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Punched-Card Systems and the Early Information Explosion, 1880–1945

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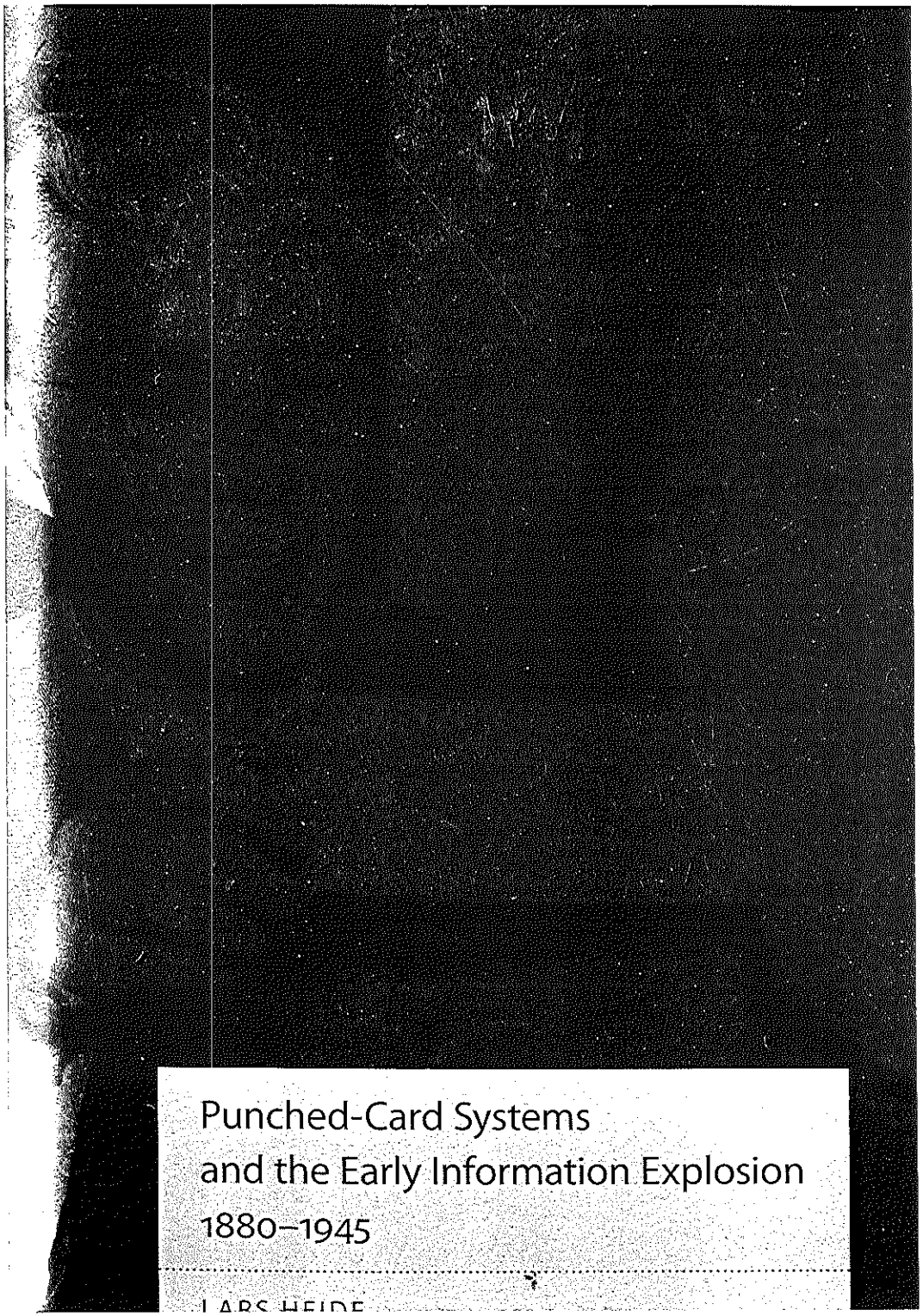

