services	29.0	0.9	12	611-Educational services	29.0	0.9	12

Table 3. Enhancement by Industry.

Two-Digit NAICS	Two-Digit NAICS Adoption Rate (%)	Standard Error (%)	Two-Digit # Obs.	Three-Digit NAICS	Three-Digit NAICS Adoption Rate (%)	Standard Error (%)	Three-Digit # Obs.
55- Mngmt of companies & enterprises	27.9	2.7	291	551-Management of companies & enterprises	27.9	2.7	291
51- Media, telecommunications, & data processing	26.8	0.9	3181	511-Publishing industries	28.5	1.3	1475
				512-Motion picture & sound recording industries	24.6	3.7	129
				513-Broadcasting & telecommunications	21.7	1.3	1076
				514-Information & data processing services	33.0	2.2	501
22-Utilities	21.1	1.7	680	221-Utilities	21.1	1.7	680
52- Finance & insurance	19.9	0.7	3933	522-Credit intermediation & related activities	20.5	1.2	1369
				523-Security, commodity contracts, etc.	25.7	2.0	503
				524-Insurance carriers & related activities	18.8	1.0	1707
				525-Funds, trusts, & other financial vehicles	11.2	3.6	74
54- Professional, scientific, & technical Services	19.6	0.7	4556	541-Professional, scientific & technical services	19.6	0.7	4556
42- Wholesale trade	17.2	0.6	5197	421-Wholesale trade, durable goods	18.5	0.8	2814
				422-Wholesale trade, non-durable goods	15.5	0.8	2383
33- Manuf. 3: metals, machinery, computers & electronics, appliances, transportation equipment, furniture, & other manufacturing	15.7	0.4	12679	331-Primary metal mfg	16.0	1.2	1019
				332-Fabricated metal product mfg	13.6	0.8	2257
				333-Machinery mfg	13.9	0.8	2575
				334-Computer & electronic product mfg	23.5	1.0	2026
				335-Electrical equip, appliance & component mfg	15.6	1.3	962
				336-Transportation equipment mfg	14.4	0.9	1825
				337-Furniture & related product mfg	11.0	1.1	912
				339-Miscellaneous mfg	14.0	1.1	1103
53- Real estate & rental & leasing	15.6	1.8	467	531-Real estate	13.9	1.6	480
				532-Rental & leasing services	15.9	2.3	256
				533-Lessors of other non-financial intangible assets	14.4	6.9	11
49- Transportation & warehousing2: couriers & warehousing	15.5	2.2	283	492-Couriers & messengers	15.8	3.1	127
				493-Warehousing & storage	13.7	2.7	156

Table 3. (Continued)

