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Martin Campbell-Kelly, Daniel D. Garcia-Swartz

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Martin Campbell-Kelly
University of Warwick

Daniel D. Garcia-Swartz
LECG LLC

The history of the computer time-sharing industry is one of the unwritten chapters in the overall history of computing. In this article, we show that the time-sharing industry constituted a major sector of the computer services industry until the early 1980s, when time-sharing was made obsolescent by the personal computer.

Time-sharing is in danger of being one of the lost episodes of the history of computing, overshadowed by popular interest in the history of the personal computer. Time-sharing flourished for nearly 20 years, from the mid-1960s to the early 1980s. As we will show, during this period it was a truly significant sector of the computer industry.

Time-sharing developed in the mainframe era. A time-sharing system consisted of a large central computer to which many terminals were connected. One terminal served one user, providing a computing experience comparable to an early personal computer, at least 15 years before PCs were routinely available. At the heart of time-sharing was an operating system that divided the computer's resources among users, so that each user had the illusion that he or she was the sole person on the machine. The market for time-sharing existed because it was the only means at that time of providing a personal computing experience at a reasonable cost.

Such history of time-sharing as exists focuses on its invention, its rapid growth, and how it faltered during the computer recession of 1970–1971.[1] Much less recognized is the fact that time-sharing recovered after the computer recession, and survived well into the 1980s.

The first, experimental time-sharing system—the Compatible Time Sharing System—was demonstrated at the Massachusetts Institute of Technology in November 1961.[2] During 1962–1963, MIT used $3 million funding from the Advanced Research Projects Agency to build a major time-sharing service, Project MAC, which served 30 simultaneous users—the facilities included problem solving using conventional programming languages and library programs for activities such as text processing and statistical analysis. Project MAC attracted considerable publicity in an era when computers were not much in the public eye.[3] In its next time-sharing venture, MIT—and its industrial partners Bell Labs and General Electric—overreached with the Multics system, which was intended to support several hundred simultaneous users.[4] Primarily due to problems with the operating system, Multics was one of the software disasters of its era. Simultaneously with the rise of time-sharing came the "computer utility" concept. The idea of a computer utility was that just as firms no longer owned their own generating plant but drew power from an electric utility, the day would come when companies would no longer own computers but would obtain computing power from a computer utility. Once this infrastructure was in place, it was argued, all kinds of markets and applications would open up, including domestic usage.[5] The rhetoric was remarkably like that of the Internet's early years, except that the predictions never came to pass.

In the history of time-sharing, the focus on early set-piece projects, the computer utility

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Table 1. Revenues from computer systems: value shipped (VS) and value in use (VU).

Year	GP VS ($B)	GP VU ($B)	Mini VS ($B)	Mini VU ($B)	Total VS ($B)
1955	0.063	0.180	—	—	0.063
1956	0.152	0.320	0.003	0.003	0.155
1957	0.235	0.540	0.010	0.012	0.245
1958	0.381	0.900	0.014	0.025	0.395
1959	0.475	1.340	0.020	0.045	0.495
1960	0.560	1.865	0.030	0.075	0.590
1961	0.850	2.605	0.030	0.105	0.880
1962	1.060	3.485	0.030	0.135	1.090
1963	1.220	4.550	0.080	0.210	1.300
1964	1.570	6.000	0.100	0.300	1.670
1965	1.910	7.800	0.150	0.434	2.060

Source: Phister, *Data Processing,* Table II.1.20, pp. 243–245.

hyperbole, and the Multics debacle have diverted attention from the many commercial systems that followed in their wake. The most important commercial provider was the Information Systems division of General Electric, which operated the first commercial service.[6] The GE service was based on the Dartmouth Time Sharing System (DTSS) developed by John Kemeny and Thomas Kurtz at Dartmouth College in 1963–1964.[7] DTSS supported up to 30 simultaneous users with a configuration that consisted of a standard GE 235 mainframe and a Datanet 30 communications processor. GE launched the GE 265 service in Schenectady, New York, in 1965 and eventually rolled out some 50 systems in the US, Europe, and Japan.

In the late 1960s, time-sharing was one of the hot computer markets. The dominant firms were GE Information Systems (GEIS) and SBC (the Service Bureau Corporation subsidiary of IBM, acquired by CDC in 1973). But scores of other firms offered time-sharing services, typically based on the standard offerings of manufacturers such as DEC or SDS. By 1970 there were some 100 firms in the market. At this point, the history of time-sharing gets progressively fuzzier. There is a popular conception that, following the 1970–1971 computer recession, the industry staggered on for a few years before fading into obscurity. In this article, we will show that this is not what happened: rather, the industry recovered and then grew prodigiously without interruption for more than a decade until the PC put it out of business.

In this article, we seek to complement the existing histories of time-sharing by considering the industry as a whole, over the entirety of its existence. We will not discuss individual firms, except insofar as they illustrate general trends.[8]

Computer systems and computer services

In the decade prior to the beginning of the commercial time-sharing industry (1955–1965), the computer industry in the US grew at a frantic pace (see Table 1). The value of shipments of the big, general-purpose (GP) computer systems grew, in nominal terms, from $0.063 billion in 1955 to $1.910 billion in 1965, at an annual compound rate of roughly 41 percent.[9] The value of shipments of smaller computers (later called ''Mini'' systems) grew from $0.003 billion in 1956 to $0.150 billion in 1965, at an annual compound rate of roughly 48 percent.[10] The value of total annual computer-system shipments thus grew from $0.063 billion in 1955 to $2.060 billion in 1965.[11]

The annual-shipment revenue figures give us an idea of the value of the flow of new computers entering the market every year. The value-in-use figures, on the other hand, convey an idea of the value of the stock of computers in use. The value of the general-purpose computer equipment in use in the US grew, in nominal terms, from $0.180 billion in 1955 to $7.80 billion in 1965, at an annual rate of 46 percent.[12] The value of the stock of ''mini'' systems grew from $0.003 billion in 1956 to $0.434 billion in 1965, at an annual rate of 74 percent.[11]

Revenue figures are, of course, a combination of quantities and prices, and they tend to hide some important underlying trends. Table 2 shows the number and average value of US computer shipments. The number of general-purpose systems shipped annually

Table 2. Number of systems shipped (SS), number of systems in use (SU), and average value of systems shipped (AVS): general-purpose systems (GP) and mini systems.

Year	GP SS (K)	GP SU (K)	Mini SS (K)	Mini SU (K)	GP AVS ($K)	Mini AVS ($K)
1955	0.150	0.240	—	—	420.00	
1956	0.500	0.700	0.050	0.050	304.00	50.00
1957	0.660	1.260	0.190	0.240	356.00	50.00
1958	0.970	2.100	0.210	0.450	393.00	67.00
1959	1.150	3.110	0.250	0.700	413.00	80.00
1960	1.500	4.400	0.300	1.000	373.00	100.00
1961	2.300	6.150	0.400	1.400	370.00	75.00
1962	3.100	8.100	0.400	1.800	342.00	75.00
1963	3.800	11.700	0.400	2.100	321.00	200.00
1964	5.100	16.700	0.500	2.500	308.00	200.00
1965	5.300	21.600	0.800	3.100	360.00	188.00

Source: Phister, *Data Processing,* Table II.1.21, p. 251.

grew from about 150 in 1955 to about 5,300 in 1965, and the number in use increased from about 240 to about 21,600 over the same time period. The number of "mini" systems shipped annually rose from nothing in 1955 to about 800 in 1965, and the number in use increased from zero to 3,100 over the same period. In the meantime, the average value of the general-purpose systems shipped declined, in nominal terms, from about $420,000 in 1955 to about $360,000 in 1965, and the average value of "mini" systems shipped increased from about $50,000 at the starting point (1956) to about $188,000 in 1965.[13]

What were the options for businesses that wanted to get access to computing power in 1965? First, there was the decision to lease or buy. The 1956 Consent Degree forced IBM to allow its customers either to purchase or lease computers from IBM, although a great majority chose to lease, either from IBM or from a leasing company such as Greyhound. After 1956 IBM leased computers to businesses on a monthly basis. The leasing companies that appeared in the mid-1960s offered more options to customers—businesses could still lease on a monthly basis but they could also lease for a longer period, typically between two and five years, likely at a substantial discount over the monthly rental. IBM did not start with longer leases until 1971, when it offered customers an 8-16 percent discount for choosing a one- or two-year lease instead of a monthly rental.[14]

Of course, businesses also had the option not to buy or lease a system at all. They could hire a data processing service company to either use the raw power of a central computer or have the company perform scientific or business calculations for them, and thereby avoid the cost and risk of computer acquisition. The time-sharing industry developed as part of this larger phenomenon, and to this we now turn our attention.

The time-sharing concept and practice were born in academia. Very soon, however, commercial firms proliferated with the hope that they would be able to make money from computer time-sharing. Commercial time-sharing services developed as part of a larger phenomenon, the so-called data processing service industry.[15] This industry had several components. First, there was the industry's so-called batch data processing component. Batch data processing services had been around roughly since 1955—companies received raw data from customers via mail or messenger, processed the data according to the customers' requests, and then delivered the processed data through the same channels. Second, there was the industry's online component. It developed rapidly in the 1960s in parallel with the progress of computer and communication technologies—here customers achieved access to computing power via communication lines and terminals rather than via mail and messenger. The remaining components of the data processing services industry included software (both programming services and products) and facilities management. Here, we are primarily concerned with the time-sharing component of the industry's online services sector.

