Wirtschaftsuniversität Wien

Vienna University of Economics and Business Administration

Working Papers Series:

Growth and Employment in Europe: Sustainability and Competitiveness

Working Paper No. 12

THE ADOPTION AND ENFORCEMENT OF A TECHNOLOGICAL REGIME: THE CASE OF THE FIRST IT REGIME

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September, 2000

This working paper series presents research results of the WU-Research Focus:

Growth and Employment in Europe, Sustainability and Competitiveness

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THE ADOPTION AND ENFORCEMENT OF A TECHNOLOGICAL REGIME: THE CASE OF THE FIRST IT REGIME

by

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Abstract

In this paper we explore the process of adoption and enforcement of a number of new information processing technologies, such as the typewriter, calculators, tabulation gears and book-keeping machines, starting from the 1880s in the United States. We show that their innovation and diffusion was inexorably coupled to the economic development in the USA in the late 19th century. It is a complex and contradictory consequence of underlying socio-economic processes that led to the formation of modern organisational structures in large scale manufacturing which required systematic and efficient information processing. The typewriter and all the complementary office automation devices that entered the scene shortly after were part of a socio-technical regime that started being established: the office work regime or as we prefer to call it the first IT regime, as for the first time a technology was set up to process information on large scale.

The logic of large scale manufacturing to produce standardised products in large series and to apply labour saving techniques was cast into the organisation of administration. This required a convergence of technical practices. The lock-in to the inferior QWERTY-keyboard is hence the outcome of the diffusion and hardening of the First IT Regime.

Acknowledgements

This paper is an enlarged version of the paper prepared for the Conference of the European Association for Evolutionary Political Economy, 2-4th November 2000, Wissenschaftszentrum Berlin (WZB), Germany. We would like to thank Robin Cowan, René Kemp, Reinhold Hofer and Daniel Eckert for comments on basic ideas presented in this paper and for useful suggestions. Isabelle Ponsolle helped us with French sources. Any omissions or errors remain our responsability.

Keywords

Technological regimes, adaption and enforcement of technologies, information technology, QWERTY

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D2, L22, L23, N8, O31, O33

1 Introduction

A remarkable clustering of innovations in information processing technologies took place in the US between the 1870 and 1900. These new technologies gave birth to a new industry, the office appliance industry, revolutionised office work and supported the rise of management by means of formalised information processing as important and widespread economic activity. This is the phenomenon we study in this paper. We describe the establishment, the widespread adoption and hardening of the First IT-regime, which we define as the complex of machinery, heuristics, organising principles, procedures and practices which make up the totality of the early information processing technology in the time between the 1870s and the coming of the computer as primary tool of information processing.

We interpret this clustering of innovations as being a *creative response in economic history* (Schumpeter (1947)) to problems of co-ordination within the evolution of the large business firm in the US. We argue that the establishment of the First IT-Regime developed out of the processes which led to the formation of large business enterprise and to the associated development of formalised hierarchical systems of business administration. As big processes of change call for big causes (Landes (1994): 653) we locate one of the primary historical roots in the exceptional position of the American economy and its tendency towards mechanisation and mass production which created the specific logic of the American System of Manufactures emphasising standardisation, mechanisation and modularization. Therefore one of the central premises of the paper is that new socio-technological regimes grew out of old systems through processes of transformation which are embedded in the specific logic of existing regimes and national "technological styles".

In contrast to other work on technological regimes which look at the processes of generation of new technology primarily from the supply side and the technological development itself, we study the adoption and enforcement of new technology by studying the needs of the adopters of the new information technology. By doing so we contribute to the debate about the validity of the dominant design concept opened up by Windrum and Birchenhall (1998) and investigate in detail the causes that triggered standardisation processes. Standardisation and dominant designs cannot be understood by looking only on the characteristics of the technological artefact, the logic and needs of adopters have to be taken in account to understand path dependence and lock-in. By this we enter also the discussion on the QWERTY-keyboard which is the most prominent example of lock-in to sub-optimal technologies in the economics of technology. Following Paul David's contributions on the matter (David (1985); David (1986)), *historical small events* have received particular attention and the need for careful historical studies in economics has been emphasised. We argue that small events are relevant only if embedded in a larger historical process.

In this respect our paper contributes to the growing field of historical economics in a genuinely Schumpeterian tradition (see Freeman (1995)) by providing a "reasoned history". We combine insights of economic theory, economics of technology, social history and history of technology to devise a co-evolutionary view (Tushman and Rosenkopf (1992), Nelson (1994)) of the processes that led to the establishment and hardening of the First IT Regime.

The paper is organised as follows: First, the co-evolution of the large business enterprise and the First IT-regime is explored by outlining the historical process of bureaucratisation of managerial hierarchies. Second, the single technologies of the IT-Regime are analysed in terms of the services they provided to the user. The relationship between the standardisation of practices and the development of design configuration is studied in detail. Concluding remarks close the paper.

2 The logic of mass production and the rise of bureaucracy in the United States

The establishment of the First IT Regime is inexorably linked to the rise of the modern large business enterprise in the United States and the set up of its typical information structures which came along with the American System of Mass Production. If put in historical perspective, this phenomenon can be viewed as the outcome of an evolutionary process, in which firms have struggled to overcome the uncertainties of a changing economic environment. More specifically they have tried to upset the increase of the uncertainty on the market by decreasing the uncertainty of the production process[1]. Their strategy was to reduce the division of labour among firms mostly through vertical integration and to augment the division of labour of their own activities. This development gave rise to a number of control problems as the volume of processed information increased sharply. The search for an organisational structure that would best allow to cope with the situation led on the conceptual level to multifunctional enterprises, while on the operational level it gave rise to new methods of communication, new organisational heuristics, new information processing technologies and new professions. This was the hour of birth of the First IT Regime. In what follows we will try to sketch this development.

2.1 The rise of mass production in history and its logic

2.1.1 The American mode of production and its logic

The American System of Mass Production grew out of the American System of Manufactures, which emerged in the 1840s and presented itself as the archetype of a national style of production and technology. It was different from and in some respects superior to the British system which became apparent during the First Industrial Revolution. Its characteristic was to engage in series production, to promote and extend the division of labour, to embody knowledge into capital in order to overcome inelastic skilled labour supply and to allocate available unskilled workers from rural areas to simple activities (Landes (1969), chap.2). But whereas the increasing division of labour and mechanisation showed itself in the British System in a vertically disintegrated organisation of production with small and specialised shops, the American system was characterised by a much greater degree of vertical integration (Fries (1975): 384) a higher specialisation of tasks of both engineers and workers and a mechanisation brought to an hitherto unknown extent through the use of labour-saving machinery wherever possible. The American producers tended to "overlook defects [of machines] more than in Europe" and were "satisfied if a machine intended to supersede domestic labour [would] work even imperfectly" (Burn (1931): 306). In some new mechanical industries highly standardised parts were introduced in production, which was made possible by the use of specialised machine tools and gave to products and the production process a high flexibility as they became modular. This was an important source for competitive advantage in the periods of intense competition to come as designs could be quickly modified and adjusted (Hoke (1989)). The economic and technological dynamics for the formation of the American System of Manufactures were manifold[2], but its logic can be traced back to three causes:

[1] For a theoretical treatment of these issues see Saviotti (1988), Radner (1992), Radner (1993), Simon (1996) and Bolton and Dewatripont (1994).

[2] The emergence of a "national technological style" is not simple a function of factor costs, it is also influenced by anthropological foundations, as the relationship between man and technology forms its own set of motivations which is independent from short term price and cost fluctuations (Radkau (1989): 37).

1. the *shortage of skilled labour* was a strong incentive to embody knowledge into capital and use unskilled labour instead, which was available due to the abundant inflow of immigrants (Habakkuk (1962), Rosenberg (1976b), Montgomery (1987)). By that soaring wage costs could be kept down.
2. The relative *abundance of natural resources* in wood, water, carbon and ores made a resource and capital intense production possible (Abramovitz (1989), Wright (1990), Rosenberg (1976a)).
3. The structure and growth of demand (Burn (1931): loc.cit.; Abramovitz and David (1995): 17; Fullerton (1988)) favoured the production of homogeneous products on large scale. Demand was growing quickly as the population more than tripled from 23 million to 76 million in the five decades between 1850 and 1900, reaching 105 million in 1920. The lower spread in income distribution and the high pace of expansion of demand made the United States a seller's market, where the satisfaction of given needs was more important than variety of given products. All these factors favoured the use of continuous process technologies and the standardisation of production.

The American System and its logic - i.e. the embodiment of skills and the standardisation of tasks and parts - diffused into all the most important sectors of the American economy through "technological convergence" (Rosenberg (1976b): 16) as the light machine tools could be used in a large number of manufacturing activities.

