HUMAN CAPITAL AND INDUSTRIALIZATION: THE CASE OF A LATE COMER (Portugal, 1890)[1]

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This paper touches on several debates in contemporary Economic History concerning the role of human capital in economic growth. First and foremost is the question of whether the early stages of the industrialisation process were essentially characterised by a substitution of capital and unskilled labour for skilled labour and therefore by a low degree of complementarity between technology (usually proxied in the literature by fixed capital) and human capital. The conventional view is that it was indeed a de-skilling process and that there was a high degree of substitutability between physical and human capital. A related set of issues arises from the consensus among growth economists that human capital is an important factor of growth in the long run and has been responsible for a good deal of convergence (Abramowitz, 1993). Given the concurrent view about the limited importance of human capital in the Industrial Revolution, however, this has led many to accept the notion that this could not have been so during the 19th century but only during the 20th century. Goldin and Katz (1998) and Goldin (2001) have tried to give substance to this argument with the claim that the reason for this secular transition has to do with the evolving nature of technology. In their view, the rise of capital-skill complementarity was determined by the spread of batch and continuous process production, of electrical power and the rise of industries profoundly permeated by scientific applications, all of which have only occurred in the last one hundred years.

The study I propose is in line with the recent revisionist work that departs from some of the assumptions that underlie this main stream view (Rosés, 1998; Bessen, 2003; Boot, 1995). It considers that during the 19th century the most important form of human capital for industry was relevant skills for the job being done. These might comprise literacy and other forms of formal education and be acquired by children and young people through schooling; but they were also practical know how and experience achieved at work in the factory. This learning represented an investment that enhanced workers' productive capacity and can be measured by the price fetched in the market by the flow of services it generated. It is revealed by the wage gap between raw and skilled labour. During training, such trainees may even have earned less than the unskilled given that their acquisition of know-how had a cost, but over their life times they came to earn much more. This approach is motivated by the descriptions of factory work that suggest that the more intense division of labour that accompanied industrialisation did not preclude the need for skills but, instead, created a demand for skills that were different from but not inferior to those in craft based production. These new skills became necessary in large quantities long before the era of electricity and batch production. In the early factories, greatly increased throughput and capital intensity than before compelled operatives to work faster, with greater regularity, and to avoid mistakes that caused costly, capital-intensive stoppages or damage to equipment. Thus technological progress required not only increased skills for the maintenance of machinery but also at most other levels of production.

To date, too little empirical evidence has been presented on these matters and most of it has had to do with the advanced economies of the 20th century. This paper, which studies the case of Portugal in the late eighteen hundreds, seeks to broaden geographically this rather limited perspective regarding the role of skill in industrialization during the 'first Industrial Revolution'. In the second place, it focuses on a late developing economy from the periphery of Europe, which allows for consideration of certain interesting particularities of such economies. One, for example, was their status as importers rather than creators of new technology, which entailed the use of equipment that was often more suitable for a different factor mix. Another was their lack of industrial background and the consequent scarcity of human capital appropriate to rapid industrial development. In the third place, this study offers the advantage of being based on a very detailed industrial survey carried out in 1890 and complemented by a somewhat less complete one made in 1881. This material provides a large amount of data on the industrial labour force disaggregated to the firm level and, within each firm, by occupation. It does not permit any time series analysis but offers excellent opportunities for a cross sectional examination of some of the above mentioned issues.

During the second half of the 19th century, Portugal could hardly be called an industrialised economy. In 1852, manufacturing establishments with more than 10 workers had a work force of just under 16,000 individuals for a total population of close to 4 million (Relatório, 1857). After a period of growth of industrial output at a rate of 2.8 % per annum, industrial labour in 1890 was still only 18% of the total labour force - agriculture was 61% - and agricultural output in 1900 was something like twice the size of that of industry (Nunes, 1989). Industry was concentrated in coastal cities, mainly Lisbon and Porto, with the exception of Covilhã, a traditional centre for woollens since the 18th century. The structure of the manufacturing sector was typical of economies, which having embarked late and slowly on the process of industrialisation, had a scarcity of suitable raw materials and a heavily protected domestic market. Around 1910, it was dominated by cottons, woollens, metal working and food, followed at a distance by cork, fish canning, ceramics and tobacco (Lains, 1986). Low productivity in all branches - somewhere around half of that in comparable situations in Britain and France – obliged industry to shelter behind high tariffs and practically disqualified Portuguese manufacturers from competing internationally. The exceptions to this were cork and fish canning, two industries whose advantage lay in an unusual local abundance of highly specific raw materials .- the bark of cork tress and sardines. Technological progress appears to have been slow, mechanisation bypassed several significant sectors and installed steam and water power was not impressive (Reis, 1986).

