Volume Title: Inside the Business Enterprise: Historical Perspectives on the Use of Information

Volume Author/Editor: Peter Temin, editor

Volume Publisher: University of Chicago Press, 1991

Volume ISBN: 0-226-79202-1

Volume URL: http://www.nber.org/books/temi91-1

Conference Date: October 26-27, 1990

Publication Date: January 1991

Chapter Title: Investing in Information: Supply and Demand Forces in the Use of Information in American Firms, 1850-1920

Chapter Author: JoAnne Yates

Chapter URL: http://www.nber.org/chapters/c7180

Chapter pages in book: (p. 117 - 160)

4 Investing in Information: Supply and Demand Forces in the Use of Information in American Firms, 1850–1920

JoAnne Yates

In chapter 1 in this volume, Daniel M. G. Raff and Peter Temin point out that, contrary to the assumptions of much economic theory of prior decades, "information is costly and hard to find." That fact has significant implications for how information is used in decision making within firms. The period from 1850 to 1920 was one of firm growth and evolution. During it, many American firms first recognized the value of and invested in systematic internal information; of necessity, they also came to recognize its costs.[1] This paper focuses on the interaction over time of supply and demand factors affecting investment in and use of internal information.

Section 4.1 briefly explores the growing demand for internal information during this period. Section 4.2 looks at supply factors affecting the use of internal information. It describes the growth of information technologies, including mechanical and bureaucratic devices and systems, that were adopted to lower the costs of handling internal information. By lowering the cost of collecting, transmitting, analyzing, storing, retrieving, and disseminating internal information to those making and implementing decisions, these technologies made it economic for firms to acquire and use more information.

The longest section (4.3) shows how these supply and demand factors interacted over time in a single company, the Scovill Manufacturing Company. This case study reveals that changes in the availability and flows of informa-

JoAnne Yates is associate professor of management communication at the Sloan School of Management, Massachusetts Institute of Technology.

The author would like to thank Peter Temin for his extensive and helpful comments on multiple drafts of this paper. She also benefited from the comments of other participants in the NBER Preconference and Conference on Microeconomic History, especially those of Bengt Holmstrom, the commentator for this paper, and Naomi Lamoreaux.

1. I have discussed this development at length in Yates (1989). Much of the historical detail in this paper is drawn from that book or from materials gathered for the book, though it is framed and interpreted differently for this paper.

tion occurred unevenly, affected by factors such as managerial needs, financial and human investments in the existing system, and costs of changing the system. Section 4.4 draws some conclusions from this case study and suggests some parallels for contemporary firms.

4.1 Information Demand: Growth, Structural Evolution, and Systematic Management

In the small, single-function American firms that predominated before the mid–nineteenth century, market prices and availability were the main sources of information used in decision making by owner/managers (Johnson and Kaplan 1987; Chandler 1977). Account books and correspondence documented external, market transactions; virtually no information was recorded or collected about internal operations, which were managed by the direct oral supervision of the owner/manager(s).

The early nineteenth-century textile factories deviated from this norm. In these factories, where multiple functions were combined in the same facility and where ownership was separated from management, factory owners created the first, relatively primitive cost accounting systems. These information systems, according to Johnson and Kaplan (1987), allowed owners to monitor the costs and profits of their operations to assure that internal, managerial coordination of multiple functions was as efficient as that provided by the market when the functions were separate.

In subsequent decades, the railroads and the telegraph companies appeared, expanding markets for other goods while growing themselves. As these firms grew, expanded their geographical range, and lengthened their hierarchies, their managers faced and gradually responded to new demands for internal information. In the 1840s, the need to assure safety and honesty in dispersed firms led to initial innovations in internal information gathering and dissemination in railroads (e.g., Salsbury 1967). Regular, if still relatively limited, flows of information up the hierarchy documented monetary transactions. Written rule books and instructions documented rules and regulations concerning railroad operations and disseminated them down the hierarchy. Beginning in the 1850s, many growing railroads encountered crises of profitability when growth led to diseconomies of scale and the competitive environment prevented passing costs directly on to customers (Chandler 1977). Major eastern railroads such as the New York and Erie Railroad and the Pennsylvania Railroad instituted extensive systems of data collection and analysis—involving major innovations in financial, cost, and capital accounting—during the 1850s and subsequent decades. They developed a system of records and reports to draw information up the hierarchy for monitoring, assessing, and comparing performance within and among their divisions.

Growth alone was not necessarily enough to create a demand for extensive internal operating information. During the same period, the Illinois Central

Railroad, for example, grew quite large (at one point it was the longest railroad in the country), but it had less competition than many eastern lines, and its profits were bolstered by supplementary revenues from the sale of land granted to it by Congress. It was buffered from the most serious consequences of operating inefficiencies and dominated by managers who believed that personal leadership and exhortation, rather than systematic collection and monitoring of information, would elicit efficient operations. Thus its management made only the minimal investments in its internal information system necessary to guarantee safety and honesty and to prevent cash flow crises. Only in 1887 did its new president Stuyvesant Fish, a financier who believed in monitoring financial and operating data in much greater detail, begin to overcome internal resistance to change, aided by new reporting requirements imposed by the Interstate Commerce Commission and decreased profitability resulting from increased competition (Yates 1989, chaps. 4 and 5).

In the mid– and late nineteenth century many manufacturing firms adopted new production technologies, expanded to serve the larger markets created by the railroads and telegraph, and took on multiple functions. At this point, they encountered their own crises of profitability. Confronted by the inefficiency and chaos that resulted from growth and vertical integration without changes in managerial methods, they began to grapple with methods of improving efficiency. Their managers began to demand systematic internal information for use in achieving efficient coordination. In developing internal information systems, manufacturing firms did not, for the most part, depend on the advances already made by the railroads; faced with similar problems, they rediscovered many of the same principles.

Their search for more efficient operating procedures was shaped by an emerging ideology. The systematic management philosophy emerged in the fledgling management literature during the final decades of the nineteenth century.[2] Writers in this tradition noted the breakdown in horizontal and vertical coordination that resulted from expansion of the hierarchy in both directions. To improve efficiency, they advocated systematizing (that is, standardizing) and documenting all operations from the shop floor to the managerial office, and establishing flows of written information up and down the hierarchy to coordinate them. Operating policies and results were documented to reduce dependence on the specific individual, whether worker or manager, and to create an organizational memory. Information was systematically recorded and drawn up the hierarchy from the shop floor to higher levels of

2. Discussions of this movement may be found in Litterer (1961a, 1961b, 1963) and Jelinek (1980). The broad but amorphous systematic management movement should not be confused with the more narrowly focused scientific management movement, which emerged around the turn of the century as one element of that broader movement. While Frederick Taylor and his followers focused on improving efficiency on the shop floor, the broader movement was concerned with systematizing operations at all levels from the top to the bottom of the firm. For discussion of the relationship of these two movements, see Nelson (1974).

management. At each level, the information was analyzed and used in monitoring and evaluating lower levels as well as in making decisions about operations. The downward flow was made up of written orders, instructions, and policies—the results of decisions based on the upward flows—communicated down the hierarchy to those implementing policy.

In the period from 1880 to 1920, growing manufacturing firms gradually adopted many of the uses of internal information advocated by systematizers, as proponents of the philosophy were often called. They came to depend on extensive vertical flows of written information to coordinate operations. This philosophy, then, spurred demand for internal information in firms.

Growth and increased organizational complexity alone did not account for the large increase in demand for such flows of information. Growth and complexity created a demand for better coordination, but not necessarily for this method of coordination. For example, Masahiko Aoki has recently pointed out that methods of coordination less dependent on vertical flows of written information were adopted in Japanese firms (Aoki 1990). In those firms, horizontal and often oral coordination and exchange of information played a much more important role than in American firms (though not displacing all vertical coordination). Aoki argues that economic efficiency alone does not account for the differences between western and Japanese patterns of coordination, and that historical and cultural factors may have shaped the patterns. One such factor was the emergence of the ideology of systematic management in American firms during the decades surrounding the turn of the twentieth century. This philosophy, which saw no benefit in building consensus, would have been less congenial to Japanese social norms and traditions.

4.2 Information Supply: Changes in Information Technology

This increased demand for internal information might have been curtailed by its high cost, except for some changes on the supply side of the equation. Changes in information technology adopted by American firms between 1840 and 1920 reduced the cost of using internal information. During that period a variety of technologies were adopted for collecting, transmitting, storing, retrieving, analyzing, and disseminating the increasing amount of information being collected. Some of these improvements were mechanical or electrical devices that fit a traditional definition of technology (e.g., typewriter, adding machine, telegraph), while others were bureaucratic techniques with only limited links to physical devices (e.g., forms, indexing systems, graphic representations). They were adopted in an attempt to control the rising costs of handling the increasing amounts of information being collected. Supplementing this cost-control motive was an added element of ideology—in this case, it might be called fad—driving adoption.[3] These technologies came to be seen

3. I am indebted to Naomi Lamoreaux for bringing to my attention the possibility of an ideological component on the supply, as well as the demand, side of the information equation.

as visible symbols of the modern management techniques fostered by the systematic management philosophy. Whatever the specific motive for adoption, these technologies generally influenced the economic trade-offs concerning the use of information, reducing costs and thus increasing the supply of internal information available at a given cost.

4.2.1 Recording and Compiling Information

The actual recording and compiling of operating information occupied increasing amounts of managerial and clerical time as demand for such information increased. Soon the costs of the task became an obvious target for reduction. Both mechanical devices (the typewriter) and clerical techniques (preprinted forms) were adopted to reduce the time and thus cost of recording and transcribing information.

The typewriter lowered the costs of all written documentation, whether recording or disseminating information. Handwriting was a slow and thus expensive method of producing documents. Over the previous two centuries there had been many attempts to mechanize the production of documents, but until the last quarter of the nineteenth century none was commercially successful because none was able to reduce the speed of this activity below that of handwriting (Bliven 1954; Current 1954). The first successful mass-produced typewriters emerged from the Remington Factory in 1874. They were not initially aimed toward the general business market, but toward court reporters, authors, and other specialized niche users. But even before touch typing was developed, typewriters operated by experienced typists could produce around seventy-five words per minute, in comparison to about twenty-five words per minute for pen and paper, a fact that quickly attracted business.

The typewriter was also instrumental in lowering costs in other ways. Before the typewriter, documents were sometimes produced in final form by clerks and sometimes by higher-paid managers or even owners. Because touch typing was a specialized skill that required training, its introduction made more strict the allocation of document production to lower-priced clerical labor. That clerical labor became increasingly female in the 1890s and the early twentieth century, further lowering its cost. Female clerks were paid, on average, less than male clerks, and the mechanization and feminization of the occupation lowered the wage for all clerks in comparison to wages of manufacturing workers (Weiss 1978; Rotella 1981; Davies 1982; Goldin 1990).

In the 1880s and 1890s growing firms adopted the typewriter just in time to decrease the rising costs of their increased written communication (both internal and external). In some cases the adoption of the typewriter was either accelerated or slowed by the status the device quickly acquired as a symbol of modern business methods. At Du Pont, for example, the older, more conservative generation was initially reluctant to adopt it, and had to be convinced of its effects on costs before investing in it. The younger, more progressive du Ponts, on the other hand, adopted such modern devices immediately, even before their management methods had increased written documentation to the

point where such devices were essential (Yates 1989, 210–19). Whatever the motivation, typewriters clearly reduced the costs of all types of written documentation.

Another technology, this time clerical rather than mechanical, specifically reduced the time and thus cost of recording and compiling standardized data on a routine basis: forms. In the early nineteenth century, information about financial transactions was recorded in ruled, double entry accounting books. Most other documents were written out in full on blank paper. As routine reporting or operating information began to increase around midcentury, daily, weekly, and monthly reports proliferated. Since the typewriter had not yet entered the picture, both the explanations and the figures had to be laboriously written out by hand for each report. Moreover, the person writing such reports could easily omit or alter some category of information, lessening the value of the record for comparative analysis. And because the figures were typically embedded in text, anyone attempting to compile sets of information at higher levels had to search for the key figures.