The American mode of production represented the source for upcoming "control problems" (Beniger (1986)) discussed in the next section but offered also the solution to overcome them. By that it determined the logic underlying the First IT Regime. It favoured the appearance of large enterprises which resulted through vertical integration and combination. This caused a number of problems as information necessary to run the business became more dispersed as the size of the market and of firms increased. There was the danger for the management to loose control over its activities. An information processing and filtering administrative body within the firm became a necessity, as economies could be achieved through better co-ordination[3]. This in turn raised two new problems: the first regarded the optimal structure of such a hierarchy, whilst the second regarded its operational implementation. The first of these issues has been discussed extensively by Chandler (Chandler (1962); Chandler (1977)), the other has only been partly touched by Yates (1989), Davies (1982), Strom (1992) and Cortada (1993) as well as by the German sociologist Pirker (1962) with focuses differing from the present essay. The attempt of business managers to regain control over the activities of their firms lead to an explosion of the volume of information that had to be processed but the shortage of skilled clerks represented a major bottleneck. The American mode of production offered the solution for a creative response to this last problem and gave rise to the First IT Regime and related path dependencies: the embodiment of clerical skills in machines and the standardisation of office practices.

2.1.2 The emergence of the large business firm as response to control problems of the American System

The information structure of the manufacturing enterprises in the US in the period of dominance of the American System of Manufactures was rather simple. As long as they remained relatively small there was no need for an explicit structuring of communication channels and information filters within and among firms, as information was available virtually without cost in an informal way. Firms were single activity units specialising in distinct niches in production and services. The national market had characteristics of a buyers market where goods were basically selling themselves.

Larger manufacturing firms relied on a form of decentralised and distributed systems of shop-floor control called *inside contracting* (Littler (1982)) where the plant manager contracted internal craftsmen to produce a given number of items in a given period of time using the manufacturer's factory, tools and materials. The contractors acted like entrepreneurs within the enterprise: they managed their own

[3] This has also been called the "economies of speed" (Chandler (1977): p.281).

workforce, determined wages and were responsible for both tool maintenance and development (Littler (1982), Clawson (1980), Montgomery (1987)). The inside contracting system was an efficient method of indirect control, as it avoided administrative overheads by acting partly "as a substitute for accounting" and distributed the risk of operations (Hopper and Armstrong (1991): 415). The accounting records reflected external market transactions and contained virtually no information about internal operations. The manufacturers could set their prices on the base of their cost information but were not able to intervene directly on their determination as they could not co-ordinate the production process. The real authority of the production process was in the hand of skilled labour and especially the contractors.

The transformation of the enterprise form a purely productive entity towards the modern large enterprise, with its differentiated activities, its hierarchy and a network of complex communication channels and information filters (Arrow (1974): 37) acting "as a substitute for market mechanisms" (Chandler and Daems (1979): 4) took place gradually as response to a crisis of the established management method of the American System. Changes in demand, technology and problems of co-ordination on the shop floor where the primary causes for this. In the period between 1870 and 1900 due to technical change and innovation new production processes, new products and new forms of distribution networks changed the patterns of demand at the same time as the technical change in continuous process technologies led to tendencies of overproduction. Frequent and rather unpredictable downturns were the result. Depressions occurred in the 1870s and the early 1890s.

Enterprises countered by changing their strategy: on the one hand they intensified competition through new designs and advertising, diversified geographically and integrated vertically into distribution. On the other hand they built up combinations and trusts to keep wasteful competition down. This development first started in the 1870s but gained momentum after the depression. Some years later the first merger wave in the early 1880s triggered horizontal combinations and fostered the pace with which firm integrated vertically (Chandler (1962): 29ff.; Chandler (1977): 244ff.).

Business managers realised that their capital-intensive and overhead-sensitive mode of production, required a large, steady and predictable demand to assure an adequate return on investment which could only be guaranteed by a high and constant capacity utilisation. The vertical integration of mass producers with mass distributors was a way to co-ordinate the two activities more effectively and allowed to better plan the utilisation of capital. It was the technology that made large scale production feasible but extensive advertising and marketing were necessary to create markets where there had been none (Chandler (1977): 287; Roy (1997)). The mass production technology established with the American System demanded to produce in any case as closing down would have involved a loss in interest and capital (Fullerton (1988): 111). This led to development of annual forecasts and to attempts to engineer demand with the help of marketing techniques and mass communication: profits and by that the returns on capital had to be made predictable. By that more market data had to be gathered, and more reports had to be delivered and to be evaluated. The size of the administrative units of large enterprises grew as they transformed themselves to units of gathering, processing and allocation of information. Production was no longer the sole aim of such a firm.

As factories grew larger the impossibility to co-ordinate hundreds if not thousands of workers in several simultaneous working departments, processing and assembling a variety of materials with traditional forms of factory organisation created a control problem which threatened the disintegration of the production process. The combination, consolidation and merger of large enterprises even amplified it. As competition was stepped up cost control became important, but with the inside contracting system it was impossible to obtain precise and comparable cost data.

The first response to this problem was the Systematic Management movement. Through Systematic Management the basic principles of the American System of Manufactures turned from an approach to solve technical and manufacturing problems arising on the shop floor into an operational management method which could be applied recursively on each domain of the firm. A further increase of the division of labour and its mechanisation up to the extent to allow an extensive standardisation of tasks and a precise recording of all costs were the means by which organisers tried to overcome the problems that had emerged. Systematic Management "based its reassertion of control and co-ordination on record keeping and flows of written information up, down, and across the hierarchy" (Yates (1989):10) with the aim to "transcend reliance on the individual in favour of dependence on system" (ibid:11) and to monitor and evaluate performance. In the late 1870s manufacturers began to introduce labour cost records and to pay wages directly to employees. This allowed to monitor the performance of single workshops, reduce the variance of cost and to redistribute profits from the contractors to the manufacturers and led to the gradual demise of the *inside contracting* system. Salaried foremen replaced contractors. These were employed at a fraction of costs though wielding much the same unlimited authority on the shop floor as the contractors in earlier time. This was a first step in the complete reshaping of internal communication systems within manufacturing enterprises. The first flow control management systems were pioneered in the late 1870s by which accounting was transformed from a method of record keeping of past performance to a current cost management tool. The practical implementation of these systems led to the transfer of many of the foreman's functions and powers to centralised staff departments. Communication became formalised: the centralised staff department communicated downwards imparting the orders of the management, while foremen had to compile reports for the work office. Reporting methods, cost accounting, production scheduling, incentive plans and other measures, were set up in order to create an unhindered flow of materials and information, to transfer authority from foremen to plant managers and force employees to pay greater attention to the management's goals (Litterer (1963)). This gave rise to a number of new communication tools for downward communication. The new accounting techniques together with rule books and manuals provided the tools for comprehensive corporate memories.

With the refinement and expansion of Systematic Management in the 1900s through the "scientific" principles enounced by Frederick Taylor, the bureaucratic control of the shop floor became even tighter. The systematic analysis of the labour process through time studies allowed to stretch the division of labour much further, as it involved the decomposition and codification of craft knowledge. The direct personal control of foremen and the authority over definition of tasks by skilled labour was replaced by the impersonal and indirect control of the management. Scientific management was the *apotheosis* of the American System of Manufactures: "Scientific management, [...] made the worker into a labour unit and judged his ability effectiveness by his ability to keep the technology flowing, had made the worker himself into an interchangeable part" (Boorstin (1973): 369). The integration of the decomposed elements of work involved the setting up of a functional organisation with planning departments providing detailed instruction to the work force. Although Scientific Management as outlined by Taylor did fail in its original form its principles were widely adopted (Littler (1982); Nelson (1980)). They spread most rapidly in labour intensive and emergent industries (Nelson (1980) p. 57). The interrelation of scientific and systematic management and its influence on the organisation of the business enterprise is exemplified by standard costing as monitoring instrument (Johnson and Kaplan (1987); Hopper and Armstrong (1991)). "True" standard costs were based "on the engineering redesign and analysis of the labour process" (Hopper and Armstrong (1991): 420) as they are determined by the engineering staff. Standard costing was also the basis for variance reporting. This combination of setting of "ideal and optimal" costs standards by experts and the evaluation of performance with the help of variance reporting made standard costing such an effective instrument of management. Systemic and Scientific Management were the means to bring the division of labour to its extremes and obtain the information necessary to co-ordinate and monitor all activities. By that the uncertainty of the production process could be decreased.

As enterprises took over new functions their complexity increased accordingly. Their hierarchies grew from the top down, as new the firms took over new functions such as marketing, or other production activities, and they grew from bottom-up as new hierarchical layers were introduced in order to gain control over the shop floor. The casting of the hierarchical division of labour into a formalised bureaucratic structure allowed that complex decision problems regarding the allocation of resources, marketing etc. could be decomposed in a recursive way into sub-problems. Decision-making was decentralised while control and co-ordination were centralised, resulting in (potentially) more efficient decision-making. The revolution in accounting and record-keeping was the key to the effective administration of large firms.