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LARS HEIDE

Conclusion

The first punched-card system grew out of problems with census processing in the United States in the late nineteenth century. This first version was extensively reshaped during the following half century in diverse ways and in the four major industrial societies of that age, the United States, Great Britain, Germany, and France. This development was not continuous but it went through four successive closures:

1. A technology for compiling counting-based census statistics, which was developed in the 1880s, stabilized in 1889, and used until about 1910
2. A technology for processing general statistics, which was developed starting in 1894, stabilized in 1907, and used until after the Second World War
3. A technology for doing bookkeeping, which was developed starting in 1906, was stabilized in 1933, and remained in use until the 1960s
4. A technology for operating large registers of people, which was developed from 1935 to 1937 and remained in use until the 1960s

This rich and complex history allows analyses of three essential aspects of how a technology is shaped in Western society—first, the shaping and reshaping of punched-card technology and business in the major industrial societies; second, concepts for studying the shaping of technology in business organizations; third, how the shaping and reshaping of punched-card technology reflected the development of Western society.

A fundamental characteristic in this story was the intimate relation between the shaping of technology and business. The invention of the first punched-card system in the United States in the 1880s grew out of a public demand for more detailed census statistics combined with the unwillingness of Congress to establish a permanent Census Office. The latter constrained the census operation due to inadequate and varying funding, which caused the frequent turnover of the administrative management. This first punched-card system was devised and built by two individuals employed in the office processing the 1880 census.

John Shaw Billings came up with the original idea, while Herman Hollerith developed the idea into a tailored system for a simple task that only required counting. In this process, Hollerith tried several designs until he found one suited for processing census returns. By adopting the first punched-card system instead of using the alternative exclusively manual systems for processing the census in 1890, the federal government came to fund the implementation of the first punched-card system. Further, this choice locked the design, because Hollerith had to produce a substantial number of punches and tabulators to fulfill the contract. Particularly, he became committed to the design of the first closure, because the many tabulators through the leasing arrangement with the census office remained his property.

When processing the United States 1890 census ended, Hollerith's punched-card business had acquired so much momentum that he chose to continue with it. In addition, his attempts had failed to solicit additional census office contracts in the United States and abroad. Therefore, to survive he had to find an additional application field for his punched-card equipment. As his new prime application field, he selected railroad auditing that reshaped his punched-card system through the introduction of a new, larger punched card and a tabulator with the ability to do addition. However, the new system did not constitute a separate closure in punched card development. Hollerith never saw the railroad system as stable, and he soon improved it through by adding a sorter and built an additional, incompatible punched-card system to facilitate processing the 1900 census.

If Hollerith had taken the alternative choice of insurance statistics as his prime application field for improving his first punched-card system in the mid 1890s, insurance users would probably have urged him first to develop a sorter, as indicated by John K. Gore's punched-card system at the Prudential Insurance Company in the 1890s. Second, they might well

have encouraged him also to provide the capacity to add numbers, like the initial request from his first railway customer. Therefore, in this case, the development of a punched-card system for processing insurance statistics might also have ended in the same set of capabilities as those actually established around 1900.

The reason that the set of capabilities for statistics processing established around 1900 became the basis for Hollerith's second closure can be found in the structure of his business. Hollerith had incorporated his business as the Tabulating Machine Company in 1896 based on his first railroad customer and the Russian and French census contracts. In the years around 1900, he came to support three incompatible punched-card systems as he acquired additional customers.

Hollerith's situation became acute after losing his largest customer, the Bureau of the Census, in 1905, which had been established as the permanent federal census organization in 1902. This caused him exclusively to focus on processing general statistics—mainly operational statistics in private companies—that caused him to serve a fast rising number of customers. Hollerith's answer was his standardized punched-card system from 1907 that came to constitute the second punched-card phase.