Printed forms (later, often typed and duplicated) with spaces for entering specific information were adopted in the latter part of the nineteenth century to make "clerical work easier than would be possible if the blank sheet of paper were used," as one systematizer later explained (Leffingwell 1927, 470). These standard forms provided all of the information that did not vary from one reporting period to the next, leaving room for the varying information to be filled in (by hand or with a typewriter) for each report. They both reduced the time spent in recording information and encouraged consistency and "system" in the data recorded. Moreover, because the same information was always in the same place on forms, they made it easier to extract the data for compilation and analysis at higher levels.

Tables further simplified extraction of data. Frequently the reports started out with figures embedded within text. Sometimes before reports were turned into preprinted forms and sometimes after, tabular formats were often adopted, reducing the amount of text and thus facilitating the recording of data and its later extraction. Around the turn of the century, the tab function was developed for typewriters, further speeding up the recording of tabular data (Leffingwell 1926).

The managerial publications that emerged at the turn of the century were full of articles recommending forms for collecting and compiling data. Many of these articles suggested specific sets of forms for specific purposes (e.g., "System for Factory Purchases," 1903). Others gave general guidelines for designing forms that would be as efficient as possible for those filling them out and those extracting data from them at higher levels for further compilation (e.g., Barnum 1925). By 1925, a book on designing forms had been published (Clarke 1925). For their ability to promote consistency in data while increasing clerical efficiency, forms came to be seen as almost synonymous with "system," one of the primary values promulgated by the systematic

management movement. Thus they acquired a popularity in their own right, perhaps even beyond their efficiency value, as a symbol of modern, systematic management methods.

Together, the typewriter and forms reduced the costs of recording and compiling information, thus allowing firms to record increasing amounts of it before cost became prohibitive.

4.2.2 Transmitting Information

The major development in transmitting recorded information, the telegraph, appeared early in the period under discussion.[4] It increased the supply of information by radically increasing the speed of transmission, not by reducing the cost of transmitting a certain number of words. The telegraph made it possible to use time-sensitive internal information that previously could not be transmitted fast enough to be of any value in decision making.[5] In addition, it facilitated rapid routine flows of information where speed was worth the extra cost.

Before the telegraph was introduced to the United States in 1844, information could travel only as fast as a person could travel, by boat, stagecoach, or other conveyance. While a firm's manufacturing facilities were usually located in a single area, owners or sales agents might be some distance away. Information could be exchanged only as fast as the mails could travel. Thus agents in hot competition with rival firms might promise goods by a certain date without knowing whether the order could be delivered on time, or cut prices to negotiate sales, making contracts without the direct input of firm management because a delay could lose them the sale. Such interactions were a frequent source of friction between firms and their agents throughout the nineteenth century (e.g., Broehl 1984, 187–91; Yates 1989, 207, 219–21). With the telegraph, information about such negotiations could often be exchanged within the necessary time frame. Thus firms could exert more central authority over agents by insisting that no unauthorized price cuts be taken or that rush orders be confirmed with headquarters.

Firms did not necessarily take full advantage of the new transmission capability offered by the telegraph. In 1856, after Du Pont finally installed a private telegraph line to connect it to the Wilmington telegraph office several miles away, the firm immediately began using it on an ad hoc basis to confirm orders and to arrange rapid delivery of powder. It did not, however, use the telegraph to rein in its sales agents disbursed around the country. Even near

4. The telephone, which appeared in the 1870s, facilitated oral communication and coordination but did not seem to curb the rapid growth of recorded information. Since my focus here is on that recorded information, I will not discuss the telephone.

5. The telegraph's influence on markets has been discussed in DuBoff (1980, 1983) and in Yates (1986), and will not be considered here. The telegraph had an interesting influence on the flow of internal information in railroads, especially as it was used in railroad dispatching. Since this use is so specialized, however, I will omit it from the following discussion.

the end of the century, after the sales function was rearranged and a few principal agents were given salaries and put in charge of commission-based subagents with contracts requiring them to follow company pricing as communicated by letters and telegrams, friction continued over price cutting by agents in the field.[6] Even with the telegraph, Du Pont was unable or unwilling to control its agents.

At about the same time, however, Repauno Chemical Company, partly owned (and later to be wholly absorbed) by Du Pont, was exerting much more control over its agents. E. S. Rice, Du Pont's Chicago agent, belittled Repauno's Chicago agent by noting that he "is unable to make necessary prices, and in fact under his instructions can not meet competition without first communicating with the home office," a policy that would have been unworkable before the telegraph.[7] In fact, however, in the early twentieth century Rice's own methods were to be revealed as inefficient and ineffective, and Repauno's methods, which took full advantage of the additional control offered by the telegraph, were to become the model for all of Du Pont.

Initially, urgent but ad hoc exchanges of information such as these about the pricing and delivery of particular orders were the principal internal uses of the telegraph. Its high per-word cost—in the 1850s, the first ten words of a message between New York and Chicago cost $1.55, while most prepaid letters cost only $0.03 (U.S. Bureau of the Census 1975)—made it unattractive for more routine uses. While the price difference did not narrow, by the 1880s some growing firms with special needs saw the value of telegraphic communication for more routine communication. The integrated meat-packing firms that emerged in that decade, Swift and Armour, paid about $200,000 per year for telegraphic communication to coordinate the processing and transportation of beef via refrigerator cars (Chandler 1977, 396). Without such rapid routine communication, many cars of beef would have spoiled when they were stranded between the midwestern slaughterhouses and eastern distribution points or when they arrived at inappropriate distribution points. Slower modes of communication were virtually worthless in coordinating flows of perishable products, and telegraphic communication was well worth its high cost. Moreover, in cases where the telegraph was used heavily for internal communication, costs could be reduced by use of telegraphic cipher codes, which also helped firms maintain secrecy over public telegraph lines.

The telegraph thus facilitated high-speed internal transmission of information, allowing much closer coordination over distances in cases where owners

6. See correspondence from E. S. Rice, Du Pont's Chicago agent, to Du Pont headquarters, in accession 500, series 1, part 1, series B, vols. 307–10, Hagley Museum and Library, Wilmington, DE. See Yates (1989, chap. 7) for more details of Du Pont's and Repauno's relations with their agents.

7. E. S. Rice to Du Pont headquarters, 30 August 1888, accession 500, series 1, part 1, series B, vol. 309. The analysis revealing Rice's high unit cost is discussed in Chandler and Salsbury (1971, 628 n. 90).

or managers recognized that the value of the communication exceeded its cost.

4.2.3 Storing and Retrieving Information

To be useful in decision making, information had to be stored in such a way that it was readily retrievable when it was needed. For comparisons of one period's operating results to those of previous periods, for example, the latter had to be available and accessible. To analyze the profitability of various customer accounts, managers had to have access to correspondence and records concerning that customer's orders. Moreover, if documentation of systems and policies was to be a useful replacement for reliance solely on individuals, that documentation had to be available for consultation both by those governed by the policy and by those monitoring and determining policy. As the amount of operating information being gathered and of policies and procedures being documented increased around the turn of the twentieth century, accessible storage became increasingly problematic. An interlocking set of devices and clerical systems for vertical filing of documents emerged at the end of the nineteenth century and was widely adopted as a way of increasing accessible storage. Soon after came vertical files of structured data cards. These innovations in storage technology increased the supply of information available to those making and implementing decisions (Yates 1982).

In the late nineteenth century, most companies stored documents and correspondence in a combination of bound volumes, pigeonhole desks or cabinets, and letter boxes. Both traditional accounts of external transactions and copies of outgoing correspondence (whether to external parties or to other company sites) were recorded in large bound volumes. Accounts were recorded directly into the volumes, initially by hand and later using special posting machines related to typewriters. Internal and outgoing correspondence and other documents freshly written or typed in special copying ink were "press-copied" into bound volumes. This process involved dampening and compressing the original between tissue-paper pages of a large volume (while other pages were protected from the dampness by inserted pieces of oil cloth). The dampness and pressure on the copying ink transferred a reverse image of the document onto the side of the tissue page facing the original. That image showed through to the other side of the thin paper, where it could be seen correctly. This form of copying and storage fixed items in the chronological order of creation.

Incoming correspondence and internal reports, on the other hand, were folded into packets and annotated on the outside with date, correspondent, and sometimes subject, then stored in pigeonholes. Locating a particular item in pigeonholes typically required pulling out and unfolding many documents.

In the late nineteenth century, as the volume of correspondence and internal documents increased in growing firms, letter boxes that stored documents flat often replaced pigeonhole storage. It was easier to find a particular document

in a given letter box than in a pigeonhole desk or cabinet, since the documents were no longer folded; yet the boxes were usually stored on edge on shelves (like bound volumes), and the user still had to pull down, open, and rifle through them to locate a given document. Then papers on top of the desired document had to be lifted out in order to remove it. A further development, cabinets with drawers of flat files, eliminated the first step but did not improve the others. Moreover, incoming and internal documents were separated from outgoing correspondence, which was still press-copied into bound volumes. Thus someone trying to trace an ongoing exchange of information had to consult multiple storage devices.

To eliminate this problem of bound volumes, copying had to be separated from storage. Two methods for copying documents onto loose sheets rather than into bound books, both adaptations of existing technology, emerged towards the end of the century. The rolling press copier simply press-copied documents onto a continuous role of tissue paper, which was then cut into pieces of appropriate lengths (Wigent, Housel, and Gilman 1916). Carbon paper had been available since quite early in the nineteenth century, but for a long time it could only be used with a stylus or pencil, not with the sharp quill or steel pens that would tear the paper or be blunted when pressed down hard enough to make a carbon copy (Proudfoot 1972). It was immediately clear that carbon paper could be used with the typewriter, which entered businesses in significant numbers in the 1880s and 1890s. Both rolling copiers and carbon paper produced the loose copies necessary to free firms from bound chronological storage of outgoing correspondence. Carbon paper proved to be the cheaper and more convenient method and was clearly more widespread in business by early in the twentieth century, according to a government study undertaken in 1912 (President's Commission on Economy and Efficiency 1912).

With loose copies of outgoing documents available, a critical step in the evolution of storage and retrieval systems could occur: the combining of all documents on a single subject, whether outgoing, incoming, or internal, into a single storage system accessible by subject. While this reorganization of information could have occurred within the existing box files, it generally awaited the introduction of vertical filing to the business world in 1893 (Chaffee 1938, 4). This method of storage involved both a device and a bureaucratic system. As a device, vertical filing consisted of the now-familiar manila folders, dividers, and cabinets of the correct size for storing them in an upright position. As a bureaucratic system, vertical filing was introduced as a method of combining all documents on a single subject, regardless of origin, into a single, centralized storage system and organizing them by subject or some other indexing scheme suitable to the needs of those using them.

Many books and articles were published on filing systems and various methods for organizing and indexing them (e.g., Wigent, Housel, and Gilman 1916; Hudders 1916). Proponents of vertical filing noted its advantages over the old systems (press books plus letter boxes or flat files) both in efficiency

of use—a folder with all the relevant information on some subject could easily be located and lifted out—and efficiency of space (e.g., Hoskins Office Outfitters 1912; Hudders 1916). They also argued the virtues of various indexing and organizing systems, from alphabetical to decimal.

The shift from a predominantly chronological system that separated documents by origin to one that combined all related documents with access based on subject or some other functional scheme clearly made information more accessible for those making or implementing decisions. In effect, this change increased the supply of internal information. (There is even some evidence that the vertical files, which quickly became decentralized in spite of expert recommendations to maintain centralized files, encouraged the generation of increased internal documentation. Presumably managers had more incentive to document facts and opinions when they knew that the documents would be accessible in the future.) In addition to their direct value in lowering the cost of retrieving information, filing systems, like forms, came to be seen as symbols of the modern, systematic methods of management. Thus, symbolic reasons reinforced efficiency reasons in firms' decisions to adopt this information storage technology.

