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Information Technology in Large Corporations: Ten Years of Evolution¹

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Executive Summary. The pace of investment in Information Technology (IT) by large corporations remains strong throughout the ten-year period 1987 to 1996. IT is becoming an ever greater share of tangible assets, ranging from approximately 2% in 1987 to greater than 8% in 1996. This trend is even more pronounced in recent years, with the share of IT assets of total tangible assets averaging 46% annual growth compared with only 13% for the first five years.

Despite the overall increase in IT stock, trends in the underlying technologies vary considerably. There is a significant trend toward distributed computing. Personal computers (PCs), high performance workstations, and minicomputers all exhibit strong growth over the period. The number of PCs burgeons from 1 per every 20 employees in 1987 to roughly 1 per every 4 employees in 1996. Similarly, there is a six-fold increase in the number of minicomputers over the same period. Concomitant with the high growth in decentralized computing hardware, net-working nodes and local area networks experienced rapid growth during

the ten-year period. In contrast, while the performance of mainframe computers has increased over the time period, their numbers have fallen from an average of nearly twelve per company in 1987 to less than seven in 1996. Taken together, these trends are consistent with the move from centralized data centers toward distributed client/server applications and from proprietary to open systems.

The variation in technology time trends between major sectors of the economy is not uniform. While the diffusion of PCs is slightly greater in manufacturing than in services, there is a major difference in minicomputers among sectors. In 1992, the services sector averaged 4 minicomputers per 1,000 employees while manufacturing averaged nearly twice that number. In contrast, mainframes are more prevalent in the services sector though the difference is not as pronounced as that of minicomputers. These differences likely reflect the contrasting modes of production between the services and manufacturing sectors.

Several measures are useful to link financial

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performance with investment in IT. The ratio of IT stock to total revenue exhibits a significant difference between the services and manufacturing sectors; services averages greater than 20% more in magnitude over the entire time period. Specific sectors with relatively high IT stock per revenue include Finance, Insurance and Real Estate and Transportation and Communication and Utilities; Retail and Wholesale are at the other extreme. In addition, we examine the

relationship between IT stock and sales, income, return on investment (ROI), return on equity (ROE), and return on assets (ROA). In 1987 and 1991, IT stock correlates well with sales and income, but not well with the other profitability metrics. In contrast, in 1996 IT stock also correlates highly with return on equity, suggestive of learning effects in the application of Information Technology.

I. Introduction

Study on Business Value of Information Technology

The Center for Research on Information Technology and Organizations (CRITO) at the University of California, Irvine is engaged in a comprehensive research effort aimed at determining the ways in which corporations maximize the return from their investment in information technology (IT). The research is supported by grants from the U.S. National Science Foundation and the NSF Industry-University Cooperative Research Center. This multiyear research effort examines the impact of IT on metrics such as efficiency and effectiveness at four levels – process, firm, industry, and country. The study uses multiple methodologies that include survey research, the case study, and quantitative analysis. The resulting research has already begun to have a significant impact on the body of knowledge and the practical implications are drawing keen interest from IS practitioners.

Current Report

This report analyzes data at the firm level from several sources in an attempt to

pinpoint the key trends in the use of information technology by large U.S. corporations over a ten-year period spanning 1987 to 1996. The primary objective is to provide the IS executive with a concise summary of these trends that is of direct use from both a strategic and an operational perspective. By presenting the data used for many of the firm-level analyses of the larger project, this report satisfies both the primary objective of summarizing key industry trends, as well as the secondary objective of providing a useful explanation of the data that are used in many other project analyses.

Data Sources

The database that underlies this report represents one of the largest of its type ever to be constructed. The two primary data sources are the Computer Intelligence Technology Database (ZD Market Intelligence) and the Compustat Database. Secondary data are drawn from internal CRITO databases.²

² CRITO's Intercorporate Measurement Program (IMP) Database; IDG/Computerworld annual surveys of IS spending.

Database

Data are available on 1,694 publicly traded manufacturing and services firms with one to ten years of data each. Exhibit 1 summarizes the number and distribution of firms over the ten-year period. Note that approximately one-third of all firms are present in all years, and there are almost 1,000 firms per year for a grand total of 9,819 firm-year observations. Roughly 70 variables are available for each firm-year of data. In the analysis that follows, we limit the data to the 517 firms that appear in all ten years to facilitate consistency and improve comparability across the time period. The

number of firm-year observations is reduced but still exceeds 5,000.

Sample

The population of interest is large U.S. firms and the sample frame is *Fortune* 1,000 firms. The number of firms in our sample is 517. The sample is reasonably representative of the population, as it does not differ substantially along profitability and size measures (Exhibit 2). Taken together the sample represents \$3.8 trillion in revenues or 49% of U.S. GDP in 1996.