In addition to his already established processing facilities, he added the 45-column punched card, which became an industry standard. During the second closure, Hollerith's business grew quickly. He received a generous offer from a conglomerate in 1911 to acquire his company, which he accepted and retired as a rich man. The conglomerate established an efficient business organization that provided substantial momentum to the punched-card business—including sales and a development department.

The growth of the punched-card trade between 1905 and 1920 attracted challengers to the Tabulating Machine Company's combination of monopoly and prime mover position. First, the United States government established its own production of punched-card equipment, which only ended up influencing the development of the punched-card trade by providing the expertise for James Powers to establish a company to compete against the Tabulating Machine Company. Powers became the second challenger by incorporating his business in 1913.

James Powers based his company on the competitive advantage of a tabulator with the ability to print numbers in a calculation. This was a substantial advantage over the Tabulating Machine Company's machines from their second closure, in which the operator copied the outcome from a display. Powers intended his equipment to be used for bookkeeping operations. However a number-printing feature was not sufficient to garner extensive customers in this field, and the Powers company did not add new capabilities to their products until the 1920s. Therefore, though Powers supplied a number printing tabulator six years earlier than the Tabulating Machine Company, he proved unable to capitalize on this position. The reason was his problems in producing reliable machines combined with low demand for number printing equipment in offices in the United States.

The third challenger to the Tabulating Machine Company's prime mover position was John Royden Peirce, who designed machines intended to perform bookkeeping operations. For this end, additional features were needed to print numbers and do subtraction, but several more features were introduced by various producers to attract bookkeeping customers, including extended cards, letter printing, the multiplication of numbers on punched cards, and mechanisms to control printing on preprinted forms. During the reshaping to perform bookkeeping operations between 1906 and 1933, the Tabulating Machine Company (which became IBM in 1924) gradually developed a third punched-card closure by selecting and implementing a combination of features, which, in 1933, encompassed all of the above-mentioned features, including the extension of the number of characters on a card (columns) from forty-five to eighty. This was accomplished through interaction with several users in various private companies, including policy administration in insurance companies and invoicing in public utilities and chain store warehouses.

At that time, subsidiaries of IBM and the Powers company had been established in Britain, Germany, and France, which to some degree established their own versions of the third closure as a result of interacting with local business: cheap punched-card systems with small, nonstandard cards in Britain, machines with high calculation capacity and without any alphabetical facility in Germany. In France, a local challenger, Compagnie des machines Bull was established in the early 1930s. In contrast to Germany, it had early alphanumeric printing and used a different representation of numbers and letters on punched cards than did IBM.

Large-scale record management became the prime application field for shaping the fourth punched-card closure. The alphanumeric punched-

card equipment of the 1930s, for the first time, enabled national governments to have direct and individualized access to all their citizens, and to this end the ability to print people's names proved essential. However, from a machine producer's perspective, large-scale record management was only one among several bookkeeping applications. When the producer could supply alphanumeric printing tabulators, it did not require developing new basic features.

IBM developed two additional punched-card devices to improve the handling of records, but they were only minor improvements compared with the development of each of the three previous closures of punched cards. For the Bull company, the large record system for the French army's conscript administration, which failed at a test in 1935, caused the company to extend their punched card from forty-five to eighty columns, mirroring what had already been done at IBM.

In 1933, IBM began supplying alphanumeric equipment capable of handling large registers, and several large insurance companies in the United States and Great Britain had established punched-card registers of their large holding of policies in the 1920s, most of them exclusively numeric, except for the name of the policyholder, which was hand or typewritten. However, the original initiative to expand insurance company punched-card registers on a national scale came from the United States government in 1936, when they decided to establish a punched-card register of tens of millions of people to facilitate the Social Security Administration's monitoring of accumulated wages as a basis for calculating peoples' old age pensions.

Increasingly, larger punched-card registers were used from the late 1930s through the 1950s, providing significant business for IBM and enhancing their dominance of the punched-card industry. Further, this success made IBM less interested in improving the computation capability of their machines, which was the core of the development of programmable and electronic calculators that had begun in the late 1930s at universities and research institutes. Eventually, this development became the basis for the building of the first computer, which became operative in the late 1940s. While IBM applied electronic technology in the late 1940s to improve their punched-card machines, it only started to build electronic computers in 1951.