Two-Digit NAICS	Two-Digit NAICS Adoption Rate (%)	Standard Error (%)	Two-Digit # Obs.	Three-Digit NAICS	Three-Digit NAICS Adoption Rate (%)	Standard Error (%)	Three-Digit # Obs.
32- Manuf. 2: wood, paper, printing, petroleum, chemical, plastics & rubber, non-metallic minerals	14.4	0.5	7161	321-Wood product mfg	11.6	1.1	964
				322-Paper mfg	15.8	1.1	1243
				323-Printing & related support activities	18.0	1.3	1030
				324-Petroleum & coal products mfg	16.0	2.5	213
				325-Chemical mfg	16.3	1.1	1440
				326-Plastics & rubber products mfg	12.0	0.9	1513
				327-Nonmetallic mineral product mfg	10.9	1.2	758
21-Mining	12.4	1.5	529	211-Oil & gas extraction	18.4	4.8	63
				212-Mining (except oil & gas)	9.9	1.9	269
				213-Mining support activities	12.6	2.5	197
48- Transportation & warehousing1: transportation	12.0	0.7	2273	481-Air transportation	12.4	2.7	152
				482-Rail transportation	12.4	3.0	137
				483-Water transportation	23.6	5.9	40
				484-Truck transportation	11.8	1.2	856
				485-Transit & ground passenger transportation	4.7	1.0	509
				486-Pipeline transportation	21.4	6.0	40
				487-Scenic & sightseeing transportation	12.2	5.5	28
				488-Transportation support activities	16.2	1.7	511
31- Manufacturing 1: food & textiles	11.5	0.6	4400	311-Food mfg	11.2	0.8	1983
				312-Beverage & tobacco product mfg	13.5	1.8	415
				313-Textile mills	8.1	1.2	612
				314-Textile product mills	12.1	1.8	368
				315-Apparel manufacturing	12.6	1.2	873
				316-Leather & allied product mfg	12.4	2.8	149
72- Accommodation & food services	11.2	0.5	4775	721-Accommodation	14.4	0.7	3066
				722-Food services & drinking places	5.6	0.6	1709
11-Agriculture, forestry, fishing & hunting	11.1	2.6	145	113-Forestry & logging	14.1	6.1	22
				114-Fishing, hunting & trapping	0.0	0.0	7
				115-Agriculture & forestry support activities	10.2	2.8	116
81- Other services (except public administration)	10.7	1.2	791	811-Repair & maintenance	14.1	2.0	321
				812-Personal & laundry services	8.2	1.4	470
56- Administrative & support & waste management & remediation services	10.6	0.7	2303	561-Administrative & support services	11.0	0.8	2078
				562-Waste management & remediation services	6.7	1.8	225
62- Health care & social assistance	9.8	0.3	14506	621-Ambulatory health care services	10.8	0.8	2129
				622-Hospitals	10.1	0.5	4406
				623-Nursing & residential care facilities	10.1	0.5	6516
				624-Social assistance	5.9	0.7	1455
44- Retail trade1 – durables	9.7	0.4	9069	441-Motor vehicle & parts dealers	20.5	1.1	1892
				442-Furniture & home furnishing stores	15.9	2.8	184
				443-Electronics & appliance stores	25.6	2.2	421
				444-Bldg material & garden equip & supp dealers	5.1	0.9	675
				445-Food & beverage stores	4.6	0.4	5319
				446-Health & personal care stores	10.7	2.7	140
				447-Gasoline stations	4.3	2.0	109
				448-Clothing & clothing accessories stores	16.2	2.1	329
71- Arts, entertainment, & recreation	9.6	0.9	1363	711-Performing arts, spectator sports, etc.	15.7	2.4	260
				713-Amusement, gambling & recreation industries	8.1	0.9	1103
23-Construction	9.4	0.6	2518	233-Building, developing & general contracting	8.7	1.1	703
				234-Heavy construction	12.8	1.4	652
				235-Special trade contractors	7.9	0.9	1163
45- Retail trade2 – non-durables	7.0	0.4	5767	451-Sporting goods, hobby, book & music stores	20.4	3.0	172
				452-General merchandise stores	5.3	0.4	5083
				453-Miscellaneous store retailers	14.6	2.2	278
				454-Nonstore retailers	21.2	2.7	234
61- Educational services	6.2	3.6	12	611-Educational services	6.2	3.6	12

engine, the automobile, or the calculator (Helpman, 1998; Rogers, 1995).[13] Only the modern fax machine comes close to having a parallel pattern, but that only occurred after decades of refinement of standards and other infrastructure, and multiple attempts to diffuse such a capability (Schmidt & Werle, 1998, Chap. 8).

More narrowly, the history of computing does offer some insight into why participation was rapid. To be sure, no previous major generations of IT hardware innovation diffused to business users this rapidly – not mainframes, general purpose mini-computers, or even PCs.[14] The closest historical analogue lies in software applications, which industry wisdom suggests diffuse quickly when installation costs are low and benefits high. More formally, this can be interpreted as applications with large benefits but without large *initial* co-invention costs. In this sense, the diffusion of email and the browser are similar to the diffusion of the spread sheet (i.e. Visicalc and Lotus 1–2–3), second-generation word-processing (i.e. Word Perfect), electronic financial planning (i.e. Quicken), and many other office software applications.