But the new problem which now arose was to reduce the minimum delay of information flows[4] (Radner (1992)), as "the volume of paper work grew enormously form a single piece for each customer order, to a piece of paper for each part of a product on a customer order, to finally, a separate written order for each operation performed in making each part of a product." (Litterer (1963): 379). New technologies for speeding up information processing were needed which allowed an efficient reduction of information and the delay of information flows. Economies of scale in information processing had to be realised to counter the growth in the administrative overhead[5]. But to achieve this a workforce whose tasks was to gather, process and redistribute information was necessary. This led to a rise in the number of clerical workers. Clerical staff in an unprecedented amount was required to put the new concepts into work, but it was not readily available.

2.1.3 The new business enterprise and clerical labour shortage

The typical office in the late 1870s was virtually untouched by technology and consisted of a predominantly male clerks, a book-keeper, a copyist, a clerk and perhaps a shorthand taker. The clerks at this time were more the predecessors of modern middle management rather than specialised clerical workers found in the modern office: Clerical work had still characteristics of a craft (Cooper and Taylor (2000): 561 Braverman (1974): 293, Wooton and Kemmerer (1996):549), which reflected itself in the social background of the clerks and the acquisition of their skills. There were no explicit vocational training institutions for clerical professions up to the early 1880s (Strom (1992): 282). In 1870 just 0,7% of the work force were clerks, in 1880 they still represented only a small 1,1% of the total workforce[6]. But in the three decades from 1880 to 1910[7] the share of clerical workers on total working population increased from 1,1% to 5,1%: the number of clerks in the United States rose from 186.000 to 1.8 million.

But as clerical work required English-language skills as well as a certain social background first generation immigrants and working class people had to be eliminated from consideration. The associated labour problem was overcome by recruiting high school graduated women especially from middle class families. Given the inaccessibility of many trades the new working opportunities as clerks were very attractive (Strom (1992): 287; (Davies (1988): 30): The share of female clerks rose from 2,4% in 1870 to 35,9% in 1910[8]. For the employers the utilisation of this 'reserve army' brought also cost savings as the earnings of female clerks were consistently 25 to 45 percent lower of their male counterparts (Strom (1992): 290, Davies (1988): 32 footnote 3).

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[4] See Radner (1993) and Bolton and Dewatripont (1994) for formal models of management as decentralised information processing activity.

[5] Melman (1951) found that in the period between 1899 to 1947 large firms despite the rise in the administrative overhead were able to keep their administrative expenditures per dollar of production expense lower than small businesses.

[6] Source: J.M. Hooks Woman's Occupations through seven decades US Department of labour 1947.

[7] The number of course continued to increase: by 1930 9% of all employed persons in the United States were clerical workers, corresponding to 4,2 million.

[8] 1880: 4,3%, 1890: 16,9%, 1900: 26,5%, 1910: 35,9%, 1920: 48,4% and 1930: 52%, Sources 1870-1940: total Clerical Workers compiled form J.M. Hooks Woman's Occupations through seven decades US Department of labour 1947 and Historical Statistics, Abstacts of the US Series D57-71 Later: US Bureau of Census Statistical Abstract (1972).

The changes in the number of clerical workers went hand in hand with a transformation and redefinition of clerical work and the reorganisation of the office. Systematic managers used their experience from the shop floor: The American System of Manufactures was cast into the administration. Clerical work was re-classified and by this broken into its composite units. This entailed also the introduction of strictly standardised activities and the radical simplification of tasks, the sequential organisation of the work flow, and the use of technologies which would answer management needs to supersede labour. What was needed were machines by which this could be achieved and workers that could operate them. Even if this minute division of labour was not caused by the new technology, the very emergence of sophisticated administrative control depended on major innovations in the information-processing and control technology. This process of increasing division of labour was not a story of de-skilling as Braverman (1974) argues, but the functional specialisation and hence sharp re-classification of the clerical profession on the basis of the new office machinery reduced the power residing in the administration of a firm by making the monitoring of the administration easier and the clerical workforce itself more interchangeable, as skills changed from being firm-specific to being general and transferable. The female clerical workforce provided the material to fill up the typing, computing and book-keeping pools, which often “were divided and divided again into finely graduated hierarchies” (Davies (1988): 30) and where no promotional ladder was attached to the occupation, leading to an internal labour market segregation of clerical work along gender lines.

3 The establishment of the IT Regime and the standardisation of practices

3.1 The emergence of the First IT Regime

“It was not an accident of fate” (Cortada (1993): 63) that an office equipment industry started emerging at about that time when large, multifunctional enterprises started being built by the early 1880s. The two decades between 1870 and 1890 showed a remarkable clustering of innovations of information processing devices (typewriters (1873), cash registers (1879), calculators (1885), Hollerith system (1889), etc.). As has been shown, these developments were paralleled by changes in organisational practices, new developments of distribution networks and of marketing tools and last but not least innovations in the organisation of production.

The application of the new information processing devices to organisational problems lead to the establishment of a new technological regime (Nelson and Winter (1982), Dosi (1982)) – the First IT Regime. Its rise is best characterised by the following quote from Beniger (1986):

> *“A crisis of control in office technology and bureaucracy in the 1880s, as the growing scope, complexity and speed of information processing [...] began to strain the manual handling system of large business enterprises, This crisis had begun to ease by the 1890s, owing to innovations not only in the processor itself (the bureaucratic structure) but also in its information creation or gathering (inputs), in its recording or storage (memory), in its formal rules and procedures (programming), and in its processing and communication (both internal and as outputs to its environment)” (Beniger (1986):390).*

It is convenient to analyse a technological regime by following the approach of Saviotti and Metcalfe (1984) who characterise a technological regime through what they have called *process technology* – i.e. the characteristics of the processes used for the production of the technologies of the regime - as well as through the *product technology* – i.e. the technical characteristics and the services these technologies provide to the final user. It is mainly the latter on which we will focus.

The most important technologies of this regime were typewriters, calculators, book keeping machines and Hollerith machines, to which we will limit the scope of our analysis in what follows. Other office machines like dictating machines, duplicating processes, cash registers, timekeeping machines, automatic addressing, folding stamping and mailing machines, sorting devices, filing systems, the telephone etc. were also part of it[9].

In order to understand why the technological development of the single technologies followed a specific path and its impact on the organisation, it is necessary to understand the requirements users[10] had in regard to the *product technology* of these appliances. In the logic of these adopters – following the principles of the American system - office machines had to be instrumental in realising a system of standardised activities aiming at the saving of labour and time[11]. Office machines should embody special knowledge and thereby allow (i) to break up existing activities into smaller tasks and (ii) to standardise information flows and activity profiles. Through detailed work preparations and the set up of organised routines knowledge should be embodied in the design of the work flow. The aim was to achieve an order of magnitude shift in productive efficiency and effectiveness in the organisation of clerical work by increasing the control over the workers and reducing the dependence on single employees. The craft knowledge of clerks had to be transferred from the workers to the machines and/or to the organisational routines of the regime. This we will call henceforth *higher order efficiency* in order to differentiate it from optimum solutions resulting from an exercise of constrained optimisation, at which economists would generally look.

The development of the process technology of office devices, depended mainly on the location of the labour saving potential, the different domains of use and the type and scale of the information processed. Among the most important early information technologies that came closest to the development of a dominant design[12] were the typewriter and the Hollerith system. Adding machines, calculators and book-keeping machines followed more ambiguous paths and a number of different designs were developed to following the requirements of different niche markets (see tables 1 and 2). Office technology followed largely the pattern postulated by Windrum and Birchenhall (1998), who have argued that the development of a technology tends generally towards a restricted number of design configurations, but that there is no basis to assume that a single dominant design needs to emerge. The office appliance technologies co-evolved with the needs of an emerging bureaucracy and shaped in turn its operational design and organisational routines. This process was by far and large shaped by the intrinsic logic of the American System. For clerks used to the office organisation of the 1870s and before this changes represented a major disrupting discontinuity as the quote from Beniger suggests.

3.2 The core technologies of the regime: typewriters, adding machines, tabulators

3.2.1 Typewriters

Typewriters started developing after the breakthrough of the front-strike design of the Underwood with its standard QWERTY keyboard and shift key in 1895 along a well established technological and technical trajectory (see Knie (1991)). By 1900 most of the technical features of the manual typewriter had been introduced. The typewriter was used in order to fix information on paper with the purpose to deliver it to other units within the same business or outside it. It was applied in all activities involving the multiplication and distribution of information, i.e. in practically all functional fields of organisations:

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[9] Brauner and Vogt (1921) provide an almost complete listing of all the office appliances available round 1921 in Germany.

[10] By users we intend the adopters, i.e. the capitalist enterprise investing in new capital equipment and not the operators of the machines.

[11] The key requirements are summarised very concisely in Leffingwell and Robinson (1950): 282-3): "When should office machines be used? To save labour, to save time, to promote accuracy and to relieve monotony."