In contrast, the Powers company (acquired by Remington Rand in 1927), which was the only substantial competitor in the United States, only announced an alphanumeric line of punched-card machines in 1938, probably as a response to IBM's success the previous year supplying equipment to set up the large-scale register needed to administer Social Security. Furthermore, this line of machines was only designed and produced later. One outcome was that Remington Rand never attracted a customer for a large-scale register.

In addition to the federal government's contributions to the shaping of the first punched-card system for census processing and the fourth system for operating large registers of people, governments influenced the shape of the punched-card industry through patent and trade regulations. In the United States, the strong protection of the rights granted to inventors and patentees was aptly utilized by IBM to enhance its monopolistic position as the prime mover, reducing the impact of antitrust legislation. IBM's German subsidiary, Dehomag, also skillfully utilized patent legislation to hamstring challengers several times. The patent laws in Austria and France protected national industry against foreign companies, enabling Otto Schäffler to establish the production of punched-card equipment in Vienna in the 1890s. Moreover, patent laws facilitated production of Bull's machines in France.

The punched-card trade was also influenced by the protectionist regulations that grew out of the worldwide economic crisis that began in 1929. In France, this supported the emergence of the Bull company, though IBM still seems to have had considerable business in that country. There was no independent producer in Germany, and the German economic autarchy ended up enhancing the position of IBM's German subsidiary in its power struggle with its parent company.

Wiebe E. Bijker and Trevor Pinch's analysis of the social construction of technology—or the social shaping of technology—is the background for this book's analysis of shaping of technology in companies, but additional analysis is required to fully understand the history of punched-card systems. Bijker and Pinch's analytical strategy facilitates discussing how the development of technology is shaped. They classify the development of a closure of a technology into three phases.

The first phase is genesis, which is characterized by the interpretative flexibility of the emerging shape of the technology, contesting interpretations, and several possible directions of development. The second phase

is characterized by more than one interpretation of the technology and applications built by relevant social groups, which narrows the spectrum of possible solutions in the subsequent phase. Closure and stabilization is the third and final phase, where a "lock-in" takes place on a specific technological solution and the alternatives are scrapped. The terms *closure* and *stabilization* imply that the chosen interpretation or solution of the technological subsequently remains stable for a period.

Bijker and Pinch's analysis is useful in examining how the first punched-card system was shaped in the 1880s for use in counting-based population census statistics, and it helped to locate possible methods for processing these statistics, including counting machines, various forms to be manually sorted and added up, punched strips, punched cards, and so on. However, the original version of their analysis failed to have a concept for analyzing the power relations in the shaping process. They assumed that all the parties involved in the process and the possible technological solutions had an equal say.

This limitation was addressed by Wiebe Bijker in his subsequent research into the closure and the stabilization process. He introduced the micropolitical and symbolic power located in what are known as *technological frames* as a means of understanding the choices made in determining the final closure. A technological frame comprises all elements that influence the interactions within relevant social groups and leads to the attribution of meanings to technical artifacts. These frames include artifacts stabilized in previous shaping processes.[1]

The development of punched-card technology through four distinct closure and stabilization phases provides a basis for improving the understanding of that part of the process. The first punched-card closure was shaped in the office of the United States census in 1880. Bijker's relevant social groups included several statisticians, including Herman Hollerith, who acted as prime users. As the idea of punched-card processing was first suggested by statistician John Shaw Billings, the statisticians sympathized with his sophisticated technical answer to the problems involved in organizing a new census operation every ten years and paved the way for the selection of Hollerith's first punched-card system for processing the 1890 census in a situation in which cost was not the exclusive concern.