Exhibit 1: Distribution of corporations across 10-year period 1987 – 1996.

	Year										Total # of Firms Per Year
	96	95	94	93	End 92	91	90	89	88	87	
87	517	30	80	24	30	38	43	51	87	77	977
88	22	0	14	1	0	5	7	12	22		983
89	33	4	18	6	5	8	13	13			974
Start Year 90	32	6	16	13	2	2	14				983
91	18	2	25	8	17	13					989
92	21	3	21	9	12						989
93	24	1	35	12							995
94	44	2	16								984
95	189	32									980
96	65										965
	9819										

Note: Cells represent number of firms with data starting in a given row-year and ending in a given column-year. Values are based on IT Stock.

Exhibit 2: Comparison of CRITO panel with *Fortune* 500 & *Fortune* 1,000.

	CRITO Panel	<i>Fortune</i> 500	<i>Fortune</i> 1,000
Revenue (\$M)	\$7,008 (12,533)	\$9,381 (14,267)	\$5,417 (10,840)
Profits (\$M)	\$390 (753)	\$494 (863)	\$282 (650)
Employees	35,380 (62,139)	40,410 (64,836)	24,574 (48,845)

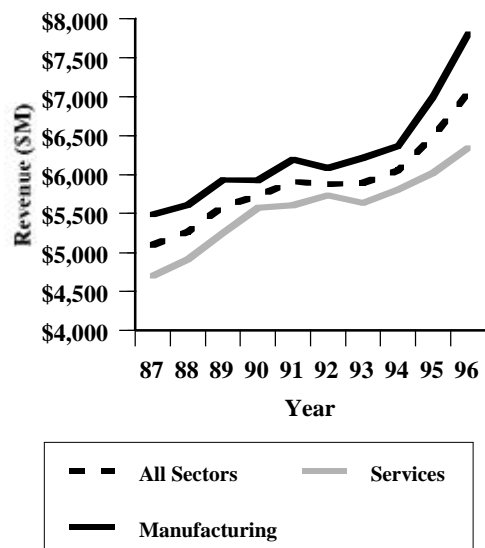
Note: Values are means; those in parentheses, standard deviations. Year is 1995.

II. Corporate Profile

Characteristics of Firms in the Sample

As shown in Exhibit 3, revenue increases steadily over the ten-year time period.³ There is a moderate difference in magnitude between manufacturing and services, both trending upward and following closely the full sample.⁴

Exhibit 3: Average Revenue per Company.

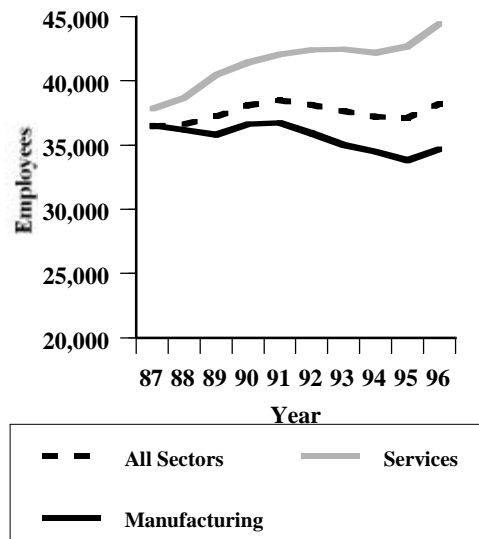


The total number of employees in the services sector increases somewhat over the sample period, in contrast to manufacturing, which decreases slightly (Exhibit 4). In addition, services sector firms have more employees than manufacturing throughout the sample period.

³ Dollar values in this report are adjusted for inflation and are provided in 1990 dollars, unless otherwise indicated.

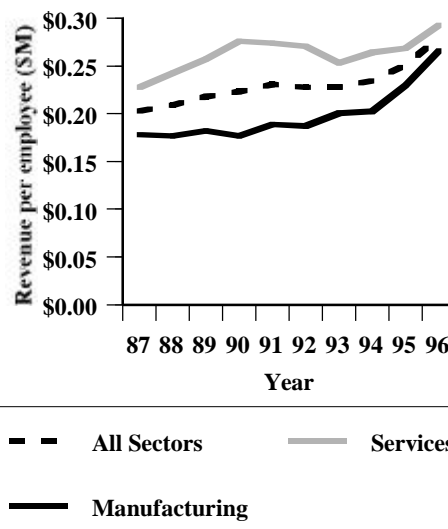
⁴ Consistent with standard practice, manufacturing firms are defined as having 2-digit SIC numbers ranging from 20 to 39, while those of services sector firms range from 40 to 87.

Exhibit 4: Average Employees per Company.



