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Abstract

This paper presents a qualitative study on the adoption of early information technologies, such as typewriters, calculators or Hollerith machines in US manufacturing in the period between 1870 and 1930, which was by all means a true systemic innovation.

Our empirical work is guided by a theoretical framework in which the theory of induced innovation is interpreted along "classical" lines in which an explicit link to the concept of technological regimes is established. We show how the presence of a distinct bias in technical change in US manufacturing led to the opening of a window of opportunity for early information technologies. We work out how the presence of this bias influenced the technological search and adoption process of firms and how this found its final reflection in the rules and heuristics of the regime, as well as the technological trajectories of the technologies. The reliance on established practices led organisation designers to cast the logic of large scale manufacturing into the administrative organisation of firms. This required the convergence of technical practices. The resulting technological trajectories and path dependencies were the outcome of the diffusion and the hardening of the early office work regime. Our analysis of US manufacturing data of the period suggests that even though electrification and "bureaucratisation" overlapped they cannot considered being the result of the same pattern of technology adoption, identified by the development of the capital-labour ratio.

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1 Introduction

Under the influence of Schumpeter's swarming hypothesis the inducement for firms to innovate, has been a subject of intense academic debate. Following Schumpeter some contributors (Mensch (1975), Kleinknecht (1981, 1990) have attributed the existence of innovation clusters to a creative response of entrepreneurs to deep economic crises, whilst on the other extreme Silverberg and Lehnert (1993) have completely rejected the hypothesis of such clustering processes on statistical grounds and have argued that the innovation arrival rates are to be considered a stochastic process following a time trend. An intermediate position was taken by other authors, such as Clark et al. (1981), Freeman et al. (1982) or Solomou (1986), who have argued that fundamental innovations exhibit a clustering behaviour but did not find any clear-cut relationship to the overall level of economic activity.

These views - covering the whole range of possible outcomes - suggest, that the economic mechanisms leading to radical innovation intended as the development of a new technology and its application to new or existing economic sectors, are anything but well understood. The ambiguous results in this field may explain, why most authors working in the Evolutionary or Neo-Schumpeterian tradition prefer to study the later stages of the innovation and diffusion process in the traditional "Schumpeter Mk.I/MK.II" dichotomy as established in Winter (1984), with neatly measurable effects on the development and the structure of an industry.[1] In these studies and models the adoption of a technology by firms takes a rather simple form. Put it in a very simplified way it is generally assumed that new feasible technologies are parachuted into the economic system from the outside and myopic firms have just to find them in a search process that is considered being localised and taking place in some subset of the technology space characterised as technological regime.

It is not clear in most of these studies why one location in the spectrum of techniques is preferred to another, how any change is timed, and once a location is chosen how this influences the activities and related heuristics of the technological regimes that are established around that location. This is what we try to illustrate in presenting the historical case of the adoption and enforcement of early information technologies in US manufacturing.[2] By that we complement contributions of Freeman (1989) and David (1991), as well as David and Wright (1999), who in their discussions of the diffusion of electric power generation technology in the late nineteenth century have repeatedly underscored the importance of parallel innovations in the management and administration of firms.

We try to extend Paul David's analysis on the differences in American and British technology in the nineteenth century (see David (1975)) along "classical" lines of thought and to link it explicitly to the concept of technological regimes/paradigms (Nelson and Winter (1982), Dosi (1982)) and more recent contributions that have started to stress the co-evolutionary character of socio-technical development.[3]

2 Theoretical propositions: The choice of technique, its technical bias, and technological regimes

2.1 Choice of technique and technical bias

The adoption of a new technology is the result of an investment decision of a firm acting in a specific natural and institutional environment. Under competitive conditions a firm will choose a technique that minimises its

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[1] Just to name but a few (coming also from very different traditions of thought): Gort and Klepper (1982), Silverberg (1984), Tushman and Anderson (1986), Acs and Audretsch (1988), Malerba and Orsenigo (1995) or Winter, et al. (2000).

[2] By early information technologies we mean all mechanical and electromechanical devices developed for and used to store, handle and process data. The specific technologies studied here comprise typewriters, calculators, file systems, pneumatic tubes etc.. We have termed this regime the "First IT Regime" in order to distinguish it from the diffusion of semiconductor devices and related data-processing machinery starting from the middle of the twentieth century, associated with classical studies such as Perez (1985), Dosi (1984), Malerba (1985) or Freeman and Soete (1994).

[3] See: Tushman and Rosenkopf (1992), Yates (1993), Nelson (1994), Freeman (1995), Windrum and Birchenhall (1998), van der Ende and Kemp (1999).

current and near term cost and allows to obtain a supra-normal profit.[4] If the viability depends on specific environmental factors, then the latter will indirectly constrain the firm's technology choice. In principle it is not clear whether it will be biased in any direction. If the constraints are nevertheless taken to be constant over some period of time a systematic bias is likely to emerge in response to the persistency of a given factor prices relation in the economy. In general the technology should be biased towards the relatively less scarce factors entering production, as the constantly higher relative prices of the scarcer input indicate to firms a higher cost-saving potential in that direction. The cost-saving potential is a function of the factor saving that can be achieved with a given research investment. Assuming that through a unit of research investment factor savings of equal proportion can be achieved, the return on the research investment in the more expensive factor will be higher (Binswanger and Ruttan (1978): p.25).

In order to specify the discussion, we have to separate the influence these environmental factors exert on the proportions with which factors are used from their influence on the scale of production. We will look first at the influence on proportions. For that purpose, let us assume - in a Classical fashion - that capital goods are infinitely accumulable as they are produced means of production, furthermore assume that natural resources as well as labour are non-accumulable, i.e. of limited availability at least in the short run.[5] If "accumulability" is taken to be a measure for scarcity a technological bias which is labour- and resource saving should result, due to the higher prices of these factors. This argument needs some qualification if we consider, invoking again the Classical theory, that an increasing accumulation will lead in the short run to an increase in real wages, which will now come to lie over the reservation wage of a part of the potential workforce and will thus lead to an entry of new labour power.[6] If we differentiate labour as consisting of a skilled and an unskilled section, then this assumption is plausible only for the latter. As it takes time to produce skilled workers, the entry rate of skilled labour in response to a changing level of the reservation wage is likely to be in-elastic in the short run. We may thus state that skilled labour and natural resources are scarce, whilst unskilled labour and capital are available in the quantities needed in any case. Under such an assumption the resulting technological bias should be resource- and skilled labour saving. Yet, this still depends on the stringency of the scarcity of these inputs in the short run, i.e. either the degree to which the input is at immediate disposal and/or the extent to which it is available. Skilled labour may plausibly be considered being available in abundance in the long run, as in analogy to unskilled labour it will be produced endogenously to the economic process, but as not being immediately available in the short run. Natural resources instead may in general be considered being available immediately but to become scarce as the depletion of their funds reaches its limits. In the short run skilled labour scarcity and resource abundance should produce a bias bending towards a more intense use of capital and resources, while in the long run skilled labour abundance and increasing resource scarcity may eventually reverse this trend. However, we have also to take into account the influence of the scale of production in order to get to a more general statement on the causes of technology adoption.

It is a common conjecture that each technology has an optimum scale of operation. The larger the scale of production, the more stringent will factor scarcities be felt. If the scale of output shifts, cost minimising firms have an incentive to search for new production processes which use abundant factors more intensely. As proportions of factors are fixed for each technique, a shift in the scale will increase the overall intensity of use of less scarce factors and costs will increase. We may conclude that shifts in scale of production will thus foster a substitution of skilled labour for capital and resources in successively adopted technologies, if the composition of output and the rate at which shifts occur and their sign remains stable over time. This is the situation we find in the historical accounts on the development of the US economy in the nineteenth century (see section 3).