A variant of vertical filing, the vertical card file, was soon adopted in many firms to create a more compact database of sales or production statistics, or even of a firm's central accounts (Clark 1916; Morse 1900; Leffingwell 1926, 1927). Initially, these card files simply used forms (often tabular ones) preprinted onto stiff cards. Cards were organized by a single scheme (e.g., a customer's name), and other information could be extracted from each card once it was located. Soon devices were added to card files to aid in the rapid retrieval of data by multiple categories. Metal tabs painted different colors were clipped to the top or bottom of the cards in designated positions to aid a clerk in locating and retrieving all cards with a particular characteristic. In some cases, punched holes or notches were used in conjunction with special drawers and rods to extract cards with certain characteristics. As one advocate of such card storage and retrieval systems noted, "The need for extensive cross-indexing which would otherwise be necessary for close and analytical utilization of the data, is by this method successfully eliminated in nearly every case" (Schlink 1918, 136).

These systems were essentially databases storing structured data that could be extracted along multiple dimensions. They greatly increased the supply of structured data readily available for analysis, thus presumably increasing its use. For example, the extensive tabbed card file maintained by Du Pont's Sales Record Division was used in 1913 to respond to twenty-three thousand routine inquiries within the headquarters Sales Department, as well as to many special requests from the field.[8] The data it provided aided in following

8. This information is based on an untitled and undated document (ca. 1914) describing and justifying the Sales Record Division's role in the department. It is in the Du Pont records (accession 500, group II, series 3, file 127) housed in the Hagley Museum and Library.

up on trade and in monitoring sales personnel. Improved storage and access made information easier and less expensive to use.

4.2.4 Analyzing Information

In the late nineteenth and early twentieth centuries, a variety of adding machines, calculating machines, and statistical tabulating machines were introduced to speed data manipulation and calculations. Some of these were specialized bookkeeping machines developed for use in accounting departments to post entries and calculate running totals. But as the systematic management philosophy encouraged the widespread use of information throughout firms, neither extensive calculations nor the office machines that facilitated them were limited to accounting departments any more.

Tabulating machines were the most powerful technological systems (each of them was actually composed of several devices) for analyzing data. They both sorted data into categories (even more rapidly than card files) and performed calculations. The electromechanical Hollerith tabulator was initially developed to process the data collected for the 1890 U.S. Census. The devices making it up were used for various functions: punching holes in the cards to record the data in encoded form, sorting the cards by categories, and counting and/or calculating as desired. Other tabulating devices, including the mechanical Powers machine, followed the Hollerith. One systematizer noted the value of such machinery in reducing the time and cost necessary for performing large computations: "Wherever the classifying and analyzing of statistics or the compiling of reports is part of the daily routine of any business enterprise, there the tabulating machine can be of invaluable service . . . because it will serve more economically and with greater speed and accuracy than a large clerical force" (Leffingwell 1926, 176). Calculators and tabulators helped firms use more information more quickly and less expensively than ever before, increasing their effective supply of internal information. As with the personal computer today, such machines may also have had a symbolic or fad value beyond their contribution to efficiency.

4.2.5 Disseminating Information

The increasing amount of information flowing up and down firms created two types of problems in dissemination. The data being recorded, analyzed, and passed up the hierarchy created what would now be described as information overload for top decision-makers. Fewer and fewer people were getting more and more information at the top levels of the hierarchy. Ways of presenting information for easier understanding were needed. Downward flows of information, on the other hand, posed a problem of getting notices of policies and procedures to increasing numbers of people at the bottom levels of the hierarchy, preferably in a form that could be consulted in the future. Presentational techniques and duplicating methods and devices were adopted to address these two problems.

Reading and absorbing even the most relevant of the enormous amount of available information was increasingly difficult for middle and top management. The tabular forms developed to ease compilation of data also made information somewhat easier for its recipients to use than did prose documents with embedded figures. Still, extracting trends and comparisons from tables took time and study, and as the amount of available information increased, decision-makers often did not have time to study all of it. Around the turn of the century, graphs and charts emerged as an important managerial tool for dealing with this problem. Such techniques may be considered a bureaucratic information technology for disseminating information in a form more efficient for its recipients to absorb.

While graphic representations of data had existed for at least a century by then, only in the late nineteenth and early twentieth centuries did they begin to be used to display managerial data (Funkhouser 1937; Yates 1985). Introduced into firms by engineers-turned-managers, graphs gained popularity in the early twentieth century as a modern way to assure that the information gathered and analyzed at some cost to the company would be used to aid in managing it. William Henry Leffingwell, an early twentieth-century expert in office systems and machinery, summarized the prevailing view: "There is . . . no doubt that a graphical chart, correctly made, shows tendencies much quicker and impresses the mind more accurately and emphatically than do figures" (1927). An earlier systematizer noted that the executive "must have reports of his costs, his sales, his profits or his loses, but he must have them in such forms that he can interpret them instantly and draw conclusions for future guidance. . . . In a modern organization the executive obtains this information through a system of graphic records, a simplified summary of countless departmental statistics and itemized reports" (Parsons 1909, 214–15). Because they were not able to get through all of the reports and documents sent to them, around 1920 Du Pont's Executive Committee went so far as to have a comprehensive set of graphs developed around the firm's return on investment formula, and to have a room specially equipped to display them to the committee for decision making (Yates 1985).

Disseminating the increasing number of notices, bulletins, and other statements of policies and procedures flowing down the hierarchy required another type of information technology: some method of duplicating documents in numbers ranging from half a dozen (e.g., for notices to department heads) to hundreds or even thousands (e.g., to all employees). Press copying made one or at most two (relatively dim) copies. Initially, there were only two alternatives for creating multiple copies: writing or typing a notice repeatedly, or having it printed. Both were costly and time-consuming processes. While railroads, with wide hierarchies and critical safety issues, depended heavily on expensive printing for such downward flows of information, manufacturing firms were reluctant to incur that expense. In the late nineteenth century, rapid and inexpensive methods of creating small and large numbers of document

copies became available and were rapidly adopted by firms to aid in disseminating information to employees (Yates 1982).

Carbon paper and the typewriter provided a solution for small numbers of copies. In addition to providing the loose copies demanded by vertical filing, carbon paper used with fine onionskin paper by a strong typist could make up to ten copies at one typing. Thus in the 1880s, as firms adopted the typewriter, carbon paper became a way for them to create small numbers of copies. This method was convenient, rapid, and inexpensive for downward communications at the upper, narrow part of the hierarchy, or in small units. It could also be used to reach a larger population by having each department head or foreman circulate a single copy around a group. When used this way, however, the individual employees did not keep a copy, thus making later reference more difficult. A method was still needed for creating larger numbers of copies.

Two such copying methods emerged in the last quarter of the century. The hectograph and related methods used a gelatin bed to transfer an original, which was typed or written in aniline dye, onto up to one hundred copies (Proudfoot 1972, 34–36). This process was the predecessor of the more convenient spirit duplicating method that was introduced in the 1920s and was still common as late as the 1970s. Duplicating methods based on the stencil principle passed ink through holes in a stencil master to make hundreds and even thousands of copies from a single master. Thomas Edison first introduced the stencil technology to America, initially with his electric pen and later with the Edison mimeograph marketed by the A. B. Dick Company (Proudfoot 1972). Like the typewriter (with which the stencil process was soon coupled), stencil duplicating was not originally marketed for use within firms; it was advertised as a way to disseminate information outside of firms, as with advertising circulars, price lists, and musical scores.[9] Large firms such as the railroads and telegraph companies, however, were quick to see the value of this technology to their internal communication, and soon stencil advertisements listed internal circulars and notices among the items the devices could be used to duplicate.

By the end of the nineteenth century, duplicating technologies were widely used for quick and inexpensive dissemination of large numbers of notices or other mass distribution items within firms. These devices ensured that those at lower levels received their own copies of such notices so they could refer to them in the future. Such copies also helped fill the vertical filing systems that quickly proliferated throughout firms.

9. The target market is revealed in contemporary advertisements, such as an advertising circular "Edison's Electrical Pen and Duplicating Press," 1876, in the Edison National Historic Site in Menlo Park, NJ, and in catalogues issued by retail businesses carrying such equipment, such as "Catalogue of Telegraph Instruments and Supplies," Western Electric Company, 1883, Trade Catalogues, Hagley Museum and Library.

4.2.6 Information Technology and Information Supply

The information devices and techniques used by mid-nineteenth-century businesses to handle information would have been hard pressed to handle the volume of internal information that firms used by the early twentieth century. In response to the growing demand for internal information, mechanical and clerical technologies emerged and were widely adopted to aid in every phase of information handling, from collecting and compiling it to disseminating it. To some extent, the mechanical and bureaucratic technologies of information came to be seen as external symbols of modern, systematic management, giving the supply side, as well as the demand side, an additional ideological component.

In some cases, the techniques or devices already existed in some form, but were only widely adopted when the need emerged. Carbon paper and graphic presentation of data, for example, fall in this category. In other cases, technologies were created or significantly developed in direct response to the market demand created by business information needs. In the 1920s Leffingwell argued that what he terms the "office appliance industry" of mechanical devices such as the typewriter, adding machine, duplicator, and tabulator resulted from the new demand for uniform, systematic methods of management:

> When business method was individual and self-centered and business aims narrow and secretive, there was little incentive for inventive genius to burn the midnight oil in the search for business machinery. The demand for mechanical office appliances did not exist because there was no similarity of method. But as similarity of method spread through the exchange of ideas, the possibilities for mass production attracted some of the keenest minds in the country, who turned to making machines and devices that would simplify the mass of problems crowded into the business man's day. As a result, an immense industry has been created—an industry which produces office machines and devices for the entire world. (1926, 18)

Thus demand factors were significant in spurring increases in the supply (and decreases in the cost) of information technologies, which in turn increased the affordable supply of information within the firms. These reinforcing tendencies were further enhanced as the technologies themselves came to be seen as evidence of modern management techniques, and thus were adopted for ideological as well as efficiency reasons.

By increasing the supply of affordable information, these information technologies played an important enabling role in the development of large firms, especially vertically integrated ones that needed to coordinate multiple functions. I would argue that without these techniques and devices, the supply of information available to firms at reasonable prices would not have kept pace with the increasing demand as firms grew, took on additional functions, and

systematized their management.[10] Thus growth and vertical integration might have been limited, or new managerial methods for internal coordination, methods less dependent on vertical, paper-based information flows, might have been developed.

4.3 Scovill: A Case Study of the Evolution of an Information System

In any given firm, the internal information system evolved unevenly, the product of continual interplay between supply and demand factors. Changes in information technology often involved significant investment in money and time, as well as shifts in power within the firm. While some changes were incremental, others involved real discontinuities in procedures and capabilities. This section demonstrates that process in the Scovill Manufacturing Company.[11]

The case discussion is organized primarily as a narrative, to preserve the complexities and interactions over time. I will periodically step back into a more analytic mode, but the narrative structure is essential to the point. The theoretical and analytic approaches characteristic of economics generally assume the actors' motives and often see a sequence of events as a single event. The narrative structure used below tries to capture the unfolding of events in time and to understand the actual motives of actors whenever possible. It examines the complex interactions between supply and demand, including the influences of factors such as ideology and power, in a single company's use of internal information. While the specifics of this case are not generalizable, it provides a view of the types of factors and dynamics that may be present in many firms and that economists must understand to make sense of firms' uses of internal information.

4.3.1 The Early Years: No Systematic Internal Information

Founded in Waterbury, Connecticut, in 1802 as a manufacturer of brass buttons, Scovill was initially a family partnership, and then several interlocking partnerships, each of which produced a product line. By 1850, when it was incorporated, there were three such partnerships manufacturing buttons, hinges, and photographic plates, as well as semifinished brass products. The

10. The supply side of the information equation may have reinforced the demand differences between Japanese and American management methods. The nature of the Japanese written characters precluded a Japanese typewriter that could produce text faster than it could be produced by hand. Thus even if the demand for extensive written communication had been high in Japan, the slow speed and high cost of producing records and documents might have prohibited the level of use that developed in American firms.

11. A more detailed discussion of Scovill is in Yates (1989, chap. 6), one of three case studies in the book. The surviving Scovill records that serve as a basis for the story reside in Baker Library of the Harvard University Graduate School of Business Administration. Scovill has survived and thrived in recent years as a diversified Fortune 500 firm.

newly consolidated and incorporated firm, which had a work force of over 150 people, thus had multiple product lines requiring several different processes. The rolling, casting, and different finishing "rooms" were essentially separate departments, run by skilled workers who reported directly to the owners. Nevertheless, at this time and for another two decades, Scovill collected virtually no internal operating information for use in decision making, depending solely on accounts of external transactions and oral interactions with the skilled workers.