Revenue per employee for all sectors increases from approximately \$200,000 in 1987 to \$280,000 in 1996 (Exhibit 5). The services sector is consistently higher than manufacturing over the entire sample period, suggestive of a difference in productivity between the sectors. This difference appears to be narrowing in the latter years.

Exhibit 5: Average Revenue per Employee.



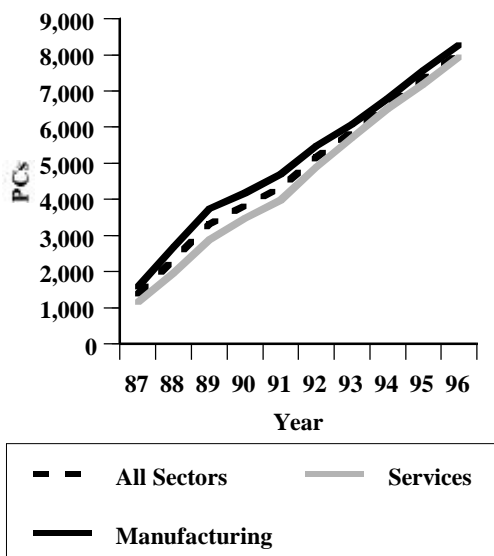
III. Technology Trends

IT Hardware

The ten year period has been one of significant changes in the deployment of hardware in companies. The trend lines show a steady decrease in mainframe computing with a rapid increase in distributed computing. The first part of this section will describe these trends in terms of the average number of types of equipment within large U.S. companies. In the second part, we will normalize the hardware counts by focusing on hardware per employee.

Microcomputers. In Exhibit 6, the diffusion of end-user computing in corporations is evident, with the average stock of PCs in all sectors growing from less than 2,000 in 1987 to approximately 8,000 in 1996.⁵

Exhibit 6: Average PCs per Company.

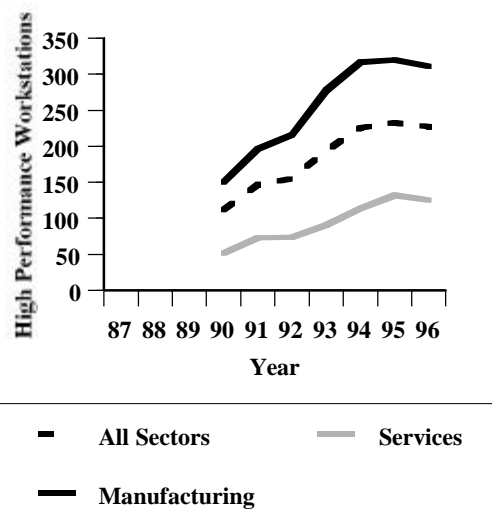


Note: Estimated values (1995 and 1996) are extrapolated based on a regression line of early series values.

⁵ Data for latter years are estimated in this and subsequent Exhibits due to inconsistencies. The estimation method is straight-line extrapolation based on least squares regression.

High performance workstations. High performance workstations – specialized computers with moderate computing power and high-end graphics capabilities used in engineering, desktop publishing, and software development applications—are present in the manufacturing sector in more than twice the quantity of the services sector (Exhibit 7). The trend is steadily upward with a flattening in the latter years.

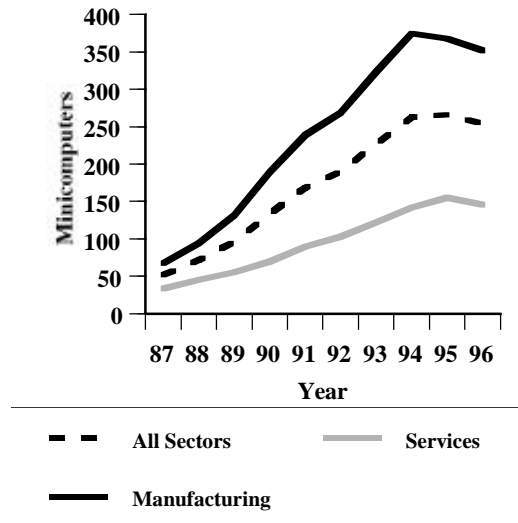
Exhibit 7: Average High Performance Workstations per Company.



Minicomputers. Though the distinction between high-end minicomputers and low-end mainframes is not always clear, in general, minicomputers have a multiprocessing system and are able to support from 10 to roughly 200 users simultaneously. They are typified by the IBM AS/400 series. Similar to the rapid growth in the stock of personal computers, minicomputers in the manufacturing sector experience a five-fold increase in stock over the sample period (Exhibit 8). The services sector displays only a three-fold increase over the period. Manufacturing is signifi-

cantly larger than services over the entire period in terms of the stock of minicomputers. All trends flatten in the latter years.