The emphasis on *initial* co-invention costs is important, because many historical IT innovations came in waves, with one generation of innovation building on the adoption decisions of a previous wave (see Bresnahan & Greenstein, 2000, for one such view). Further modifications of basic Internet use – such as e-commerce – may require coordinating multiple users within the same establishment or across establishments. These co-invention costs can be high if the organizations involved have complex processes or idiosyncratic needs.

In our sample, investments in such innovations are likely to appear in our measurement of enhancement. We expect, therefore, that the adoption of enhancement will not be as widespread as participation, but positively correlated.

Enhancement

In Table 3, we provide the estimates for adoption of enhancement. The lead adopters exceed adoption rates of 25%. These are NAICS 55, management of companies and enterprises (27.9%), and NAICS 51, media, telecommunications and data processing (26.8%). These two industries are not statistically different from each other, but they are statistically higher than all other NAICS 2 industries.

These first two lead user industries are very different. NAICS 55 represents the financial side of the Internet revolution. It includes corporate headquarters for multidivisional firms, securities firms and financial holding companies. NAICS 51 includes publishing firms, thus representing the change the Internet brings to media. It also includes information and data processing services (NAICS 514), an industry that includes firms like America Online and other Internet access

providers. This variety at the top is not a surprise, as the business press has largely described the wide impact of this technology's diffusion. The Internet has been used in a variety of industries to create competitive advantage. However, our results confirm the varied impact of the diffusion of Internet technology – a theme that we will repeat as we look further down the table.

The second tier of lead users again includes a wide mix from two-digit industries, such as finance and insurance, professional and scientific services, utilities, and wholesale trade. These latter two industries include heavy users of sophisticated applications combining database software with communication technologies. The third tier of enhancement adopters includes NAICS 32 and 33, which together cover over 80% of manufacturing. Within this group a few notable lead industries at the NAICS three-digit level are NAICS 334, computer and electronic manufacturing (23.5%), NAICS 323, printing and related support activities (18.%), and NAICS 211, oil and gas extraction (18.4%). These are all long-time lead users in computing, but for very different reasons. Other lead users at the three-digit level include NAICS 483, water transportation (23.6%); NAICS 486, pipelines (21.4%); NAICS 441, motor vehicle and parts dealers (20.5%); NAICS 443, electronics and appliance stores (25.6%); NAICS 451, sporting goods (20.4%); and NAICS 454, non-store retailers (21.2%). These last four are leaders in consumer e-commerce.

Low adopters (under 6% adoption) at the NAICS three-digit level do not surprise us, nor should it surprise any long-time observer of computing. These include transit and ground passenger transportation (NAICS 485, 4.7%), food services and drinking places (NAICS 722, 5.6%), social assistance (NAICS 624, 5.9%), and amusement (NAICS 713, 8.1%).

Industry and Location

Table 4 shows that MSAs with more than one million people are nearly 50% more likely to adopt enhancement than MSAs with less than 250,000 people. We argue that industry composition is one possible explanation for this disparity. For a variety of reasons, industries tend to cluster in the same locations (e.g. Krugman, 1991; Marshall, 1920). The substantial differences across industries in the propensity to adopt frontier Internet technologies suggests that geographic variation in the propensity to adopt may simply be a function of pre-existing industrial composition.

Table 4 shows that large MSAs have a larger percentage of establishments in leading industries, and they have a relatively low proportion of retailers, a laggard industry. Table 5 provides further evidence for this. For large, medium, and small MSAs, the ten leading MSAs for enhancement adoption have a much

Table 4. Percentage of Establishments in Top Quartile Industry for Enhancement, by Size of MSA.