The selection of Hollerith's first punched-card system to process the census in the United States in 1890 definitively commercialized the technology, providing weight to the "click-in" act and explaining why the technology subsequently tended to remain stable for some time. Historian Thomas P. Hughes has suggested *momentum* as a concept for understanding this process. While click-in alludes to a momentary act, momentum has duration and facilitates more nuances in an analysis through its association with the concepts of mass, velocity, and direction. The momentum of punched cards leading to the selection in 1889 of Hollerith's first punched-card system was established through his personal relations to the statisticians and their sympathy for his sophisticated method. Once the first punched-card system had been chosen, it gained additional momentum as production of the technology was established and users invested in equipment and gained expertise in managing processing census returns using this technology. For Hollerith and the successor companies, the momentum of each closure of punched-card technology was enhanced by the leasing of the big machines, as they remained the property of the producer. However, this simultaneously weakened the technology's momentum with its users. The 1890 census operation was of a limited duration and the steam fueling the momentum of the first closure soon ran out.

The punched-card system for processing general statistics differentiated fundamentally from its predecessor in that it used a standardized column punched card designed to represent numbers instead of the original field punched card, which was designed to represent varying data about people. The shaping of the technology for this closure was restricted by the choices in the previous closure, which excluded manual means and punched strips. Moreover, this shaping was generated through the selection of prime users of the technology who significantly influenced the choices in this process, thus reducing options and risks. For the Tabulating Machine Company, the substantial momentum of this closure can be observed in the company's extensive growth in the 1910s and in that the company, for six years, successfully avoided supplying a tabulator with the ability to print numbers in spite of a competitor offering this capability.

Systems for handling bookkeeping were shaped as the competing punched-card producers in the United States, Great Britain, Germany, and France tried to extend their business beyond processing statistics in public organizations and private companies. While each of the two first closures had been shaped in a single organization, now several companies shaped

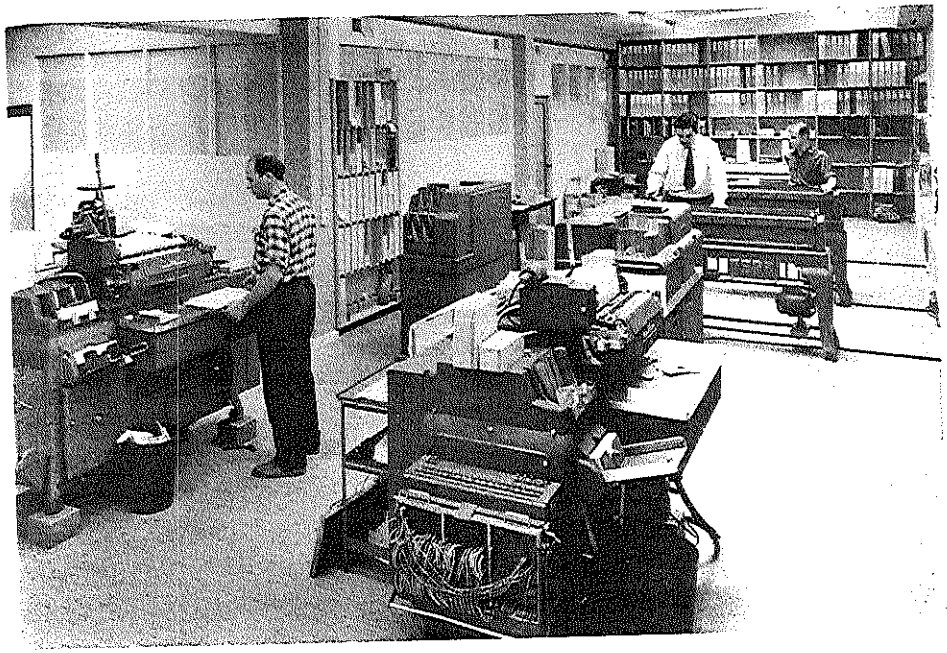
punched-card-based bookkeeping systems, and they never reached a common closure.