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[4] Although we do not postulate that firms indeed follow such a behavior, it will become clear that the assumptions put forward in this section suffice to describe the development of the First IT Regime. In the exposition we draw on David (1975): chapt. 1, Radner (1975), Binswanger and Ruttan (1978): chapt.2, Nelson and Winter (1982), Kurz and Salvadori (1997) and Foley and Michl (1999).

[5] We have to distinguish between non-reproducible resources and exhaustible resources. The former do not exhaust, but are of limited size and show with increasing intensity of use they diminishing returns, while the latter merely "evaporate" due to the entropy law and become increasingly scarce. Economic history shows that even though exhaustible resources are limited and single deposits exhaust, in most cases new deposits are found. It follows that only in a situation where demand is such that there are capacity constraints decreasing returns arise, as also the least profitable deposits have to be exploited (see Kurz and Salvadori (1997); p.359 ff.).

[6] An alternative explanation is that technical progress sets free enough workers so that at any wage there are enough workers seeking employment.

If we consider instead that the case where sign of the shifts in output changes frequently and/or the composition of output changes due to an unstable composition of demand, cost-minimising firms will attempt to keep the utilisation rate of capital at the highest possible level, as capital represents fixed costs of production whilst labour is a variable cost component. For this reason they may not have an incentive to build up capacities through an increase of the capital stock, but to use of scarce skilled labour more intensely, which in situations of positive output shifts will drive up wages, but allows to adjust quickly to changes in the size and composition of output. This was the situation in the United Kingdom in the nineteenth century (see Habakkuk (1962), and especially Fries (1975)).

These environmental conditions, will act as a mere signpost in the firms search for alternative techniques in the way postulated by Nelson and Winter (1982). They will give rise to technological regimes. It should hence be possible to deduce some general characteristics of the heuristics emerging in these regimes from the general technological bias in the economy in which firms act.

2.2 Technical bias and technological regimes

A starting point for such an analysis is the approach suggested by 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 technologies with certain technical characteristics - as well as through the *product technology* – i.e. the services these technologies provide to the final user given certain technical characteristics of the final product.[7] The question becomes then one about the general properties of the product technology vector and how it co-evolves with the process technology of any potential technology. Here a few more considerations on the characteristics of a technology are in place.

In the crude state of technological development the production of any commodity may be assumed to be non-separable in its inputs, as they enter the production process in virtually fixed proportions. In an expanding economy this would lead to diminishing returns, as the non-accumulable inputs represent a limit to growth, which has to be compensated by an increase in productivity. Cost-minimising firms will thus search for ways to use accumulable factors at higher intensities. But for that the production process has to become as independent as possible from non-accumulable inputs. The central question becomes then what determines the postulated indivisibilities. A closer look indicates, that on the one hand, the production process will always be indivisible from resource use. Fixed capital is produced of matter and due to the entropy law all resources will eventually become scarce. A higher intensity of use of fixed capital may also come along with a more intense use of variable capital, especially when the state of art in technological development is such that the tools applied operate in a rather resource using way. The only way out is to substitute scarce for less scarce resources, to use more resource saving technologies which can be achieved either through the overall reduction or an increase in the intensity of use of joint products or through the closure of material cycles.[8]
On the other hand a high degree of separation of the production process from specific types of labour is achievable through the codification of activities and their transformation into blueprints. The division of labour is a mean to reduce the tacitness of knowledge in the production process and shorten the time needed to produce specific skilled labour types.[9] Knowledge on the workflow of a given production process is codified into specific designs and sequences of activities, which now can be executed jointly. This reduces education time of skilled workers, speeds up production and gives rise to disembodied technical progress at first. Once the division of labour has progressed so far that the original skills are reduced to single chunks of interrelated information, then a complete codification through their embodiment into specific mechanic movements of machines becomes possible. By that roundaboutness of production is substituted for education time. The degree to which this will happen will depend on the one hand on how economical a complete

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[7] More formally Saviotti and Metcalfe (1984) assume that a vector of technical characteristics: $\mathbf{x}\rightarrow\mathbf{t}$, which gives the process technology. The vector of process characteristics in turn spans a Lancasterian service characteristics space: $\mathbf{t}\rightarrow\mathbf{s}$. This projection is called product technology. Assuming a simple linear transformation the latter relationship may be described by a linear system of inequalities $\mathbf{At}\geq\mathbf{s}$, with $\mathbf{A}$ being the transformation matrix. $\geq$ reflects the constraint that a minimum number of technical characteristics must be present in order to give rise to a viable product technology. The discrepancy between product and user technology determines the development pattern of the industry producing the technology as adopters act as selection mechanism of technological designs, see Windrum and Birchenhall (1998).

[8] The qualifications of footnote 5 nevertheless apply.

[9] By tacit knowledge we mean specific process experience and expertise acquired by an operator of a technology through the work with it, by refining and developing some basic operations. This reflects the properties of knowledge, which represents the capacity of an individual to link pieces of information and basic actions in a way that he or she can creatively operate with it. This tacitly acquired knowledge is not codified as it is context dependent and reflects the intellectual history of the operator. The transfer to other individuals thus cannot be immediately.

embodiment is in a specific socio-technical environment, as the costs of codification may plausibly be considered an increasing function of the complexity of the involved knowledge. On the other hand an embodiment will also depend on the frequency of recurrence of specific patterns of action in an activity. If the latter change continuously, an embodiment may not be possible. This fundamental characteristic of technologies and a specific technological bias will influence the character of operational heuristics of the regime which represent the linkage between the single elements in the input vector of new activities. They will shape the service characteristics adopters require from a new technology.

Although we will limit our analysis to the sub-case where skilled labour is comparatively more expensive than capital and a shift in the scale of adopters processes takes place, the analysis could easily be generalised to any constellation of demand composition, scale and technical bias. From what has been said before we should expect the new processes to run at a higher capital intensity, than previous activities. This means that the capital-labour ratio should increase over time towards a technologically optimal configuration. Of course this trend could also be reversed, if capital saving innovations in other activities take place.[10] The technical characteristics of the new technologies should be such as to allow a maximum degree of separability between the factors, or in other words show a maximum of embodiment. Where this is not possible at all or only to a very limited extent, the human-machine interfaces are likely to play a crucial role, as they represent the part of the technology that links labour and capital and the locus where human skills are translated into mechanical operations. In the search for a separable design standards are important, as they are the premise for an increase in the division of labour and disembodied technical progress.[11] The specialisation of skills and standardised activities are a premise for an increase of productivity. Hence the design of standardised human-machine interfaces that allow for such a specialisation, is essential. In cases where an embodiment is not possible, we should expect the emergence of new professions of skilled workers being specialised in the operation of one particular interface of a machine. By that the time education time and hence the pressure on the factor prices and the labour market should decrease. In the case where full embodiment is possible, the interface is not important and embodied skills become obsolete. This will reduce the skill requirements and thus shift labour inputs from the skilled to the unskilled pool.

3 Changes in the constraints in American technology in the 19th century: the opening of a window of opportunity

3.1 The Bias in American technology and the American System of Manufactures

There is substantial agreement that the cause for this capital deepening bias are related to three factors: First, the *shortage of skilled labour* provided 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)). Second, the relative *abundance of natural resources* in wood, water, carbon and ores allowed a resource and capital intense mode of production (Abramovitz (1989), Wright (1990), Rosenberg (1976a)). And third, the *structure and growth of demand* favoured the production of homogeneous goods on large scale, as demand was growing at the pace of the increasing population, which more than tripled in the five decades between 1850 and 1900 (Burn (1931): 306; Abramovitz and David (1995): 17).[12] The relatively low 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 the *variety* of given products. The combined effect of these factors explains why foreign observers noticed that 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): ibid). The technological development in the US was located at and biased towards the capital intense end of

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[10] This is not a contradiction to what has been said, we have just to consider innovations that substitute some capital intense sub-processes in each firm with the production of the substitute taking place in a centralised form. Nevertheless, in the analysis developed so far we would have talked about such a case as a paradigm shift, as the fundamental relationship between input factors has changes.