Exhibit 8: Average Minicomputers per Company.



Mainframes. Mainframe computers is the largest of all computing categories (with the exception of supercomputers) and support up to thousands of users simultaneously. In contrast to all other computer categories, the stock of mainframes has dropped significantly over the ten years, from twelve in 1987 to six in 1996 (Exhibit 9). This is a manifestation of both the move to PCs and distributed computing and the increasing power of mainframes.

MIPS. The computing power of mainframes and minicomputers as measured by millions of instructions per second (MIPS) is shown in Exhibit 10. The dramatic increase in all sectors is an indication of the rapid technical progress that has been made in the underlying components of minicomputers and mainframes. Although manufacturing has fewer mainframes on average in the latter years of our sample, the relatively greater number of minicomputers in manufacturing (Exhibit 9) is one likely source for the

difference in MIPS between the sectors. The drop-off in the latter years is consistent with that of minicomputers and mainframe computers.

Exhibit 9: Average Mainframes per Company.

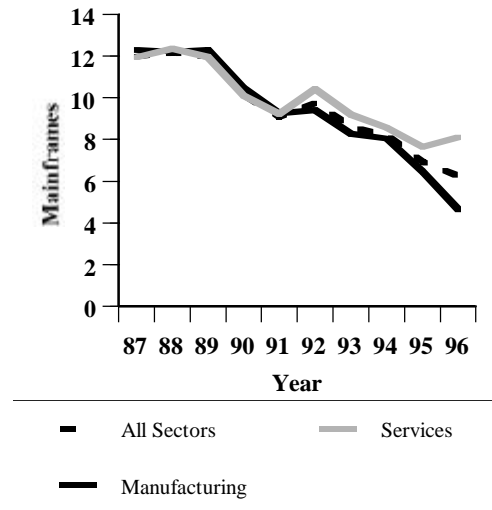
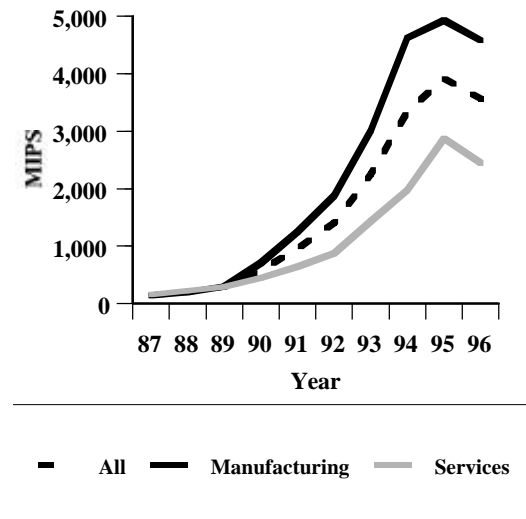


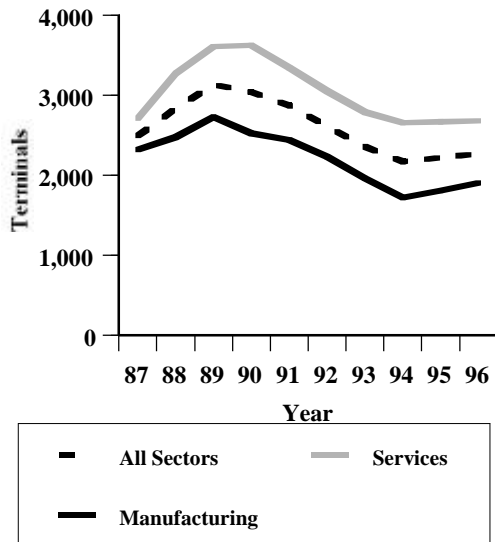
Exhibit 10: Average MIPS per Company.



Terminals. Terminals, defined as the combination of a keyboard and display and ranging from “dumb” (no processing capabilities) to “intelligent” (CPU and main memory), are present in larger numbers in the services sector than the manufacturing sector throughout the sample period (Exhibit 11). Both sectors experience a steady

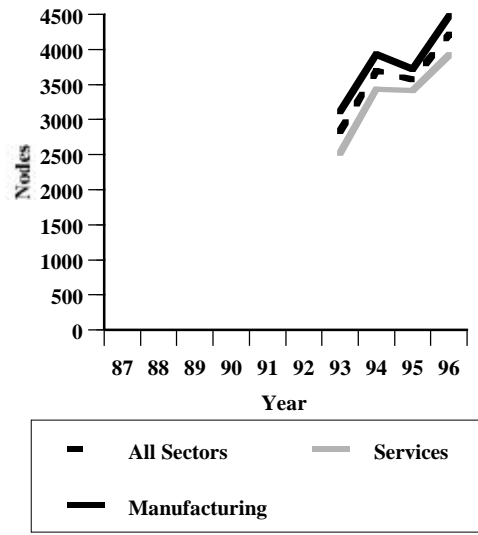
decline in the stock of terminals, after peaking in 1989. Computing is more decentralized in manufacturing, with individual plants frequently having their own computing capacity in minicomputers. Because of the need to share customer databases among many distributed customer services centers, e.g., the airlines, computing is more centralized in the services sectors.