Population	Average Enhancement (%)	Percentage of Establishments in Top Quartile Industries (%)	Percentage of Establishments in Top Quartile of Non-retail Adopters (%)	Percentage of Establishments that are Retailing (%)	No. of Areas
>1 Million	14.7	27.5	32.1	14.3	57
250,000–1 Million	11.2	19.5	23.5	16.7	116
<250,000	9.9	19.0	23.3	18.3	143

larger percentage of establishment in leading industries than do the bottom ten MSAs.

These results suggest that industrial composition plays a role in regional variation in adoption propensity. In Forman, Goldfarb and Greenstein (2003), we provide more conclusive evidence of the relative importance of industry and location, relying on estimates of marginal effects. Nevertheless, the average effects presented in Tables 4 and 5 strongly suggest that industrial composition plays an important role in regional variation.

Comparison with Others' Findings

We compared our findings against two other recent studies of Internet technology use and against a summary of historical adoption.

First, we compared our estimates with Census estimates for 1999 on the use of networking by manufacturing plants, as reported in Atrostic and Gates (2001). This data was compiled from 40,000 surveys of large and small plants. The large plants in their samples and ours largely overlap; but their sample contains

Table 5. Leading Adopters of Enhancement Among MSAs With Over One Million in Population.

MSA	Adoption Rate (%)	% Establishments in Top Quartile
Average of top ten large MSAs	16.5	26.6
Average of bottom ten large MSAs	10.7	21.7
Average of top ten medium MSAs	17.9	24.4
Average of bottom ten medium MSAs	4.4	16.3
Average of top ten small MSAs	18.0	16.4
Average of bottom ten small MSAs	2.1	11.1

plants with fewer than 100 employees and ours does not. Atrostic and Gates focus primarily on three measures of networking and business process adoption: percentage of firms that use networks; percentage of employees that use networks; and percentage of plants with fully integrated enterprise software.

We find that our data and theirs give a similar picture, though not an identical one. Despite differences in sampling frame, our estimate of enhancement is close to theirs for adoption of networking and enterprise software (correlation coefficients for NAICS three-digit manufacturing industries is 0.40 and 0.48). Not surprisingly, their question about employee use of networking is less correlated with our estimate (0.18). We conclude that our measure partially overlaps with the Census results because we both measure similar phenomena. But we also conclude that our measure captures something distinct beyond just networking.

Second, we also compared our estimates with Bureau of Economic Analysis (BEA) data on communications and capital service flows per industry, as used by Stiroh (2002b). Although the BEA data uses Standard Industrial Classification (SIC) codes rather than NAICS codes, we were able to match forty-three industry categories. We found that investment in computers and communication is positively but weakly correlated with both participation ($\rho = 0.121$) and enhancement ($\rho = 0.080$). This weak correlation is not surprising since the two series use different units, which are not very comparable. Our estimates measure enhancement adoption per establishment in an industry, whereas the BEA numbers measure dollars for all firms in an industry.

The Spearman Rank Coefficient eliminates this mismatch of unit scale and, accordingly, is much higher and statistically significant for both participation and enhancement (respectively 0.37 and 0.34). In other words, Internet technology-intensive industries tend to be those where a high fraction of establishments are adopting the Internet for enhancement, but one should take care in translating industry leadership into dollar differences in investment. Information technology investment involves a wide array of activities, not just the Internet. A ranking of extensive involvement of many establishments in Internet technology, which is what we measure, need not correlate perfectly with a ranking of dollar investment in all information technology, which is what BEA measures.[15]

Finally, we compared our list of lead industries with similar lists from more than two decades ago.[16] The list of "leading" computer users in the late 1970s to early 1980s remains on our list of medium to large adopters. Cortada (1996) lists lead industries as banking and finance, utilities, electronic equipment, insurance, motor vehicles, petroleum refining, petroleum pipeline transport, printing and publishing, pulp and paper, railroads, steel, telephone communications and tires. We find that these are lead industries in our data too.