[12] See Tushman and Anderson (1986) and Anderson and Tushman (1990).

mail, internal memos and communications, customer, personnel and book-keeping records, contracts, etc. Thus the typewriter was used to codify information fulfilling co-ordination functions within organisation. The character of the information processed was mainly qualitative and changing continuously. The content of the typescripts could not be easily standardised, although mail became more standardised in design and formulation (Cortada (1993): 23, Pirker (1962): 53, Leffingwell and Robinson (1950): 163). The mechanical construction of the typewriter did not embody any specific knowledge or skills. It was the operator who made the typewriter a useful device not its mechanical features. The technological improvements and the search for standards had hence to focus on the typist and the interface. This was achieved in two ways: on the one hand touch-typing was developed that allowed an increase of the typing speed. Through that a higher level efficiency, a higher degree of uniformity of required skills and a reduction of the variation of the output could be achieved, guaranteeing the application of standard costing and control tools. The labour saving effect was remarkable: a skilled typist was able to write sixty words per minute on average, right twice as much as the speed record for handwriting of thirty words a minute established in 1853 (Pirker (1962): 41; Yates (1989): 37). More specialised machines such as the Smith Premier that combined a typewriter with an adding machine could reach even larger labour saving effects. Current account booking tasks performed on special paper forms with such a machine on average sped up the amount of data processed in the order of nine to twenty times (see table 3).

The mechanical improvements of the typewriter – its *process technology* - aimed at the reduction of the typing effort. The dominant design (see table 2) emerged with the appearance of the Underwood 5 on the market. Its front stroke design was so judged to be so superior to competing designs that it basically lead to the closure of the era of ferment in the typewriter industry. It met better than other designs the needs of users as with the visible writing field it allowed to increase the typing speed although the mechanic movement was not as smooth as the ones of competing designs (Knie (1991):117). After the path breaking breakthrough of the Underwood design, the Royal Typewriter Company modified F.X. Wagner's design (Underwood 5) of the type levers in order to reduce the typing effort. Later with the introduction of electrical movements, the speed could be further increased. The regime of appropriability must have been low, as nine years after the entry of the Underwood the Royal and in the following years all other producers shifted to this technological design. By that the conditions for the emergence of one dominant design were given. Further improvements regarded complementary technologies such as dictating machines and the electrification of the typewriter.

3.2.2 Adding, calculating, and book-keeping machines

Adding and calculating machines[13] were the second main pillar of the First IT Regime. Rationalisation studies cited in Pirker (1962) showed that almost 60% of all tasks performed in office work consisted of calculating and 80% of these of pure counting and adding. These machines were thus applicable to a vast range of uses, such as the calculation of daily ledger balances, daily cash balances, daily recapitulation, checking invoices, freight bills and disbursements and so forth. It was hence very difficult to define a precise market, but as stated by Cortada (1993): 166, "the key to demand was accounting".

Computing devices embodied the most important skill that made a good book-keeper up to the appearance of these machines: quick and reliable adding. They brought an order-of-magnitude improvement in this activity. Long rows of numbers could be condensed into one single key figure much faster than before, Together with accounting the computing devices were an important monitoring tool. Some machines, such as the Burroughs, incorporated automatic control devices so that mistakes could not occur. The labour saving effects were remarkable. A well trained operator was able to do the work

[13] Adding machines could only perform the additions and in rare cases also subtractions, while calculators could perform all the basic arithmetic operations and some more elaborate mathematical operations, like calculating directly percentages.

for which three clerks without mechanical aides were needed. This could result – with the necessary qualifications - in savings of salaries up to 70% (see Pirker (1962): 67).

Book-keeping machines, which were used to enter data on forms and then to perform normal calculations, developed out of adding machines. They were basically combinations of an adding machine with a typewriter or a cash register or just normal adding machines with mechanisms allowing special carriage movements, and hence they combined also the advantages of these machines (see table 2).

From both, a technical and a methodological point of view computing devices and book-keeping machines presented much more possibilities of development and use, so that a clear dominant design did not emerge. Depending on the specific use of computing machines and the amount of data processed, several niche products for calculating devices developed: non-printing hand-calculators, printing adding machines with ten keys, printing adding machines with full keyboard, ten key calculators. The same was also true for book-keeping machines, where the designs varied in size and function so that they could be used economically used by large and small firms. In many cases they were tailored for the specific uses of certain businesses such as insurance companies, payroll departments, governments and so forth (Cortada (1993): 160-1). As the locus of the labour-saving potential was primarily the embodied computation capabilities, the interface between human and machine was not central and hence did not standardise. Later the standardised keyboards of typewriters and adding and calculating machines were combined in further developments of book-keeping machines.

3.2.3 Tabulating machines

Tabulating gears, Hollerith and Powers machines, were very different from the previously mentioned technologies in as they were conceived in order to operate on quantitative data on the largest possible scale. They were first developed and marketed for public institutions with the purpose to speed up counting and sorting processes which were prone to mistakes and very laborious. The first tabulation was done in 1886 on death statistics for the health department of the city of Baltimore. Later tabulating was used for the evaluation of the US Census in 1890, where the evaluation time of the data could be reduced from seven to little more than two years, marking a milestone in the history of data processing. The first business user was the New York Central Railroad in 1896 using Hollerith gears to process up to four million freight bills a year in order to produce summary reports more frequently. After 1900 large firms in other sectors than railroads started using these equipment as well[14]. Tabulating machines allowed to increase bureaucratic control as the size of the organisations grew: it was used to tabulate sales statistics, sort consumer trend analyses, for payroll and inventory management, and so forth. It was an important tool for the monitoring of business activities. Like book-keeping and calculators it allowed to compress a large number of data to a few key statistics, but on a much larger scale and with a much larger labour-saving effect. This is what made them so valuable to firms and enhanced the role of accountants in the large organisations. With expanding business activities the associated rise in the volume of data the processing capacity of tabulating machines had to be increased as well. Unlike the typewriter and like the book-keeping and adding machines, tabulating gears embodied a number of skills but went far beyond that as they transformed data processing into a completely automated, continuous process. In this technological trajectory accountants played a crucial role. As Cortada (1993) remarks the influence of accountants on the evolution of tabulating equipment "was at least as pronounced as the actual activities of inventors and product managers" (p. 102).

The key requirement adopters had towards this appliance was processing speed, which could be obtained by increasing the amount of data stored on each card, by optimising the working of the

[14] The most important first users were insurance companies which used the machine for evaluating mortality statistics. Among other large firms were Marshal Field, Eastman Kodak, Scoville Co., National Tube, Pennsylvania Steel, Western Electric (see Cortada (1993): 50 and 54 and Yates (1993)).

mechanical parts for sorting and tabulating, and by further mechanising the exchange of cards between the different machines. This in turn depended also on the speed and the reliability with which information was codified. These needs shaped the technological trajectory of this technology. Just to mention a few examples: tabulating speed increased from 415 cards an hour in 1900 to 4500 cards in 1926, and the sorting box could process 4800 cards an hour in 1890 which increased to up to 18000 cards in 1926. The number of columns and rows on the cards and with that their potential information content increased from 12 rows and 24 columns in 1890 to 80 rows with 10 columns in 1928 (see also table 2). The competition between Hollerith and Powers, the only two companies to share the market, lead to an improvement of the key punches, and the introduction of printing capability so that tabulated totals were automatically written down (see Cortada (1993): 53-54). The introduction of the collator device increased the degree of mechanisation of the process as this machine loaded sorted cards automatically into the tabulator. The domains of use of the machine could be extended by embodying further mathematical capabilities and allowing to re-program the machines: in 1931 the multiplying punch was introduced which multiplied two numbers punched on a card and punched the result back on the same card.

The key technology of tabulating systems was the electric hole-sensing mechanism which controlled the sorting mechanism and was very advanced for its time. The whole trajectory evolved around this key feature. A dominant design emerged even though appropriability was very high as the whole technology was protected by a number of patents[15]. The machines were tailored for the processing of large data amounts in large organisations. The programming capabilities made them very flexible, so that distinct niche markets did not appear. The latter were covered by specialised adding equipment (Cortada (1993): 161). Especially accountants had a strong influence on the evolution of various pieces of equipment. Hence, unlike typewriters, adding and book-keeping machines there was no era of ferment with a high number of new designs and many new entrants in the market. It was a duopoly from the very beginning where the technologically superior design and the best business strategy prevailed. By 1940 IBM had established a market share of 90% (Gray (2000)).

The role these technologies played in order to overcome the labour-shortage and information processing capacity problems has already been discussed. On the level of the organisations they influenced their operational design as the economical use of these machines required a precise work preparation and by that a careful design of the work flow, and, on the level of the single activities they contributed to the standardisation of office practices and defined also vocational training requirements.