Exhibit 11: Average Terminals per Company.



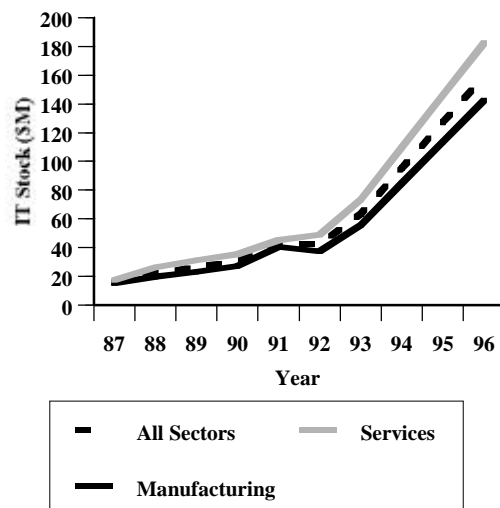
Nodes. One measure of the diffusion of networking in corporations is the number of nodes per company, defined as the connection of a computing or peripheral device to a network (Exhibit 12). While data are available only for the years 1993 through 1996, a clear upward trend is observed. The data for LANs, an alternative measure of networking in corporations, is only available for the most current two years, but exhibits similar growth. This trend is likely to continue and perhaps even increase in magnitude in concert with the transition to network computing.

Exhibit 12: Average Nodes per Company.



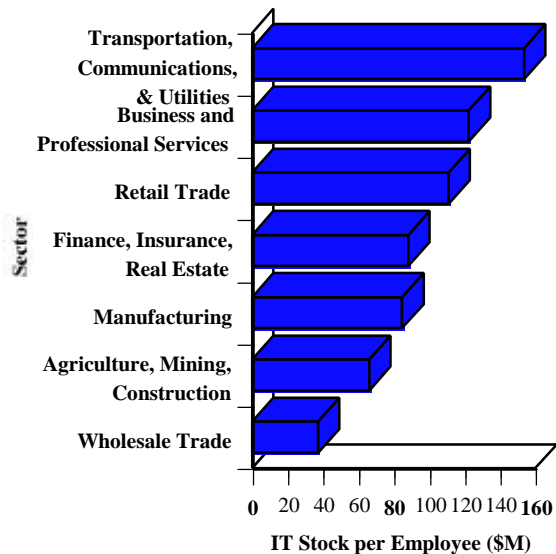
IT stock. An overall measure of computing in large firms is the total value of IT stock, which includes the value of all computing systems. There is a clear upward trend for all sectors throughout the sample period, ranging from approximately \$20 million in 1987 to greater than \$100 million in recent years (Exhibit 13). The services sector leads manufacturing in terms of magnitude of IT stock, and this difference appears to be widening.

Exhibit 13: Average IT Stock per Company.



Note: Estimated values (1995 and 1996) are extrapolated based on a regression line of early series values.

Exhibit 14: Average IT Stock per Company: Sector Disaggregation (1994).



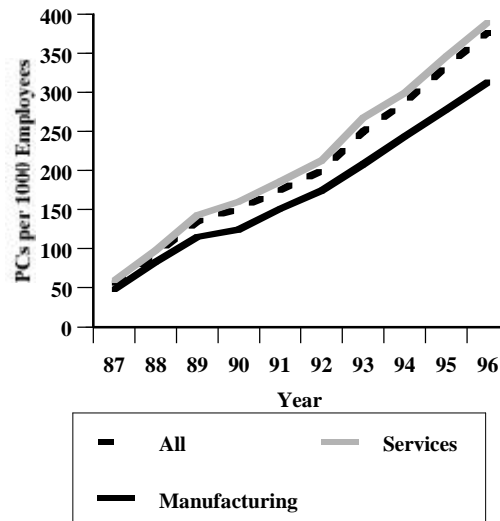
IT stock by sector in 1994 reveals that Transportation, Communications, and Utilities, Business and Professional Services, and Finance, Insurance, and Real Estate lead other sectors, with Manufacturing and Retail at the lower end of the scale (Exhibit 14).

IT Investment Strategy

The following graphs normalize the stock of computing in corporations by the number of employees. This provides a complementary perspective on the stock of computing and facilitates interfirm comparison.