[11] In modern industrial organisation literature authors are mostly concerned with how inseparabilities and standards between technologies are a result of strategic behaviour.

[12] The population was grew from about 23 million in 1850 to 76 million in 1900, reaching 105 million in 1920.

the spectrum of feasible techniques (Ames and Rosenberg (1968), Abramovitz and David (1973), Rosenberg (1976a)).

The stability of the factor price relationship determined embodied technical progress (David (1975): p.88) and the specific composition and scale of demand favoured the production of standardised final goods. In reaction to these circumstances a new mode of production emerged in the mechanical industries and spread from there to different sectors of the economy. Firms had started to direct their attention towards the development of a specific production method which used standardised parts produced by means of specialised machine tools. This lowered the dependence on critically skilled labour, but came at the expense of a more intense use of natural resources (Ames and Rosenberg (1968): p. 831). The American System of Manufactures, as it has been called, emerged in the 1840s (Hounshell (1984), Hoke (1989)). This mode of production was economically viable only when production and assembly were carried out within one plant, as the high capital costs could be offset only trough lower costs in the assembly and product design processes. This contributed to increase the minimal efficient scale of operation and firm size (Fries (1975): p.384).

That the American System of Manufactures in the United States was an archetype of a national style of production and technology becomes evident if it is compared to the British development. In Britain more marked differences in the distribution of income and expensive natural resources favoured a labour intense but resource saving increase in the division of labour which gave rise to a system of vertically disintegrated but highly flexible shops which could match quickly changing demand patterns (Landes (1969): chap.2, Fries (1975): p.384). It becomes evident here that macroeconomic conditions had an influence on micro-level technology choices.

3.2 The opening of a window of opportunity and the formation of a niche of application for information technologies

3.2.1 Inconsistencies in the American production system and the emergence of large business organisations

The information structure of the manufacturing enterprises in the US in the period of dominance of the American System of Manufactures was rather simple. Firms were single activity units specialising in distinct niches in production and services. As long as they remained relatively small information was available virtually without cost in an informal way.

Larger manufacturing firms relied on a form of decentralised system of shop-floor control called *inside contracting* (Littler (1982)) where the plant manager contracted internal craftsmen to organise the production of a given number of items in a given period of time for a negotiated price using the manufacturer's factory, tools and materials. It was left to the contractor to hire and pay workers and organise work. This was an efficient method of indirect control, as it avoided administrative overheads (Hopper and Armstrong (1991): p. 415). The accounting records reflected external market transactions (sales, purchases and payments to contractors) and contained virtually no information about internal operations.

In the period between 1870 and 1900 the competitive pressure intensified due to the development of continuous process technologies and the extension of transportation and communication networks. The increasing urbanisation of the US led to a change the patterns of demand making it more volatile, increasing the danger of overproduction. Frequent and rather unpredictable downturns were the result. The divergence between demand pattern and technology lead to an inconsistency of the production system. Depressions occurred in the 1870s and the early 1890s (Fullerton (1988): p.111). The American System of Manufactures approached an organisational bottleneck. Total factor productivity calculations show a marked slowdown of total factor productivity in manufacturing in the period between 1889 and 1929.[13] The growth rate of the US economy slowed down from a average value from 6.55 % in the period 1879 to 1888 to a 3.35 % in the period of 1889-1889.[14] These development caused a persistent fall of the profit rate and an economy wide fall of the capital utilisation rate in the years between 1889 and 1898 (see the data presented in Duménil and Levy (1993): p. 354-56).

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[13] See Kendrick (1961), table D-I: p. 464, and David (1991), table 2 and figure 4: p. 323. But also the calculations of Duménil and Levy (1993).

[14] Own calculations from Kendrick (1961): table A-XXII: p. 333-35.

Business managers realised that the mass production technology established with the American System with its capital-intensive and overhead-sensitive mode of production, required a large, steady and predictable demand to assure an adequate return on investment. This could only be guaranteed by a high and constant capacity utilisation. Firms started pursuing a market segmentation strategy through new product designs, advertising and geographical diversification. In order to co-ordinate production and distribution better, mass producers integrated vertically into distribution. This development was favoured by antitrust legislation, as in the early 1880s the formation of collusive trusts had been outlawed. The first merger wave of the 1880s resulted. The rise in size required new methods of management for the co-ordination on the shop floor and new forms of financial management as larger funds had to be administered. On the conceptual level the multifunctional enterprise (or the U-form) emerged, but this required the operational set up of an administration.

3.2.2 The opening of a niche of application for information technologies: new business organisations and clerical labour shortage in the late 1870s

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 acting "as a substitute for market mechanisms" (Chandler and Daems (1979): p.4) took place gradually.

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, which "based its reassertion of control and co-ordination on record keeping and flows of written information up, down, and across the hierarchy" with the aim to "transcend reliance on the individual in favour of dependence on system" and to monitor and evaluate performance (Yates (1989):10-11). 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, as salaried foremen replaced contractors.

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 grater attention to the management's goals (Litterer (1963)).

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 division of labour was brought to its extremes. Standard costing became the chief monitoring instrument: "true" standard costs were based "on the engineering redesign and analysis of the labour process" as they are determined by the engineering staff. Standard costing was also the basis for variance reporting (Johnson and Kaplan (1987), Hopper and Armstrong (1991): p.420). 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. By that the uncertainty of the production process could be decreased.

Business hierarchies grew from the top down through vertical integration and the take over of new functions, and from bottom-up as new hierarchical layers were introduced in order to gain control over the shop floor. The problem that arose under this circumstance was to reduce the minimum delay of information flows, 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): p.379). To handle this problem new information processing technologies and clerical staff to operate them were needed.

In regards to the labour market for clerical services, the situation did not look rosy. The typical office in the late 1870s was virtually untouched by technology and consisted of predominantly male workforce: a book-keeper, a copyist, a clerk and perhaps a shorthand taker. These clerks 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): p. 561 Braverman (1974): p. 293, Wooton and Kemmerer (1996): p. 549), which reflected itself also in the social background of the clerks and the acquisition of skills. There were no explicit vocational training institutions for clerical professions up to the early 1880s (Hartman Strom (1992): p.282).

In the period spanning the 1880s and early 1890s the problem of labour supply was most pressing. It was overcome in the short term by recruiting high school graduated women especially from middle class families, as clerical work required English-language skills and a social background that virtually excluded first generation immigrants and working class people. For these women opportunity to work as clerks were very attractive, as many other trades were inaccessible to them: The share of female clerks rose from 2,4% in 1870 to 35,9% in 1910.[15] They provided the material to fill up the typing, computing and book-keeping pools leading to a segregation of the labour market for clerical work along gender lines, where management activities were carried out by men and labour intense and routine operations were done by women (Hartman Strom (1992): p.287; (Davies (1988): p.30). After 1890 the number of private commercial schools increased very rapidly and their graduates contributed together with the increasing mechanisation of the office to relax the pressure on the labour market (Pirker (1962): p.69).

4 The establishment of the First IT Regime in US manufacturing and the standardisation of office practices

"It was not an accident of fate" (Cortada (1993): p.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 most information processing devices were invented and innovated (1873: typewriters, 1879: cash registers, 1885: calculators, 1889: Hollerith system, etc.), paralleled by complementary changes in organisational practices, new developments of distribution networks and of marketing tools and innovations in the organisation of production. The new technological regime consisted of a number of (electro-) mechanical devices, such as typewriters, calculators, dictating machines, mimeographs, cash registers, timekeeping machines, automatic mailing machines, sorting devices, filing systems, etc. and supported the establishment of new standards of practice in office.[16] We will limit the scope of our analysis to typewriters, calculators, book keeping machines and Hollerith machines.