The data processing industry's online sector had two subsectors. First, there was the online

remote batch component. Remote-batch terminals usually had a card reader and a line printer, and allowed customers to submit jobs and obtain results through those peripheral devices. Second, there was the interactive online component, also known as the conversational or the time-sharing component. In this case customers interacted with a central computer via teletypes or visual display units. Interactive time-sharing was the most direct ancestor of today's Internet.

By 1971, the data processing service companies were generating nominal revenues on the order of $2.085 billion, of which pure data processing constituted $1.525 billion (see Table 3). Of the pure data processing amount, the batch (i.e., messenger/mail) component accounted for roughly 70.5 percent, the online remote-batch component accounted for about 7.5 percent, and the online interactive component accounted for the remaining 22 percent. In other words, the interactive (or time-sharing) component was significantly larger than the online batch component, but considerably smaller than the more traditional mail/messenger batch dimension of the industry.[16]

The industry grew and changed dramatically in the 1970s. By 1978, the data processing service industry generated nominal revenues of about $7.685 billion. Of these, $4.915 billion came from pure data processing. Of the pure data processing amount, mail/messenger batch processing accounted for 43 percent, remote batch processing accounted for 22 percent, and online interactive processing accounted for 35 percent. In other words, in the 1970s the overall online component grew much faster than the mail/messenger batch component. In fact, at the end of the decade the combined online batch and interactive components made up a larger portion of revenues than the traditional batch component. Furthermore, the interactive component alone had become roughly 83 percent as large as the traditional batch component.[17]

We can develop a deeper understanding of these trends if we look at these figures in light of the overall evolution of the electronic data processing industry, including system shipments. Shipments of computer systems of all kinds (mainly general-purpose) generated nominal revenues of $0.063 billion in 1955. In the same year, the services sector of the industry (at this stage, the traditional mail/messenger batch-component) generated $0.015 billion—in revenue terms, therefore, the size of the computer industry's service sector was about 24 percent of the size of the computer system sector.[18]

By 1965, when commercial time-sharing was being born, system shipments generated revenues of $2.06 billion and the service sector of the industry (excluding software and facilities management) accounted for revenues of $0.355 billion—the service sector's size had declined to roughly 17 percent of the size of the computer system sector.[18] At this stage, the traditional batch component of the service industry accounted for 96 percent of all sector revenue and the newly born online component (interactive online) accounted for the remaining 4 percent. More specifically, the interactive online component generated revenues of $0.015 billion and was roughly 1 percent as big as the computer system sector.

Toward the end of the 1970s, in 1978, system shipments generated nominal revenues of $10.313 billion, and the service sector of the industry (excluding facilities management and software) accounted for revenues of $4.915 billion—at this stage, the service sector's size was roughly equal to 48 percent of the computer system sector's size. The online processing component accounted for a larger fraction of the service sector revenues than the traditional mail/messenger batch component. Furthermore, the interactive online sector generated revenues of $1.738 billion. In revenue terms, therefore, the size of the computer industry's interactive online sector was roughly 17 percent of the size of the computer shipment sector.[18]

The conclusions we can draw from these trends are clear. First, the computer industry's service sector tended to grow considerably faster than the computer system sector. Second, the interactive online portion of the service sector tended to grow faster than the overall service sector and than the computer system sector. From being nonexistent in 1965, in revenue terms the interactive online business had become 17 percent as large as the traditional computer system sector toward the end of the 1970s. This is a remarkable achievement given the speed at which the computer system sector grew between 1965 and the late 1970s. Furthermore, these trends reveal that the time-sharing business was booming well after the 1970 recession forced some of the firms out of business. Regardless of whether or not the concept of the computer utility persisted after the recession, computer time-sharing survived and blossomed.

Table 3. The data processing service industry, revenues in $ billions.

Year	Total Shipments	Total DPS Industry	Total DP	Mail Batch	Online		
					Remote Batch	Interactive	Total Online
1955	0.063	0.015	0.015	0.015			
1956	0.155	0.020	0.020	0.020			
1957	0.245	0.025	0.025	0.025			
1958	0.395	0.040	0.040	0.040			
1959	0.495	0.090	0.090	0.090			
1960	0.590	0.125	0.125	0.125			
1961	0.880	0.180	0.180	0.180			
1962	1.090	0.220	0.220	0.220			
1963	1.300	0.270	0.265	0.260		0.005	0.005
1964	1.670	0.317	0.295	0.285		0.010	0.010
1965	2.060	0.410	0.355	0.340		0.015	0.015
1966	3.330	0.540	0.430	0.410		0.020	0.020
1967	4.030	0.735	0.530	0.480		0.050	0.050
1968	4.835	1.040	0.720	0.600	0.010	0.110	0.120
1969	4.919	1.460	0.950	0.740	0.050	0.160	0.210
1970	4.355	1.900	1.260	0.930	0.090	0.240	0.330
1971	4.275	2.085	1.525	1.075	0.115	0.335	0.450
1972	5.620	2.480	1.820	1.235	0.145	0.440	0.585
1973	5.945	3.100	2.240	1.405	0.205	0.630	0.835
1974	7.030	3.850	2.685	1.580	0.280	0.825	1.105
1975	6.663	4.620	3.115	1.740	0.350	1.025	1.375
1976	7.079	5.455	3.585	1.860	0.565	1.160	1.725
1977	8.913	6.490	4.185	1.935	0.840	1.410	2.250
1978	10.313	7.685	4.915	2.100	1.077	1.738	2.815

Source: Phister, *Data Processing,* Table II.1.26, p. 277, and Table II.1.26a, p. 610.

Computer time-sharing industry—supply

Here we look at the computer time-sharing industry from the perspective of supply—and, later, demand—to understand the history of the industry and its users. What kinds of companies provided computer time-sharing services? What kinds of services did they provide and with what technologies? How fast did they grow? What kinds of companies demanded the services of time-sharing firms? We can try to answer these questions by looking at industry surveys that market research companies conducted periodically. The surveys available to us include three Auerbach reports on the time-sharing industry (1968, 1969, and 1979) and two by Datapro (1972 and 1975).[19]

Time-sharing companies

Toward the end of 1968, there were roughly 36 companies supplying computer time-sharing services. These companies operated about 112 computer systems connected to approximately 10,000 terminals at customers' sites, and generated roughly $70 million in revenues in nominal terms.[20]

Two different types of companies provided time-sharing services in 1968—some were connected to established computer-system companies; the rest were independent providers of time-sharing services. The two market leaders in 1968, GEIS (with a 40 percent share of the market) and SBC (with a 19 percent share) were of the first type. Four independent providers—Call-A-Computer (with a 7 percent share), Com-Share (6 percent), Tymshare (5 percent), and Allen-Babcock (3 percent)—trailed behind the two leaders. About 30 smaller firms split the rest of the market, with a median nominal revenue figure of about $500,000 each.[21]

Entry into the time-sharing business proceeded at a breathtaking pace between 1965 and 1970. According to the Auerbach (1968) report, by the end of 1965 only five commercial time-sharing businesses were in operation; four new companies entered the field in 1966, 14 entered in 1967, and at least 13 entered in 1968.[22] The Auerbach (1968) report suggests

that at least 36 companies were in operation in late 1968. The Auerbach (1969) report covers 57 companies, which implies that there was significant entry during 1969. The Datapro (1975) market research report identifies 98 companies providing time-sharing services in Canada and the US.

Figure 1 shows the number of firm entries by year, and this clearly illustrates the diminished interest in time-sharing after the recession of 1970–1971. By about 1972 there was a steady state of 100–120 companies with relatively few firm entries and exits.

The evolution of the computer time-sharing industry followed a pattern that many other industries have followed and that was first studied by Gort and Klepper.[23] They found that a sample of industries followed an evolutionary process of five stages. Stage I begins with the commercial introduction of a new product or service. Stage II shows a sharp increase in the number of producers/service providers in the market. In Stage III the number of exiting firms roughly balances the number of new entrants, leaving net entry basically at zero. Negative net entry characterizes Stage IV. Finally, Stage V is another period of roughly zero net entry and lasts until technological change launches a new product or service cycle. We suggest that, in the case of the computer time-sharing industry, Stage I took place in 1965 and Stage II may have lasted roughly between 1966 and 1969. Stages III and IV are more difficult to disentangle, but we suggest that they may have covered the years between 1970 and 1972. We hypothesize that Stage V covered a longer period starting around 1973 and lasting through the early 1980s.

GEIS was still the market leader in 1972.[24] Market leadership seems to have shifted immediately after that year, however, from General Electric to the Control Data Corporation. As part of an out-of-court settlement of its private antitrust lawsuit against IBM, CDC acquired the Service Bureau Corporation. The combination of its own Cybernet services with those offered through SBC allowed CDC, with more than $100 million in nominal revenues from computing services in 1974, to surpass GE that year.[25] (It is worth noting, however, that a good portion of SBC's revenues originated in the traditional mail/messenger batch approach to data processing.)