Scovill lagged behind the contemporaneous textile factories discussed above in its use of systematic internal information for coordination. The internalization of multiple products and processes left it without pricing information once provided by the market. Nevertheless, the firm as a whole, though it faced competition in its various markets, was a successful and growing concern.

One fairly unsystematic source of internal information for Scovill was its correspondence with sales agents and later store employees. Until 1846, when Scovill established its own store with salaried employees in New York, sales were handled principally by commission agents (Marburg 1952). Relations with the sales agents and initially with the store were relatively unstandardized, with no systematic flows of information except for the rendering of semiannual accounts of transactions in traditional form. Otherwise, correspondence was ad hoc and situation-specific.

Minor developments in correspondence between the New York store and Waterbury headquarters reflect changes in the cost of transmission and duplication. In 1845 and 1851, postal rates dropped significantly, lowering Scovill's cost for letters to New York from 12.5 cents per sheet to 3 cents for most letters (U.S. Bureau of the Census 1975). The change from hand copying to press copying of letters (sometime before 1854) reduced the time and thus cost of copying the increased number of letters into bound volumes. In a change that probably reflects both increased business and decreased costs, the number of letters exchanged had increased significantly by the mid-1850s, while the length of each letter had decreased. Still, except for the traditional semiannual accounts, the flow of information continued to be unsystematic.

Predictably, a major source of friction evident in the correspondence was a tendency for agents to cut prices to meet the competition. As an agent stated his case in one such dispute with the owners in Waterbury, "I am bound to comply with your instructions but I do presume you do not wish me to adhere to a stipulated price when your competitors are selling for less."[12] Since letters took from a day to a week (depending on weather) to travel from Waterbury to

12. Taylor to Scovill, 16 March 1829, case 13, Scovill Collection 2, Baker Library, Harvard University Graduate School of Business Administration. Hereafter materials from this collection will be inserted parenthetically in the text, in this form: Scovill 2/13, 16 March 1829.

New York, requiring approval from headquarters for any changes in price would have lost many sales. This situation continued until after the telegraph came to Waterbury in 1849. The telegraph reduced, though it did not entirely eliminate, this friction.

Although the firm gradually came to use the telegraph fairly frequently,[13] it was used almost exclusively to exchange price and timing information about specific, urgent orders. Thus it enabled the firm to improve service to distant customers. Because of the high cost it was not used for less time-sensitive communication, which continued to take place in correspondence.

4.3.2 The Late Nineteenth Century: Initial Progress in Using Internal Information

The first major change in Scovill's use of internal information came in the 1870s at the hands of C. P. Goss, company secretary, and M. L. Sperry, company treasurer. These two men, who were hired as bookkeepers in the 1860s, established a managerial dynasty that governed the firm longer than the Scovill family did. They instituted "a system of bookkeeping from which the profits of the various sections of the business—mill, . . . button, burner, aluminum departments, and so on—could be discovered" (Bishop ca. 1950, 73). Various record-keeping forms and a monthly statement were created as part of the system.[14] On the basis of these records, the main office recorded into bound volumes monthly and yearly figures for sales, production, labor, and interdepartmental transfers of materials for each department, as well as sales by sales office. The information provided by this bookkeeping system did not allow costing of the different specific products produced by each department (e.g., the many types of buttons made by the Button Department), but it at least gave Sperry, Goss, and the president a picture of overall results of each department.

Why was this primitive cost accounting system introduced at this time, rather than at the point of incorporation in 1850 when several functions had been combined in a single firm, theoretically creating a need for internal information to supplement market signals? The addition of the firm's first layer of general management under the top executive may be significant in the actual timing. Before Goss and Sperry rose to secretary and treasurer, the owners were aided only by skilled workmen and bookkeepers. The two men represented a significant new layer of management that had to be vertically coordinated. By inventing or, more likely, adapting a cost accounting system already used elsewhere, they improved their ability to serve as the link be-

13. By 1877, one in ten communications in the press book of outgoing correspondence (Scovill 1/461) was a telegram.

14. These forms have not survived to the present, but they survived past 1945, when they were noted by a company historian in a historical list of forms (which has survived in the Scovill Collection in Baker Library), and were used by Bishop in preparing his manuscript. Only one of the bound volumes has survived (Scovill 1/242, 1881–87).

tween the president, on the one hand, and foremen and workers, on the other. While Johnson and Kaplan (1987) have identified the internalizing of multiple functions in a single firm as the main factor responsible for the rise of cost accounting, Scovill's history suggests that the introduction of a layer of general management under the owners (a factor also present in the textile mills) was significant as well. This conclusion is in agreement with Chandler's (1977) emphasis on the growth of middle management as a key innovation in the development of the firm.

The new system remained the principal source of systematic internal information for the next few decades. It survived from the 1870s, when the firm numbered just over three hundred employees and assets were about $1 million, into the early twentieth century, when the firm employed well over a thousand and assets were about $3 million (see tables 4.1 and 4.2), virtually unchanged (Bishop ca. 1950).

No corresponding downward flow of recorded information was instituted

Table 4.1 **Growth in Employment at Scovill**

Year	Approx. Number of Employees
1850	157
1874	314
1880	~400
1887	~1,000
1892	1,157
1914	~4,000
1916	~12,000

Source: All figures are from Bishop (ca. 1950), 200, 205–6, except that for 1880, which is from penciled notation in case 253, Scovill Collection 2, Baker Library, Harvard University Graduate School of Business Administration.

Table 4.2 **Growth at Scovill in the Late Nineteenth Century**

Year	Net Earnings	Assets	Year	Net Earnings	Assets
1880	$ 80,133	$1,225,743	1891	117,502	1,628,227
1881	136,141	1,308,841	1892	149,026	1,722,060
1882	76,473	1,519,395	1893	94,066	1,686,475
1883	62,505	1,621,621	1894	84,975	1,724,408
1884	36,696	1,547,413	1895	198,567	1,945,496
1885	81,238	1,571,330	1896	62,027	1,816,572
1886	101,476	1,639,342	1897	254,745	1,905,208
1887	93,280	1,617,765	1898	338,745	2,058,286
1888	338,745	1,671,508	1899	427,958	2,322,483
1889	209,629	1,614,152	1900	242,649	3,081,492
1890	76,767	1,657,297			

Source: Cases 253 and 254, Scovill Collection 2, Baker Library, Harvard University Graduate School of Business Administration.

within Scovill's plant during this period, in spite of the growth in work force. In fact in 1887, when the firm already employed about one thousand, Sperry explicitly stated his opposition to written policies:

> We have never had any shop rules printed. There is a general understanding that ten hours constitute a day's work and that the hands are expected to do a day's work if they get a day's pay. Each department is under the direction of a foreman, in whom we trust and who sees that the hands are industrious and attend to their business. If they do not do it, he sends them off and gets others. . . . We do not think printed rules amount to anything unless there is somebody around constantly to enforce them and if such a person is around printed forms can be dispensed with. (Bishop ca. 1950, 205)

An internal telephone system was installed early in the 1880s to allow oral exchanges between the office and foremen at various mill and shop facilities, but the foreman retained informal and direct control over the workers.

In the last two decades of the century, correspondence with Scovill employees outside of Waterbury continued to provide relatively unsystematic information. By the 1880s Scovill had stores in Boston and Chicago as well as New York. The firm's correspondence with all parties, including customers and suppliers as well as its own stores, was increasing rapidly. Early in the decade, Scovill filled five 1,000-page press books per year. From 1883 through 1885 this total climbed to six, seven, and then eight volumes per year, then leaped to ten volumes in 1886. For the rest of the decade and into the next, the number hovered around nine to ten volumes each year.[15]

In 1888, after the big increase in correspondence, Scovill adopted the typewriter (Scovill 1/315, 1888). The timing suggests that the acquisition was motivated by need more than by fad and that it was a response to, rather than a cause of, the increase. This time-saving device, along with the hiring of a female typist by 1889 and a second one by 1893 (Bishop ca. 1950, 460), relieved the increasing burden of document production on Goss, Sperry, and other office personnel. The new recording technology and division of labor lowered the costs of document production, thus enabling the firm to continue expanding its correspondence without incurring excessive costs. The flow of information from its stores, however, continued to be unsystematic.

4.3.3 John Goss and the Systematic Expansion of Internal Information

The next major set of changes in Scovill's acquisition and handling of internal information came when the second generation of Goss management introduced the philosophy and techniques of the systematic management movement into the firm to cope with growth. When the company president under whom C. P. Goss amd M. L. Sperry had worked for three decades died in 1900, they served consecutively as presidents of the firm. In the years be-

15. Since most letters were one page long, the shift from handwriting to typing did not radically alter the capacity of a single press volume.

tween the turn of the century and World War I, the firm grew to four thousand employees, the managerial hierarchy expanded, and a series of different departmental forms were adopted. Early in the period C. P. Goss's son, John, became first superintendent of the Burner Department and later general superintendent of manufacturing. During that time this proponent of the period's managerial trends created an extensive internal information system at Scovill.

In his 1905 "Report Made to the General Manager on Timekeeping in the Departments" (Scovill 2/34, "Notices, 1905–1907," 22 February 1905), John Goss revealed his sympathy with the systematic management philosophy. He noted that potentially costly inconsistencies in payroll timekeeping—one area of data collection—had emerged across departments over time. The problem arose, he asserted, because "the responsibility unchecked rests entirely upon the department superintendents and their subordinates to systematize or leave unsystematized those details which are vital to the payroll scheme." He urged "those in authority over all the departments to get together with the data and decide upon a plan which shall be simple and at the same time applicable to all alike." Thus he wished to take some authority from the department superintendents, including himself, and draw it up to a higher level of management by centralizing and standardizing information collection. To prevent any misunderstandings or deviations, he recommended establishing a set of regulations, to be disseminated downward by printing them in each payroll book. His analysis of the problem and recommendations for solving it suggest that his belief in systematic management transcended his own local interests.

Over the next decade, he and other Scovill executives instituted many systems for collecting and analyzing internal information. For example, he stated in one document, "It is desirable to get systematized as soon as possible the method of receiving goods on our various orders from outside sources of supply, so that we may be sure of getting a reasonable report from the proper source of information upon the quality of each lot of material that arrives" (Scovill 2/34, "Orders and Instructions," 20 July 1909). Such a process was systematized by creating forms or tickets on which information about the material was recorded. This information had immediate value to those using the material next. It could also be analyzed later to aid in the choice of suppliers, as well as to track the inputs into particular orders and to reduce waste. This was one of many such systems put in place.

In 1907 John Goss developed a new set of monthly cost analysis sheets for the Burner Department (Scovill 2/333). After demonstrating the usefulness of his new methods on a small scale, he extended them to the rest of manufacturing as he rose to general superintendent of manufacturing in 1910. Tabular forms were used for recording monthly costs for each room of each department, with the costs categorized into maintenance and repairs, supplies, direct and indirect labor, and interdepartmental transfers. Each of these categories was further subdivided to provide greater analytic detail. Monthly summary sheets for the whole department were compiled from these sheets. Finally,

from these the office prepared yearly analyses, including totals, overhead figures, and the ratios of each of the other types of costs to direct labor costs. The yearly summary also included a column for the previous year's figures, for comparison. The yearly summary report for 1907 left blank the column for the previous year's figures, since the old Sperry and Goss system did not provide the information necessary to make direct comparisons.

A brief history of Scovill's system of accounts, written decades later by a company historian, labels this set of changes the "formalization of cost factors in a series of analytical records, the results of which could be reported to the main office executives and there used in decisions. . . . This seems to have been developed into a well articulated 'cost office' in or soon after 1910."[16] By 1916 this system of cost accounts was so extensive that employees were issued bound, printed books, each about one inch thick, describing the system and explaining the forms and criteria for charging costs to different accounts. This documentation of the system explained its role as follows: "The price at which goods are sold is based on their cost; they are not sold at less than cost, but at cost plus a profit. Since no manufacturing business could exist long without making profits, it becomes evident that the success of any business depends to a great extent on the accuracy of its cost system. The system of accounts is, now-a-days, closely interwoven with the cost system and has become of equal importance" (Scovill 2/236, 1916).