3.3 Standardisation of office practices and the emergence of path dependencies

Office machines influenced the operational design of large enterprises in two ways. On the one hand, they were capital equipment and were hence most economically used when idle times were minimised. This led to the set up of centralised services for typing, computing, filing and so forth (see Leffingwell and Robinson (1950): 34) and by that to functional office departments, in which all standardised activities were pooled. A number of new classes of clerical trades with narrow fields of activity and very well specified skills appeared: typists, stenographers, file clerks, book-keeping machine operators, billing machine operators, calculating machine operators, key punch operators and others (ibid. p. 493-5). As on the shop floor such pools and machine rooms required a careful preparation and scheduling of work. On the other hand, the use of book-keeping and tabulating machines required to redesign the business processes of adopters on a even larger scale. These machines had to be fed with standardised and indexed accounting information, which could only be obtained if the single record keeping activities

[15] At first it was used only on machines from CTR (later IBM), the successor of Hollerith's own Tabulating Machines Company. Powers, which later merged with Remington Typewriter and Rand Cardex to form the Remington-Rand Co. in 1927, used only mechanical sensing which was technologically inferior. Powers sought licensing for this mechanism in 1914, but it was not granted (Gray (2000)). After the expiration of the patent protection electric hole sensing became the industry standard.

within the organisation were designed accordingly. “A salesmen [for such machines] had not to sell the machine but the organisation” (Pirker (1962): 79). This was important as only in that way the users could get the full value out of the investment and by that it was assured that the firms would keep using the machines. Salesman had hence to be advisors and organisers as well. Once a successful design was developed for a business in one particular sector, the machines were sold or rented together with adjustments of these schemes (McPherson (1992)) to other firms in the same branch. This was a major difference in regard to other office appliances: tabulators and book-keeping machines were not just mechanical solutions for a given problem, but went far beyond that, they were an integral part of a rational information system, represented by the new accounting methods which had developed with Systematic and Scientific Management (Pirker (1962): 86).

In both cases the organisation started embodying working knowledge via the design of the work flow. With the help of office machines administrative activities could be decomposed and reorganised - by recursive application of the principle of the division of labour - into a functional office department responsible for the standardised tasks of clerical work and other functionally specialised departments (see Leffingwell and Robinson (1950): 31). With the mechanised organisation new, precisely outlined clerical occupations appeared, work flows were designed, office manuals[16], work-flow charts, post descriptions and so forth started being used: A corporate memory was set up. Through a clear definition of practices useless work could be avoided, job requirements could be standardised and by that new hires more easily integrated in the working process. But what was even more important was that, as on the shop floor, standard cost and output measures could be deployed. The related variance analysis was important for monitoring the work: standardisation avoids moral hazard or "systematic soldiering" by workers. The rise in administrative overhead was caused partly by Systematic and Scientific Management and office work was immediately also a target of this tendency of rationalisation.[17]

The process of standardisation of office machine work practices was achieved in three ways: through a standardisation of the manipulated data, through a standardisation of the human-machine interface, and through a standardisation of machines. To each of these three strategies was attached a different weight in dependence on the location of the labour saving potential, or in other words through which of these strategies the order-of-magnitude shift in operations could be achieved: for the typewriter it was the operator, for key-punches it was in part the operator and in part the codification mechanism, for tabulating gears and sorters it the sorting mechanism, and the way data were codified, and for adding machines and calculators it was the embodied knowledge in the form of the mechanical adding mechanism.

3.3.1 Typing

The standardisation of the human-machine interface was the single most important step in regard to the adoption of typewriters. By the use of a standardised keyboard a convergence of technical practices could be achieved. This in turn guaranteed a reduction of variance in the output of typists, and by that a better control of their work through standard output and cost measures (Leffingwell and Robinson (1950): 539). Prospective new hires' abilities could be more easily assessed through standardised typing tests (ibid. p. 430, 435) and single typists could stand in for each other in case of a vacancy. What counted was hence not the top speed in typing that could be achieved by a single champion on a given keyboard but the highest speed typists could reach on average, which was about 60 words per minute. The touch typing method on the QWERTY-keyboard could guarantee exactly that. It was so

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[16] Leffingwell and Robinson (1950): 470), suggests manuals for: telephone etiquette, correspondence, stylebook, incoming - outgoing mail, order procedure, accounting, sales, a stenographer's stylebook and an employee handbook.

[17] As Baldry (1997) shows clerical work was subject to some apparently 'Taylorist' practices of control already from the beginning. But this process gained momentum only in the 1920's when clerical work was definitively shifted to a "low-trust" employment relationship.

unquestionably better than any other, that Leffingwell and Robinson (1950): 430, proclaimed "that no typist should be employed who does not use it". The choice of the QWERTY keyboard with the touch typing method was the result of a search process for a standard of practice[18] in order to achieve order-of-magnitude labour-saving improvements. This is something Paul David has not made very explicit in his contested contributions (David (1985, David (1986))[19]. At the time the typewriter started playing an important role in administrative work in the mid-1880s this method was already available. In 1882 a first textbook on the touch-typing method appeared (Martin (1949): 479) as a result of the marketing efforts undertaken by Remington in order to boost the sluggish sales of its Model II in the late 1870s. The machine was valuable only with a skilled operator, and as has been argued, there were not many of them. So Remington started setting up its own typing schools and to furnish trained operators with each machine sold (see Keep (1997): 406). In this context the touch-typing method was devised. Beside the attainable speed it was also superior to any other method with regard to the spelling accuracy. This was an other important feature, as with the early typewriters the written text was not visible, and a letter full of typing mistakes was without value. What determined hence the choice of the touch method with the QWERTY keyboard was not necessarily the result of the most efficient method establishing itself, as argued by Liebowitz and Margolis (Liebowitz and Margolis (1990); Liebowitz and Margolis (1995)) but it happened to be the most effective standard of practice available at the time it was needed. The reasons why later switches to other reportedly more efficient keyboards, such as the Dvorak, did not occur lies in the very logic of the American System: a order-of-magnitude improvement had already been attained with the touch method. The introduction of another method would have only lead to an increase of the variance of the average typing speed, annihilating by that the effectiveness of the established monitoring method and would have caused switching costs (re-training, change of keyboards on typewriters). What was important was the effectiveness of the solution to a business problem and not the hypothetically most efficient choice.[20] Further improvements on the established standard of practice were attained through the standardisation of letter styles and formulations, influencing by that the whole way business correspondence was done (see Leffingwell and Robinson (1950):143 ff.).

3.3.2 Adding and calculating

Things were different for adding machines and calculating machines. Here the locus of the labour saving potential was embodied and the uses were very diverse. The human-machine interface was less important. The safety and the speed in manipulating numbers attained dominated all other considerations. Full keyboards with 81 keys and 10-key keyboards coexisted up to the 1950s. Both had their disputed advantages and disadvantages. "Contradictions were so numerous that vendors had difficulty defining market demands exactly and developing good selling techniques" (Cortada (1993): 166). Large producers like Burroughs, NCR or Underwood offered both solutions. A standardisation of codification of information made no sense, as it were numbers to be manipulated. The only standardisation by which gains could be attained was to use coherently only one type of interface in the computation pools, where mostly larger machines were used, and train the operators on the job. By that, as in the typing pools, operators could step in for each other and machine maintenance could be standardised as well.

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[18] This argument was put forward by Gardey (1999).

[19] All the major theoretical contributions to the issue of path dependence, such as Arthur (1988), Arthur (1989), and Cowan (1991) treat the number of adoptions as exogenous. But the path-dependence issue is of importance only, if the bigger historical processes leading to the adoption of a technology are understood. This is where all this contributions fail. Strong points in this regard are made by Landes (1994).

[20] As Martin (1949) remarks, already in the early 1920s the speed potential of the typewriter exceeded the capacity of typists by large. While with a optimised keyboard design could make typing more user-friendly and ergonomic, less onerous and less error-prone, the speed of typing could have been increased only in a marginal way. This shows that there is no one-dimensional way to judge the efficiency of a key-board.

3.3.3 Book-keeping

For book-keeping machines basically the same holds true as for adding machines. But unlike them, these machines could be only effectively used if the way data were manipulated, i.e. the book-keeping methods, changed as well. The first step was to separate pure entry activities from activities of analysis. By that the dichotomy of book-keeping and accounting emerged[21]. Book-keeping regarded record keeping only. As this was achieved, the use of mechanical devices was possible. A major change was the replacement of bound ledger books and registers with a loose-leaf system of accounts (Wooton and Kemmerer (1996): 553). Another major improvement was the single-entry system, by which, through the use of carbon paper, all the necessary entries in the different registers could be done in one single step (Pirker (1962): 80). The human-machine interface was of secondary importance only: book-keeping machines based on typewriters required typing skills. But the major labour-saving was achieved through a redefinition of the book-keeping and accounting system as such and the implementation of adding machines.