An important change in the market structure occurred around the mid-1970s. The diffusion of minicomputer systems allowed a large number of small local organizations and computer cooperatives to set up time-sharing services at prices below those that the nationwide organizations were charging. Competition in the time-sharing industry, however, did not take place on the basis of price only—the nationwide companies still had the most sophisticated software and databases and the largest networks, and could thus offer their customers a differentiated product.[26]

Toward the mid-1970s, there were more than 100 companies providing time-sharing services in the US, Canada, and certain parts of Europe.[27] Many of these companies offered both conversational and remote-batch services. Out of almost 100 companies that Datapro surveyed in 1975, about 70 percent offered both, about 26 percent offered conversational only, and the rest offered remote batch only.[28] Furthermore, out of all companies surveyed in 1975, about 57 percent were ''regional'' firms in the sense that they provided services in some specific set of major US cities or states. About 12 percent of the companies were based in Canada, and about 30 percent provided time-sharing services across the US.[28]

Toward the late 1970s, we find the same two types of companies supplying time-sharing services. On the one hand, large companies—such as GEIS, CDC, and Tymshare—supported a wide range of services and covered vast portions of North America and even Europe. On the other hand, smaller firms offered essentially local or regional services—some of them were general-purpose and others were focused on some specific application area. Ross Systems in Palo Alto, California, and Computer Resource Services in Arizona and Oregon were examples of this type of company. In addition, there were franchisees and marketing agents that provided technical support for other companies, and also companies that marketed an application package or service but used another company's computer or network facilities.[29]

Interestingly, about 29 percent of all time-sharing offerings surveyed in 1979 were ''regional'' plans whereas about 61 percent offered nationwide service in the continental US. In other words, relatively more companies had nationwide scope in 1979 than in 1975.[30] Two factors may have encouraged this transition. First, the irruption of minicomputer systems let smaller companies enter the business on a local or regional basis as a starting point. Second, the decline in the cost of telecommunications probably then allowed many of these smaller companies to venture into providing service with national scope.

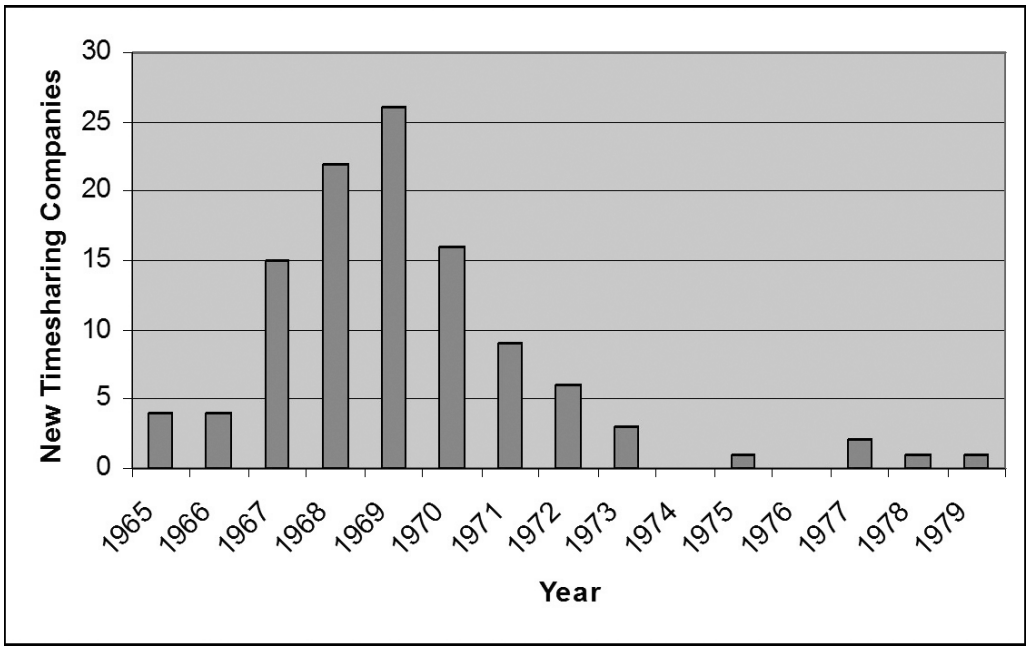

Figure 1. Number of entrants into the time-sharing business, 1965–1979, by year. (Source: Auerbach 1979.)

Profitability

In analyzing the profitability of the time-sharing companies, a distinction should be made between those that were part of a larger organization (like GEIS,[6] University Computing,[31] or the SBC) and those that were not. Regarding the first type of companies, it is reasonable to assume that the parent organization may have been willing to subsidize the provision of time-sharing services for a time in the expectation that it would eventually become profitable. Regarding the independents, they could sustain losses only for a limited time without going out of business.

In fact, it seems that, although their revenues grew quickly almost from the beginning, few of the independents, if any, were profitable in the first few years of operation. A look at the financial statements of Tymshare, for example, one of the independents that survived the 1970 recession and thrived in the 1970s, reveals that the early years were a period of growth without profits (see Table 4).[32]

A look at the financial ledgers of Comshare (see Table 5), another independent, reveals a similar picture. (It also shows how remarkable Tymshare's growth was in the 1970s in comparison with companies, like Comshare, that were of a similar size in the late 1960s.)

A different source, a report prepared for the trade association ADAPSO, reveals the differences in the evolution of profitability between companies that had a narrow focus on time-sharing and companies with a more encompassing business model.[33] The report studies the financial performance of eight computer service vendors in the late 1960s and early 1970s. It focuses on online services companies (Cyphernetics, Keydata, and Tymshare), batch service bureaus (ADP, Datatab, and United Data Centers), and specialized companies (Bradford and Computer Sciences Corporation). Table 6 presents their gross margins (i.e., the ratio of income before taxes and extraordinary items to revenues). Apart from the fact that this source reports a profit for Tymshare in 1969, the picture is consistent with the interpretation we presented here—companies like ADP were in good shape before and after the recession; companies focused solely on time-sharing, on the other hand, did poorly in the 1960s, struggled to survive through the 1970–1971 recession, and (if they did survive) did well after that.

Computing technologies

The companies supplying time-sharing services in 1968 used 112 systems and 20 different computer models. General Electric accounted for roughly 52 percent of all installed systems, IBM accounted for 20 percent, SDS for 14 percent, and Burroughs, DEC, Varian, CDC, Honeywell, and Univac split the rest. The dominance of the GE and IBM systems did not reflect these computers'

technical superiority, but rather the fact that GE and IBM deployed machines of their own manufacture in their time-sharing businesses. Time-sharing companies not subject to a captive market would have been more likely to select computers by merit, such as those made by SDS, DEC, and Univac.

By 1969 the computer time-sharing companies had deployed about 257 systems.[34] GE accounted for 57 percent of all systems, DEC for 23 percent, IBM for 8 percent, and various other companies (including SDS, Univac, Burroughs, and Varian) accounted for the rest. DEC's PDP-8 and PDP-10 systems were very popular. (In fact, commonly, an installation consisted of a pair of PDP-8 machines combined with a pair of PDP-10 machines.[35])

In 1975, time-sharing companies had more than 420 systems in operation. Honeywell (which had acquired GE's computer interests after 1970) accounted for about 34 percent, IBM for about 15 percent; Xerox Data Systems (which had acquired SDS), CDC, DEC, and Univac each had around 10 percent of the market.[36] Some of the most common systems in 1975 were the DEC PDP-10, the Univac 1108, the CDC large-scale systems, the Honeywell 6000 and 635, the IBM 370/168, the Xerox 940 and the Xerox Sigma 9.[36]

By 1979, the time-sharing companies had 507 systems in operation. Of these, IBM accounted for 196 and DEC for 92. CDC, Univac, Xerox, and Honeywell each had 30 to 40 systems. Among the most popular were the DEC PDP-10, the IBM 370/168, the IBM System 7, the Univac 1108, and the Xerox 940.[30]

By studying certain measures of quantity and performance for the deployed systems at various points in time (see Table 7), we can grasp the evolution of the computer power that time-sharing companies put at their customers' disposal. The GE-265 was the modal system in 1968–1969: it was a combination of a GE-235 machine and a GE Datanet-30 computer. The next most common installation in 1969 was a combination of PDP-8 and -10 machines. The PDP-8's CPU performance measure was 0.00132 MIPS, whereas the PDP-10 performed at 0.19976 MIPS.[37]

As Table 7 shows, between 1969 and 1975 the number of systems increased by 65 percent—and it had more than doubled between 1968 and 1969. The Univac 1108 and the large-scale CDC systems were among the most common in 1975. A CDC large-scale system, like the 6600, performed at 5.36 MIPS.[37] Another common system in 1975, the IBM 370/168 performed at 1.40 MIPS.[37] In terms of performance, the DEC PDP-10 was likely at the upper bound of the most common systems in 1969 but probably at the lower bound of the most common ones in 1975. Among the most commonly used systems, the ratio of the performance index of the most powerful one in 1975 (likely the CDC 6600) to the most powerful one in 1969 (probably the PDP-10) was about 27.

Table 4. Tymshare's revenues and net income, 1966–1979.

Year	Revenues ($)	Net Income ($)
1966	111,557	−239,095
1967	1,001,853	−344,857
1968	2,617,716	−898,072
1969	6,371,895	−640,022
1970	10,233,113	98,709
1971	12,519,859	365,275
1972	24,242,000	1,531,000
1973	35,200,000	2,654,000
1974	46,455,000	3,298,000
1975	64,412,000	5,094,000
1976	81,837,000	6,713,000
1977	101,174,000	8,008,000
1978	149,559,000	10,594,000
1979	193,092,000	14,644,000

Source: Tymshare Inc., *Annual Reports,* 1970–1979.

Communications technologies

In the 1960s, the prohibitive cost of long-distance calls or private wires constrained the time-sharing companies to providing a local service in major metropolitan areas. Time-sharing firms, therefore, adopted an expansion strategy based on rolling out additional time-

Table 5. Comshare's revenue and net income, 1968–1977.