4.1 The search for new standards of practice, viable technology choices and the rise of the office work paradigm

As with the new large business administrations information was produced and processed on large scale, the pressure on the labour market became stringent. Clerical workers were scarce and their employment was relatively expensive. In 1899 the average annual earning of a clerk was more than twice as high as that of a worker (Census (1976): P1-12; 1929 prices). The production of information was not only constrained by the shortage of clerical labour but also by the scale and the rate of increase at which it was produced. This put an even higher strain on labour market and salaries. These circumstances replicated on smaller scale the environment that had led to the development of the American System of Manufactures four decades before.

One of the most interesting characteristic of the American System was that it represented a meta-heuristic or a solution algorithm for any problem in the production sphere. In the design of the new administrative organisations which came along with the giant enterprises, engineers played an important role. They tried to cast the logic of the shop-floor into the organisational machinery: in their conception office machines had to

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[15] 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, Abstracts of the US Series D57-71 Later: US Bureau of Census Statistical Abstract (1972).

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

be instrumental in realising a system of standardised activities aiming at the saving of skilled labour and time.[17] The aim was reduce the dependence of administrative processes on critical clerical skills and hence increase the separability of labour and capital good inputs, in analogy to the production process, where they pursued the ideal of a completely modular production system based on standardised parts and activities.

This was obtained at first through the standardisation of the manipulated data and of tasks which led to a minute division of labour. Once these improvements had been realised the potential for further productivity gains through capital saving innovations was rather limited, but it was nevertheless an important precondition for the introduction of machines, as on the one hand they could unfold their full productivity potential only if a smooth flow of standardised and indexed information was available. This in turn could only be obtained if the record keeping and processing activities within the organisation were designed accordingly. On the other hand, out of these simple, elementary tasks routines could be constructed as well as critical knowledge and bottlenecks be isolated. Once this had been achieved a mechanisation could take place through the use of machines that embodied critical knowledge, executed mechanically whole sets of routines or which supported a further specialisation of work profiles.

Through the embodiment strategy productivity advances could be made independent from the limiting factor to a large extent, but due to the peculiar characteristics of the commodity processed, this was only possible where the information was quantitative, standardised or purely numeric. Where this was not the case, with activities that were either knowledge intense or where the processed information was qualitative, an embodiment was not possible. But if it was not possible to pursue the embodiment strategy, machines should support the specialisation strategy, to which a standardisation of the required skills is implicit, so that productivity gains could be achieved either through new practices made possible by the technologies or through the improvement of existing ones. In these cases standardised human-machine interfaces became a crucial adoption criterion, as they were the mean by which a specialisation of the operator could be achieved. Where this was not the case, its importance was secondary and hardly if ever any standardisation took place. The standardisation of skills was instrumental in relaxing the wage-pressure on the labour market, as it contributed to make the structure of the potential work-force more homogeneous and increase the elasticity of labour supply. This was particularly the case for typists. The utilisation of the female 'reserve army' brought considerable cost savings as the earnings of female clerks were consistently 25 to 45 percent lower of their male colleagues (Hartman Strom (1992): p.290, Davies (1988): p.32). The average annual earnings of clerks in US manufacturing fell during the two decades between 1899 and 1919.[18]

From the evidence presented so far we may summarise three necessary conditions which office machinery had to fulfil in order to be adopted: they had to complement a function of the administration of a firm, and they had to have a cost minimising effect. The third and most important condition was that they should allow to increase the independence of operations from scarce clerical labour, i.e. they should be instrumental in increasing the separability of office activities from the scarce input. We will discuss these criteria more in detail for the single technologies in the next section.

4.2 The product technology of office work

[Table 1: Early information technology: innovation characteristics of the most important technologies of the IT Regime, **about here]**

4.2.1 Typewriters and typing: technical characteristics, the viability of the technological choice and new activity profiles

Typewriters were the first and single most important technology of the new office work regime. Their domain of application were all activities involving the multiplication and distribution of information on small scale, i.e. in practically all functional fields of organisations producing mail, internal memos and

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

[18] The average annual earnings of clerks in US manufacturing dropped from 1920US$ in 1899 (1929 prices) to 1385US$ in 1919. In the same period the average annual earning of a worker increased from 767,6 US$ to 784,9 US$, (Census (1976), P 1-12).

communications, customer-, personnel- and book-keeping records, contracts, etc. By that typewriters supported co-ordination functions within the organisation. The character of the information processed was mainly qualitative and changing continuously. The content of the typescripts could not be easily standardised (Cortada (1993): p.23, Pirker (1962): p.53, Leffingwell and Robinson (1950): p.163).

Typewriters were thus instrumental in introducing a new, more specialised and thus more productive activity into the administrative work, but did not represent a technical advance *in itself*, as the mechanical construction of the typewriter could not embody any specific knowledge or skills. As this section will show, the best way how this could be achieved was through a human-machine interface which would guarantee a fluid execution of the work. Productivity increases were not separable from the operator whose skills made the typewriter a useful device. As is well known, this special interaction of service requirements by adopters and technological characteristics gave birth at first to the QWERTY keyboard, with which its inventors succeeded by way of a trial and error procedure to order the keys in such away that during high speed writing the types would not entangle (Adler (1973), David (1985)). The subsequent development of the touch-typing method played a crucial role in making the typewriter a viable technology for business administrations, as it contributed, first to produce a homogeneous labour supply, and second, to increase productivity.

If the technology did not allow for a complete separation of the operation of the mechanical device from specific skills workers needed to operate them, then the skill requirements had to be such as to generate a labour supply that emulated the effects of a technology separable in fixed capital and labour by being elastic to any increase of demand, i.e. an elastic labour supply. The co-existence of different keyboards with different practices would have lead to a segmentation of the labour market and the elasticity of labour supply would have been inevitably lower on such a market than on one large standardised market.[19] In the late 1870s Remington, the first mover in the typewriter industry, started setting up its own typing schools and to furnish trained (female) operators with each machine sold in one package (see Keep (1997): p.406). In 1882 a first textbook on the touch-typing method appeared (Martin (1949): p.479) as a result of the marketing efforts undertaken by Remington to boost the sluggish sales of its Model II.

By using the touch typing method a skilled typist was able to type sixty words *on average*, which was twice as much as the speed *world record* for handwriting of thirty words a minute established in 1853 (Pirker (1962): p.41, Yates (1989): p.37). This was a remarkable increase in productivity. Considering that in 1879 Remington sold its Model II for 100US$ (157,3US$ in 1929 prices) a piece (Cortada (1993): p.17) and that by the employment of female typists the salary expenses could be reduced by 400 to 800 US$ a year per employee as compared to a male clerk, the choice of the typewriter reduced cost and increased the speed and the scale at which memos, letter and the like could be produced.

As typewriters like all other office machinery and equipment represented fixed capital it was an obvious choice for cost-minimising firms to organise their operation in a way that their rate of utilisation was maximised. This led to the set up of centralised services for typing, computing, filing and so forth (see Leffingwell and Robinson (1950): p.34) and through that to functional office departments, in which all standardised activities were pooled. Here the use of one single method proved an important monitoring tool, as variance measures could be used in order to control the output of each single typist (ibid.: 539). By that typewriting became a profession and an administrative process on its own right. Typist-clerks had a sharply circumscribed activity profile which consisted in taking (shorthand-)notes and writing them on paper with the machine using a particular method. 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): p.143 ff.)

After an initial period of fermentation, where different keyboard designs and typing methods competed for dominance, the QWERTY keyboard with the touch-typing imposed itself as the dominant process. This happened as the technological closure came after Underwood had introduced its Model 5 in 1895 that used first a front-strike type design and the QWERTY keyboard with shift keys. It met better the needs of users than any other competing design as with the visible writing field it allowed to increase the typing speed even though the mechanic movement was not as smooth as the ones of competing designs (see Knie (1991): p.117). By 1900 most of the technical features of the manual typewriter had been introduced. Further improvements regarded complementary technologies such as dictating machines and the electrification of the typewriter. As Martin (1949) remarks, already in the early 1920s the speed potential of the typewriter

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

exceeded the capacity of typists by large. While an optimised keyboard design could have made 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.