3.3.4 Tabulating

Tabulating gear was used mainly for tasks of book-keeping and record analysis. Therefore the developments in book-keeping methods eased remarkably the codification of data on punched cards. Tabulating gears differed from the previous technologies in as they processed data on industrial scale. Pirker (1962) : 95, noted looking at the organisation of tabulating machine rooms, that “for the first time something appears in the office, that can be compared to the working practice on the shop floor”. It gave birth to a number of new occupations, differing mainly in their skill profile: key-punch operators codified and controlled the loaded information; sorters and tabulators were responsible for the physical execution of the sorting and the tabulation of the cards; lead-machine operators were responsible for the wiring of the control panels and the verification of the machines; programmers were mostly graduated mathematicians responsible for the cybernetic part of the job: programming and designing process flows.

Sorters and tabulators were gradually replaced by mechanical devices. The punching of the cards could not be mechanised, but as it was a simple activity it could be standardised by standardising the human interface: Key-punches used either a typewriter-keyboard for alphanumerical coding or a 10-key numerical keyboard with the keys lying in four rows. By that the index of the left hand could follow numbers on a table whilst the right hand could insert data on touch. As many of the mechanical problems related to 10-key keyboards in adding machines were not given here, the 10-key keyboard was the more obvious, because ergonomically better choice. We conjecture that it was out of the key-punch pools that the 10-key keyboard design imposed itself in the long run.

4 Adoption and enforcement of early information technologies in Europe

While Europeans invented typewriters which were functional (e.g. Ravizza in Italy in the 1850s, Mitterhofer in Austria 1864-69) and were the first to produce and market adding machines on a small scale (Charles Xavier Thomas in France from 1820 on) invented and used punched cards with silk looms (Jaquard 1804) and had devised concepts for automatic computing by means of punched cards (Babbage's Difference Engine in the 1820s and after) the IT-regime and its technologies established itself in the US in the period between 1870 and 1920 and diffused from there to Europe. Our analysis suggests that very specific historical and institutional conditions determined the development and the adoption of information technologies and the logic underlying the American techno-economic style shaped their development trajectories. The strong emphasis of the American System on embodiment and

[21] As Wooton and Kemmerer (1996): 554), note this was reflected also in the gender of people executing these tasks: "The bookkeeper probably was a woman; the accountant probably was a man".

standardisation in the face of high volume production and shortage of skilled labour made that typewriters, calculators and other devices were identified and marketed as labour-saving devices. The moment the modern large American business enterprise started emerging organisers faced the same problems as production engineers had long before them. Labour-saving office devices were an important means to cope with the problem and promote the standardisation of office work. The number of adoptions of typewriters, followed by calculators, book-keeping machines etc. increased and enforced the technological regime. Path dependencies emerged in dependence on the location of the labour saving potential of each single technology. Now, one is tempted to ask why this did not happen in Europe.

For the diffusion of the IT-Regime it is useful to distinguish two different but issues: the adoption of the technology and practices on the demand side and the building up of a office appliance industries the countries other than the US.

4.1 Why the IT-Regime was established in the USA

That the first IT-Regime was established in the USA and not in Europe is closely related to the national specificity in the technological and economic system. No country in Europe had the same prerequisites than the USA: the technological style was not dominated by the tendency towards labour-saving innovations but by economising on materials, production especially in the machine tool sector was oriented towards small series production as nowhere in Europe a mass market for durable consumption goods was established at this time. This differences show themselves also in the reasons for the growth of big business: in the US the large enterprise arose primarily from the internalisation of the flow of goods through vertical integration, while in Europe the large business firms were much more result from the internalisation of the allocation of human and financial resources (Suzuki (1991)). The American innovations in accounting and the associated rise of the bureaucracy resulted from attempts to overcome the problems of controlling the flow of goods within the firm, and the driving forces behind the accounting innovations in the US were engineers. In Europe the large firms were smaller than the American ones and due to the production of small series problems of flow control were much less relevant. In Europe own traditions of systematic management developed. In France and Germany they were much more influenced by the bureaucratic traditions of the public administration and the military (Gablenz (1926), Kocka (1969), Kocka (1999))[22]. Later the engineering elites in Germany and France were instrumental for the introduction of the new American techniques of organisation and productions associated with Taylorism and Fordism. In the UK the family firm was dominant, and an engineering elite comparable to the US, France and Germany was missing (König (1999), Maier (1970)). From this follows that the IT-Regime was established in the US because (i) due to the scale of operations and the specific characteristics of the mass production process the volume of information to be processed critical levels were reached earlier, (ii) there existed a tendency in favour of labour saving innovations and (iii) there existed a production culture which would turn the new innovations as soon as possible into relatively cheap mass-produced products.

4.2 The demand side

The IT-regime established itself in the United states and its adoption was deeply influenced and favoured by the systematic and scientific management movements, which aimed at a rationalisation of the shop floor through bureaucratisation. The rationalisation of internal information and control systems shows itself in interrelated but different processes, (i) in the replacement of patriarchal-traditional

[22] While each country developed - so to speak - its own elements of systematic management, only in the US this developed into the movement as Litterer (1963) describes. In Germany the "rationalisation before the rationalisation" was especially important in the machine tool and electrical industries (see e.g. König (1999)). In France the thinking of Fayol, who stressed direct authority, was very influential for the organisation of firms (see Bhimani (1994)).

authority with rational-legalistic forms of authority in larger enterprises and (ii) in the replacement of personalised organisation with formalised hierarchical organisational structures whose efficiency is related to the observance of abstract rules, continuous accounting and written communication. The diffusion of the IT-regime to Europe is directly connected to this process of rationalisation and presents itself as a history of the transition from an entrepreneurial to a bureaucratic mode of control within large enterprises.

The fundamental problem to cast the history of the diffusion of the IT-regime into a systematic story presents itself in the general historical phenomenon of the *concurrency of the non-chronological* which is especially virulent in regard to the organisation of firms: New and old forms of office organisation, shop floor organisation and - more general - management were in use at the same time. Nevertheless firm size and sectoral differences were the most important factors influencing the adoption of the new office technology not only within the USA but also the diffusion to Europe. The IT-regime diffused through the adoption of office machinery produced in the US, the related practices and organising techniques. The adoption of the new office machinery in Europe was fast: Typewriters were introduced in 1874 in the UK, in 1875 in Germany and in 1883 in France and were part of the standard office equipment in all these countries starting from the early 1900s (Martin (1949), Gardey (1999)). Even tabulating machines diffused fast, especially after WWI. They were first used as in the US by government offices for national census and later in the business for accounting purposes. In Germany Hoechst, Bayer, AEG, Siemens-Schluckert, Osram and Brown Boveri used tabulating gear before WW1 (Pirker (1963). The accounting and record-keeping revolution which created the modern office did not occur in each country at the same time, as the mechanisation of the office was directly connected with the growth of large administrative bureaucracies. This development favoured the adoption of the new office machinery. At the same time the new technology and techniques of office organisation had a tremendous impact on the service sector, especially in insurance and banking. In all countries the new office technology was instrumental to rise of the large service business[23]. The United States and the United Kingdom were leading in the expansion of clerical work and therefore also in the large scale adoption of the new office technology. In the UK the expansion of clerical work is related to the service sector, which was always important in the UK (Jones (1997)). Germany and France were followers. As in the US in Europe the mechanisation of the office went hand in hand with the feminisation of the clerical workforce. Everywhere in Europe with the growing size of both private and public administrations the number of clerks increased and businesses were restructured in such a way that that the once inclusive category of clerk was increasingly subdivided between those tasks which required decision-making skills and those, like typing, which were merely 'mechanical' in nature. Zimmeck (1986) argued that in UK the feminisation of clerical work led to differentiation between intellectual work, being the province of men, and mechanical work being the province of women. Lüsebrink (1993) shows that similar pattern can be found in Germany, where feminisation of the office was stronger in those sectors were already traditions of female work existed. In general, the female workforce was much more specialised (typists, stenographers, book-keepers) than the typical male clerk. The essentially new workforce was instrumental for the smooth diffusion of methods of organisation. Indeed, taylorist methods did diffuse faster in the office area than on the shop floor. Tendencies towards standardisation became pressing when the new technologies were used primarily as business tools.

the standardisation of practices: typing

The standardisation of the practice set in when the new technology was seen and used primarily as business tools. For most of the machines the standardisation of practices followed the path outlined in the previous chapter, the typewriter keyboard being a notable exception due to the role of language specificity. Everywhere in Europe the first typewriters were American imports with American keyboard

[23] An example for the expansion of the service sector is the provided by the Banque National de Crédit (later BNP) which had a work force of 965 worker in 1913 and of 11.000 in 1930 (Gardey (1994)).