Year	Revenues ($)	Net Income ($)
1968	1,135,000	−1,729,000
1969	3,872,000	−2,518,000
1970	4,879,000	−3,123,000
1971	5,280,000	−1,272,000
1972	6,773,000	−18,000
1973	8,515,000	766,000
1974	9,509,000	764,000
1975	12,312,000	1,499,000
1976	13,758,000	1,172,000
1977	18,213,000	1,475,000

Source: Comshare, *Financial Statements, Auditors' Report, and Ten-Year Summary,* 1977.

Table 6. Gross margins for 8 computer services vendors, 1966–1974 (%).

Year	ADP	Bradford	CSC	Cyphernetics	Datatab	Keydata	Tymshare	UDC
1966							L	20.00
1967	14.90				9.20		L	21.00
1968	16.30	1.30	10.00		1.90		L	6.80
1969	16.00	22.50	14.70		L	L	0.50	L
1970	17.00	22.70	9.80		7.00	L	3.4	5.00
1971	18.80	26.60	7.60		6.40	0.50	7.4	7.00
1972	17.00	14.70	L	13.80	3.60	1.90	12.4	8.40
1973	18.70	16.20	L	30.30		4.70		8.30
1974			1.60	26.00				

Source: *ADAPSO, The Computer Services Industry: 8th Annual Report,* 1974, p. 74; L = loss.

sharing systems in different metro areas. For example, by 1969 GEIS, the market leader, had installed GE 265 systems in 50 different locations in the US, Canada, and Europe.

In 1967, however, AT&T introduced its Wide Area Telephones Service. WATS was a form of long-distance service designed for customers requiring many calls with widely scattered distant locations. Another option for the time-sharing companies was the Foreign Exchange (FX) service. This was effectively a private exchange that allowed the multiplexing of multiple calls between a metro area and a central computer over a single private wire. These developments allowed all time-sharing firms, including the smallest, to offer nonlocal access at local call rates. By 1969, a wide variety of companies served the major metro areas with local dial-up facilities. Of the 57 companies surveyed in the 1969 Auerbach Report, 34 (60 percent) offered local dial-up in New York City, 15 (26 percent) did so in Boston, 19 (33 percent) did so in Philadelphia, and 21 (37 percent) did so in Washington DC.

In the 1970s, the national time-sharing firms sought to differentiate their services from the local operators by acquiring large computers that offered far greater capacity to run advanced software and support large-scale databases. The national firms also promised 100 percent availability, 365 days a year. They achieved these goals by networking several large computers and replicating software and databases globally. The major national networks included GEIS Mark III service, CSC's Infonet, UCC's Datran, and Tymshare's Tymnet.

In 1969, GEIS established its first "supercenter" in Cleveland, Ohio, a powerful centralized computer that would serve the entire network. Local-call access was provided in major cities and a satellite link was leased to London for European customers. During 1973–1974, another supercenter was established in Washington, D.C., and another satellite link was leased for Japan and Australia. In 1977, a third and final supercenter was installed in Amsterdam. At this stage the service was available with local call access from over a hundred locations, from Puerto Rico to Helsinki.[6]

CSC began development of Infonet in 1968, at a projected cost of $100 million, and planned to network eight of Univac's most powerful model 1108 computers.[38] The network began commercial operations in 1970, but was severely hit by the 1970-71 computer recession. Profitable growth resumed soon after, however, and Infonet thereafter achieved double-digit growth without a break until 1983, when revenues peaked at $135 million.[39] By that time the network was operating in 60 countries, using over 130,000 miles of private lines connected by 150 communications processors.

UCC and Tymnet also developed private networks. However, they quickly realized that besides selling computer power, they could also sell data communications facilities. The biggest attempt to establish a public data communications network was Datran, floated as an independent company by UCC's Sam Wyly.[40] A flamboyant entrepreneur, Wyly secured massive investment funds and during 1970–1975 constructed a network at a reported cost of $375 million. The development's early years were hampered by Wyly's inability to obtain regulatory approval to act as a common carrier from the FCC. Although approval was eventually obtained, by the time the network started operating in 1975, AT&T was offering tariffs well below Datran's, which

Table 7. Systems frequently deployed by time-sharing companies, 1969–1979.

Manufacturer	System	Introduction	CPU Performance (MIPS)	Knight Index (scientific)	Knight Index (commercial)
1969 (number of systems = 257)					
GE	GE-235	1965			
DEC	PDP-8	1965	0.00132	1.77	0.99
DEC	PDP-10	1968	0.19976		
1975 (number of systems = 425)					
CDC	6600	1964	5.36	7,020	4,090
DEC	PDP-10	1968	0.19976		
IBM	370/168	1973	1.40		6,008
Univac	1108	1965		2,075	2,088
1979 (number of systems = 507)					
DEC	PDP-10	1968	0.19976		
IBM	370/168	1973	1.40		6,008
IBM	System 7	1970			
Univac	1108	1965		2,075	2,088

Sources: Auerbach Corporation (1969) and (1979); Datapro Research Corporation (1975); Phister, *Data Processing*, Table II. 2.11.1, pp. 338ff and Table II.2.11.1a, pp. 630ff; and http://www.jcmit.com/cpu-performance.htm.

filed for bankruptcy. Datran's failure, however, helped clear the path for deregulation.

Tymshare had much greater success with its Tymnet network. Tymnet originated in 1971 as the network for the delivery of Tymshare's remote-computing services. In 1972, responding to organizations' requests for a network to connect their computers and terminals, Tymshare opened Tymnet to non-Tymshare computers. By the late 1970s more than 50 non-Tymshare computers were connected to Tymnet.[41]

Another packet-switched network, Telenet—opened officially in 1975—was created by BBN (which also offered the Telcomp time-sharing service) based on technology it had developed for ARPA.[42] Toward the late 1970s, Telenet had roughly 200 subscribers: private corporations, time-sharing companies, educational institutions, and government agencies.[43]

The price of transmitting a million bits declined considerably between the mid-1960s and the late 1970s; the cost of transmitting bits over larger distances seemingly fell much faster than for shorter ones.[44] The presence of networks like Tymnet and Telenet, particularly after they introduced distance-independent pricing, may have contributed to this by pressuring AT&T.

We have observed that, by the late 1970s, the number of time-sharing companies offering their services nationally increased considerably, even with respect to 1975—most likely a response to the declining cost of transmitting data over long distances. Out of the almost 120 time-sharing companies included in the Auerbach (1979) report, more than 70 were delivering their services nationwide.[30]

For all practical purposes, then, by the end of the 1970s commercial computer networks of various sorts populated the US and Canada. Many of these networks, furthermore, were the ones that the time-sharing companies had set up to deliver their services.

Computer time-sharing industry—demand

What proportion of companies in the economy demanded time-sharing services? From industry reports, we can infer that roughly between 15,500 and 23,250 companies hired the services of time-sharing firms in the early 1970s. This is approximately between one half of one percent and 8/10 of one percent of all the companies in the economy. Recall, however, that only about 1 percent of all US establishments had computers installed at the time.[45]

Furthermore, a simple application of Bayes' rule suggests that roughly between 37 and 58 percent of the companies having an in-house mainframe installation also resorted to time-sharing services for some of their computing needs.[46] This number means that, among companies that found computers useful enough to justify an in-house installation, slightly more than one third and perhaps more

than one half of them also concluded there was a role for time-sharing in their organization.

Who demanded the services of the time-sharing companies and for what purposes? In 1968, businesses hired time-sharing companies mostly for two reasons—to have access to raw computing power and to have someone perform calculations with specialized software. Regarding the demand for calculations, time-sharing companies' services were used predominantly for engineering and scientific applications (e.g., circuit network analysis, chemical process simulation, nuclear power research) and, somewhat less frequently, for business, financial, and statistical problem-solving applications (investment portfolio analysis, inventory analysis, linear programming). They were also used for computer program design, educational purposes, and business data processing.[47]

A wide spectrum of companies demanded computer time-sharing services in 1968. Manufacturing establishments represented roughly 50 percent of users. Other users included consulting firms, research centers, educational institutions, banks, insurance companies, investment brokers, and government agencies.[48]

In 1968, the customers of time-sharing services were predominantly large organizations: 60 percent employed more than 1,000 persons; only 20 percent employed fewer than 100 people. Furthermore, almost 70 percent of those businesses also had in-house computing facilities. It seems that, toward the end of 1968, however, the larger time-sharing companies were systematically trying to acquire customers in the small-business segment. More generally, the percent of small businesses using time-sharing services was increasing considerably at that time.[49]

Customers hired the data processing service companies for various reasons. Sometimes they just demanded raw computing power—this made up roughly 25 percent of the $1.5 billion total industry nominal revenue in 1971. More often, they wanted the data processing company to perform certain scientific or business-related calculations with the vendor's software—this accounted for roughly 69 percent of all industry revenues in 1971. In other cases, customers wanted to access business files with the vendor's software.[50]

The distribution of customer demands varied across the sectors of the computer services industry (see Tables 8 and 9). In 1971, in the industry's messenger/mail batch component, the demand for calculations using vendors' software accounted for roughly 91 percent of revenues. In the computer time-sharing industry (or interactive online component), on the other hand, the purchase of raw computing power accounted for roughly 60 percent and the demand for calculations using vendors' software only for roughly 15 percent. That is, in 1971 companies used mail/messenger batch services mostly for computations but used time-sharing services largely for accessing raw computing power, at least in revenue terms.

By 1978, in the traditional batch data processing sector, calculations made with vendors' software accounted for 95 percent of revenues. In the interactive online sector, access to raw power accounted for 45 percent of revenues; calculations with vendors' software accounted for 31 percent. In the 1970s, businesses were shifting slowly toward running vendors' software and away from the raw computing power.