4.2.2 Accounting devices and accounting: technical characteristics, the viability of the technological choice and new activity profiles

As our discussion in section 3.2.1 shows the rise of large administrative organisations in the US manufacturing resulted to a large extent from an attempt to gather and evaluate more quantitative data on the production process with the aim of developing standard cost measures, analyse market development, derive operating ratios and deliver financial reports and indicators for the management and investors. Out of a pure mean of coordination, business organisations grew to become entities of their own right conceived to co-ordinate and monitor activities as well as raise and allocate funds. Book-keeping became thus the most important organisational set of processes consisting of activities of gathering, classifying, coding, sorting, calculating, summarising and reporting of financial information. Within these activities simple mathematical operations were of foremost importance: rationalisation studies showed that almost 60% of all tasks performed in office work consisted of doing calculations that consisted to 80% of pure counting and adding (Pirker (1962): p.66). Adding and calculating machines as well as accounting machines were thus the second main pillar of the First IT Regime.[20]

In order to be a valuable source for entrepreneurial decision the volume of data had to be processed quickly and without mistakes. Bookkeeping positions required individuals to have reading and mathematical skills as well as the social background to work closely with their employers. A requirement that in the 1880s and 1890s excluded working people (Wooton and Kemmerer (1996): p.548). As with typing this put the labour market under pressure. A rationalisation of methods, organisations and processes in order to increase the independence of these activities from skilled labour took place, leading to a switch to new activities that used machinery and un-skilled labour. The first step in that direction was to separate pure entry activities from activities of analysis. By that the dichotomy of book-keeping and accounting emerged.[21] While book-keeping regarded record keeping only accounting entailed analytical activities. This led to the emergence of accounting as a profession and the foundation of professional societies of accountants and auditors.[22] The second step was to generate activities in which capital equipment was used and which were separable in their inputs. This led to the adoption of adding machines, calculators, accounting and billing machines and Hollerith systems.

Adding and calculating machines were general purpose tools, as were typewriters. They were applicable to a vast range of uses, such as the calculation of daily ledger and cash balances, daily recapitulation, the checking of invoices, freight bills, disbursements and so forth. These machines embodied the most important skill that made a good book-keeper, which was quick and reliable adding. Their rationalisation effect consisted in two main features: first, long rows of numbers could be condensed into one single key figure much faster than before. Second, some machines, such as the Burroughs, incorporated automatic control devices so that the accuracy of these sensible operations did substantially improve. A well trained operator was able to do the work for which three clerks without mechanical aides were needed, resulting in savings of in total salary costs of up to 70% (Pirker (1962): 67). Considering that in 1885, in the year of its market introduction, Burroughs offered its machines for 790US$ (1929 prices; Cortada (1993): p.32), the adoption of calculators was a cost minimising choice for firms.

Accounting machines evolved out of other office appliances and entered the market only in the 1920s. Up to that time book-keeping operations on larger scale were done on large adding machines and calculators. They were basically combinations of an adding machine with a typewriter or just normal adding machines with mechanisms allowing special carriage movements. In most cases they were tailored to specific uses in order to increase productivity even further. For small or medium enterprises it did not pay to set up own accounting

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[20] Adding machines could only perform 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.

[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".

[22] In 1882 the Institute of Accountants and Book-keepers of the City of New York was founded. In 1887 the American Association of Public Accountants was incorporated in New York, and in 1896 the State of New York issued a law restricting the use of the title of Certified Public Accountant to people having passed a state exam (see Ibid. : p.546).

machine departments, so that very often these tasks were outsourced. Nevertheless, for large firms it was a viable choice: the rental rate varied between 150 to 500 US$ a month (165-520US$ 1929 prices; Cortada (1993): p.125), summing up to an annual expenditure of 1800 to 6000 US$ a year which amounted to the cost of one to three clerks. Taking into account the productivity factors that could be achieved by the application of such machines shown in Table 2 savings were considerable: current account transactions could be carried out ten to twenty times faster as a single clerk could do in purely manual execution.

Very different from the previously listed technologies were Hollerith and Powers machines. They represented a system of electromechanical devices conceived in order to codify and operate on quantitative data on the largest possible scale. It consisted of punched cards which were the media on which operating instructions and information were stored, card punch machines, used to transfer the information on the cards, sorting machines, that allowed to sort the cards at high speed through a hole sensing mechanism and finally a tabulator used to count the sorted cards. The sorters could be programmed with punched cards on which a sorting routine was codified, so these machines could be used for a large number of operations, as they could be flexibly re-programmed.

Developed and marketed first for public institutions with the purpose to speed up counting and sorting processes which were prone to mistakes and very laborious, very soon they awakened also the interest of large business firms, in as they would allow to increase the control over all business activities as these machines could be used to tabulate sales statistics, sort consumer trend analyses, for payroll and inventory management, and so forth.[23] Tabulating machines were a superb tool for processing information needed to monitor activities and allocate physical and financial resources in large businesses. In this function they competed with large accounting machines, but while it made sense to use Hollerith machines for company wide applications (Cortada (1993): pp.159-61).

As Table 2 shows, the volume and the speed of information processed shifted upwards by two to three orders of magnitude. The bottleneck remained the codification of the data. Yet this operation was carried out faster on punch card machines than on any other data-processing machine. In 1896 Hollerith offered his machine for a yearly rental rate of 1000US$ (approx. 1950US$ 1929 prices) and sold a package of hundred cards for one dollar (2 dollars in 1929 prices). A large firm used several millions of these cards each year. In the 1930s the rental rate ranged from 3000 to 6000 US$ a year (Cortada (1993): pp.49-50). The enormous productivity shift made Hollerith machines a viable technology for large firms.

[Table 2: Data processing capabilities of early accounting machines round 1926**, about here]**

Most of these devices were innovated in the late 1880s, but reached a larger diffusion only about ten to twenty years later. They could only be effectively used if the way data were manipulated, i.e. the book-keeping methods and other institutional conditions, changed as well. Bound ledger books and registers were replaced by a loose-leaf system of accounts (Wooton and Kemmerer (1996): p.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): p.80).
This had to be paralleled by changes in the legal system, that regulated accounting practices and established the actual requirements for registers and ledgers. The laws that passed in order to make the adoption of these accounting innovations possible, contributed also to the standardisation of accounting data.[24] These legal and organisational changes levelled the way for the adoption of accounting devices which in turn gave shape to new and more rational administrative activities.

Book-keeping was spliced into a sequence of distinct and specialised occupations. Roughly we may distinguish between activities of work preparation and activities of data manipulation. The first, such as the sorting of vouchers and receipts and the search of related ledgers, were executed without mechanical aides,

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[23] 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. The first business 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)).

[24] We will mention only two important developments in this regard: in 1902 the United States Industrial Commission recommended that larger corporations should issue an audited annual report. In 1909 the first corporate income tax was passed. For further details see Hawkins (1963) and Miranti (1986). A summary is presented in Hartman Strom (1992): p.28-35.

but reached a high degree of specialisation in manpower. The latter entailed the codification, processing and evaluation of data and were supported by mechanical equipment (Pirker (1962): p. 81-3). The level of rationalisation and standardisation that was reached was dependent on the type of equipment used which in turn was determined by the scale at which the information was processed.