For example, each producer had its proprietary system for alphanumeric representation on punched cards, which contrasted the standard representation of digits determined by Herman Hollerith in the 1890s before any competitors emerged. Also, this shaping process was much more complex than the one that shaped general statistics, as bookkeeping operations were more divergent than statistics operations, and the critical part of this shaping process was deciding which capabilities punched-card-based bookkeeping should have. The selection of these capabilities was decided through shaping processes at many punched-card companies, with each company gradually improving technology directed at selected prime users, actual or imagined.

The fourth closure of punched cards for handling large registers had two dynamic components, the momentum of the various punched-card companies' established bookkeeping closures and their prime users. For IBM in the United States and the Bull company in France only minor technical changes were needed to achieve this closure—two new devices for IBM and the transition from 45- to 80-column cards for Bull—while basic technical changes were needed for the Powers companies. The small momentum needed explains the feasibility of establishing the new closure—while it does not explain why it actually took place. This required power that was supplied by prime users, the Social Security administration in the United States and the army's conscript administration in France.

This closure exemplifies the distinctions between the technological facilitation and the financial dynamic supplied by prime users. In determining how the four punched-card closures would be shaped, prime users provided foci for the design of technology and the selection of technical alternatives was based on assumptions of sales. This made efficient sales essential to locate and assess potential prime users, which was a key reason for IBM's success. At the same time established applications and customers lead to a status quo that curtailed development.

The primary focus in this book is how technology was shaped and produced. Just as easily the primary focus could have been sales. However, to become comprehensive using sales as an analytic strategy would also have needed to encompass the available technology. Therefore, providing a comprehensive analysis of shaping and producing technology requires



The IBM tabulator Type 405 in the punched-card installation of the Association of Danish Dairies (Mejerikontoret) in 1959. It is the machine to the left operated by the gentleman with the checked shirt and the machine in the center. It remained a core workhorse in IBM punched-card installations until the machines were replaced by computers in the 1960s. (Landbrugets EDB-Center, Risskov, Denmark)

reasonable concepts for the technical development and production, for business contributions, and for linking these two fields of analysis.

Observations of variations between punched-card systems in the United States, Great Britain, Germany, and France raise the question of what these different systems represented, how they were motivated, and their implications for the development of Western society. Several historians of technology have studied variations from one country to another, and they have used the concept of "national style" for their comparisons.[2] In an analysis of German and French diesel engines for cars in the interwar years, two historians raised the question of what constitutes a "style."[3] They stipulated reasonable stability to describe a national "distinction" in a technology as a "style," which is implied by technological closures. Further, they found that a national style, if it existed, should be the out-

come of conscious choices made by members of one group in opposition to other groups. However, their study of German and French diesel engineering led them to prefer the more modest term of distinction.

The second question was what motivated the distinctions. While most technology historians have studied technical engineering practices or traditions, Thomas P. Hughes in his study of the emergence of electric power systems in Berlin, Chicago, and London found most of his distinctions in public regulations.[4]

The national statistics offices were the customers for the first shaping of punched cards for counting-based population statistics before 1900. The choice in the United States to introduce mechanized processing of census returns was contrasted by the negative reception in most European census offices to the suggestion of compiling population statistics using punched-card equipment from the first closure. Among the countries with regular census taking, except for Norway, which had a small population, only Austria and France introduced Hollerith's first punched-card system to accomplish their transition to individual records and the central processing of returns to compile more detailed and reliable statistics.[5]

Once they had completed this transition, all European census offices returned to manual means until the first punched-card system improved. First, this exemplified the importance of reliable organizations. Second, the negative reception to punched cards in the various European census offices set off the choice of a sophisticated technical solution in the office processing the United States census in 1890, instead of the reliable manual means applied in European offices, a choice that was repeated in 1936 when technically sophisticated punched cards were selected for use by for the Social Security administration. Both cases substantiate historian David Nye's observation of a preference in the United States for the technologically sublime.[6]