At the end of the 19th century, the state carried out two major national enquiries into the condition of Portuguese industry, respectively in 1881 and 1890.[2] Both met with mixed results largely as a result of resistance on the part of entrepreneurs. Information was gathered only from a fraction of the firms in question and often the questionnaires were only partially answered. On both occasions, they were concerned with a wide range of aspects. These included the value of fixed and circulating capital, raw materials and output; the number, gender, age, wages and literacy of the work force; and the sources of power and the machinery employed. Apart from statistics, numerous interviews and visits to factories were undertaken and provide additional valuable insights.

The present study makes use principally of the second of these enquiries because it is the most informative in terms of the remuneration of labour. We have chosen to focus on Lisbon alone, which was the largest industrial centre of the time. Altogether 2,900 questionnaires were sent out there to as many firms, which gives an idea of the size of the universe in question. Only 1,614 were returned and they covered firms employing a total of 17,403 men, women and children, but the total work force in Lisbon's manufacturing can be reckoned, by extrapolation, at approximately 31,000.[3] Since our interest lies in the link between technological and skill development, artesanal units are left out of our sample and only firms with more than ten workers are therefore considered.

The paper consists of four sections. The first part shows that skills were important for Portugal's late 19th century industrialisation effort. The Portuguese industrial labour force contained a large proportion of skilled workers, that is, who earned significant skill premia, and their distribution will be discussed in terms of the degree of technological sophistication of the various branches of manufacturing. Hourly rates of pay and skill premia are used to make this point. The second part tries to ascertain whether formal education contributed to the working skills used on the shop floor. It tests whether cognitive skills acquired through schooling had any impact in this respect. It further considers whether it was youth or childhood practical learning which was the most important influence on the development of industrial human capital into adulthood, and concludes that literacy was not correlated with the capacities that bettered labour productivity. The third part tries to gauge the importance of this stock of human capital in industrial production. This is done in a growth accounting framework that estimates the contributions of capital, raw labour and human capital to value added. The fourth and final section tries to establish whether there was capital-skill complementarity in Portuguese industry at this time using ordinary least squares regression analysis. It makes an effort to distinguish between high and low throughput firms, as suggested by Goldin and Katz (1998), but unlike them and more realistically, it uses skill premia rather than the educational achievement of the work force as the yardstick. It finds that such complementarity did indeed exist.

I

In this part of the paper, we try and measure the extent to which human capital was present in the Lisbon industrial work force in 1890. A priori it is not evident what one should expect from an economic sector with the characteristics we described above. On the assumption that there was capital-skill complementarity, one might think that a prevalently backward, low capital-intensity industry would not be a heavy user of this factor of production. Indeed, a scarcity of human capital in general is often considered the curse of societies with a low level of GDP per capita and, if true, should lead us to expect from this exercise a low endowment of qualifications among workers in manufacturing. On the other hand, this backwardness might be precisely the reason why we should find a relatively high level of human capital. In the view of those opposed to the notion of capital-skill complementarity, this would happen as a result of the presence of costly traditional skills, before they became obsolete and were replaced by modern industrial machines.

Human capital here is equated with job-related skills, and is proxied by the market value of the services derived from this endowment. As proposed by McIvor (2001: 48), it was 'a combination of manual dexterity with knowledge (of materials and tools) and discretion acquired through a long training period, traditionally of several years'. It is measured in the standard way by the premium paid to each worker above the remuneration of raw labour, the latter corresponding to the effort of workers who are totally unskilled.

Several doubts have been raised regarding such a Mincerian approach. Besides differences in human capital endowment, individual wage gaps could be explained to some extent by variation in innate ability or strength between workers. They could also stem from imperfections in the labour market that would make wages unlikely to equal the marginal product of labour. The first case of distortions is largely avoided because the 1890 Inquerito does not allow us to use individual observations anyway. It only gives us the maximum and the minimum daily wages for all the workers in each job, in each productive unit. It makes no distinction between males and females, but it distinguishes between adults, over the age of 16, and young people, between 12 and 16. The more detailed information contained both in the 1881 Inquérito and in the trade union inquiry of 1909 (Cabral, 1977) tells us that the averages of these maxima and minima provide a good approximation to the average earned in each occupational group, which is the variable that we shall be using here. This means that we can reasonably ignore the difficulty posed by differences in individual innate characteristics. On the other hand, it implies also that we are obliged to ignore all groups that include males and females, given the large pay discrepancies associated with gender. We can presume that in general the maximum wage was earned by men and that the minimum was received by women but we do not know what were their minima amd maxima, respectively, and, consequently, this analysis is restricted to homogeneous groups in terms of gender composition.