designs. The keyboard design became immediately a contested terrain. The rational use of language was the primary issue in this discussion. In the UK the common language was certainly the primary reason for the smooth adoption of the QWERTY. There the standardisation of the keyboard is especially interesting in the cases of France and Germany as the technical arguments for the adoption of the QWERTY-keyboard never existed because of different frequencies of letters in the languages. Soon in France and Germany two different nationally specific designs of the universal keyboard appeared, the AZERTY and the QWERTZ. Not very much is known about why and how these two designs became established quasi-norms[24]. In the case of the QWERTZ the letter with the lowest frequency on the upper line the Y (frequency in percent of 0.02) was simply replaced with the replaced with the letter on the left lower line Z (frequency in percent of 1.35), in the case of the AZERTY the W and the Z and the A and the Q changed place, all other letter remained on the same place as with the QWERTY. As the typewriter production was based on the principle of interchangeable parts (Hoke (1989)) the production of typewriters with different keyboard designs for different markets was no problem for the manufacturers, being it American or European ones. Both the QWERTZ and the AZERTY keyboard design were not uniform at the beginning, especially the arrangement of special characters did not follow a standard design (see Klockenberg (1926): 53 and Navarre (1910)). In Germany the discussion about an ideal German keyboard existed only in the special trade journals, a number of keyboard designs were proposed but not one reached the stage of being adopted on a wider scale by manufacturers. The QWERTZ imposed itself as quasi-standard for universal keyboards in Germany and was standardised as *DIN 2112* in 1928. Buhr and Buchholz (1996) report, when the AEG in 1903 wanted to enter the typewriter market, AEG choose the universal keyboard for their second prototype even knowing that the Remington-keyboard was not practical for the German language - AEG constructed even a first prototype with an Ideal-keyboard - because "the power of the masses used to the Remington-keyboard presents a business obstacle for the introduction of every new keyboard"[25] - (*sic!*). In 1903 there were certainly no masses of typists used to the universal keyboard in Germany. The committee of standardisation was established in 1920 in the "Normungsausschuss der deutschen Industrie". And was concerned not only with the keyboard but with the whole typewriter. It even set up guidelines for new constructions (Martin (1949): 491). The standardisation committee found in 1920 that "the universal keyboard is not handy; it is not justified on a rational basis but only historically" (reprinted in Klockenberg (1926): 198). But in the end it decided to standardise the universal keyboard. In France a true French keyboard was introduced in 1907 , the *clavier francaise*[26] which gained even the support of two of the leading American producers in 1908 , Underwood and Smith Premier and by the French producer Manufacture d'Armes et de Cycles de Saint Etienne in 1909 (Gardey (1999): 325). Yet the French keyboard proved to be a short intermezzo. After WW1 when Taylorism diffused to Europe in France the AZERTY established itself (i) because most of machines in use had a AZERTY or a even a QWERTY keyboard, and (ii) because touch-typing the favoured method by the Taylorians was deeply associated with the universal keyboard which reinforced its use.

The standardisation of typing set in when the typewriter was seen primarily as business tool that allowed to standardise a number of business practices. The quantitative and qualitative demands made by employers led to a professionalisation of typing, and issues of how to transfer skill and know-how

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[24] Gardey (1999): 324 remarks that the German Adler Typewriter was marketed in France in 1901 with a modified QWERTZ-keyboard and in 1911 with a AZERTY-keyboard. Seidl (1900) who wrote the earliest typewriter manual we were able to obtain already concentrated on the QWERTZ-keyboard design, as all the other manuals we looked at. Other keyboard-designs were discussed in passing, if at all.

[25] Hackmann, W. (1903), Gutachten über die neue A.E.G. -Schreibmaschine vom 20.6.1903, Thüringisches Landeshuptarchiv Weimar, Akte 466, Weimar as cited in Buhr and Buchholz (1996) p. 12.

[26] the arrangement of the clavier francaise was (Gardey (1999): 325, Navarre (1910): 212):

ZHJAYSCPG
XVIEQRTND
KWOULMBP

from one typist to the other, of which is the most efficient equipment of typing pool, and of the interchangeability of typists became dominant. In the case of France and Germany even more than in the English-speaking countries the standardisation of the universal keyboard shows that the consolidation of practices did not revolve around the optimality the keyboard-design - it was the *higher level efficiency* associated with the uniformity of practice that drove the standardisation.[27]

4.3 The supply side

The American presence in European markets for office equipment reflected what was happening with other light machinery products. The American office appliances industry dominated the European markets from the beginnings (Martin (1949); Cortada (1993); Morgenroth (1939)). The first movers from the US established dominance quickly, making it difficult for European rivals to become significant treats. In 1930s the United Stated produced approximately 80 per cent of the world export market for office machinery (Morgenroth (1939)). Especially in cash registers (NCR) and tabulating machines (IBM and Powers) the American firms could sustain a quasi-monopolistic position for a long time by setting up early sales offices and factories in the European countries: By WW1 nearly 50 % of NCR's sales came from overseas. In 1911 the company had 965 salesmen operating out of 271 branches outside the US and factories in Dayton, Toronto and Berlin (Cortada (1993): 73). The tabulating industry operated in a similar way by setting up subsidiaries and licensed agents in the European countries.[28] Only in the 1920s with the French firm Bull a producer of tabulating equipment emerged which could compete with the American firms CTR (later IBM) and Powers (later Remington-Rand) on the European market.

In typewriters, calculating and adding machines and other office equipment European firms could challenge the American first movers. Especially Germany developed a strong office appliances industry. The German industry was dominated by firms operating already in precision mechanics industries producing, rifles, weapons, sewing machines and bicycles. These entered the market for office appliances in order to diversify their operations to counter capacity utilisation problems. The comparative advantage of German firms to their European competitors was their competence in precision mechanics and their reservoir of skilled labour. Therefore the logic behind the building up of the office appliance industry in Germany was much less guided by an entrepreneurial motive, than born out of a craft logic[29] of technical differentiation based on specialisation. The first German producer of typewriters was the sewing machine producer Frister & Rossman in 1893. Between 1898 and 1899 bicycle producers as Wander, Stoewer, Adler and Seidl & Nauman entered the market to compensate for the decline in bicycle demand. Of these firms only Adler remained in the market for a longer period, reflecting the high turbulence especially in the typewriter industry[30]. Only one new established firm (Mercedes AG) founded to produce typewriters survived its early times. Nearly all of the German firms produced on the basis of American patents (the notable exception being calculating machines based on the patents of Ohdner originally developed in Russia) and took over the American state of the art. The German producers did not develop new typewriter designs but helped to petrify the dominant design, also reflecting the often short-termish diversification strategies of the German firms. Whereas the most

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[27] Interestingly the standardisation of shorthand was an issue at approximately the same time as the standardisation of the typewriter-keyboard. But as shorthand was much more language specific, for each language a own standard was set.

[28] For a more detailed account see Cortada (1993).

[29] A counter example to this rule is Grimme, Natalis & Co with its successful Brunsvinga calculating device (see Faulstich (1992) for the history).

[30] For the typewriter industry Eye (1941) counts 15 firms engaged in the production of typewriters and 60 Firms which already exited the market. For the turbulence in the American market see Cortada (1993) and Engler (1970).

of the American firms built up extensive distribution and sales networks in the US and in Europe, of the German firms only Olympia, a subsidiary of AEG, did pursue this strategy (Unger (1940): 67).

Nevertheless, the German industry was immediately export oriented and successful especially on the European markets: In 1906 Germany became a net exporter in typewriters and later in office machinery. The picture for France and the UK is different, as in these countries no strong office appliance industry developed. This is surprising given that the UK was the earliest adopter country of office technology in Europe and as typewriter and adding machine manufacturers were set up earlier than in Germany. And France was the country where the first adding machines were produced on a commercial basis (although on a very small scale) and exported them throughout Europe. But both the UK and France were all the time net importers of office appliances Morgenroth (1939). The international trade shows with the exception of the USA strong intra-industy patterns. Nevertheless, there tendencies towards specialisation for single European countries can be identified: Germany, Switzerland and Italy were especially strong in typewriters, Sweden in adding machines and the UK in copying devices.

5 Conclusions:

In this paper we discussed the historical conditions leading to the adoption and establishment of the First IT Regime in the United States. We showed that the process of innovation was related to institutional and historical factors specific to the United States. The existence of a "national technological style" given by the principles of the American System of Manufactures, favoured the process of adoption and enforcement, as it acted like an algorithm of solution to the ensuing problems in organisational matters, which were the sharply increasing volume of information to be processed and the shortage of skilled clerical labour. We showed that during this processes path dependencies arose as a result of the logic dominating the adoption process. By that we found support for Landes (1994) view that big processes call for big causes: small events will eventually lead to path dependencies only if they happen to be embedded in a process of adoption on large scale.

We analysed how user requirements and the single technological trajectories co-evolved, leading to dominant technological designs in some cases and to a number of niche markets in others, depending on the scale on which the technologies were applied and the location of their labour saving potential. By that we found support for the view put forward in Windrum and Birchenhall (1998), that it is not sufficient to study the particular combination of opportunities, appropriability and cumulativeness conditions in the analysis of activities of innovation and production but to include also the institutional and historical framework of demand creation and the logic of adoption into the analytical considerations. The diffusion of the typewriter presents an especially good example. The technological closure was decided by the needs of producers to establish a state of the art, while the standardisation of practices followed the need of business users.