The second punched-card closure was developed for general statistics processing and its diffusion from about 1900s was primarily based on operational statistics tasks. This made punched-card applications a measurement of the establishment of the various industrial forms of governance in big industrial companies, as portrayed by Alfred Chandler and other business historians. There were notable distinctions between the diffusion of punched cards in the United States, Germany, Great Britain, and France in the years up to the First World War. The rapid and substantial diffusion of punched cards for operational statistics in the United States, Germany, and Great Britain confirms Chandler's conclusions, as did the slower and less extensive diffusion that took place in Great Britain.[7]

Economist Maurice Lévy-Leboyer extended this conclusion to encompass France. He found that French companies lacked industrial integration, so firm size, measured by total assets, was smaller than in the United States, Germany, and Great Britain. Also, large French firms were slow to adapt new organizational forms such as multidivisional structures.[8] These observations are corroborated by the delayed spread of punched cards in France.

Apparently, this observation provides new insight into a question concerning the substance of the claim that there was a "decline of Britain" from the end of the nineteenth century compared with Germany and the United States.[9] However, histories of the early spread of punched cards in census organizations exemplify the importance of well-established organizations. The bureaucracy at several large British office organizations in the late nineteenth century substantiated this, as did the manually operated registers established in Germany in the 1930s to control the population.

An additional explanation for national distinctions could be the varying efficiency of the sales activities in the four countries. In the United States and Germany, the Tabulating Machine Company and its German subsidiary, Dehomag, established efficient sales organizations in the 1910s, in contrast to Great Britain and France, where punched-card companies only established capable sales organizations in the 1920s.

The shaping of punched-card systems for bookkeeping tasks followed discernibly different paths in the four countries and the systems, to some extent, remained different up to the Second World War. In the United States, IBM was the first one to develop punched-card machines with a considerable ability to calculate, which by 1931, included subtraction and multiplication. Then, only two years later, it began supplying an alphanumeric punched-card system. Through this shaping process, IBM determined the essential features of punched-card closure for bookkeeping in the United States. In contrast, the Powers company tried and failed in the late 1920s to gain a competitive advantage using a system exclusively for letter printing with a reduced alphabet. Subsequently, it only followed IBM's lead, introducing the same features, though with a delay of several years.

British punched-card applications distinguished themselves via the emergence of the earliest letter printing tabulator, which was marketed by the British Powers company in 1921. However, this feature did not become a major success. Instead, the British Powers company focused on developing and marketing of cheap punched-card machines using small nonstandard cards, which found substantial success.

In Germany, the Powers agency marketed the alphabet printing tabulator that had been developed by the British Powers company, but success in Germany was also limited. German demand focused on numeric calculation capabilities, a need for alphanumeric punched-card systems only emerging during the Second World War. In contrast, French punched-card applications developed an emphasis on alphanumeric printing systems in the 1930s.

These systems for bookkeeping were shaped in the four countries by the producers' selection of actual and imagined prime users. The choices varied between countries and from one company to another. These varying paths provide insight into the process of technological development, though it is quite complicated to discern clear national distinctions because of the low number of companies in each country. In addition, the distinctions are more a question of which path of development was followed rather than of which features the punched card-based bookkeeping systems had by the Second World War. The patterns of features are most distinct in Great Britain and Germany.

In Great Britain, cheap punched-card machines using small, nonstandard cards had substantial success, which possibly indicates a demand among medium-sized companies for punched-card processing of their office tasks. Nevertheless, this strategy did not provide the British Powers company with an increase in the number of customers, nor was it pursued with much vigor by the competing British Tabulating Machine Company. The limited success of the British Powers company in using its cheap punched-card systems to attract additional customers should be contrasted to the large number of mediums-sized companies in Britain. At the same time, the British Tabulating Machine Company achieved substantially growth of its assets due to its main sales strategy of equipment using standard punched cards.