Prices

The market research reports repeatedly pointed out that the time-sharing companies priced their services in such a complicated manner that users could not possibly choose their service provider on the basis of price, or at least on the basis of price only. It seems, however, that switching from one time-sharing vendor to another was not uncommon, which suggests that experienced users had enough information to actually compare price/performance across time-sharing companies.[51]

The pricing of time-sharing services had five components. First, an initiation fee was charged when a customer first hired the service. Second, a monthly minimum charge was applied to a customer contract (rather than to each terminal under the contract). Third, a terminal connect charge was applied during the time a user's terminal was connected to the central computer. Fourth, a central processor charge was applied to the actual use of the CPU. Finally, there was a file storage charge.[52] Although pricing schemes were indeed complex, certain central tendencies or typical pricing behaviors can be characterized.

In 1969, for example, 35 company plans had no initiation fee, and 27 had a $100 fee.[53] Forty-two company plans lacked a monthly minimum, and 12 had a $100 minimum. Twenty-four company plans had a $10/hour terminal connect charge; nine had a sliding scale with prices ranging from $9/hour to $6.50/hour; additionally, five plans had a $9/

Table 8. The data processing service industry in 1971, revenues in $M.

	Means of Accessing Computer			
		Online		
Computer Use	Messenger/Mail	Remote Batch	Interactive	Total
Raw power	95	100	185	380
Calculations	960	25	45	1,030
Files	5	5	80	90
Total	1,060	130	310	1,500

Source: Phister, *Data Processing,* Table 1.26.1, p. 29.

hour terminal connect charge. In terms of central processor charges, 10 plans had no charge, 11 had a 10-cent-per-core-unit fee, and 12 had a 3-cent-per-second charge.[54] The tariffs for file storage were even more heterogeneous.

A comparison of prices over time is extremely difficult and unlikely to yield a definitive picture of pricing trends. With the exception of the median central processor charge, no other prices seem to have increased. In fact, the typical terminal-connect and storage charges declined 30 to 50 percent in real terms. The typical central processor charge rose, in real terms, by a factor of 4 between 1969 and 1975. However, this reflected the availability of considerably more powerful computers. As we pointed out, among the most commonly used systems, the ratio of the performance index of the most powerful one in 1975 (likely the CDC 6600) to the most powerful one in 1969 (probably the PDP-10) was about 27. The performance-adjusted price of time-sharing services most likely declined over this period.

Some economic considerations

In this section we present a set of hypotheses on the economic logic of time-sharing and its impact on the computer industry.

Economic logic of time-sharing

Why did computer time-sharing grow as it did? Many years ago, the industry analyst Montgomery Phister provided an interpretation in terms of customers solving a cost minimization problem.[55]

Phister described what we could label the computation market in the US in the early 1970s in terms of price-performance combinations. Electronic pocket calculators appeared around 1974 and offered performance of at most 100 operations per second (ops/sec). Accounting machines had existed in the US for decades before the advent of electronic computing and, in the 1970s, offered performance of between 10 and 1,000 ops/sec for between $100 and $1,000 per month.

Computer time-sharing companies offered performance of between 100 and 1,000 ops/sec to customers who paid between $100 and $2,000 per month. Phister assumed that the machine supplying this performance was a 1-million ops/sec central computer that rented for about $8,000 a month. He calculated the total operating costs of the machine to be roughly $26,000 per month. Such a system could accommodate 100 users at any one time—from 100 full-time users to 1,000 part-time users that logged on to the system for short periods. Therefore, the computer time-sharing company operating such a system could provide performance of between 0.1 and 1 percent of the system's capacity (1,000 to 10,000 ops/sec) at between 0.1 and 1 percent of the system's cost ($26 to $260).

Other factors played a role in the calculation—the system's overhead reduced the capacity available for users and the computer time-sharing company wanted to make a profit, among other things. This means that the price of computer time-sharing capacity was probably close to $100 for 1,000 ops/sec and to $1,000 for 10,000 ops/sec (or $200 and $1,100 respectively, if there was a $100 terminal monthly charge). The conclusion that Phister (1979) drew from this analysis is that time-sharing services were extremely competitive, "providing processing capacity in the range between that provided by accounting machines and small computers at a cost substantially less than either."[56] Note, by the way, that these calculations do not consider that time-sharing, in addition, reduced the labor costs of computer ownership.[57]

The competitive advantage of time-sharing arose from the nonlinear relationship between total operating costs and performance—the larger the time-sharing system, the lower the

Table 9. The data processing service industry in 1978, revenues in $M.

	Means of Accessing Computer			
		Online		
Computer Use	Messenger/Mail	Remote Batch	Interactive	Total
Raw power	60	505	770	1,335
Calculations	1,995	555	530	3,080
Files	45	17	438	500
Total	2,100	1,077	1,738	4,915

Source: Phister, *Data Processing,* Table 1.26.1a, p. 530.

per-user cost.[58] Phister pointed out, further, that as time-sharing costs dropped, the terminal's cost became the dominant factor. At the same time he observed that, as the cost of processors and bulk memory continued to decline, calculators, accounting machines, and computer systems would become more powerful and cheaper. His forecast was that "the use of such small stand-alone systems will grow much faster than the use of time-sharing services."[56] Although he did not discuss the personal-computer revolution of the 1980s, he clearly foresaw in the late 1970s that the gilded age of computer time-sharing was almost over.

That time-sharing companies were competitive with pocket calculators, accounting machines, small computers, and even large systems, cannot be the full explanation of why time-sharing flourished, however. After all, it is well known that all other approaches to computation continued to exist along with the development of computer time-sharing companies. In fact, the Auerbach (1968) report observed that about 70 percent of the businesses that used time-sharing also had in-house computing facilities.[59] Although this means that many businesses using time-sharing services in the late 1960s had access to computers primarily through the computer time-sharing companies, it also means that most businesses that resorted to time-sharing used it for some, but not all, of their computing needs.

We can think of two additional reasons why time-sharing flourished as it did. First, the possibility of accessing computer power through time-sharing probably let companies adjust more efficiently to changes in demand for their own products. Second, most businesses had widely diverse uses for computers—companies dealt with issues related to personnel, vendors, parts, products, customers, markets, general ledger, assets, budgets, procedures, and finance/law.[60] Apart from these, many businesses performed specialized calculations of a scientific/engineering nature. It is likely that businesses often satisfied some of their computing demands via in-house installations and others via time-sharing. For example, some businesses that did all, or most of, their accounting at home probably hired the time-sharing companies when they needed to perform calculations demanding significant amounts of computer power and/or specialized software libraries.

Time-sharing as a differentiated-product industry

In a sense we can think of computer time-sharing companies as a differentiated-product industry—that is, an industry in which members competed not just on price but by offering different value propositions to customers. Although computer power per se became sort of a commodity during the 1970s, the companies delivering it were far from homogeneous and therefore the services their clients "consumed" were truly diverse. The Auerbach (1979) report, for example, details the various dimensions along which the time-sharing companies were heterogeneous.

For one, even though most companies toward the mid-1970s offered both conversational and remote-batch online services, some companies were specialized in one or the other. In the case of conversational services, users had full interaction with the computer while executing their programming jobs—they could create and modify code and files, interrupt and restart execution, and correct errors along the way. In the case of remote-batch services, on the other hand, users sent batches of coded input to the central computer through an expensive terminal. The output was then resent to the terminal or printed and mailed to users—there was no interaction between users and computers.

Conversational services were particularly suitable for programming and applications where fast turnaround and interaction were fundamental, like engineering applications

and sales forecasting. Remote-batch processing was more appropriate when large I/O was required and immediate response was not essential.[61] This probably led to some sort of matching of customers with companies—scientists and engineers, who required fast turnaround and the ability to interact with the computer and make changes along the way, likely tended to deal with companies strong in interactive services.

Furthermore, companies were heterogeneous along software dimensions. Time-sharing companies used either the hardware manufacturer's operating system, their own, or a modified version of the manufacturer's system. Operating systems were diverse in several dimensions, mainly resource allocation and storage management.[62] In addition, a wide variety of programming languages let users communicate with the system. Although 90 percent of the programs in the late 1970s were written in either Fortran or Basic, companies differed in system control languages, debugging languages, and text editors.[63]

Companies were heterogeneous along other dimensions as well, support services among them. Companies differed concerning the extent they helped their customers with program development, documentation, availability of databases, and provision of library programs.[64]

Perhaps more fundamentally, the companies' network schemes differed. Some time-sharing companies offered services based on one or more centrally located computers, which serviced either a small area or the whole country. This structure was particularly suitable for customers having many branches needing access to a core of common information, but the system was also prone to breakdown and delays. Other time-sharing companies had small regional, interconnected processing centers, which facilitated the provision of efficient customer assistance.[65]

Finally, the companies' pricing schedules varied, which surely encouraged the matching of customers with companies. Customers prone to establishing a connection for several hours with the central computer but keeping the CPU busy only for a fraction of that time certainly avoided companies with high terminal-connect charges. The fact that the ''product'' the time-sharing companies offered was differentiated, in any case, gave these companies some degree of market power—they could likely change prices somewhat without experiencing a massive migration of their customers to the next competitor.

Economic impact of time-sharing

We argue that the development of the time-sharing industry had a profound, although short-lived, impact on the computer industry's development.