Microcomputers. Exhibit 15 displays the dramatic rise in the number of PCs per employee over the 10 year period. In the services sector there were roughly five PCs per 100 employees in 1987. By 1996, this figure had burgeoned to roughly 25 per 100, or one PC per every four employees.

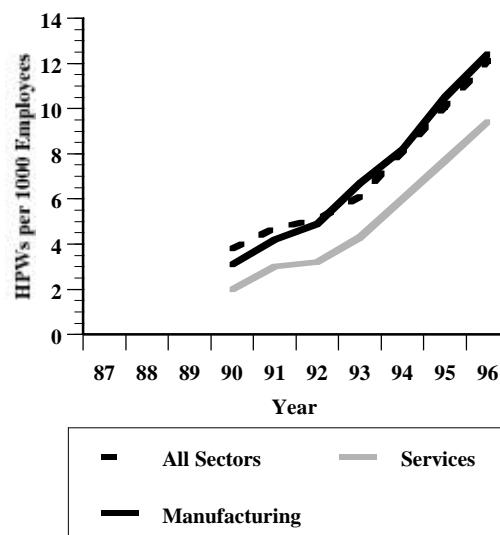
Exhibit 15: Average PCs per Thousand Employees.



Note: Estimated values (1995 and 1996) are extrapolated based on a regression line of early series values.

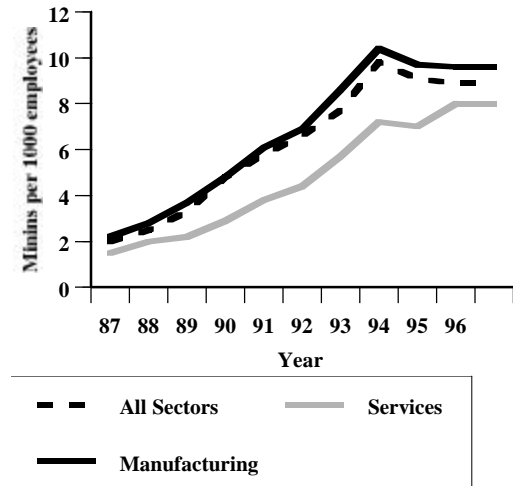
High performance workstations. Similar to PCs, workstations trend upward over the period (Exhibit 16). However, in contrast to PCs the manufacturing sector leads the services sector by a factor of 1.5 over the time period, reflecting the differing processing requirements of a manufacturing environment relative to services.

Exhibit 16: Average High Performance Workstations per Thousand Employees.



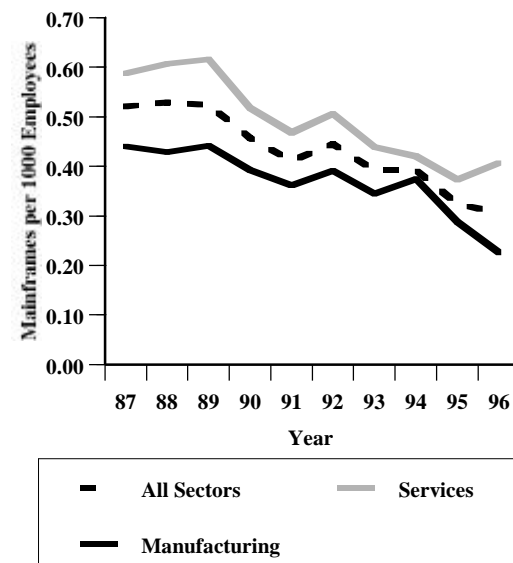
Minicomputers. Minicomputers per 1,000 employees follows a similar trend to that of high performance workstations (Exhibit 17). There is roughly 1 minicomputer per 500 employees in 1987; this figure grows to almost 1 per 100 employees in 1994.

Exhibit 17: Average Minicomputers per 1,000 Employees.



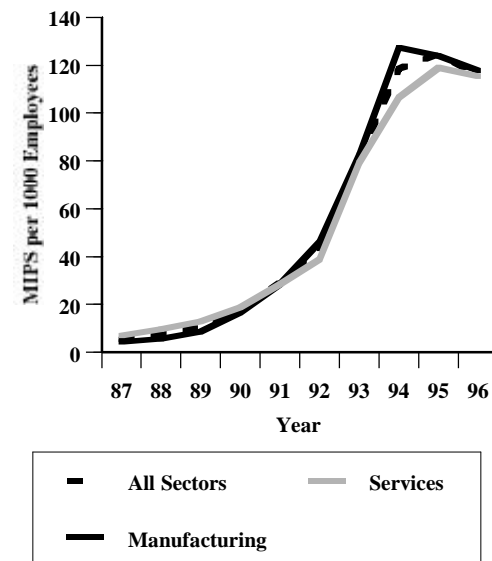
Mainframes. Over the 10 year period, the number of mainframes per employee trends downward. The decline is evident for services and manufacturing (Exhibit 18).