On a small scale small adding machines and calculators were adopted in order to support accounting clerks in their work. Their use induced a more rational design of the workplace and a more rational work preparation. The efficient use of these pieces of capital equipment required a certain volume of data to be processed in each moment, but only rarely this need gave rise to specialised workplaces within the office when the scale at which information was processed was small.
But even when larger adding and calculating machines were used for large scale data processing in computation pools, no profession with a specific skill profile appeared as previously it had been the case for the typewriter. The reliability and the speed of the computing mechanisms dominated all other considerations, and the human-machine interface played only a secondary role. This becomes evident, if we consider that Felt and Tarrant, the inventors of the Comptometer, tried to follow Remington's strategy in the sale of typewriters, by setting up Comptometer-Schools (Pirker (1962), p.62). Comptometer Co. and Burroughs, the two first-movers in the industry, offered full keyboard machines with 81 keys. Dalton and Sundstrand, the two most important followers in the industry used 10-key keyboards. Eventually both designs co-existed up to the 1950s. The two elements determining the positive feedback leading eventually to the convergence and lock-in of skills and keyboards to the QWERTY standard in typewriting were irrelevant for this particular technology. The diffusion of the typewriter critically depended on the availability of a certain method to operate the machine and an adequate supply of operators capable in that method. In the case of adding and calculating machines the locus of the labour saving potential was completely embodied. By that basic accounting and billing activities became separable from skilled labour inputs and the interface lost its importance. This in turn led to an increase of the elasticity of labour supply, as workers with a lower skill profile could be employed. Typical candidates for these jobs were female grammar school graduates, who were able to learn the use of these machines on average within a few days (Pirker (1962), p.82).

The highest possible degree of rationalisation was achieved in the use of tabulators and accounting machines. These technologies were used to process company wide data on a large or very large (industrial) scale. Unlike adding machines, they were not just mechanical supports for a given problem, but went far beyond that, they were an integral part of a rational information system.
This becomes clear if we consider that to sell such devices "a salesmen had not to sell the machine but the organisation" (Pirker (1962): p.79). Salesmen acted as technical advisors as well as organisation designer. Organisational concepts developed for businesses in one particular sector were then used as a blueprint (and sale argument) for other firms in that sector (Mcpherson (1992)).

For the sake of shortness in what follows we focus on the development of the activities related to the use of tabulators. The operation of these machines was split into three distinct activities: the codification of sorting and tabulating routines, the codification of the information to be evaluated and the evaluation itself, i.e. the actual sorting and tabulating of information. The codification of routines was carried out by accounting and organisation specialists. Specific sorting and tabulating processes were stored on punched cards and used when necessary. The programming of routines and routine sequences was an activity that happened only sporadically at the set up of the machine and subsequent organisational changes. The codification and evaluation of information were instead recurrent tasks.

Through their codified programs these machines embodied procedural knowledge on clerical operations on a hitherto unknown extent and almost completely isolated productivity increases in data processing from the skills of the operators of these machines. This finds also its reflection in the technological trajectories the single components of the system followed (see Table 1, last column).[25] With the appearance of tabulating machine rooms "for the first time something appears in the office, that can be compared to the working practice on the shop floor" (Pirker (1962): p.95). The high specialisation and division of labour typical for the shop-floor in the American System found its correspondence in a number of new occupations, that differed mainly in their skill profile: key-punch operators codified and controlled the information; sorters were

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[25] An exception were key-punches. Their efficient operation relied on the speed with which the codification could take place. In first place this led either to the adoption of the typewriter keyboard (for alphanumerical insertions) or a 10-key keyboard (for purely numerical insertions) with the keys ordered in four rows. Both allowed to use touch-typing methods. As the codification of data continued to be the bottleneck in this technology, the use of standardised interfaces was important.

responsible for the supervision of sorting and tabulating processes; lead-machine operators (also called tabulators) were responsible for the wiring of the control panels and the verification of the machines and programmers finally were responsible for the cybernetic part of the job: programming and designing process flows. The skill requirements increased in ascending order: the skill requirements for key-punch operators and sorters were primary school degrees, while tabulators needed to have specific technical skills and held mostly secondary school. Programmers instead were university graduates in mathematics or engineering, but they were seen as professional organisers and operated away from key-punch pools and tabulating machine rooms (in Table 1 is given an overview on the skill profiles and training periods of these jobs) in a middle management environment.

The high degree of skill embodiment of most of the technologies discussed here finds its reflection also in their technological trajectories. A glance at the last column of Table 1 reveals that the improvements regarded mostly the data throughput which was achieved through increases of the processing speed, the simultaneous data processing capability and increased mechanisation as well as the widening of the scope of application of the devices.

4.3 The technological bias and the economic implications of the adoption of the First IT Regime in US manufacturing, 1889-1937

The historical and technical evidence presented so far supports the view that there was indeed a capital deepening bias in the development of the First IT Regime which was strongly reflected in the development of its heuristics. In this section we will try to find some evidence in the data available to us. In section 2.2 we put forward the hypothesis, that given the peculiar characteristics of the American technological style, the capital intensity of office work should have been increasing and that the choice of these technologies should have had cost reducing effects.

In support for this conjecture we find , that the per-capita value of capital used for administrative purposes in relation to administrative personnel in US manufacturing increased over the years between 1889 and 1937 (see first row, Table 3).[26] This crude ratio does not tell us however whether these changes were only due to a general tendency in manufacturing to increase the capital stock at any level of employment or whether the ratio increased even though the number of clerks increased. Indeed the capital-labour ratio for manufacturing as a whole and the ratio for office work do highly correlate over the whole period. Nevertheless, the degree of mechanisation and the degree of "bureaucratisation", given by the ratio of clerical to production workers are also positively correlated. The correlation is very strong for the sub-period between 1889 to 1919 and weakens somewhat if the whole period (1889-1937) is taken into consideration as the relationship turns ambiguous in the years between 1919 and 1937.

The evidence presented so far supports our hypothesis of an increasing capital intensity in office work in a period of expanding administrative machineries in firms. Yet it does not tell anything about the capital intensity in terms of the cost structure of the production process, which can give a measure of cost related substitution effects.[27]

[Table 3: Capital-labour relationships in US manufacturing and the First IT Regime and its bias in technical change, 1889-1937**, about here]**

The changing relationship between capital stock and labour over time is measured best if we analyse the ratio of the value of capital stock per man hour to wages or salaries per man hour, but now the picture turns ambiguous.[28] A quick glance at Table 3, row 3 reveals that production in overall manufacturing was clearly capital intense, but surprisingly the ratio declined after 1899 and started levelling out only in 1929. Office work instead remained labour intense over almost the whole period. An exception was the period between 1909 and 1919, where the value of office machinery and furniture used per man hour exceeded the expenditures on salaries.

The single factors composing the two coefficients follow closely the pattern of total factor productivity in manufacturing. The value of capital as well as the wage costs fell over the period between 1899 and 1919

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[26] For indications regarding the data sources and the calculations see the remarks to Table 3 and Table 4 .

[27] We cannot account for changes in productivity of the single factors as for office work as there is no adequate output measure, nevertheless, the single factors of the coefficients strongly correlate with TFP in manufacturing (Kendrick (1961): Table D-I) over the period 1889 to 1937: CMH_{off} r= 0,65, CMH_{tot} r=0,91, WMH_{off} r= 0,93, WMH_{tot} r=0,97.