So important a change had both costs and benefits to the firm. In addition to the costs of devising the scheme and creating new forms, there were costs for disseminating instructions on how to use them and costs for monitoring their use. Still, the new system had clear benefits, as well. While the old Sperry and Goss system allowed the firm to compute an approximation of the overall profits of each room or department, the updated system focused on the cost structure of each unit's operations and eventually the costs of specific products. As implemented in 1910, it allowed management to monitor the relative contributions of different types of costs and to see at a glance the ratio of each category and subcategory to direct labor cost. Such amounts and ratios could be compared from room to room and over time. It also provided figures on the supplies and labor wasted on spoiled work, allowing them to address quality issues. As the system was further articulated, it provided more and more detail on specific costs. Whether all of this detail was worth its costs or whether John Goss and Scovill were at some point simply following the dictates of systematizers cannot readily be determined.

The cost accounts and other new data collection and analysis systems being introduced by John Goss and others brought more and more information to executives. At the same time that they were introducing such systems, they

16. E. H. Davis, "System of Accounts," a typed document inserted in a 1916 instruction book for the accounting system (Scovill 2/236). Internal evidence suggests that the summary was written in the 1940s.

began to adopt graphic techniques of presenting some of the new data being generated. To make cost comparisons between the Burner Department in 1907 and its successor Manufacturing Department in 1908 easier to comprehend, Goss had the data from the sheets graphed for easy comparison (Scovill 2/328). A few years later, cost data was being graphed as a time series. Clearly extra clerical time was required to make such graphs. The cost was outweighed for Goss by some combination of the time savings, the improvement in understanding for the executives, and the symbolic value of using graphs.

At the same time that Goss was establishing an upward flow of internal information, he also established a downward flow to standardize and document policies, rules, and orders. In the late nineteenth century, C. P. Goss and Sperry had initiated the first upward flow, but they rejected on principle a corresponding downward one. By the early twentieth century, the work force was still larger, and additional levels had been added to the hierarchy. Still, a change in ideology as much as size probably drove the introduction of written downward communication at exactly this time.

Sometime before 1905, John Goss began issuing to his workers and foremen in the Burner Department a variety of written announcements, notices, and specific orders, generally aimed at systematizing their procedures.[17] As he rose to the position of general superintendent, he continued to issue them to a wider audience, including department heads, and also to diffuse this practice throughout the organization. By at least 1908, C. P. Goss was also issuing occasional notices, and by the second decade of the century, notices, instructions, and manuals were being issued at all levels of the organization (Scovill 2/34, "Orders and Instructions," 1905–14). The idiosyncratic methods of individual foremen, superintendents, and other lower and middle managers were curbed by the increasing systematization of procedures at every level.[18]

Consistent methods for handling such internal communication had not yet been devised; individual notices were produced, disseminated, and stored in a variety of ways. Rather than copying them in the press books used for outgoing correspondence, John Goss had them typed with multiple carbon copies. He kept the original and one copy in his own box file.[19] Another copy (or several copies, when he became superintendent of manufacturing) was rubber-stamped with a list of rooms in the affected department. This copy was circulated from foreman to foreman, each one checking off or initialing the appropriate room name. Such a system guaranteed that all foremen saw the

17. The earliest surviving written order (in Scovill 2/34, "Notices") is dated 28 January 1905, but it is designated Superintendent's Order no. 137, suggesting that Goss had been issuing such orders for many months.

18. The content of these notices and their role in systematizing procedures are discussed in detail in Yates (1989, 172–76).

19. The originals and copies in the folder labeled "Notices, 1905–1907" (Scovill 2/34) have two holes punched at the top, indicating that they were stored in a Shannon file, a box file with an arched wire that held papers in place through the punched holes. The carbon copy in each case is stamped "File."

notice, but not that they had ready access to it for future reference.[20] Goss was to note later that each foreman had his own way of doing things and wanted to change his methods as little as possible (Davis ca. 1968, 13). Thus the system was clearly suboptimal because it depended on the foremen's easily distorted memory of the notice instead of the notice itself. Nevertheless, it was not until sometime in the second decade of the century that the firm adopted duplicating technology. The delay may have been linked to another problem, the lack of a system for local storage of documents. That problem was soon to be addressed comprehensively.

4.3.4 Investing in Storage and Retrieval: Vertical Filing

By the second decade of the twentieth century, Scovill's information storage and retrieval system was under increasing pressure from internal and external sources (Yates 1982). New categories of documentation were being generated within the Waterbury facilities, as part of the upward and downward flows of recorded information John Goss initiated. These had no obvious storage place in the system of press books and letter boxes used for correspondence. This internally generated information was stored haphazardly and inconsistently, if at all.

Waterbury's rapidly growing correspondence with the external world, including its own stores, posed additional problems. Shortly after the turn of the century, Waterbury established a separate series of press books for its correspondence with the New York store (Scovill 1/510–58), presumably to make this internal correspondence easier to find, as well as to reduce the volume of the main series. In the first decade of the century, this new series filled two to three press books a year. By the second decade, however, this series alone exceeded in yearly volume that of Scovill's entire correspondence in the late nineteenth century. In 1911, headquarters started using the more convenient carbon copies and rolling press copies instead of copying directly into press books. For the first three years after the change, however, they bound these loose copies into chronological volumes functionally equivalent to the press books, generating twelve and thirteen volumes a year in 1912 and 1913. While neither the main press book series nor the letter boxes of incoming correspondence have survived from the early twentieth century, probably because of their enormous bulk, they no doubt increased correspondingly.

The enormous growth of this correspondence had consequences for storage and retrieval. Storage space alone clearly posed a problem, but retrieval was potentially more problematic. Consulting all of the correspondence with and about a single customer or transaction (e.g., to resolve a dispute, assess a request for credit, etc.) required searching many press books and letter boxes.

20. One foreman, E. G. Main, had each notice retyped in his office and stored the typed copy on his own Shannon file. This system gave him access to the notices, but at a high cost in retyping them.

The chronologically organized press books of external correspondence were indexed by correspondent but not by subject. Unless the precise dates of the desired letters were known, the indexes and then the press copies of several volumes (each covering a month or less) might have to be consulted. In addition, the searcher would have to consult the box files of incoming correspondence and the separate press books and box files for correspondence with the New York store about that customer. Clearly, retrieval was more time-consuming in the early twentieth century than it had been in the late nineteenth.

There is some evidence that by 1913 more significant problems of storage and retrieval had begun to appear, though their frequency and severity are hard to judge. A letter from Waterbury to the New York store admitted defeat in one attempt to retrieve a requested piece of information: "Replying to yours of the 24th regarding terms to Jos. L. Porter & Co., we are sorry that our record for 1908 is quite as inaccessible as yours seem to be, and, unless you consider the matter of enough importance, you will let the matter pass" (Scovill 1/558, 26 December 1913). Accessibility had become a limiting factor in consulting some recorded information. This incident may have been an isolated one, or it may represent a recurrent event indicating that Scovill's correspondence was exceeding the firm's ability to handle it with its existing storage system.

Even before this incident, Scovill had begun looking into new storage and retrieval systems, though it is not clear whether they were driven primarily by the inefficiencies and accessibility problems of the current system or by a desire to adopt the most modern office methods for symbolic reasons. Redesigning the firm's entire storage and retrieval system required both purchasing equipment and changing procedures, and this investment was considered carefully in advance. In late 1912, an investigation of filing practices at another brass company resulted in a report on "Vertical Letter Filing; as practiced by the Bridgeport Brass Co." (Scovill 2/26, 12 December 1912). This report described the organization, principles, equipment, and procedures used at that firm in minute detail, indicating the importance Scovill itself put on these matters as it explored the options for its own use. The report noted, for example, Bridgeport's total dependence on carbon, rather than rolling press, copies; its methods for combining all correspondence to, from, and about a customer in a single place under that customer's name; its use of subdivisions by subject headings "where they control the correspondent, as in the case of their own agents or stores"; and its method of moving old correspondence, in vertical file transfer cases, into a fireproof vault every six months.

Establishing a similar system at Scovill required a considerable investment. Scovill had to obtain new equipment, including such items as file cases, folders, dividers, and tabs. In addition, it had to abandon its previous investment in letter presses and rolling press copiers, as well as any inventory of letter press paper and letter boxes. Finally, and perhaps most significantly, it had to

abandon the human investment in the old, familiar procedures and invest in new procedures, including overcoming any resistance to them. One year after the Bridgeport Brass report, and only one week after the letter confessing inability to locate a desired piece of information, Scovill announced the new system.

Headquarters timed the introduction of the new system to take effect at the beginning of 1914, stating in its correspondence with the New York store, "On January 1st we shall start a new system of filing our letters and we shall use the vertical system of filing" (Scovill 1/558, 27 December 1913). It gave the New York store careful directions about its letters to Waterbury, requiring that they limit each letter to one subject, usually a particular customer, and that they provide that customer's name at the top of the sheet as a subject indicator to aid in filing it. The change increased standardization at the expense of store autonomy, and thus encountered some resistance. A follow-up letter a few days later noted the store's failure to follow the new rules in some letters and stated, "We are changing our system of filing, and we must INSIST that you pay particular attention to this matter" (Scovill 1/558, 31 December 1913). This reminder seems to have elicited better compliance.

The firm was thus committed to making the new files an effective storage and retrieval system allowing them ready access to stored information. After the initial investment, the system clearly increased the supply of accessible internal correspondence by reducing the cost of searching for it. Moreover, the carefully planned centralized correspondence file was soon supplemented by unplanned decentralized files in the offices of managers down to the level of foremen.[21] These local repositories of information soon included copies of downward notices (the adoption of stencil duplicating technology in the second decade of the century now allowed each foreman to keep a copy of each notice) and of upward reports of the sort introduced by John Goss.

Repositories of readily retrievable information were now available at all levels of management. A foreman or superintendent could consult downward directives (or be referred to them by a higher-level manager) to determine standard operating procedures. The general superintendent and other superintendents and managers could consult cost summaries and other types of reports to analyze performance over time and to compare performance among units. The new filing system provided an accessible organizational memory that reduced the incremental cost of future reference to information.

The unplanned proliferation of decentralized files also seems to have stimulated increased documentation of lateral exchanges (Yates 1982; 1989, 184–86). While many upward and downward communications have survived from before the advent of the vertical filing system, there is no surviving lateral

21. A set of files for two foremen and for E. H. Davis, the statistician, have survived from this period (Scovill 1/26).

correspondence within the Waterbury facilities from that period. The surviving post-1914 set of files from a single foreman, however, is dominated by lateral messages. The new filing system was responsible for the survival of these documents, and probably for their numbers, as well.

Many of these lateral memos were clearly written for documentation more than for conveying new information—they were intended to create a record that each party could keep on file. Many started out "confirming our discussion" or "confirming our telephone conversations." A series of communications between the foreman of the Casting Shop and someone of comparable level in the Research Department, for example, documents the high level of tension between the two departments about power and authority issues. One message from the foreman of the Casting Shop begins by quoting a previous message from the Research Department about suspending certain weekly reports and analyses. It continues as follows:

> I would like to go down on record as saying that if at any time I wish to have any part of the program, which has been agreed upon by the Research Committee and myself, suspended I will notify the Research Committee. This to my mind is a serious subject and unless you feel that it is impossible for you to give us the required information, in so far as analyses are concerned, I will expect that the program agreed upon by the Research Committee and myself, be adopted and not the program outlined in your letters of above dates. (Scovill 2/26, 25 March 1918)

Managers had very little incentive to document lateral exchanges of position if they were not available to both parties for future reference. Before vertical files, there was no consistent way to store them to guarantee their availability in the future. After the proliferation of files throughout the organization, each party could keep copies in a local set of files, and thus had more incentive to create them.