Exhibit 18: Average Mainframes per 1,000 Employees.



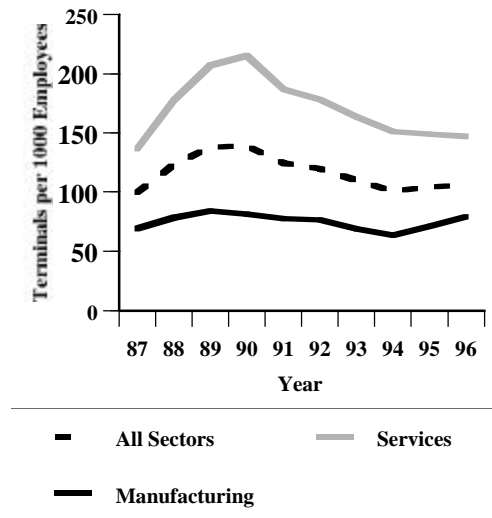
MIPS. MIPS per employee ranges from 1 MIP per 200 employees in 1987 to well over 1 MIP per 10 employees in later years (Exhibit 19). This is another dimension of increasing computing power within corporations. The drop-off in the latter two years is similar to that of MIPS per company and suggests that computing power is moving away from centralized facilities and toward the desktop.

Exhibit 19: Average MIPS per 1,000 Employees.



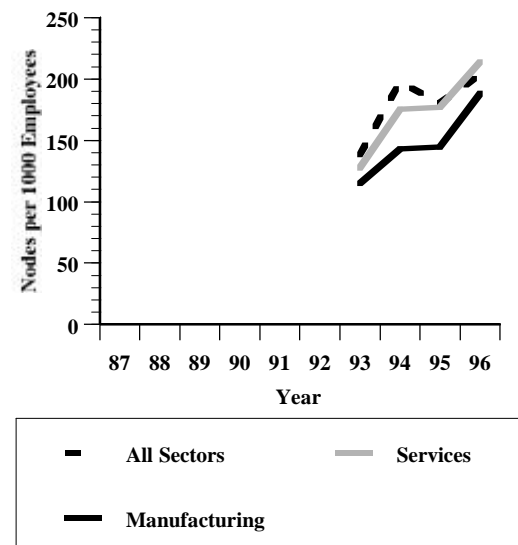
Terminals. The trend in total terminals per thousand employees increases in the early years of the sample period, peaks at the end of the decade, and then steadily declines through the 1990s (Exhibit 20). This general trend is similar for all sectors but is more pronounced for the services sector. Moreover, the services sector is consistently and significantly higher than manufacturing. For example, in 1994 there are approximately 70 terminals per 1,000 employees in the manufacturing sector and twice that in the services sector, reflecting the higher degree of transaction processing via terminals connected to mainframes in the services sector.

Exhibit 20: Average Terminals per 1,000 Employees.



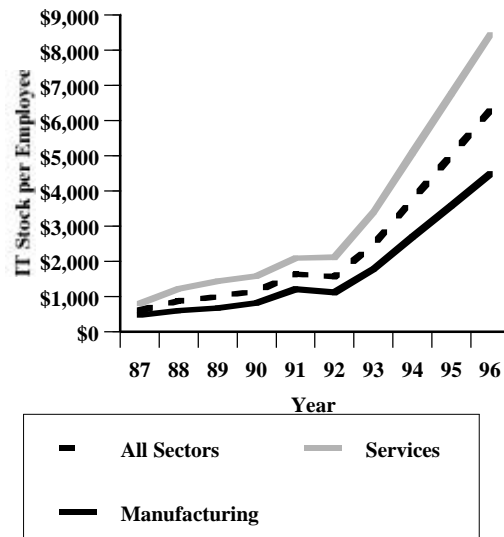
Nodes. Nodes per 1,000 employees is a measure of connectedness within corporations. Exhibit 21 reveals that connectedness nearly doubles from 1993 to 1996. Services is slightly higher than manufacturing throughout the period. The overall trend is consistent with burgeoning electronic communication within and across corporations in the 1990s.

Exhibit 21: Average Nodes per 1,000 Employees.



IT stock. IT stock per employee trends steadily upward throughout the sample period (Exhibit 22). Interestingly, the value is roughly the price of a personal computer in the early years. The services sector is much more IT intensive on a per employee basis than the manufacturing sector. The service sector leads manufacturing and the gap appears to widen in the latter years.

Exhibit 22: Average IT Stock per Employee.