Impact on computer system shipments. One could hypothesize that the advent and evolution of computer time-sharing may have produced a slowdown in the growth rate of computer system shipments—the very nature of computer time-sharing allowed businesses access to computing power without the need to acquire their own machine. Shipments of computer systems grew at an average annual compound rate of 45 percent before the advent of time-sharing, from 150 in 1955 to 6,100 in 1965.[66] (The annual growth rate was 31 percent between 1956 and 1965, and 28 percent between 1957 and 1965.) The shipments' annual rate of growth between 1965 and 1975 declined considerably to 23 percent per year. Growth accelerated somewhat in the late 1970s (to 26 percent per year between 1975 and 1978) but did not approach what it had been before the time-sharing industry's advent. [67]

This slowdown in the growth rate of shipments is remarkable because it happened when many old, expensive, general-purpose systems were being replaced with considerably cheaper minicomputer systems. In 1955, for example, the big, general-purpose systems made up 100 percent of all shipments in the US—the average nominal value of all systems shipped was $420,000.[68] In 1965, at the dawn of the time-sharing industry, the computer industry shipped 5,300 general-purpose systems (87 percent of all shipments) and 800 minicomputer systems (13 percent). The average nominal value of the general-purpose systems shipped was about $360,000, and that of minicomputer systems shipped was about $188,000, so the weighted average nominal value of all systems shipped was about $337,468.[68] In 1975, a decade later, the US computer industry shipped 6,700 general-purpose systems (14 percent of all shipments) and 34,500 ''minis'' (70 percent)—the rest were the so-called small-business computers. The average nominal value of the general-purpose systems shipped was about $837,300; the average nominal value of the ''minis'' was about $21,300. The weighted average nominal value of all systems shipped (considering also the so-called small-business computers) was roughly $134,965.[69]

In summary, the growth rate of computer shipments declined during the time-sharing era, even though computers got cheaper and the market was far from saturated. This is true even if we disregard some phenomenally high growth rates in the first couple years of our shipment data. We hypothesize that time-sharing had an impact in terms of slowing down shipments' growth—faced with the possibility of accessing computing power and software through time-sharing, some companies may have decided not to acquire a computer, and others may have suspended or postponed plans to acquire a second or third computer. (*Ed. note*: The authors have prepared a technical appendix in which they perform an econometric analysis of these issues. For space reasons, the appendix is only available online. See the ''Web Extras'' sidebar.)

Impact on the development of computer networks and the creation of a national market for computer power. Time-sharing computers had a profound impact on the evolution of computer networks.[70] Most early time-sharing networks were rather rudimentary, typically ''star'' networks—a set of dumb terminals attached to a single mainframe computer. During the 1970s, however, the larger networks became far more complex, consisting of multiple mainframe computers, communications processors, and terminals, using both circuit- and packet-switched technologies.

The leading networks included the GEIS Mark III network, Computer Sciences' Infonet, CDC's Cybernet, and Tymshare's Tymnet. Of these, Tymnet was probably the most influential because it was the first commercial network to deploy packet switching and to extend its reach to third-party providers.

Tymnet grew out of Tymshare's attempt to address the lack-of-dependability issue in the transmission of data between central computers and terminals. It slowly became, however, a true computer network interconnecting dozens of computers.[71] The Tymnet network's core computing power was located under one roof in Cupertino, California. In each city serviced, however, there were communication processors called Tymsats (Tymshare satellites), essentially Varian 620 minicomputers (in the early 1970s) with at least 8K words of memory.[72] In fact, it seems that the Tymsats were frequently installed in the customers' own offices.[71]

Tymnet's evolution is interesting. It arose as Tymshare's approach to ensuring reliable communications with its time-sharing customers. By the mid-1970s, it had already evolved into a more general public network connecting computers and terminals of various organizations—in fact, Tymshare opened the Tymnet network to non-Tymshare computers as a response to demand from outside organizations.[73] Toward the late 1970s, Tymnet had local call access in about 180 cities, encompassed 400 access nodes, had roughly 250 host computers connected to it, and supported a monthly volume of 15 billion characters.[74]

Furthermore, in the late 1970s Tymshare started leveraging the experience accumulated with Tymnet to venture into the private-network market. More specifically, at that time Tymshare started selling technology to organizations interested in building their own intranets. The only announced sale in 1979 was the one made to TRW, a 20-node network for their credit information business. There were others, the details of which Tymshare was not allowed to make public.[74]

In summary, the first public commercial network in the US arose as a response to a data-transmission reliability problem posed in the context of the development of computer time-sharing. As the demand for a commercial public network to link computers and terminals of various organizations became obvious, Tymshare opened its network to non-Tymshare computers. Toward the end of the 1970s, Tymshare not only had created a phenomenal public commercial computer network in the US (with ramifications in Europe) but also had begun selling its expertise and technology to companies interested in building their own networks.

Furthermore, the development of the time-sharing industry (including the development of public commercial networks like Tymnet) has to have contributed to the emergence of a national market for computing power. We have emphasized that the services that time-sharing companies offered were heterogeneous—from this perspective, we would not expect truly homogeneous pricing of computing power. However, the fact that customers all over the country could have access to the large time-sharing companies with national scope probably meant, among other things, that the price of a unit of computing power tended to be determined in a national market.

In short, the time-sharing industry survived the 1970–1971 recession and shaped the

structure of the computer industry through the early 1980s. It provided affordable computing power to businesses small and large, helped spawn the development of commercial public and private networks, and helped create a national market for computing power. No small feats for an industry that has been basically forgotten in the computer history books.

Decline of the time-sharing industry

The time-sharing industry was killed by the rise of the PC. However, this did not happen overnight, and it was not until 1983 that industry revenues started to turn down.

IDC tracked the "remote problem solving services market." IDC reported double-digit growth rates until 1983 without interruption for a decade (see Table 10). In 1983, however, it reported a 6 percent decline compared with 11 percent growth the previous year. IDC noted:

> [M]icros have opened the door for potentially millions of new, computer-illiterate users who are using micros (unfortunately for remote problem solving vendors) for those functions which timesharers have claimed …. financial modelling and planning, graphics, and data management.[75]

IDC predicted a slow decline for the industry through the rest of the 1980s. In fact, the industry declined less gradually than IDC predicted and by the end of the decade the industry had all but ceased to exist.

That time-sharing declined over some years should not be a surprise. Although the PC's rise is often portrayed as an overnight phenomenon starting in 1978, it was not until 1985 that the US-installed base of IBM-compatible PCs numbered 5 million (representing about a quarter of all domestic and industry PC shipments up to that date).[76] Thus, time-sharing firms continued to expand, and even prosper, until about 1983. This gave them sufficient breathing space to find new business opportunities. Time-sharing was an industry in transition—migrating to areas such as computer services, software products, and data communications. Unfortunately, none of the major firms whose records are available to us broke out their revenues into these different businesses.

The most complete record of a time-sharing firm during this period of transition we could locate is for Ross Systems (see Table 11). Although Ross Systems was a second-tier player (only one-twentieth the revenues of Tymshare, for example), it is a good proxy for the mid-sized players in the industry.[77]

Ross Systems was founded in 1972 as a programming services company and diversified into time-sharing in 1975. Its time-sharing services rapidly outgrew programming services (which it continued to supply), so that by 1981 time-sharing constituted nearly three-quarters of its $4.27 million revenues. Although 1981 was the year when the IBM PC was introduced, it took several years for PCs to become widely deployed, and Ross Systems' time-sharing revenues continued to grow, peaking at $6.2 million in 1983, accounting for more than 70 percent of its total revenues. The company continued to invest heavily in new time-sharing plant during this period. Only in 1984 did Ross Systems experience the first decline in time-sharing revenues in its history. By this time the rise of the PC and the decline of remote time-sharing were plainly inevitable.[78] Ross Systems was shielded somewhat from a precipitous decline because, rather than supplying raw computer power, it had developed specialized software for decision support, which customers continued to use (often using their PCs as time-sharing terminals). At this time Ross Systems saw the need to unbundle its services, and offer its software either as a stand-alone product for use on an organization's own computer, or as a traditional time-sharing service. Between 1984 and 1987, it invested heavily in further software development, and its dominant revenue stream gradually shifted from time-sharing to software products. By 1987, software products accounted for 60 percent of its revenues, and time-sharing for only a vestigial 12.4 percent. Ross Systems was acquired by a group of investors in 1988.

Tymshare, an industry leader, was less dependent on time-sharing than most of its competitors. It had already diversified into data communications through its Tymnet service established in the early 1970s. In 1980, its revenues were about equally divided between time-sharing and data communications. With the advent of the PC, the firm was "frantically trying to change horses," although time-sharing services would remain "cash cows" for a few years yet.[79] Once the PC gained traction, however, time-sharing income plummeted, and by 1983 Tymshare "was near death."[80] In 1984, it was acquired by McDonnell Douglas Automation, then one of the second-tier computer services organiza-

Table 10. Remote problem-solving services market, revenues in $M, 1979–1983.

Year	Interactive	Remote Batch	Total
1979	1,110	597	1,708
1980	1,375	741	2,117
1981	1,565	890	2,454
1982	1,750	981	2,731
1983	1,649	904	2,553

Source IDC, *1983 Processing Services Reference Book,* 1982, and IDC, *1984 Value-Added Services Reference Book,* 1983.

tions but richly endowed by its aerospace-manufacturer parent.

The industry leader GEIS was ''jolted in the late seventies with the advent of microcomputers'' and began to redirect its business away from the supply of raw computing and communications toward value-added services.[6] For example, in 1981 it acquired four software companies to make its time-sharing service more attractive to sectors such as banking and energy. GEIS already claimed to operate the world's largest private network—primarily for the supply of time-sharing services—and this was now re-focused on its Quik-Comm email service and EDI (business-to-business) services. Finally, in 1985, a consumer network GEnie was created to provide online services for the corporate and domestic market. Although GEnie never became a consumer service to rival CompuServe or AOL, it did offer a new use for its existing time-sharing plant.