4.3.5 E. H. Davis and the Postwar Rationalization of the Information System

With the new filing system, all the essential elements of Scovill's information system were in place. In the next few years, the firm grew rapidly in response to the demands and opportunities of World War I (see table 4.3 for some financial measures of the firm's growth during this period). The information system grew increasingly vast and complex. By 1919, over two hundred different routine reports (each of them issued at intervals ranging from weekly to yearly) drew information in a variety of forms into the general superintendent's office. Because the various reports had emerged at different times over the preceding fifteen-year period and responded to a variety of needs, some of which had changed over time, the reporting system itself needed to be systematized. In 1918 the Research Department, which had been

Table 4.3 **Growth at Scovill in the Early Twentieth Century**

Year	Net Earnings	Dividends	Assets
1900	$ 242,649	$ 200,378	$ 3,081,492
1901	200,000	199,088	3,368,376
1902	492,999	199,168	3,368,376
1903	331,123	211,430	4,621,494
1904	413,700	255,116	4,718,145
1905	392,647	324,210	5,159,167
1906	595,575	290,162	6,266,330
1907	767,286	323,064	6,366,026
1908	469,229	324,106	6,324,836
1909	497,864	324,112	6,772,851
1910	517,082	324,112	7,257,228
1911	501,344	324,112	8,128,503
1912	709,854	377,694	8,213,958
1913	402,624	400,000	8,086,591
1914	456,995	400,000	8,351,659
1915	5,974,362	900,000	17,520,561
1916	13,403,462	5,550,000	28,001,237
1917	9,204,884	6,500,000	33,528,791
1918	2,130,903	2,425,000	27,970,944
1919	2,156,025	1,000,000	30,260,896
1920	983,967	1,000,000	30,722,660
1921	937,764	1,507,782	28,702,416
1922	989,408	1,000,000	28,771,904
1923	3,167,761	2,062,500	35,020,027

Sources: Figures from 1900 to 1910, plus assets for 1911 and 1912, come from case 254, Scovill Collection 2, Baker Library, Harvard University Graduate School of Business Administration. Subsequent figures come from Moody's (1916, 1919, 1924, 1931).

created shortly before the war, hired E. H. Davis to establish a Statistics Office. In doing so, Scovill was investing further resources in its internal information system.

In his attempt to improve statistical analysis of data for decision making, Davis was forced to begin by exploring and assessing the entire upward flow of information in the firm. In an initial report mapping out the task before him, Davis described the development of the existing information system:

> In this plant as in all plants, notation is made locally covering productive progress. In the beginning certain basic records—such as memoranda, job tickets, etc.—were essential for the consistent performance of the work itself. From this, gradually, more permanent records were organized—either as files in which the working records were preserved or in the form of summarized rescripts [i.e., reports] from them—and thus a sort of numerical history was developed as a background in the more important production offices. Subsequently they became the basis for comparative estimates, contract making, etc. (Scovill 2/34, 13 August 1918)

His preliminary tasks, as he stated them in this report, did not involve analyzing the statistics but rather improving the quality and consistency of the data to be analyzed by addressing shortcomings in the information-gathering system. His initial goals were as follows:

X. A general survey of the existing statistical or record situation in the plant as a whole through a study of printed forms now in use.
Y. Repair work in department record systems, by filling gaps, remedying present deficiencies and inaccuracies, etc.
Z. Standardization of department records.
W. Anticipating and providing for changes of record necessitated by future changes in the work of production departments.

Davis intended to achieve these goals gradually, first gathering and investigating all data collection forms and making his office "a clearing house of reference as to *what* current records actually exist, and *where* they are available." He would then make inquiries into the appropriateness of records of various departments. "Eventually," he continued, "this office may become the regular depository of carbon copies of many such reports or records, as they are made; and thus a general body of statistical data covering the entire plant will be accumulated, by a sort of evolution rather than by radical change effective by executive order." John Goss, as a rising member of a managerial dynasty, had initially recommended and later instituted increasing numbers of executive orders effecting radical changes in the information system in the early years of the century, overcoming opposition when necessary. Davis was a newcomer with neither familial ties nor line position to give him authority. Moreover, by the time of his arrival, substantial material and human investment had already been made in the elements of the current system. What was possible and necessary, he decided, was an incremental approach to rationalizing it.

His first steps in this process, described in a follow-up progress report three months later, involved gathering records and reports from throughout the firm (Scovill 2/34, 8 November 1918). He saw the data as falling into six areas: "Production Statistics," "Process Statistics," "Inventory of Stores Statistics," "Industrial or Employment Statistics," "Financial or Monetary Statistics," and "General and Economic Statistics." Cost accounting was (and continued to be) handled by a separate organization, the Cost Office (Scovill 2/34, 16 May 1919). The records and reports Davis gathered revealed many inconsistencies, but in accordance with his incremental plan he did not attempt an immediate revision of the reporting system. Instead, in some cases he established an "intermediate step": "The receipt of original reports is now, in many cases, followed by a consistent tabulation of the information, and then by charting the results."

This strategy, while avoiding conflict with line managers, had costs. In the

following passage from a memo concerning production reports for the Wire Mill, Davis revealed both the inconsistencies in reported information in the firm and the difficulties and costs of dealing with them:

> Comparing these reports with the production reports now being made by the Statistics Office for the Rolling Mill and for screws and rivets, I note the following differences in arrangement:
>
> 1st. The Wire Mill report, being weekly, does not permit of exact summary for even months. The report does not give the items per day, so that a reference to the Office books will be necessary to determine a 31-day month total. This was done, I recall, several months ago when a special production report was called for by Mr. John Goss.
>
> 2nd. The items are given in total, without analysis into orders and shipments for manufacturing departments and orders and shipments for outside customers.
>
> 3rd. No record is kept and no figures are given respecting undershipments or overshipment on orders. Mr. Roper's opinion is that there is an average overshipment not in excess of 10%, but probably in excess of 5%.
>
> Should it be desired to present a monthly production report from this Mill on the same basis as the others I have mentioned, it would be necessary either to make a periodical survey of the books in Mr. Roper's Office or else to establish a duplicate set of bookkeeping similar to that which the Statistics Office is now doing for the Rolling Mill and, in a lesser measure, for screws and rivets. Unless this should be desired by the officers who now receive Mr. Roper's report, I should advise leaving the matter alone, for the time being at least. The present work of the sort which we are doing occupies the whole time of one clerk, or about one-fifth of our present clerical force.
>
> The general question of production reports, their form, content and analytical detail, is one which I think may properly be raised for consideration at some appropriate time. The question might be raised in regard to each one of the departments, with the possible exception of the Manufacturing Department. For this, the question will have to do more with certain types of product than with the entire output of the department. Such a conference would, I suppose, be properly one of the various officers to whom such reports are of interest. My connection with the matter would only arise later, after it had been decided just what should be done.
>
> The uniformity and comparability of reports of this sort are as important as their completeness and almost as important as their accuracy. (Scovill 2/34, 16 May 1919)

While Davis explained that certain types of analysis were made difficult or impossible by the inconsistencies between these production reports and those of two other segments of the firm, he also stated that the clerical cost of having the Statistics Office compile such a report on the basis of existing information was, at this point, prohibitive. The obvious solution was to revise the whole system of records and reports at the source to make them uniform and com-

parable. While Davis saw such a radical revision of the reporting system as an issue "which I think may properly be raised for consideration at some appropriate time," he recognized that any such change would challenge the power of the Wire Mill management to determine what information was collected. That decision, he stated, must be made by the "various officers to whom such reports are of interest." Changing the system required considerable investment in power to overcome vested interests. Thus he was forced to move slowly, taking on only as much as he could handle at any given time.

To help him in the statistical work his office undertook, Davis turned to devices that would, after an initial investment, reduce the costs of analysis. Scovill's Cost Office already had a Hollerith machine for tabulating large amounts of data (Scovill 2/34, 12 November 1918). Nevertheless, Davis immediately requested a Powers tabulator and files to hold the punched cards, justifying his need as follows: "The Powers Machine will open up a large field of statistical investigation and presentation. A certain amount of preliminary experimentation is necessary in handling data susceptible of treatment in any one of several ways. This machine will make possible a series of provisional experiments now prohibitive on account of the time and labor required, and will facilitate actual operation along the lines eventually adopted" (Scovill 2/34, 8 November 1918). The symbolic appeal of such a modern piece of machinery was probably significant and may have contributed to the early timing of this request. The need for more analytic capacity, however, seems to have been real. One example illustrates why extensive manipulation of data without the aid of a tabulator such as the Powers machine was prohibitive: the hospital accident report, one of several that Davis took over from the Cost Office, had used 17,000 Hollerith punch cards in 1917 alone. The clerical work required to manipulate that much data without a tabulator, even with the help of calculating machines for the actual calculations, would have been prohibitively time-consuming and expensive. Thus he saw the value of investing in the most versatile labor-saving machinery to reduce the cost and increase the supply of quantitative analysis in the future. An office inventory taken three years later reveals that Davis also had a Monroe Comptometer, a Burroughs Electric (Adding or Calculating) Machine, and a Millionaire Calculator (Scovill 2/34, 18 August 1921).

Davis knew that his job was not done when he completed his statistical analysis; he also invested in techniques and devices for disseminating data. One of his first steps was to standardize the format (including scale, type of chart, form of data, etc.) of graphic reports issued by his office.[22] The standards both supported the integrity of the data and decreased the cost of rou-

22. A note (presumably written by Davis) on the back of his file copy of his first report, noted the need to establish these standards. Within two months, he issued a "Scale Selection Chart and Plotting Guide" establishing standards for the size of paper and the scale to be used on cumulative charts, given their expected or actual total accumulation (Scovill 2/34, 12 October [1918]).

tinely creating such charts. A publication on "Graphs in the Presentation of Business Statistics and Reports" from a series entitled "Modern Business," found in Davis's files, laid out many of the principles he followed, and may have been his inspiration:

> The form of statistical or graphic reports made in any business house should be carefully worked out and standardized, so that reports may be compiled from month to month as a matter of clerical routine rather than as a matter of special investigation. By thus standardizing the reports the data likely to be required can be on hand promptly when needed by the executives and can be compiled at small cost, since such compilation is a matter of routine and likewise is apt to be more free from error than a special investigation, which also requires expert work.[23]

Davis used graphs frequently in presenting his analyses in subsequent years, for everything from daily graphic analyses of metal mixtures used in casting (Scovill 2/34, 25 February 1919) to a major study comparing the firm's statistics from 1914 and 1920.[24] By standardizing graphic methods, he reduced the cost of using graphs to making information more accessible to those using it, as well as following another popular trend.

Davis also acquired an electrical device to aid him in presenting his graphs and other forms of information to decision-makers. In outlining his progress three months after his original report, he included the category "Publicity of Results," under which he noted that "a reflecting lantern has been ordered, and on its receipt and installation in a suitable room we shall be ready for illustrative conferences" (Scovill 2/34, 8 November 1918). This early equivalent of an overhead projector would enable him to present and comment on his data to company executives, further increasing the supply of information to decision-makers. The fact that he ordered this piece of equipment so early, before he had made much progress on standardizing the content of the various routine reports, suggests that in this matter, like that of the analytic machinery, he was motivated by a desire to keep up with modern trends in office equipment as well as to disseminate information efficiently.

While Davis's main goal in all his actions was to increase the flow of meaningful statistical analysis to executives, his efforts had the side effect of reducing the amount of unnecessary information reaching the general superintendent's office. In attempting to make his office a "clearing house of reference," Davis first compiled lists of all the reports that were supposed to be sent to the general superintendent's office, then began filing copies of all these reports in his own office. To make sure his "database" was complete, he compared his lists with what he received and queried any discrepancies.

23. "Graphs in the Presentation of Business Statistics and Reports," Modern Business, report no. 84, found in Davis files (Scovill 2/34). The report was apparently issued by some subscription service. Internal evidence suggests that it came out between 1915 and 1918.