Note: Estimated values (1995 and 1996) are extrapolated based on a regression line of early series values.

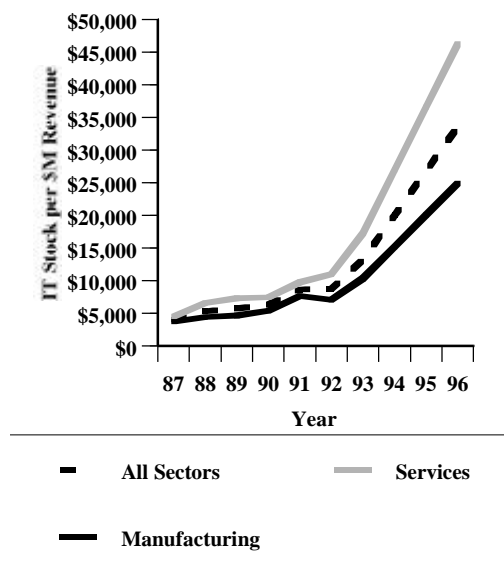
IV. Performance

We examine the relationship between IT stock and sales, income, return on investment (ROI), return on equity (ROE), and return on assets (ROA). In 1987 and 1991, IT correlates well with sales and income, but not the other profitability metrics. In contrast, in 1996 IT stock also correlates highly with return on equity, suggestive of learning effects in the application of Information Technology. These results remain robust when we examine the same relationships using multivariate regression techniques with IT stock as the dependent variable.

It is useful to compare IT stock, which is a measure of IT spending over a span of several years, to revenue. While both have increased over the sample period, it is clear from Exhibit 23 that the increase in the stock of IT has outpaced that of revenue. The magnitude ranges from roughly \$5 of IT stock per \$1000 of revenue in 1987 to greater than \$20 of IT per \$1000 of revenue in 1996.

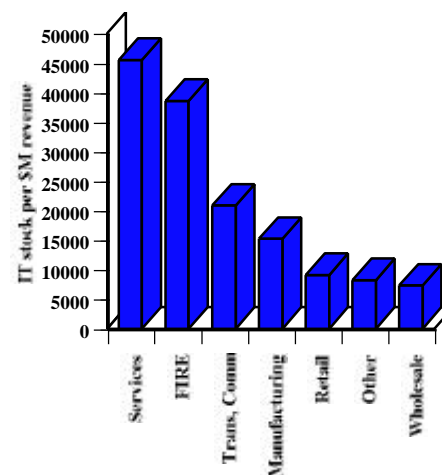
In Exhibit 24, IT stock per revenue is disaggregated by industry sector. The graph suggests that IT spending in the Business and Professional Services and Fire, Insurance, and Real Estate sectors significantly outpaces that of other sectors by a margin of almost two to one.

Exhibit 23: Average IT Stock per \$M Corporate Revenue.



Note: Estimated values (1995 and 1996) are extrapolated based on a regression line of early series values.

Exhibit 24: Average IT Stock per \$M Corporate Revenue: Sector Disaggregation.



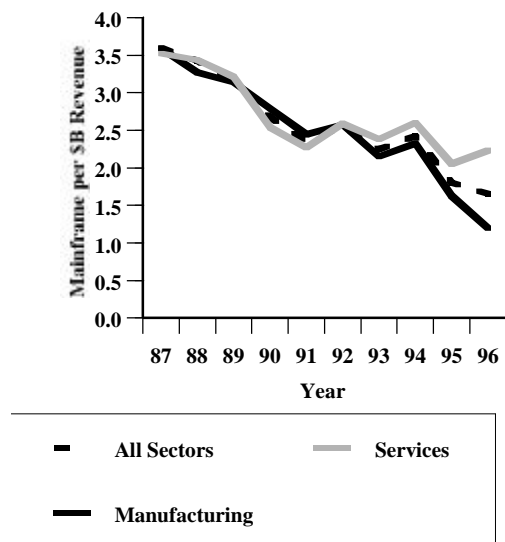
FIRE - Finance, Insurance, Real Estate

Other - Agriculture, Mining, Construction

Trans, Comm - Transportation, Communications, Utilities

The mean ratio of the number of mainframes to corporate revenue is presented in Exhibit 25. In all sectors, fewer and fewer mainframes with time are needed to produce a given amount of corporate revenue. Part of the reason lies in the increasing MIPS ranking per mainframe, which could imply a steady amount of processing or even increasing processing power with time.

Exhibit 25: Average Mainframes per \$B Corporate Revenue.



Percentage IT stock of total capital stock increases steadily throughout the sample period (Exhibit 26). This measure provides one indication of the differing investment strategy across sectors.

Exhibit 26: Average Percentage IT Stock of Total Capital.