Conclusion

We have tried to address one of the fundamental weaknesses of business histories of the IT industry—the almost exclusive focus on large firms. In the case of the mainframe industry, the focus on individual firms is not so problematic, because there were fewer than a score of significant firms, and the study of one firm and its interactions with its competitors gives a reasonably balanced view of the industry as a whole.[81] On the other hand, the software industry is poorly represented by the histories of large firms, since such histories generally ignore the tens of thousands of small and midsized software firms. This is likely to remain a persistent problem. Because of the great variety of software markets and the many thousands of firms, a comprehensive analysis of the software industry would be a truly formidable undertaking. This study of the time-sharing industry thus represents something of a middle road. We have considered the whole population of our selected industry, but this has only been possible because the population was of modest size (around 100 firms) and they exhibited some degree of homogeneity. We conclude with a review of our broad findings and a discussion of our sources and methodology.

We showed that the time-sharing industry flourished for nearly two decades, from 1965 until about 1983. This is an unusually short life cycle. Within the IT industry, few sectors have undergone the complete industrial cycle—the few other examples would include typewriters, punched card machines, and magnetic core memory. We showed that, like these other industries, time-sharing exhibited the classic multistage, boom-to-bust cycle described by writers such as Gort and Klepper,[23] and Utterback.[82] We noted that it took several years for firms to achieve profitability—a result that echoes much anecdotal observation in the computer industry, from the Univac Corporation in 1950 to recent Internet startups. We found that the industry could be characterized as ''boulders and pebbles''—a small number of very large firms (GEIS, SBC, Tymshare, and so on) and a much larger number of midsized firms. Because of the relatively high capital requirements for entry, there were no small firms like those that have populated the software industry, which has been characterized as ''boulder, pebbles and sand.''[83] (The mainframe industry would be just boulders.)

Our analysis was necessarily constrained by our sources. For statistics on computer systems and computer services, we used Phister's *Data Processing* (1979). Although this superb compilation is the only comprehensive industry survey known to us, it is also one in which we place a high degree of trust. Unlike most industry analysts, Phister is meticulous in citing his sources, in using multiple sources, and in reconciling them. For the time-sharing industry, our sources consisted primarily of contemporary industry analysts' reports and the annual reports of individual firms. Both types of records were essential, and both were highly incomplete (a not unusual situation for historians). Analysts' reports are the most important sources for economic studies of the IT industry. Although holdings are incomplete, they still contain large volumes of data for which traditional archival access (i.e., yellow pad and pencil) is unsuited. The material is physically too voluminous for photocopying in extenso, and too dispersed for easy note taking. We found these difficul-

Table 11. Ross Systems Inc., revenues in $ K and pre-tax income, 1977–1987.

Year	Total Revenue	Time-sharing	Software	Services	Other	Pre-tax Income
1977	509					
1978	942					
1979	1,689					
1980	2,391					
1981	4,271	3,155	338	700	76	719
1982	5,917	4,033	569	1,048	264	−208
1983	8,564	6,237	859	1,120	351	525
1984	8,273	5,775	1,419	801	278	−162
1985	8,220	3,567	3,295	785	573	506
1986	9,105	2,517	5,048	730	810	977
1987	11,274	1,402	6,822	1,207	1,847	691

Source: Ross Systems Inc., *Annual Reports,* 1981–1987; available at The Information Technology Corporate Histories Project, http://www.computerhistory.org/corphist/.

ties relatively slight because there were only a hundred firms and a dozen analysts' reports. The difficulties, however, would be formidable for a study of the software industry where there are potentially thousands of analysts' reports and tens of thousands of firms.

Two other difficulties we encountered were that analysts do not generally disclose their methodologies, and their market definitions are vague. As a result, measures ostensibly of the same sector (for example, the revenues of ''time-sharing'' and ''interactive problem solving'' firms) are sometimes reported as differing by factors of up to 50 percent. This establishes the boundaries of what researchers can legitimately do with the data. We can, for example, rely on the trend reported over a period of years by a single analyst, and on the relative sizes of the different sectors reported by that analyst. On the other hand, conclusions drawn from comparing data from different sources at a given point in time are suspect. More generally, what we cannot do is to pool or commingle the data from two different analysts, or to put two independently derived time series end to end. In this article, we have been careful in our tables to use only time series from a single analyst. We have good confidence in the trends we've described, and less in the absolute dollar values reported.

We used conventional corporate annual reports to address questions about which our analysts' reports were silent. Regarding the time-sharing industry, we found that analysts' reports faded away once the industry was in decline. The reason for this is obvious—firms were exploring new markets and were much less interested in purchasing reports that depicted the industry's decline. As far as we know, no reports on time-sharing were produced at the end of the 1980s when the industry drew its last breath—certainly we know of none extant. To track the decline of the industry, then, we made use of the annual reports of two prominent firms (Tymshare and Ross Systems) as proxy for the rest. We thus have no absolute dollar values for the sector in its terminal years, but we have persuasive evidence for the cause and the time of its decline—the rise of the PC, in 1983.

Web Extras

Visit the *Annals* Web site http://www.computer.org/portal/pages/annals/content/webextras.html for the authors' technical exploration of the impact of time-sharing on the growth rate of computer shipments.

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References and notes

1. On the decline of the time-sharing industry in the early 1970s, see for example: N. Foy, ''Hard Recession in Software,'' *Management Today*, Apr. 1971, pp. 95-97, 136; Datapro Research Corp., *All About Computer Time-sharing Services,* Delran, N.J., 1972, p. 70G-900-01c, Charles Babbage Institute (CBI) archives; GE Information Services, ''20 Years of Excellence: Special Edition Commemorating the Twentieth Anniversary of General Electric Information Services Company,'' *GE Information Services Spectrum,* Dec. 1985, p. 8; http://www.computerhistory.org/cybermuseum/corphist.
2. M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Westview Press, 2004, pp. 186-187.
3. For example: R.M. Fano and F.J. Corbató, ''Time-Sharing on Computers,'' *Scientific Am.*, Sept. 1966, pp. 128-140.
4. Campbell-Kelly and Aspray, *Computer*, pp. 196-197.
5. For example: M. Greenberger, ''The Computers of Tomorrow,'' *Atlantic Monthly*, July 1964, pp. 63-67.
6. GE Information Services, ''20 Years of Excellence: Special Edition Commemorating the Twentieth Anniversary of General Electric Information Services Company,'' *GE Information Services Spectrum*, Dec. 1985; http://www.computerhistory.org/cybermuseum/corphist.
7. J.G. Kemeny and T.E. Kurtz, ''Dartmouth Time-Sharing,'' *Science*, 11 Oct. 1968, pp. 223-228.
8. To a degree, time-sharing can be considered a multisided market. Many time-sharing vendors encouraged software developers to write library programs to stimulate the consumption of interactive services by regular users; third-party developers were usually remunerated by a slice of the revenues generated by the use of their software. This was, however, a marginal and complex phenomenon beyond the scope of this article. For a discussion of time-sharing applications software, see M. Campbell-Kelly, *From Airline Reservations to Sonic the Hedgehog: A History of the Software Industry*, MIT Press, p. 131.
9. The rate of growth was roughly 38 percent in real terms.
10. The rate of growth was roughly 45 percent in real terms.
11. M. Phister Jr., *Data Processing: Technology and Economics,* 2nd ed., Digital Press and Santa Monica Publishing Co., 1979, Table II.1.20, p. 243.
12. The rate of growth was 43 percent in real terms.
13. Phister, *Data Processing*, Table II.1.21, p. 251. The average value of general-purpose systems shipped increased after 1965, however. It was $808,000 in 1970. On the other hand, the average value of ''mini'' systems shipped decreased after 1965—it was $30,000 in 1970.
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15. See Phister, *Data Processing*, p. 28ff.
16. Phister, *Data Processing*, p. 29.
17. Phister, *Data Processing*, Table II.1.26a, p. 610.
18. Phister, *Data Processing*, Table II.1.20, p. 243, and Table II.1.26, p. 277.
19. Auerbach Corp., *A Jointly Sponsored Study of Commercial Time-Sharing Services,* 2 vols., 1968, CBI archives, CBI 30, box 79, folders 9-10; Auerbach Corp., *Auerbach Time-Sharing Reports,* 2 vols., 1969, CBI 55, box 69, folders 8-11; Auerbach Corp., *Auerbach Computer Technology Reports: Time Sharing,* 1979, CBI 55, box 67, folder 11; Datapro Research Corp., *All About Computer Time-Sharing Services,* 1972, CBI 55, box 72, folders 3-4; Datapro Research Corp., *All About Remote Computing Services,* 1975, CBI 55, box 74, folder 64.
20. Auerbach, *A Jointly Sponsored Study*, 1968, pp. 1-2.
21. Ibid., pp. 1-2, 1-3, 2-5-2-13.
22. Auerbach, *A Jointly Sponsored Study*, 1968, pp. 2-1-2-5.
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25. Datapro, *All About Remote Computing*, 1975, p. 70G-900-01c.
26. Auerbach Corp. (1979), ''Time Sharing—What Is It?,'' p. 1.
27. Datapro, *All About Remote Computing*, 1975, p. 70G-900-01b.
28. Datapro, *All About Remote Computing*, 1975, p. 70G-900-01r and ff.
29. Auerbach, *Computer Technology Reports: Time Sharing,* 1979, ''Time Sharing—What Is It?,'' p. 6. For details on the companies, see Auerbach Corp. (1979), ''Specification Chart: U.S.- and Canadian-Based Remote Access Services—Companies A–K,'' document 952.0000.510, pp. 1-22, and ''Specification Chart: U.S.- and Canadian-Based Remote Access Services—Companies L–Z,'' document 952.0000.511, pp. 1-19.
30. Auerbach, *Auerbach Computer Technology Reports*, 1979, ''Specification Chart: U.S.- and Canadian-Based Remote Access Services—Companies A–K,'' document 952.0000.510, pp. 1-22, and ''Specification Chart: U.S.- and Canadian-Based Remote Access Services—Companies L–Z,'' document 952.0000.511, pp. 1-19.