However, wholesale trade is a low user, so too is water transportation. How did these industries change status in two decades? In short, these industries include many establishments that use communications to enhance logistical operations, which was difficult to do electronically more than two decades ago. Aside from this exception, his list of laggards also corresponds with our list.

We conclude that the industrial identities of the leading and lagging users of the new economy are a lot like leading and lagging users in the old computing economy, even if the names of the firms in the lead role has changed. This also opens questions about why the costs and benefits of innovative information technology have not changed much in decades.

Industry Investment in Broader Perspective

Our findings lead us to four broad lessons. First, we find Internet technology use is widespread, both at simple and complex levels of investment. We find that Internet technology producers (as well as their distributors) are frequent adopters. This echoes a finding that information technology and electronics manufacturers are intensive users of computing and communications as inputs (e.g. Stiroh, 2002a). However, there are two differences: Manufacturers and *distributors* of electronics both are lead adopters. Moreover, these establishments are far from being the *only* lead adopters. They are two among a crowd. Consequently, we warn strongly against the conclusion that principal benefits to the large investment in IT in the late 1990s largely accrued to only IT-producing industries.

Second, the composition of this distribution has old as well as new information to investigate. There are the familiar lead industries from information service industries, scientific and technical industries, and finance, insurance and real estate. The flip side of the coin is similar: Most laggard industries (i.e. infrequent computing and computer adopters two decades ago) did not suddenly become Internet-intensive. The exceptions are informative about the nature of building competitive advantage using Internet technologies. The appearance of water transportation and warehousing as lead industries shows that the Internet influenced establishments where logistical processes played a key role.[17] At the same time, it confirms our hypothesis that there is durability in the factors shaping the dispersion of innovation information technology across industry.

Third, our findings warn against inferring too much from the experience in manufacturing. The Census collected a lot of detail about manufacturing, but its establishments are medium to high adopters, neither leaders nor laggards. Establishments in other industries are outside this picture. Finance and media have many more lead adopters – as a fraction of total establishments within each sector – and possibly a very different set of applications.

Fourth and finally, these estimates foreshadow further findings about the geographic distribution of enhancement (Forman, Goldfarb & Greenstein, 2003). First, participation is almost at saturation, so the same will have to be true across most locations – simply for the sake of statistical consistency. It is also well known that some lead industries in enhancement, such as corporate headquarters and financial firms, disproportionately locate establishments in dense urban settings. That said, there are many industries from disparate settings that are close to these leaders. If the location of establishments from these industries does not overlap much (and they will not), then adoption will disperse widely across locations.

CONCLUSIONS

The diffusion of the Internet to commercial establishments did not occur in one layer. Adoption patterns for participation and enhancement are distinct. Adoption of participation approached saturation levels by the end of 2000, while enhancement was adopted much less frequently. For participation, and especially for enhancement, there is wide variation in the propensity to adopt across industries. Leading industries are similar to previous information technology leaders with the addition of fields with high logistical demands such as pipelines and warehousing. This variation influences the variation in average adoption propensities across geographic areas.

Distinguishing between different layers of Internet technology is essential to understanding the diffusion process. While participation diffused widely and rapidly, enhancement did not. Adoption of the two technologies is only weakly correlated across industries.

Participation and enhancement each provide distinct strategic and productivity benefits to private firms, and each should be the focus of distinct economic policies. The economic transactions associated with participation diffused quickly. As of late 2000 there was not much room left for growth. Its diffusion both took advantage of existing capital and motivated additional expenditure on software, hardware and networking service. In addition, the dispersion associated with participation became table stakes for most firms, a necessity for doing business. We conclude that if there was an economic benefit to GDP as a result of participation, it was a one-time benefit affiliated with outfitting establishments with the equipment to support participating in email and browsing.