The second type of distortion is allegedly caused typically either by the presence of non-economic factors in wage determination, such as employer paternalism or discrimination regarding certain groups, or by the payment of wages for assiduity and good behaviour, particularly at the end of the worker's career, or for informal supervisory duties. In the cases of 19th century Lancashire and Catalonia, Boot (1995) and Rosés (1998) have shown that there is little reason to be concerned about these effects and the same position seems warranted in the present instance. For one thing, the evidence on wage-age profiles for Lisbon, although scant, shows a clear decline in wages at the end of the working lives of industrial workers, not a rise, as this argument would require (Carqueja, 1916). This is corroborated by the oral testimony from trade unions at the beginning of the 20th century, which maintained that employers only kept workers on the payroll as long as they were healthy, productive and necessary (Cabral, 1977)[4]. The same source stressed that managers paid wages in accordance with what workers produced, even when they were not on a piece rate system, a view that contradicts the existence both of 'paternalism' and of wages unlinked to productivity.

The rates of pay considered here are hourly, not daily. This is important because there was quite a wide range of lengths of working day within manufacturing in Lisbon in 1890 - it could vary between four and fourteen hours.[5] The 1890 Inquérito distinguishes in addition between the length of summer and winter working days, the

latter being usually shorter by one or two hours. We incorporate this information here by assuming for the whole year an average of these two figures. In cases where complete information was unobtainable, we presumed that the firm in question followed the timetable of the other firms in its branch of activity. Where a range of hours was given, instead of a single figure, we took the mean of the extremes of the range. Children's pay is not been treated here for two reasons. One is that the data available is for the 12-16 age group, one in which the range of wage variation is strongly affected by physical strength, as well as skill, and this renders it difficult to establish how much of wage differences is ascribable to skill and not greater size and vigour. Altogether, we have been able to take into account 6,468 adult workers divided into 142 occupational groups belonging to 114 different businesses. The average hourly rates for men varied between 236 and 20 reis and for women between 21 and 42.[6]

The data on wages are summarised in table 1, which is divided into two parts, one for male workers, the other for female ones. Regarding male workers (panel A), the first point to be made is that the lowest paid categories were those receiving 40 reis or less per hour, this being the normal rate for unskilled workers in Lisbon, that corresponded therefore to the greatest level of physical effort, without any skill. [7] According to our tabulation, just over 4 % of the adult male labour force belonged in this group and this means that the overwhelming majority of industrial operatives performed tasks that involved some skill, however acquired. The well off workers, at the other end of the spectrum, were those who received more than 100 reis an hour. They were compared in terms of earning power to minor civil servants or better and couild support a family of four or five comfortably on one wage alone.[8] This group comprised only 697 individuals or just over 11 % of the sample considered. Below them, however, there was another 2,086 males earning double or more the wage of unskilled workers and therefore still at an immense economic distance from the latter. The largest group, between these two strata, were the 50 % of this work force, i.e. just over 3,000 employees, who could face hardship if it had to live off the earnings of a single bread-winner or if there was temporary unemployment, but who could manage reasonably well under fair conditions. Altogether, the picture that emerges is that of a surprisingly qualified work force, where high premia for skills rewarded a large proportion of its members, and few belonged to the stratum at the bottom of the earnings heap, who were paid exclusively for their strength and stamina.

Table 1

Distribution of average hourly earning of industrial occupations, Lisbon 1890

Panel A

Male Adults

	number	Percentage
« 40 reis	274	4.5
40 - 60 reis	1059	17.3
61 - 80 reis	2019	32.9
81 – 100	2086	34.0
101 - 120 reis	265	4.3
121 - 140 reis	123	2.0
»140 reis	309	5.0
Total	6135	100

NB.:based on firms where there were only male workers

Panel B

Female Adults

	number	Percentage
«22 reis	25	7.5
22 - 25	301	90.4
»30 reis	7	2.1
Total	333	100

NB.: includes only female workers employed in firms where there were no adult male workers
Source: Inquérito Industrial de 1890

To what kinds of occupations and branches of activity did these classes of remuneration correspond? If we continue to follow the organisation provided by panel A of table 1, the first thing to note is that in the top group, not surprisingly, jobs were characterised by considerable manual dexterity, even some degree of artistic capacity, and the operation of sophisticated precision machinery, such as printing presses or equipment for minting, electroplating and zincography. In 1890, some of these activities involved recent technological developments based on electrical and or chemical processes. In some cases - e.g. M. Herman, a manufacturer of electrical apparatuses - worker categories were not even described, only the product, probably

because their jobs defied traditional classifications. Some occupations such as carpenters, metal workers, boiler-makers and blacksmiths, which were usually situated further down the hierarchy of pay, intruded into this elite apparently when they became engaged in special production. This happened in carriage making, steam engine manufacturing or large foundries (e.g., the Empresa Industrial Portuguesa) with complex orders to carry out.