All these results taken together shows that a technological regime owes its very life to a specific historical situation, which determines the establishment of practices on the user side which in turn influence the technological trajectory. This finds support by our analysis - only in glances - of the causes and the rationale underlying the diffusion of the IT Regime to Europe.

Last but not least our paper challenges the view put forward by other authors (e.g. Freeman and Soete (1994), Nakano Glenn and Feldberg (1979)) on the social consequences of modern ICT. Freeman and Soete (1994), for instance, indicate (p.47) that "i) speed and accurancy, ii) storage capacity for large quantities of information, iii) flexibility in organising manufacturing, design and administration, iv) networking within and between firms and other individuals and organisations" and "v) display of information" are the headings under which the advantages of ICT can be subsumed. Our paper suggests, that at least the first three points are equally true for the First IT Regime.

We believe that the First IT Regime entailed a major change in the "techno-economic paradigm" (Freeman and Perez (1988): 47), as it gave rise to new industries and to completely new professions. Information technologies were applied in almost all sectors of the economy and they radically changed the way office work was done. It changed the gender of office workers. It supported changes in the established accounting systems. If modern ICT changed the course of economic life in the last decades, especially with regards to clerical activities, then mostly because of its complementary network technologies and to a much lesser extent as a cause of the increase of the computing capacities they embodied. The latter experienced already a quantum leap in the period we have portrayed in this essay (see table 3).

Table 1. Embodied information processing functions and supported economic functions in organisations of selected early information technologies

Technology	**Supported economic function of organisation**	**Embodied information processing functions**	**Type of processed information**	**Source of labour saving effect**	**Application domains in organisation**
Typewriters	Co-ordination	Multiplying and codifying information	Mostly non standardised qualitative information	User interface – touch typing, complementary technologies (carbon paper, dictating machine)	All types of companies in company wide applications, e.g. correspondence, etc.
Adding and calculating machines	Monitoring	Processing information (arithmetic operations)	Standardised and non standardised quantitative information	Adding or calculating mechanism, automatic entry controls (in order to reduce entry and computation mistakes), user interface	All types of companies in company wide applications, e.g. adding and balancing, computing discounts, etc.
Book-keeping machines	Monitoring, allocation	Codifying and processing information (arithmetic operations)	Standardised and non standardised quantitative information	As above plus reduction of double entry mistakes (avoided trough work preparation made necessary by the machines).	Banks, insurance companies, railroads, payroll dept. of large corporations, retail firms, governments; on smaller size specialised machines for different company- wide applications.
Hollerith systems (punching, sorting, and tabulating machines)	Monitoring, allocation	Codifying and processing (sorting, arithmetic operations) of information	Standardised quantitative information	Electric contact principle, codification of information, sorting and tabulating mechanisms	Purchase records, inventory management, overhead allocation, payroll analysis, sales projections and market forecasting.
Cash registers	Monitoring	Codifying of information	Standardised quantitative information	None; saving effects through direct control of inventory vs. sales.	Sales departments, counters, bank counters, retailers and chainstores, warehouses.
Filing systems	Monitoring, co-ordination, allocation	Storing and indexing of information	All types of information	Labour saving effects through information indexing and centralised handling.	Company wide.

Table 2. Early information technology: innovation characteristics of the most important technologies of the IT Regime

Technology	**User side**			**Supply side**	
	Effect on established competencies, i.e. clerical work before IT Regime	***New professions***	***Required skills***	***Characteristics of dominant design***	***Incremental improvements / trajectory***
Typewriter	Replacement of copyists	Typist; establishment of typing pools.	Touch typing (round 60 words a minute), shorthand writing at least 60-75 words a minute (partly replaced by Dictaphones), good language and grammar skills, letter writing ability. High school degree preferred. Training period: approx.250-400 hours	Front stroke types, QWERTY keyboard, shift key.	Reduction of typing effort and increase of possible typing speed (electrical typewriters), noise (noiseless typewriters) and size (portable typewriters – but mostly for non-business uses)
Adding and calculating machines	Replacement of mathematical skills;	In large enterprises Comptometer or adding machine operators; used in functionalised book-keeping, sales or billing departments also on sporadic base. Establishment of computation pools.	Machine use. Touch typing. Training period: ???	Large number of application domains – no clear dominant design. Two main principles: adding machines based only on the operation of addition. Calculators that could perform four basic operations. Full keyboards and ten key keyboards.	Size, user interface (ease of touch), electric movements, automatic entry controls, available mathematical operations
Book-keeping machines	Replacement of book-keepers (mathematical skills, book-keeping skills replaced through different work preparation)	None; used in functionalised book-keeping departments (i.e. by operators who have to have simple double-entry book-keeping skills but do not need to know balance sheet analysis or budgeting methods) which took also the form of book-keeping pools.	Machine use. Training period: accounting clerks with double-entry skills two weeks.	Several niche application domains for large scale and back office processing; no clear dominant design. Interface depending on the base machine, i.e. typewriter, calculator or cash-register.	
Hollerith – Powers systems (card punch, sorter, tabulator, and collator)	Replacement of mathematical and statistical skills; sorting and indexing tasks.	Card Puncher Sorter Tabulator Programmer; Establishment of card punch units, and machine rooms.	<u>Puncher</u>: in some cases typing skills mostly not; primary school degree. No further skills needed. Training period: 1-4 month <u>Sorter:</u> No special skills, but strong physical constitution required; primary school degree. Training period: round 6 month. <u>Tabulator:</u> secondary school degree and technical skills. Training period: 1,5 to 2 years. <u>Programmer</u>: organisational skills, business skills; preferably university degree in mathematics or a technical discipline. Training period: 4 years.	Punched cards as data and as program memory, punch, sort and tabulate process, electric contact principle; interfaces are typewriter – like or typewriter keyboards, 10-key keyboards.	Speed of all parts of the system (e.g. tabulator speed 1900: 415 cards an hour; 1926: up to 4500 cards an hour), size and information content of cards (12 rows 24 columns in 1890, 10 rows 37 columns in 1906, 80 rows 10 columns 1928, 90 column format by Remington Rand in 1930) and related processing capacity (e.g. multiplying punch 1931), improvements of punch process, and further mechanisation of processes (e.g. collator device).
Compiled using information contained in Brauner and Vogt (1921), Meuthen (1926), Leffingwell and Robinson (1950), Pirker (1962), Cortada (1993), Martin (1949).					

Table 3: Data processing capabilities of early office machinery round 1926

Type of machine	Information processing capacity[31], Bit/hour	Current account transactions per hour	Processing speed machine/clerk
Clerk, manual execution	270 (0,03 kbytes)	6	1
Burroughs Adding machine	5400 (0,675 kbytes)	120	20
National Cash register	6300 (0,78 kbytes)	140	23,3
Smith Premier (typewriter combined with a calculator)	2475 (0,31 kbytes)	55	9,166
Elliot Fisher (typewriter combined with a calculator)	2475 (0,31 kbytes)	55	9,166
Ellis (typewriter combined with a calculator)	5400 (0,675 kbytes)	120	20
Underwood book-keeping machine	2925 (0,37 kbytes)	65	10,83
Hollerith or Powers card punch machine	6750-11250 (0, 84 – 1,4 kbytes)	150-250	25 – 41,6
Hollerith or Powers sorting machine	675000-810000 (84,375 – 101, 250 kbytes)	15000-18000	2500 - 3000
Hollerith or Powers tabulating machine	162000-202500 (20,25 – 25,31 kbytes)	3600-4500	600 – 750

[31] For the calculations we have used information contained in Meuthen (1926). We used the figure of a punched card for a current account transaction (p. 43) and the table of single cases that could be performed by the single machines (p. 48). On the displayed punched card for such a transaction on 45 columns of 10 digits each the following information was stored: date of the transaction (6 columns), the number and page of the main register (3+3 columns), the type of the transaction (2 columns), the department (2 columns), the main and secondary number of the current account (5+2 columns), debit and credit (8+8 columns) and finally the day and month of the booking (2+2 columns). The information in each of the 45 columns represents 1 bit (on of the ten rows is punched or not punched). It should be noted, that this is only the information contents of the card due to the punches and not the information contents if the data contained would be codified by binary numbers, which is likely to be much higher. We calculated hence the implicit information processing capacity and not the effective one. Furthermore we compare the transactions on the basis of how the most advanced technology (Hollerith: punched cards) of the time codified information. This entails that with the purely manual system information was not just written on one single card, but that entailed to fill in fields in several different registers manually, for which a clerk on average needed 10 minutes for one single current account booking operation, Meuthen (1926): 47. Strictly speaking we compare different production functions with the same outcome.

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