In Germany, Dehomag designed and produced exclusively numeric punched-card machines for statistics and bookkeeping tasks. This choice was based on demand from local customers, nourished by the shield against foreign products provided by Germany's policy of autarchy in the 1930s. Such a choice most likely indicates that calculation capacity was the fundamental feature preferred by German users of punched cards for bookkeeping applications, which might also have been the case for users of punched cards for bookkeeping tasks in the United States, Great Britain, and France. The alphanumeric punched feature for card systems only became crucial when large registers of people were established and as letters to customers widely began to be addressed using punched cards from the late 1930s.

However, this type of development hampered the improvement of bookkeeping jobs through letter specifications and the use of punched cards for large registers of people. The absence of a large alphanumeric register in Germany during the Second World War distinguished it from the United States, France, and Great Britain, though the major reason for this absence was the lack of demand from the Nazi regime for such registers, rooted in the chaotic organizational structure of the Third Reich and the establishment in the late 1930s of nationwide local registers of the population created by manual means.

Notwithstanding the national distinctions, a general picture arises from the histories of punched cards in the United States, Great Britain, Germany, and France. Tasks and ambitions in national governments and private companies changed as Western societies were being reshaped at the end of the nineteenth century up to the Second World War. Originally, punched-card systems were designed and applied in the late nineteenth century to produce more detailed census statistics, which national governments saw as an important contribution to facilitate industrial society.

During the following fifty years, the ambitions of the national governments grew, contributing to the shaping of society. This is manifest when comparing the census operations around 1900 with the governments' endeavor to control industrial production and transport during the two World Wars, where mass warfare required optimal performance by industrial societies.

The First World War consisted of extensive warfare that required supreme industrial efforts, making it crucial to control the use of resources and industrial production. This was facilitated by the frequent collection of statistics in narrow fields compiled by the use of punched cards in Ger-

many, the United States, and Great Britain. For example in Germany, the supply of bread grain was closely monitored through statistics using copies of invoices from all transactions in the sector, allowing efforts to be optimized. However, the German system for controlling these efforts lacked an efficient tool for controlling sharing of resources across activities.

The absence of an ability to focus resources on diverse activities was addressed in the Second World War, where mobile tactics and open formations were applied, posing additional demand on the ability to control the use of resources. In 1942, the German minister of munitions and armament, Albert Speer, established a matrix structure of committees for this purpose. He formed thirteen vertical committees for managing the various kinds of weapons production, while the allocation of raw materials and intermediate goods were organized through a similar number of horizontal committees. To facilitate the operation of this system—and Speer's control—he had a punched-card service that produced precise and detailed statistics, which gradually came to be created by a monthly comparison of the consumption of resources and production of diverse war-related commodities in all relevant companies in the Third Reich. Close monitoring of war-related production gradually led to the introduction of register techniques, as this could improve the precision of the outcomes from traditional statistical inquiries.

In France, the United States, and Great Britain, large punched-card registers were introduced to monitor the soldiers. After the war, huge alphanumeric registers became essential for the organization of modern industrial society. Many registers were manually operated card index files, but several organizations found that punched-card registers, and later computer databases, were more efficient and provided more options. Similarly, growing punched-card-based bookkeeping applications in the 1930s showed an expansion of the scope of administrative ambitions in private companies and public utilities that differentiated from the earlier more simple applications of various key office machines of scale, like typewriters and adding machines.

By the Second World War the punched-card industry had been shaped to provide services crucial for the functioning of ambitious bookkeeping systems in many companies and public institutions and to compile and process information on large numbers of entities in large industrial societies. Furthermore, these developments took place in democracies, authoritarian regimes, and dictatorships. Punched cards were applied to monitor industrial producers of articles of military importance in Germany, soldiers for mobilization in France, and the United States soldiers in action. These jobs could have been accomplished by simpler means, but they were made easier by the rigorous standardization of the number of characters that could be stored on a punched card and by the mechanized handling of the cards. Punched cards did not shape society, but increasingly sophisticated punched-card closures came to facilitate steadily increasing complex operations in private companies and public organizations that became essential for societal changes between the late nineteenth century and the Second World War.