Enhancement diffused less widely and its diffusion may be far from over. As opposed to participation, enhancement was optional – motivated by the development of competitive advantage – and it had variable benefits and co-invention costs. There are strong hints in our results that the incidence of these costs and benefits fell primarily on traditionally intensive users of computers. If there is an economic benefit to GDP as a result of enhancement, these benefits were widely dispersed, but dependent on industry. There is still a large possibility that the economic gains will occur in the future. This conclusion also varies with standard approaches to measuring productivity from investment in information technology, where prevailing research makes no allowance for the composition of capital, nor its motivation.

Finally, while we found GPT theory useful for formulating our measurement framework, we relied on the principle that dispersion should reflect economic constraints that foster different behavior across industry and location. These constraints are necessarily localized in contemporary experience. Therefore, we speculate that historical comparisons of the dispersion of the Internet with the dispersion of other GPTs are apt to be badly posed unless the comparisons are heavily qualified. It is misleading to compare the diffusion of the Internet with agricultural improvements, the railroad, electrical networks, telegraph, telephone or PC without accounting for the unique factors that shape co-invention costs and produce dispersion in each episode. Although aspects of similar economic issues arise in historical cases, the Internet's combination of economic motives, speeds, and environments has no precise historical precedent.

The high adoption propensities in some regions are not necessarily a consequence of region-specific spillovers and benefits to adoption. We have shown that they are partly a consequence of pre-existing industrial composition. The speed of the diffusion of the Internet means that firms did not have time to relocate in response to the new technology. The high levels of enhancement in some industries such as computer manufacturing, imply that regions with a large number of establishments in these industries such as Silicon Valley, will have high levels of adoption. In Forman, Goldfarb and Greenstein (2003) we separately identify the relative importance of industry and location through analysis of marginal effects.

In this study we focus on aggregate trends in the dispersion of Internet technology. But this represents only the beginning of uses for such data. Our conclusion begs the question of why some industries use Internet technology more intensively. We show that the identities of leading industries tended to be the same over decades, and we did offer the outline an explanation for this phenomenon. But our explanation begs further questions. What does the persistence of IT use within an industry say about the strategic benefits to using the Internet and the co-inventive expenses during this GPT's diffusion in comparison to those of the past?

We also did not address questions about the distribution of costs and benefits within an industry. To do so, we would need information about the micro-determinants of adoption among the medium- to large-scale firms in our sample. Do co-invention costs differ between single- and multi-establishment organizations? Between different applications of enhancement? What part of co-invention costs are attributable to local economic factors and what parts are attributable to costs imposed by competition between establishments from similar industries? Forman (2002) offers a framework for addressing these questions using microlevel data, which is a step in the right direction.

We also did not measure a third of all employment, namely, small commercial establishments of less than 100 employees. We conjecture that these establishments follow similar patterns in participation and different patterns in enhancement, but this is an open question.

Finally, our study also raises questions about the regional distribution of the economic impact from the use of the Internet. How did local and industrial applications influence the intensity of use of information technology? To what extent can state and local development policies foster a positive environment for lowering these costs? There is room for much economic research applying the estimates in our study to models of regional growth.

NOTES

1. For 2000 estimated personal consumption of IT goods and services was $165 billion. For business it was $466 billion. See Henry and Dalton (2002).
2. For example, see Oliner and Sichel (2000), Brynjolfsson and Hitt (2000), Baily and Lawrence (2001), Litan and Rivlin (2001), Henry and Dalton (2002), and the brief survey in Jalava and Pohjola (2002).
3. See e.g. Forman (2002), Jones, Kato and Pliskin (2002), Gertner and Stillman (2001), Carlton and Chevalier (2001), Tan and Teo (1998).
4. See e.g. Bresnahan and Trajtenberg (1995), Bresnahan and Greenstein (2000), Helpman (1998).
5. Examples of participation include browsing and posting text-based web pages, advertising on the World Wide Web (WWW), WWW browsing, and a basic intranet.
6. Careful readers will notice that this varies from the definitions employed by Porter (2001). This is due to a difference in research goals. Throughout his article, Porter discusses the determinants of, and shifting boundaries between, investments that provided table stakes and those that complement a firm's strategy and enhance competitive advantage. He argues that these levels vary by industry and differ from firm to firm. This is the proper variance to emphasize when advising managers about their firm's strategic investment. However, when *measuring* this variance for purposes of formulating policy advice it is useful to shift focus. Our measurement goals require both a standardized definition (of something of interest for policy, but consistent with the spirit of strategy research) and a consistent application across industries and locations.
7. See for example, Malone, Yates and Benjamin (1987), Hubbard (2000), Hitt and Brynjolfsson (1997), or Bresnahan, Brynjolfsson and Hitt (2002).