[28] For the sake of shortness we will call the capital stock per manhour unit-capital stock and the wage/salary per man hour the unit wage/salary.

corresponding to a general slowdown in total factor productivity, reaching their lower peak between 1909 and 1919. Taken over the whole period the value of office capital employed per man hour increased steadily exceeding the salaries in 1919 and reaching a maximum in 1929. Nevertheless, in the decade between 1919 and 1929 the unit-salaries almost doubled and reached a level that remained constant in the three decades that followed. Although all the other factors grew in close relationship to the soaring total factor productivity in that period, unit-salaries grew over-proportionately with the increase of the unit value of office capital slowing down. This suggests that, first, the capital intensity increased indeed up to 1929, which was the period in which the large office machine pools were set up. Second, the diverging growth pattern between wages and salaries increased the wage premium on clerical work, which entails either that the productivity of clerical work had sharply increased or that managers attributed the sharp increases in total factor productivity in the period between 1919 and 1929 to the activities of the bureaucracies of their firms. Other reasons for this pattern could have been either the relative shortage of clerical workers or their higher wage negotiation power, but these alternatives do not find support in the historical sources. Whilst the first point is not relevant, as the sources indicate that by that time the problem of clerical labour shortage had largely been overcome, the latter is equally of scarce importance, as overall union power declined over this period and unionisation played a role only in industrial trades, as clerical workers were not unionised (Douglas (1927): p.573ff., Hartman Strom (1992): p.203).[29]

Up to the late 1920s the pattern of mechanisation of office work followed the grand pattern of the American System and changed thereafter. By that time most of the office machine pools had been set up and an optimum degree of mechanisation had been reached. Nevertheless, office work remained a labour intense activity because of the qualitative character and the knowledge intensity of many clerical and managerial activities, so that the extent of mechanisation reached on the shop floor was not feasible in office work.

During the same period the development in the manufacturing sector as a whole somewhat differed from that in its administrative units, as the unit value of capital in relation to the unit wage declined. This development contradicts the logic of the American System of Manufactures, but after 1899 a paradigm shift on the shop-floor had taken place: it was the age of electrification. The increasing use of electric power drives in industry saved fixed capital (David (1991): p.334), so that the rate eventually declined. Indeed, the degree of electrification strongly correlates with the unit capital-labour rate (Table 3, last row). While the achievement of scale economies through capital deepening and standardisation characterised the American System of Mass Production, the conspicuous characteristic of the new paradigm was mobility (Freeman (1985): p.38). Capital costs could be lowered through decentralised power units and the possibility to transport energy over long distances brought mechanisation even to the remotest places. Energy intense production methods no longer depended on the presence of a factory owned power generation unit. It becomes evident that although electrification and bureaucratisation overlapped, the pattern of technological adoption was a different one.

[Table 4: Economic effects of the First IT Regime in US manufacturing: correlations, 1889-1937.**, about here]**

There remains the question, whether the adoption of the First IT Regime indeed helped to lower production costs and to achieve "economies of speed". Table 2 shows that the use of office machines increased the speed and by that the scale with which information could be processed as compared to manual labour by one to three orders of magnitude. Larger firms benefited more from their use than smaller ones, indicating that scale economies played an important role. 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.

Nevertheless, the raise in administrative overhead generally also raised the profitability of production through better co-ordination and organisation of the shop floor. Table 4 shows that value added strongly correlated with the share of clerks in total staff as well as the share of office machinery and furniture in total capital. This relationship is particularly strong in the sub-period between 1899 and 1919. In that period the changes of these shares and the changes in value added also correlated strongly, but the effects became ambiguous after 1919, so that the correlation between the rates of change over the whole period is weakly negative.

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[29] This was indeed the time where Taylorism and standardisation entered offices opening up the profession to even more persons. Organisations had already reached or were reaching their critical size, see Cortada (1993): 96 ff.

5 Summary and conclusion

The adoption of early information technologies was a true change of the technology system (Freeman and Perez (1988); p.46). It led to the constitution of a new industry and it diffused into almost all sectors of the economy. It shaped the working profile of the emerging white collar working class and supported the establishment of new professions. The First IT Regime was a manifestation of the rise of managerial capitalism.
Given the pervasive nature of the phenomenon this paper tried to shed light on the circumstances that triggered the search for the new technologies and on the influence macroeconomic and institutional factors exerted on actual technology choices of firms. We worked out how these factors found their reflection in the new activities composing the technological regime.

As our study shows firms started their search for new administrative techniques, the moment a given set of productive activities became inconsistent with the scale of production required. It should be noted that this problem resulted out of previous changes in the macroeconomic production system. The American System of Manufactures became inconsistent with new demand conditions and increasing competition, so that large business administrations were set up in order to cope with these problems, which in turn caused the crisis of the established set of clerical activities. It is obvious that there is a lag involved between the unfolding of a crisis and responses in subsystems of the economy. The inconsistency of the established office work regime resulted from its incapacity to cope with the information flow to be processed. Firms reacted by trying to identify and isolate the bottlenecks through an increase in the division of labour. Typical bottlenecks were high information throughput activities and the factor increasing the overhead over proportion was scarce clerical labour. The response to the identification of this problem reflects the factor price history and engineering experience in the US: through the application of the heuristic underlying the American System of Manufactures organisational designers tried to overcome the problem by a full-embodiment strategy which allowed to isolate the critical factor, clerical skills, and by that to make clerks themselves exchangeable parts of the system of information production. The extent to which this separation was possible finds its reflection in the subsequent innovations, technological trajectories and emerging path dependencies of the new regime. Finally, we showed that although electrification and "bureaucratisation" overlapped our data suggest that they should not considered being the result of the same pattern of technology adoption.

As far as it is possible to generalise from one single case, we may derive four necessary conditions leading to a successful systemic innovation, none of which is sufficient by itself: first, new activities have to match the required output scale and be cost-minimising as related to competing ones. Second, the new activities must be complementary to the production system of the adopting firm. This entails that new activities can have competence destroying consequences only on a subset of processes and must be compatible with others. Third, as viability depends also on the uncertainty attached to a technological option, the new technologies must be compatible with an existing institutional framework, such as vocational training institutions or the legal system, and finally they must separate the production process from factors that are being perceived as critical for the profitability of firms. These conditions result from the peculiar character of systemic innovation, as it gives rise to a *new* industry *and* to new activities in *established* industries. This shows that systemic innovation is not just the outcome of chance, but a complex and contradictory consequence of underlying socio-economic processes.

Table 1: Early information technology: innovation characteristics of the most important technologies of the IT Regime[30]

Technology	**User side**				**Supply side**	
	(i)Supported economic function of organisation and (ii)type of processed information	***(i) Source of productivity gains and (ii) effect on established competences, i.e. clerical work before IT Regime***	***New professions***	***Required skills***	***Characteristics of the technical design***	***Incremental improvements / trajectory***
Typewriter	(i) Co-ordination (ii) multiplying codifying of qualitative information	(i) user interface, touch typing and complementary technologies (ii) 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	Dominant design: 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	(i) Monitoring (ii) processing of quantitative (accounting) data	(i) Mechanical adding or calculating mechanism, automatic entry controls, user interface (ii) 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: few days. Girls round 17 years of age with two years in secondary school.	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
Accounting machines	(i) Monitoring and allocation (ii) processing of quantitative accounting data	(i) As for adding machines plus reduction of double entry mistakes through better work preparation (ii) Replacement of book-keepers (mathematical skills, book-keeping skills)	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.	Corresponding widely to improvements in adding and calculating machines.
Hollerith – Powers systems	(i) Monitoring and allocation (ii) processing of quantitative (accounting) data	(i) Electric contact principle, codification of information, sorting and tabulating mechnisms (ii) Replacement of mathematical and statistical skills; sorting and indexing tasks.	Card Puncher Sorter Tabulator Programmer; Establishment of card punch units, and machine rooms.	Puncher: in some cases typing skills mostly not; primary school degree. No further skills needed. Training period: 1-4 month Sorter: No special skills, but strong physical constitution required; primary school degree. Training period: round 6 month. Tabulator: secondary school degree and technical skills. Training period: 1,5 to 2 years. Programmer: organisational skills, business skills; preferably university degree in mathematics or a technical discipline. Training period: 4 years.	Dominant design: 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).

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[30] Compiled using information contained in Brauner and Vogt (1921), Meuthen (1926), Leffingwell and Robinson (1950), Pirker (1962), Cortada (1993), Martin (1949).

Table 2: Data processing capabilities of early accounting machines 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 accounting 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

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[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, Ibid. : 47. Strictly speaking we compare different production functions with the same output.