31. University Computing Corp., annual reports, 1965, 1966, 1968, CBI archives, CBI 12, box 47.
32. Tymshare Inc., annual reports, 1970, 1971, 1974, 1976,1979, CBI archives, CBI 12, box 46.
33. Assoc. of Data Processing Service Organizations (ADAPSO), *The Computer Services Industry: 8th Ann. Report to ADAPSO*, Quantum Science Corp., 1974, CBI archives, CBI 172, box 1, folder 5.
34. See Ref. 30. This assumes that General Electric had installed one GE-235 model and GE Datanet-30 model in each one of its operating centers.
35. Ibid. The PDP-8 was a ''mini'' system, whereas the PDP-10 was a large mainframe. See Campbell-Kelly and Aspray, *Computer*, 2004, p. 198ff.
36. Datapro, *All About Remote Computing*, 1975, pp. 70G-900-01r-70G-900-01kk.
37. The CPU performance measures are taken from ''Cost of CPU Performance through Time 1944–2003''; http://www.jcmit.com/cpu-performance.htm.
38. ''CSC News—25th Anniversary Issue,'' *CSC News*, Apr. 1984, pp. 14-15, 29, CBI archives.
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41. Auerbach Corp., *Tymnet Inc. Value Added Common Carrier*, 1979, pp. 1-2, CBI archives.
42. L.G. Roberts, ''The Evolution of Packet Switching,'' *Proc. IEEE*, vol. 66, 1978, pp. 1307-1313.
43. Auerbach Corp., *Telenet Communications Corp. Packet Switching Network*, 1979, p. 1, CBI archives, CBI 12, box 44.
44. Phister, *Data Processing*, p. 548ff.
45. The 1968 and 1969 Auerbach reports tell us that the typical time-sharing customer was a company that had set up 2 or 3 time-sharing terminals and spent roughly $600 per terminal per month. The 1968 report counts 10,000 installed terminals at about $7,200 per terminal per year, equivalent to annual time-sharing revenues of about $72 million. (See Auerbach, *A Jointly Sponsored Study*, 1968, pp. 2–5.) This seems consistent with the data in Phister, *Data Processing,* Table II.1.26 and Table II.1.26a. Phister estimated total interactive online revenue at $50 million for 1967 and $110 million for 1968. If we assume that the $7,200 per terminal/year and the 2–3 terminals/company remained roughly constant for a few years, then there were about 46,500 time-sharing terminals installed in 1971 (i.e., $335 million in industry revenue / $7,200). Thus there were roughly 23,250 companies with access to time-sharing at 2 terminals per company, or 15,500 companies at 3 terminals per company. There were 3.7 million establishments in the US economy in 1971, equivalent to roughly 3.06 million firms, at 1.21 establishments per firm (see Phister, *Data Processing*, p. 447).
46. From the Auerbach (1968) report we know that 70 percent of the companies that had access to time-sharing services also had in-house computing facilities. See Auerbach, *A Jointly Sponsored Study*, 1968, pp. 3-7. If we define M = in-house mainframe installation, and T = access to time-sharing services, then the probability of having an in-house mainframe installation conditional on having access to time-sharing services is P (M | T) = 0.70. We know that the unconditional probability of having an in-house mainframe installation was P (M) = 0.0096. All told, about 1 percent of all companies (in a strict sense, establishments) in the economy had an in-house computing installation. We also estimated that, under the assumption of 2 terminals per company, about 8/10 of 1 percent of all companies in the economy had access to time-sharing services, which means that P (T) = 0.008. Now, P (M | T) = 0.70 = P (M & T) / P (T) = P (T | M) * P (M) / P (T). Based on our estimates, 0.70 = P (T | M) * 0.0096 / 0.008, or P (T | M) = 0.58. So then, among companies having an in-house mainframe installation, about 58 percent also resorted to time-sharing services. Under the assumption of 3 terminals per company, about one half of one percent of all companies in the economy had access to time-sharing, that is P (T) = 0.0051. In this case, 0.70 = P (T | M) * 0.0096 / 0.0051, and P (T | M) = 0.37.
47. Auerbach, *A Jointly Sponsored Study*, 1968, pp. 1-4, 1-5.
48. Ibid., pp. 1-5. See also pp. 3-3 through 3-8.
49. Ibid., pp. 3-7 and 3-8.
50. Phister, *Data Processing*, p. 29.
51. Auerbach, *A Jointly Sponsored Study*, 1968, pp. 1-3.
52. Ibid., pp. 2-20.
53. We express these figures in terms of company plans because some companies had more than one plan on offer for their customers.
54. Auerbach, *Timesharing Reports,* 1969, ''Service Summary Charts: Service Fees.''
55. See Phister, *Data Processing*, pp. 164-165.
56. Ibid., p. 164.
57. Auerbach, *Computer Technology Reports,* 1979, ''Time-Sharing Services versus In-House Computing,'' p. 2, discusses comparative labor costs of remote and local computer operations. The report points out that the advantage of time-sharing from this perspective is twofold—first, the person supervising the time-sharing operation does not need to be a computer programmer

and, second, she can devote a portion of her time to other tasks.

58. The computer pundit Herb Grosch estimated that computing power *p* increased as the square of the cost *c,* that is $p = kc^2$, where *k* was a constant. See ''Grosch's Law,'' *Encyclopedia of Computer Science,* 3rd ed., A. Ralston and E.D. Reilly, eds., van Nostrand Reinhold, 1993, p. 588.
59. Auerbach, *A Jointly Sponsored Study*, 1968, pp. 3-7.
60. Phister, *Data Processing*, pp. 126-127.
61. Auerbach, *Computer Technology Reports*, 1979, p. 2.
62. Ibid., 1979, p. 3.
63. Ibid., 1979, pp. 3-4.
64. Ibid., 1979, p. 5.
65. Ibid., 1979, pp. 5-6.
66. Phister, *Data Processing*, Table II.1.21, p. 251, and Table II.1.21a, p. 600.
67. Ibid. In fact, if we compare growth rates in 5-year intervals, we find that shipments grew at their lowest rate in 1965–1970, precisely when time-sharing revenues were skyrocketing at an annual rate of growth of about 74 percent. As the growth rate of time-sharing revenues settled to a more reasonable pace (34 percent in 1970–1975 and 19 percent in 1975–1978), the growth rate of shipments seems to have slowly picked up speed again (to 26 percent in 1970–1975 and in 1975–1978).
68. Phister, *Data Processing*, Table II.1.21, p. 251.
69. Phister, *Data Processing*, Table II.1.21a, pp. 600-601.
70. ''A *computer network* consists of a set of communication channels interconnecting a set of computing devices and nodes that can communicate with each other. These nodes may be computers, terminals, workstations or communications units of various kinds distributed in different locations''—''Networks, Computer,'' *Encyclopedia of Computer Science*, pp. 924-929.
71. See, for example, Tymshare annual report, 1970.
72. See ''Tymnet: A Distributed Net,'' *Datamation*, vol. 19, no. 7, 1973, pp. 40-43.
73. See Auerbach, *Tymnet Inc. Value Added Common Carrier,* 1979, CBI archives.
74. See Tymshare, ''A Tymshare Presentation for the New York Society of Security Analysts,'' 18 June 1979, CBI archives, CBI 12, box 46.
75. IDC, *1984 Value-Added Services Reference Book*, Int'l Data Corp., 1984, p. 45, CBI archives.
76. Campbell-Kelly, *Airline Reservations to Sonic the Hedgehog*, p. 238.
77. IDC's *1984 Value-Added Services Reference Book* lists 48 firms in the US remote processing services industry. In this list Ross Systems would have ranked midway in the 30 second-tier firms with annual revenues in the range $1 million to $20 million.
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82. J.M. Utterback, *Mastering the Dynamics of Innovation*, Harvard Business School Press, 1996.
83. Campbell-Kelly, *Airline Reservations to Sonic the Hedgehog*, p. 167.

Martin Campbell-Kelly is a professor in the Department of Computer Science, Warwick University, where he specializes in the history of computing. His publications include *Computer: A History of the Information Machine* (2nd ed., Westview Press, 2004), co-authored with William Aspray, and *From Airline Reservations to Sonic the Hedgehog: A History of the Software Industry* (MIT Press, 2003). He is a special consultant with LECG.

Readers may contact Martin Campbell-Kelly about this article at M.Campbell-Kelly@warwick.ac.uk.

Daniel D. Garcia-Swartz is a senior managing economist in the Chicago office of LECG. He holds a joint PhD in economics and history from the University of Chicago. For many years he has been conducting research on the economics of high-technology industries, including electronic payment instruments, computer software, the Internet and e-commerce, and embedded computing components.

Readers may contact Daniel D. Garcia-Swartz about this article at dgarcia-swartz@lecg.com.