24. A description of the 1914/20 comparative study, which has not itself survived, remains (Scovill 2/34, 28 July 1939).

This process led Davis to uncover a number of reports that had once been mandated during John Goss's push to increase reporting of internal information, but that no longer served a very useful purpose to him. Many of them had been silently eliminated already, but never officially removed from the books. In one such instance, for example, Goss made the following determination about a report:

> With reference to the weekly fire inspection report and the report of indicator post gate shut-offs made by Mr. Barker of the Plant Protection Department, I do not think it necessary to send these reports to me in the future unless to draw attention to some peculiar or abnormal condition. I shall depend upon you to keep the inspections going, but the clerical work of making out the reports can be saved. If there are any other similar reports which you think can be cut out please give me an expression of your opinion with reference to the same. (Scovill 2/34, 8 March 1920)

In general, Davis's investigations combined with postwar pressure to cut costs as earnings fell (see table 4.3) led Goss to question the value of specific reports. His belief in a basic tenet of systematic management, the value of information in measuring and improving internal efficiency, had initially driven a vast proliferation of reports to pull information into his office. Now, however, he weighed the value of the information more carefully against its costs, as he stated in another such instance: "I am giving up certain reports that do not seem to me worth while to continue further in view of the labor required to compile them" (Scovill 2/24, 25 April 1921). The net impact of this reassessment of the internal information system may be approximated by looking at Davis's lists. While the 1919 list of reports to the general superintendent contained 200 reports, that figure had dropped to about 150 in 1920, and to about 50 by 1921 and 1922. While some may still have been compiled and used at lower levels, evidence suggests that many were eliminated.

4.4 Conclusion: Uneven Acquisition and Use of Internal Information in Firms

This paper has explored some aspects of the supply and demand for information within firms during the late nineteenth and early twentieth centuries, when most firms first established extensive internal information systems. The case study highlights some important interactions among technical, organizational, and financial factors in acquiring and using information during that period. This historical case also seems to have some suggestive parallels in today's firms.

4.4.1 Investing in Information in Yesterday's Firms

In Scovill and many other manufacturing firms in the late nineteenth and early twentieth centuries, information demand was being driven by growing

firm size and complexity, coupled with the ideology of systematic management. At the same time, developments in office methods and devices—which often became symbolically associated with the systematic management ideology—decreased the cost of handling information, thus enabling firms to increase their supply of information at a given cost. Without these technological developments, even discounting for their symbolic appeal, the cost of acquiring the amount of information desired for the systematic management of a large multifunctional firm would probably have been prohibitive. Such firms might not have evolved in the same way without the supporting changes in information technology. Other forms of coordination might have replaced vertical coordination by flows of written information, or firms might have remained smaller and less functionally complex.

The case study of Scovill shows the ways in which supply and demand forces interacted in real firms, and the unevenness of changes in the acquisition and use of information. Investments in Scovill's information system did not necessarily take place at the point when we might expect the demand first to be felt. For example, cost accounting was not introduced at the point when the multiple processes and products initially coordinated by the market through separate (though interlocking) partnerships were internalized into a single, incorporated firm. Only twenty years later was a cost system introduced, initiated by a new layer of management. Similarly, the desire to appear modern and systematic may in some cases have led to an increase in the supply of information before it was needed. For example, E. H. Davis purchased devices for the analysis and dissemination of statistical information before he had solved the more basic issues concerning what types of information should be collected.

In addition, the information system did not immediately respond to reduced or modified demand for certain types of information. E. H. Davis discovered many reports that John Goss judged no longer worth the clerical time to compile, but that were not completely eliminated until Davis drew attention to them in his review of the reporting system. He also discovered that some reports did not provide information in the form that would be most valuable to the firm's executives in monitoring and comparing its own production across units. Since these reports were entrenched among middle managers who used them on the departmental or unit level, changing them to another form required writing off the local investment in the existing form, challenging the power balance within the managerial hierarchy, and overcoming inevitable resistance. The units did not want to give up familiar procedures to provide better information for the firm as a whole. In addition, improved comparability across units may have been perceived as a threat to those with weaker records. Somehow both local and firm-level perspectives needed to be taken into account, requiring an evolutionary, rather than revolutionary, approach to change.

By 1920, when my study ends, Davis was just beginning to get the existing reports under control. Over time, he must have been just about as successful as those in similar firms, since Scovill continued to grow and its rank by asset within its SIC code did not vary much from 1917 (seventh with $33.5 million) to 1930 (eighth with $48.2 million) to 1948 (sixth with $72.1 million; Chandler 1990, appendices A.1, A.2, and A.3).

4.4.2 Parallels in Today's Firms

Today, rapid changes in information technology continue to reduce the cost of acquiring, analyzing, and presenting a unit of information, at the same time that increasingly global markets, demands for customization, and rapid changes in all types of products and technologies augment the demand for information. Changes in the supply of information are particularly salient, with computer and telecommunications technologies evolving at an extremely rapid rate.

While the declines in cost per unit of information processed have been and continue to be dramatic, at 30–40 percent per year for components such as logic devices and random access memory, the expected improvements in productivity, especially in white-collar occupations, have not always materialized (Jonscher 1988; Yates and Benjamin 1991). The preceding historical analysis suggests at least two general explanations for these facts, one focusing on the stage of the information-handling process facilitated by various technologies, and the other focusing on complex interactions between organizational and technological change over time.

Modern information technologies have radically improved the speed and reduced the cost of collecting (e.g., computerized capturing of data from manufacturing processes), transmitting (e.g., via computer and phone lines or satellite transmission), storing and retrieving (e.g., standard and relational databases), and analyzing (e.g., mainframes, parallel processing systems, personal computers) information. There have also been improvements in the physical aspects of dissemination (e.g., rapid electronic dissemination to any number of recipients via electronic mail or fax). These stages of information handling have also, at least in theory, become more integrated, allowing information to flow from one to the next without pause or reentry of data. Compatibility problems, however, continue to make the benefits of integration elusive, and sometimes undercut the benefits of improvements in the separate stages of information handling.

Still, these changes have greatly increased the amount of information available within firms. As we saw in the historical case, increases in the amount of information available to executives brought a mounting burden of information overload. Corresponding changes in the nature of the analysis and in the presentational aspects of dissemination are needed to make increasing amounts of information yield their potential value to the firm. Such improvements may

be gained in part through further advances in computer technology (e.g., expert systems and enhanced graphic capabilities linked to standard business applications) and in part through more intelligent use of existing ones.

This first explanation also suggests the need for the second one, which focuses on organizational and technical change over time. In modern firms, as in Scovill, new technological capabilities are adopted at uneven intervals, not continuously and incrementally. Investment decisions interact with issues of information needs, ideology, and organizational power. As each element of an organization's information system is established, it becomes entrenched locally by virtue of the human and nonhuman capital invested in it. Further change may thus be resisted until a crisis point is reached. In periods of rapid change, today as in the early twentieth century, new systems may be introduced on top of or beside each other, with additions made almost haphazardly, sometimes for reasons of ideology rather than of efficiency or economy (e.g., when a firm buys new technology because one executive believes that computerization is necessary to keep pace with other firms, but no one has a clear vision of what need it will fulfill). Often, entrenched systems remain in place, as well. In some cases unanticipated organizational consequences may result in barriers to full implementation, or to modifications in the main results or capabilities of the system.

Many firms today are in a situation similar to that faced by Scovill when it hired E. H. Davis. They have adopted a patchwork of information technology responding to perceived or actual needs, but have not yet stepped back to take an integrated look at the system as a whole. Thus some information may be collected and processed (however cheaply) that is not worth the cost of executive time to consider. Conversely, some valuable information may not be available because of inconsistencies in the information systems of different organizational units. All of these factors could undercut the expected productivity gains, at least in the short term.

Judging by an earlier period of rapid change in information needs and information supply, mismatches between the supply and demand for information may develop at any given time because of the complexity of organizational and technical issues involved. This paper suggests that incorporating the cost and scarcity of information into economic models requires understanding the process by which information, especially internal information, is acquired and used within firms. Acquiring information involves making large and often long-lasting investments in capital, human and nonhuman. The decisions to make these investments are shaped by many organizational and technological factors, as are their consequences. The assumption that firms can buy information in increments of any size and that they will do so at the moment when its value exceeds its theoretical cost is appealing but may not reflect the unfolding dynamics of information acquisition and use within firms.

References

Aoki, Masahiko. 1990. Toward an economic model of the Japanese firm. *Journal of Economic Literature* 28(March):1–27.

Barnum, C. L. 1925. The layout and arrangement of printed forms. *Office Manager* 1(April):74.

Bishop, Philip W. Ca. 1950. History of Scovill Manufacturing Company. Manuscript. Baker Library, Harvard University Graduate School of Business Administration, Scovill Collection 2, case 59.

Bliven, Bruce, Jr. 1954. *The wonderful writing machine.* New York: Random House.

Broehl, Wayne G., Jr. 1984. *John Deere's company: A history of Deere and Company and its times.* Doubleday and Co.

Chaffee, Allen. 1938. *How to file business papers and records.* New York: McGraw-Hill.

Chandler, Alfred D., Jr. 1977. *The visible hand: The managerial revolution in American business.* Cambridge: Harvard University Press.

———. 1990. *Scale and scope: The dynamics of industrial capitalism.* Cambridge: Harvard University Press.

Chandler, Alfred D., Jr., and Stephen Salsbury. 1971. *Pierre S. du Pont and the making of the modern corporation.* New York: Harper and Row.

Clark, E. A. 1916. How we keep costs in our 75-man plant. *Factory* 17(October):405–8.

Clarke, Wallace. 1925. *Shop and office forms: Their design and use.* New York: McGraw-Hill.

Current, Richard N. 1954. *The typewriter and the men who made it.* Champaign: University of Illinois Press.

Davies, Margery. 1982. *Women's place is at the typewriter.* Philadelphia: Temple University Press.

Davis, E. H. Ca. 1968. Recollections of Scovill and Waterbury, 1916–1968. Informal, typed memoir. Baker Library, Harvard University Graduate School of Business Administration, Scovill Collection 2, case 59.

DuBoff, Richard B. 1980. Business demand and the development of the telegraph in the United States, 1844–1860. *Business History Review* 54(Winter):459–79.

———. 1983. The telegraph and the structure of markets in the United States, 1845–1890. In *Research in Economic History* 8:253–77. Greenwich, CT: JAI Press.

Funkhouser, Howard Gray. 1937. Historical development of the graphical representation of statistical data. *Osiris* 3(November):281–342.

Goldin, Claudia. 1990. *Understanding the gender gap: An economic history of American women.* New York: Oxford University Press.

Hoskins Office Outfitters. Ca. 1912. Trade catalogue. Philadelphia. Hagley Museum and Library, Wilmington, DE.

Hudders, E. R. 1916. *Indexing and filing: A manual of standard practice.* New York: Ronald Press Co.

Jelinek, Marian. 1980. Toward systematic management: Alexander Hamilton Church. *Business History Review* 54(Spring):63–79.

Johnson, H. Thomas, and Robert S. Kaplan. 1987. *Relevance lost: The rise and fall of management accounting.* Boston: Harvard Business School Press.

Jonscher, Charles. 1988. An economic study of the information technology revolution. Management in the 1990s Working Paper 88-053. Cambridge: MIT Sloan School of Management.

Leffingwell, William Henry, ed. 1926. *The office appliance manual.* National Association of Office Appliance Manufacturers.

———. 1927. *Office management: Principles and practice.* New York: A. W. Shaw Co.

Litterer, Joseph. 1961a. Alexander Hamilton Church and the development of modern management. *Business History Review* 35(Summer):211–25.

———. 1961b. Systematic management: The search for order and integration. *Business History Review* 35(Winter):461–76.

———. 1963. Systematic management: Design for organizational recoupling in American manufacturing firms. *Business History Review* 37(Winter):369–91.

Marburg, Theodore F. 1952. Commission agents in the button and brass trade a century ago. *Bulletin of the Business Historical Society* 16(February):8–18.

Moody, John. 1916, 1919, 1924, 1931. *Moody's analysis of investment and security rating book.* New York.

Morse, F. C. 1900. Keeping accounts without books. *System* 1(September): no page numbers.

Nelson, Daniel. 1974. Scientific management, systematic management, and labor, 1880–1915. *Business History Review* 48(Winter):479–500.

Parsons, Carl. 1909. *Business administration.* New York: System Co.

President's Commission on Economy and Efficiency. 1912. Memorandum of conclusions reached by the commission concerning the principles that should govern in the matter of handling and filing correspondence and preparing and mailing communication. . . . Circular 21. National Archives, Washington, DC.