Table 3: Capital-labour relationships in US manufacturing and the First IT Regime and its bias in technical change, 1889-1937

Year	1889	1899	1904	1909	1914	1919	1929	1937
C_{total}/L_{total} (1929 US$)[*]	2171,17	3260,98	3259,57	3375,85	3871,34	2816,42	6115,11	5586,13
C_{office}/L_A (1929 US$)[*]	13,04	17,31	17,72	20,49	23,68	20,02	49,90	30,60
Coefficent of correlation between the two series								0,92
CMH_{total}/WMH_{total} (1929 US$)[**]	2,58	3,34	n.a.	3,20	n.a.	2,77	2,04	1,96
CMH_{office}/WMH_A (1929 US$)[**]	0,47	0,60	n.a	0,52	n.a	1,14	0,70	0,53
Coefficient of correlation between the two series								0,03

	Total period: 1889-1937	Subperiod: 1889-1919
C_{office}^{+}/L_A with A/P	0,458	0,935
CMH_{office}/WMH_A with A/P	0,18	0,72
CMH_{total}/WMH_{total} with degree of electrification	-0,79	-0,97[***]

Remarks:
C_{office}, C_{total}: office machinery and furniture, total capital
L_A, L_{total}: index A non-production workers, classified as clerical workers, index total, all employed persons
WMH_A, WMH_{total}: wage bill per man hour; A: salaries, total: total wage bill
CMH_A, CMH_{total}: value of capital stock per man hour; A: office machinery and furniture, total: all capital
+: computation of C_{office}: Series P357, P358 from Census (1976), giving the yearly output of office machinery and furniture were deflated by the wholesalesprice index, E42, to prices of 1929. For each year an export share of 20% for office machinery and 10% for office furniture was assumed following indications in Engler (1970): p.100ff., and Unger (1940): p.57. Due to the specific US tarif history (see Engler (1970)), imports were deliberately set to zero. These data were cumulated assuming a simultaneous exit after ten years. A comparative analysis with linear scraping or progressive scraping methods have shown, that this method tends to overestimate the absolute stock of capital. The growth trends are nevertheless identical. The imputation of the so calculated US capital stock of office furniture and machinery to manufacturing was done by calculating the share of manufacturing in total worked man hours in the national economy given by Kendrick (1961). This coefficient was then multiplied with the share of non-production workers to production workers calculated from series P1-12 in US manufacturing. The resulting coefficient of clerical labour intensity in manufacturing was multiplied with the calculated total capital stock value, thus assuming a fixed coefficient production function for clerical activities. It has to be remarked that regardless of the previous explanations the C_{office} coefficient heavily underestimates the real capital stock used for administrative purposes, as we do not take into account buildings dedicated to these activities, which was rapidly increasing in that period (building of skyscrapers).
* ratio: value of capital stock in 1929 US$ to number of employees
** value of capital stock in 1929 US$ per man hour to wage cost per man hour; correlation for the subperiod 1889-1909: r= 0,9
*** sub period is 1899-1929; value for sub period 1889-1919: r= -0,12; sub period 1899-1937/39: r= -0,98

Datasources: Census (1976), series P1-12, P123-76, E42, Kendrick (1961) table A-XI, p.341, David (1991), p.327, table 3, first column (for degree of electrification in US manufacturing).

Table 4: Economic effects of the First IT Regime in US manufacturing: correlations, 1889-1937.

	Total period: 1899-1937	Subperiod: 1899-1919
VA to A/P	0,685	0,975
VA to C_{office}/C_{total}	0,762	0,858
	Total period: 1904-1937	Subperiod: 1904-1921
ΔVA to ΔA/P	-0,143	0,857
ΔVA to $\Delta C_{office}/C_{total}$	-0,20	0,883[++]

Remarks:
VA: value added
A/P: ratio of non-production to production workers
C_{office}, C_{total}: office machinery and furnitures, total capital
L_A: non-production workers, classified as clerical workers
++: subperiod 1904-1919.

Datasources: Census (1976), series E42, P1-12, P123-176, P357, P 358, Kendrick (1961) table A-XI, p.314.

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difference in technology adoption in developing countries, relative to developed countries. Due to the. multidimensional nature of technology adoption and innovation, a difference in rates of adoption of. technology across countries can be attributed not only to economic and technological factors, but also to. socio-cultural factors. According to [1], existing cultural conditions are determinants of diffusion of an.Â While the US and UK are low in PDI with 40 and 35 respectively, Nigeria and Ghana each score 80. These. scores reflect the inequitable distribution of power in Nigeria and Ghana. In Nigeria for example, a major.Â information to affirm their decision. This process is also influenced by cultural differences. Table 1: The Stages of Innovation Diffusion [adapted from 7]. We provide a description of recent technological innovations, summarize the available research on the extent of adoption in the United States, and then review the available research on the impact â€“ both intended and unintended â€“ of each form of new technology on crime prevention and police performance.Â â€œWith the proliferation of telephones in the early twentieth century, policing changed. Citizens called â€“ and in fact were encouraged to call â€“ the police to deal with a multitude of problems, and the police responded to those calls from dispatch via a two-way radio, and sped quickly to locations via patrol cars. These technological advances, along with changes in police admin-istrative procedures, helped to create the police as we know them todayâ€ (Harris, 2007: 153). From the point of view of information technology, information is viewed from three sides: syntactical, semantic and pragmatic. Syntactic the approach reflects the physical characteristics of information, is related to the way information is presented and does not take into account its semantic content. With the semantic approach to the consideration of information, the meaning of information, the relationship between the semantic values of information elements is explored.Â On the basis of a byte, the units of information derived from it are formed: kilobytes, megabytes, gigabytes, terabytes, petabytes, etc.: 1 KB = 210 bytes = 1024 bytes; 1 MB = 220 bytes = 1024 KB Information and communication technologies are those technologies, which enable society to create, collect, consolidate, communicate, manage and process information in multimedia and various digital formats for different purposes by using telecommunication techniques. Introduction. The use of modern ICT in managing material production, culture, everyday life, science, education, in all branches implement through the introduction of computer technology and it is a major factor in the development of society.Â Information technology play vital role in the human being in particularly in field of sports and games. It helps to avoid mistake in organization and administration of various sports and games at world level.

Abstract: This paper presents a qualitative study on the adoption of early information technologies, such as typewriters, calculators or Hollerith machines in US manufacturing in the period between 1870 and 1930, which was by all means a true systemic innovation. Our empirical work is guided by a theoretical framework in which the theory of induced innovation is interpreted along "classical" lines in which an explicit link to the concept of technological regimes is established. We show how the presence of a distinct bias in technical change in US manufacturing led to the opening of a window of opportunity for ... ABSTRACT We provide a history of past periods of rapid technological change starting from the Indus-trial Revolution continuing up to today. We find that it takes decades for technological break-throughs to make a difference to the aggregate economy.Â Other adjustments were necessary to fully reap the benefits of the new technologies. For example, enjoying the benefits of electricity required manufacturing establishments not simply to adopt electricity where steam power had been used previously, but instead to completely reorganize their shop floors.Â They just could not have conceived of a world where manufacturing was no longer the dominant provider of middle class jobs (and perhaps of a Congress unable to respond to this change). We then turn to an extended discussion of changes in the structure of wages in the U.S. labor market over the past 20â€“30 years. We highlight the shifts that are poten-tially consistent with simple versions of the SBTC hypothesis and the shifts that pose either a problem or a puzzle for the theory.Â A. Aggregate Trends in Technology. A first task in making the SBTC hypothesis testable is to quantify the pace of technological change.Â Qualitative information on the pace of technological change is poten-tially helpful in drawing connections between specific innovations and changes in wage inequality.Â III) points to technological innovations that occurred very early in the computer revolution (around the time of the original IBM-PC) as the key skill-biased events.