8. The investor in IT seeks the same process at lower cost or the same process at the same cost and with improved features – such as lower error rates, more timely supply of inventory, or better real-time decision support for firms in rapidly changing market environments. For our purposes it is not relevant whether this conceptual framing resembles economic models of labor saving or capital deepening/augmenting innovation. In any case, Cortada (2003) argues that the appropriate model varies between industries and even within industries over different eras.

9. This section provides an overview of our methodology. For a more detailed discussion, see Forman, Goldfarb and Greenstein (2002).

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

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

12. This was particularly apparent in underreporting of IT usage by Walmart. That said, this non-response bias cannot fully explain why retailing is lower than other industries. For example, if all of Walmart's establishments answered in the affirmative to participating in the Internet, then the estimate for general merchandising would increase from 36 to 60%.

13. Speed is usually associated with an incremental technical advance aimed at a narrow set of adopters, such as the replacement of iron by steel rails, of steam by diesel engines, of black and white by color broadcasting, and so on. Even so, these canonical innovations did not diffuse to all potential adopters in less than a decade.

14. The PC comes closest. The commercial PC began gestating in the early mid-1970s and did not diffuse to a majority of businesses until well into the mid-1980s. The commercial Internet became available around 1992 and was nearly ubiquitous by 2000, the time of our survey.

15. We also experimented with separating communications and computing, following Stiroh (2002a, b). The results are qualitatively similar. The rank correlation between communications and enhancement is mildly lower. There is a high rank correlation between computing and participation that is mildly higher.

16. Our estimates cannot be directly compared against another historical study of lead users, Bresnahan and Greenstein (1997). That study examines the diffusion of client-server technology to former mainframe users in the early 1990s. First, the Bresnahan and Greenstein study concerns mainframe users, and it over-samples some industries relative to this population. Second, the results highlight the role of co-invention costs, which overwhelmed the benefits of adjusting at many traditional information-intensive users. This prevented or slowed down adoption of new technology on a large scale in many industries, except those with scientific or engineering users. In contrast, after several years of the diffusion of the Internet, the benefits were large enough to induce new investment activity in virtually every industry. See Forman (2002) for a discussion of co-invention costs in Internet technology when it first diffused.

17. Their appearance is also echoed in recent surveys of IT capital investment across industries. See, for example, Triplett and Bosworth (2003).

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VALUING INTERNET RETAILERS: AMAZON AND BARNES AND NOBLE

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ABSTRACT

Many Internet retailers must raise margins in the future if they are to survive. This raises the important issues of whether they will be able to raise margins as well as how valuation estimates made today should evaluate projected changes to margins in the future. In this paper, we describe retail strategies of pricing for market share in growing markets and show how measures of the price elasticity of demand facing retailers in the current year can be combined with standard accounting variables to inform calculations about future margins. Our analysis suggests that the capital market projects greater future margin improvements for Amazon.com than for BN.com and that this may be due to Amazon benefiting from network effects.

1. INTRODUCTION

In this paper, we show that measuring the elasticity of demand facing a company can provide important insights into each company's expected future profitability and that this information is not completely captured in standard accounting approaches. In our empirical example, we examine the future prospects of Amazon.com and BN.com and we do so using only publicly available data. While publicly available, these data have not been incorporated into previous valuation strategies.

Many researchers and analysts have considered the question of how to value companies for which current financials are poor indicators of future prospects

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