Proudfoot, W. B. 1972. *The origin of stencil duplicating.* London: Hutchinson and Co.

Rotella, Elyce J. 1981. The transformation of the American office: Changes in employment and technology. *Journal of Economic History* 41(March):51–57.

Salsbury, Stephen. 1967. *The state, the investor, and the railroad: Boston and Albany, 1825–1867.* Cambridge: Harvard University Press.

Schlink, F. J. 1918. Getting the most out of index cards. *Industrial Management* 55(February):135–38.

System for factory purchases. 1903. *System* 3(January): no page numbers.

U.S. Bureau of the Census. 1975. *Historical statistics of the United States: Colonial times to 1970. Part 2.* Washington, DC: Government Printing Office.

Weiss, Janice Harriet. 1978. Education for clerical work: A history of commercial education in the United States since 1850. Ed.D. diss., Harvard School of Education.

Wigent, William D., Burton D. Housel, and E. Harry Gilman. 1916. *Modern filing: A textbook on office systems.* Rochester, NY: Yawman and Erbe Manufacturing Co.

Yates, JoAnne. 1982. From press book and pigeonhole to vertical filing: Revolution in storage and access systems for correspondence. *Journal of Business Communication* 19(Summer):5–26.

———. 1985. Graphs as a managerial tool: A case study of Du Pont's use of graphs in the early twentieth century. *Journal of Business Communication* 22(Spring):5–33.

———. 1986. The telegraph's effect on nineteenth century markets and firms. *Business and Economic History,* 2d series 15:149–63.

———. 1989. *Control through communication: The rise of system in American management.* Baltimore: Johns Hopkins University Press.

Yates, JoAnne, and Robert I. Benjamin. 1991. The past and present as a window on the future. In *The corporation of the 1990s,* ed. Michael Scott Morton, 61–92. New York: Oxford University Press.

Comment

Bengt R. Holmstrom

Yates's paper is an admirable piece of investigation, rich in fascinating details about the early developments of modern information technology. It begins with a very informative, general summary of the evolution of this technology around the turn of the century and follows it up with a case study of the Scovill firm, one of three case studies described in Yates's excellent book on this same topic. My discussion cannot do justice to the great effort and care that has gone into this enterprise. My limited objective is to comment on potential connections between this work and modern organization theory. I share Daniel Raff's and Peter Temin's optimism that there is scope for more interaction between business historians and organization theorists. I am particularly convinced that historical accounts can and should have more influence on the development of organization theory. Of course, I would hope that the reverse exchange is of benefit too, though I must leave this to the better judgment of historians, since I do not have a real perspective on their scientific mandate. To test the case, I will offer an alternative, theoretical lens through which one could view Yates's topic. I hope it will go a little distance towards convincing doubting historians (and apparently there are many, judging from this morning's heated debate) that there is some export value in organization theory.

But first a few words about the import value (from my perspective) of business history.

For some time already, microeconomists have been busy developing a better understanding of the economic role of organizations. It is fair to say that we have had measurable success. We have identified trade-offs that appear central for explaining organizational variety, and we have learned to model them reasonably well. In fact, the ability to model has developed so fast that the bottleneck no longer is in the methods of theory, but rather in our limited knowledge of the complexion of organizations. It is an understatement to say that we are behind in testing our theories. The truth is that we are in desperate need of facts. Without empirical guidance, we no longer know in what direction we should proceed.

Business history can obviously help quench some of our thirst for facts. Empirical work on organizations is unlikely any time soon to become a sophisticated econometric exercise. By its very nature, facts about organizations are not easily captured in simple numerical tables to which regressions can be applied in any meaningful sense. The initial kind of empirical work I am envisioning, therefore, is very much in the spirit of the historical accounts I have witnessed at this conference.

Indeed, most of the information about organizations that we presently draw on is anecdotal. It is collected from the popular press, from trade journals,

Bengt R. Holmstrom is the Edwin J. Beinecke Professor of Management Studies at the School of Organization and Management, Yale University.

and from case studies. But there are obvious drawbacks in relying on contemporary evidence. Besides being poorly organized, such evidence has not passed the test of time. Observing today's events does not allow us to separate fads from lasting organizational improvements. Take for instance the recent wave of leveraged buy-outs. In my view, there is no way of telling yet whether these should be considered successes. They could prove failures, and we could be over with them in a hurry. To interpret them as optimal organizational responses, before more evidence is gathered, or to proclaim an eclipse of the corporation, as some have done, is certainly premature.

I am afraid that we often make the mistake of placing too much weight on recent developments. We behave like the market analysts, who find reason in every turn of events. And reason is easy to find, given the arsenal of explanations that modern theories possess. To maintain discipline, a more systematic approach is called for. This is where historical studies can play a major role. History, with its long-term perspective, naturally filters out aberrations, leaving in clearer view the organizational characteristics that account for survival. Also, by scanning a larger landscape in one sweep, a historical study circumvents some of the selection biases present in monitoring everyday developments. The temptation to focus on organizational features that match one's own theories, while overlooking the ones that do not, may be the most serious empirical problem for organization theory. Under the historical lens, tailored theories cannot escape scrutiny as easily.

Historical studies have a second advantage over contemporary studies. A look at the formative years of business enterprise is a look at simpler organizational forms, operating in simpler environments. I think the recent accounts of medieval trading arrangements are illustrative. They seem to point unambiguously to the presence of incentive problems. Apparently, fear of mismanagement and fraud shaped ancient agency relationships. By contrast, attempts to understand modern executive and management contracts are hampered by complications such as tax effects. By the same logic, studies of primitive societies, some of them contemporary, have provided clearer evidence that risk-sharing and incentive problems impact the design of cooperative organization, because the setting is much purer than today's complex economy.

Finally, I should stress the importance of having history remind us that organizations evolve all the time. Modern organization theory is largely premised on the notion that the institutions we observe are driven by the demands for transaction efficiency. Of course, optimizing models can in principle take dynamics into account, but in practice they rarely do. Static models that attempt to explain firm boundaries or their internal structure overlook the constant change in their shape and scope. A theory of the life cycle of a typical firm remains to be developed. The need for such a theory is well underscored by tales such as Yates's description of Scovill.

Let me now turn to Yates's paper. The paper has two major themes. One is to argue that information technology and organizational change are closely

linked. The other is to point out that the interaction between the two does not take place as smoothly as theory would lead one to believe. Rather it is discontinuous and often triggered by crises or by coincident changes in the executive office. For this reason, Yates notes, new methods at Scovill are adopted sometimes later, sometimes earlier than implied by marginal calculus. That seems quite believable, though the paper does not really present any hard evidence. In fact, there is surprisingly little reference to financial data. Linking performance figures to the changes that took place would have been quite desirable.

The emphasis on idiosyncratic details (or seemingly so) is in keeping with the traditions of historical analysis. To some extent at least, historians are out to unearth and preserve the "raw data." This has much to commend itself. Sifting through the details can provide ideas for new theories. Also, for students of management, for instance, the organizational and technological dynamics described in the paper hold important lessons about the role power, personalities, and past policies play in the day-to-day affairs of running a business.

Yet I am less convinced that many of the details are important in trying to identify what accounts for the ultimate success of organizations. I am reminded of a case I taught recently, which recollects the Japanese entry into the U.S. motorcycle market. From a distance, the case reads like a textbook instance of a producer exploiting economies of scale in a large home market to enter profitably a smaller market dominated by less efficient firms. In a few bold moves, the small firms are all but driven out. Yet when one reads the detailed history of the case, a very different story emerges. It turns out that the Japanese did not have much of a strategy at all, and what there was of it was completely flawed. Only by accident, it seems, did they hit on a winning combination. But what difference does this make? The fact remains that, whether chosen by serendipity or by conscious calculation, the strategy proved successful. And the reason it did so had a lot more to do with the economic logic of the situation than with its idiosyncratic path. I submit that the moral of this story may often carry over to the historical study of organizational change.

Yates's other theme, that innovations in information technology interact closely, if not in lockstep, with organizational developments, is of particular interest to modern organization theory, as this theory almost exclusively derives its predictions from the assumption that information is costly to communicate and process. In a general way, Yates's account confirms this basic premise. She points to evidence that coordination needs created a demand for centralized information processing, and she also indicates that there were concerns about misappropriation of financial assets and hence a need to control operations more tightly. But perhaps the data would have allowed more significant contact with recent theory. Let me illustrate it with one example.

The theoretical work closest to Yates's study is the work by Milgrom and

Roberts on modern manufacturing.[1] They develop a model that attempts to explain the recent move away from mass production to flexible production. The roots of the theory can be traced to Jay Galbraith, a sociologist, who articulated the view that firm organization is largely conditioned by uncertainty.[2] Firms respond to uncertainty either by reducing it or by adapting to it. Uncertainty can be reduced by controlling the environment (as the American automobile industry is claimed to have done) or via improved internal communication (as in Scovill's case). Adaptation can be accomplished by maintaining more slack (e.g., by raising inventory levels) or by decentralizing authority (which Scovill also tried).

The notable aspect of Galbraith's theory is that it makes significant reference to market structure and technology. It makes clear that one cannot look at information systems and organizational design in isolation. This is so, not only because production and demand functions condition what can be done internally, but because the list of instruments for coping with uncertainty include technological and product choices as well. According to this theory, we should be asking questions such as, How well could Scovill control the demand side? What did its production technology look like? What technological options did it have? Can one detect any systematic changes in inventory management in conjunction with shifts in information systems? Did the firm make to order at any point? Yates does refer to production technology and market conditions, but rarely and rather disconnectedly from the rest of her story. They should be given more serious attention, because they exhibit important complementarities with organizational variables.

The significance of complementarities is well developed in Milgrom's and Robert's work. They note that complementarities induce convexities in the objective function of firms: marginal adjustment in a single instrument (e.g., information acquisition) is often suboptimal, because other instruments (e.g., incentives and control variables) complement it. When changes eventually occur, they tend to be discrete and involve the full range of instruments, organizational as well as technological. The shift from mass production to flexible production illustrates this principle. That it was triggered by reductions in the cost of data processing and flexible technology seems accepted. The key insight is that these factors reinforce each other in a way that causes the shift to take place in one big move, rather than insidiously (in any given firm).

Put differently, Milgrom's and Robert's theory tells us that organizational, informational, and technological attributes of the firm tend to appear in clusters. Flexible manufacturing technology, low levels of inventory, low investment in demand information, multiskilled labor, all go together because they complement each other. By the same logic, a firm with mass-production tech-

1. Paul Milgrom and John Roberts, "The Economics of Modern Manufacturing: Technology, Strategy, and Organization," *American Economic Review* 80(1990):511–28.

2. Jay Galbraith, *Designing Complex Organizations* (Reading, MA: Addison-Wesley Publishing Company, 1973).

nology is likely to choose the opposite attributes. What we do not see is a random mix of these attributes. This is a significant prediction.

One of the virtues of focusing on comovements in firm attributes is that such a theory is not rendered useless when there are multiple equilibria. By this I mean that the theory is not predictively empty as soon as it must admit that there can be several possible outcomes. To take an example, much has been made of the differences between Japanese firms and U.S. firms. Many have asked, How can this be consistent with a single theory of optimization? And most have concluded that culture must play a significant part. That may well be the case. An alternative interpretation is that we are witnessing two different equilibria of the same system (indeed, at some level this is almost a tautological statement). But whichever interpretation one gives to the history of events, it need not change the conclusion that firm attributes should cluster in particular ways. If Milgrom and Roberts are correct, the flexible manufacturing firms in the United States should soon exhibit patterns of operation and organization significantly similar to their Japanese counterparts.

Studying the firm as a cluster of attributes is reminiscent of modern business cycle theory, which concedes that it cannot predict business cycles but still is capable of explaining comovements within the cycle.

This leads me to end on an optimistic note. Historians like to stress idiosyncrasies and path dependence. We are where we are, in part because of historical accident. What I have said above implies that path dependence and other noneconomic factors need not conflict with organization theory nor make its optimizing premise irrelevant. Even if economic theory cannot single out the path of development, it can say a lot about comovements along the path. Thus, there is a road we can travel together.

This Page Intentionally Left Blank