The category immediately below, of those earning from 80 to 100 reis per hour, contains a very wide variety of skilled occupations, many of them to be found also in the previous group, such as typographers, compositors and dyers though less prevalent than there. New and significant presences concern tasks relating to the operation or production of steam engines, such as machine operators and boilermen. A few carpenters, stonemasons, painters and others associated with construction also appear now along with less skilled members of the precision trades of the preceding category. The group is dominated, however, by trades connected with metal - blacksmiths, boiler-makers, turners, founders and gun makers. Altogether these come to 1,034 workers, or close to one third of this stratum. Their high pay probably reflected the exceptionally good performance of this sector over the last few decades, which rendered these skills scarce and their price consequently high. Naval construction appears here too, with a large contingent of carpenters who were specialised in shipbuilding, an occupation with close links to some of the metal trades. Other trades associated with wood, like sawyers begin to emerge in the lower ranks of this earnings category, as happens also with the modern segment of the food industry, in the shape of flour milling. Textiles are represented by their most skilled workers - dyers and finishers.

The third group in panel A, from 40 to 80 reis, encompasses a much broader range of occupations and industries. It still includes a representation of metal and precision workers but now in quite small amounts while the bulk comes from the 'traditional' branches of industry, that is, food (sugar, bread, beer and margarine, but not meat because the abattoir was municipalized and had artificially high wages), leather and shoes, rope, soap, furniture, construction and the production of its inputs (nails, sawing, quick lime). Generally speaking, these were the consumer-oriented sectors, where technical progress, including mechanisation, had been less intense, long term growth had been slower and their origins were further back in time.[9]

The lowest and smallest category, at 40 reis an hour or lower, includes the lowest paid and the practically unskilled male industrial operatives of Lisbon in 1890. Among its members one finds hardly any of the jobs listed in the top first and second categories. On the other hand, 30 % of them have no specific description at all and belong to vague occupations such as 'worker', 'operative', 'attendant' or 'helper'.[10] To these must be added all whose tasks have little specialised content, such as guards, carters, drivers and doormen. Low skill occupations like washers, starchers and bakers are also frequent. Interestingly, the only workers paid by the day in textiles and cork, a minority in their respective industries, are also numerically quite relevant at this level. This is to be expected given that in these sectors their work had little complexity and they could do it with little supervision. The more sophisticated tasks were paid by the piece presumably in order to save on supervision costs.

Among women (table 1, panel B), unskilled workers and highly skilled workers were rare too, if we are to judge by the premium received over and above the unskilled rate of 22 reis per hour. On the assumption that this is a representative sample, less than 10% of women workers were unskilled and 2,1 % of them occupied the earning peak of this ranking. This means that even more than in the case of their male counterparts, skills and skill premia were widely prevalent among female workers. On the other hand, the vast majority were not earning little for these skills. Most of them were engaged in light work requiring considerable manual dexterity, such as glove making, cloth napping, yarn winding onto spindles, checking the size and quantity of packages of tobacco or packing sardines by hand into tins. But their effort was not associated with the operation of sophisticated machinery, capital-intensive production or technically advanced processes and this perhaps explains why their skills were so much less prized than those of many men. As a consequence, their wages could hardly give them any chance of economic autonomy, in contrast with the situation of the masculine world. This was definitely the world of 'the male bread winner' but it is difficult to say at present to what extent this reflected discrimination and to what extent it arose from actual productivity differences between genders.[11]

It thus would seem that in the case of male adult workers – there is too little evidence on women - wage gaps were associated with the level of workers' aptitudes and with the exigencies of the tasks they had to carry out. Those that did the more demanding jobs, in these terms, were on the whole higher up the pay scale, while those whose jobs required mostly brute force were lower down. It appears then that, as theory would have it, employers valued their workers' skills or human capital by paying them a premium over and above what was earned by the workers who lacked these attributes, i.e. unskilled workers, and this comprised, in Lisbon, in 1890, a larghe proportion of the industrial labour force.

II

Up till now we have not specified the exact nature of the human capital considered here nor the manner of its acquisition. Broadly speaking, the literature considers two possibilities in this respect. The most common equates this factor of production with skills and aptitudes of a cognitive nature that are normally acquired in the course of formal education mainly carried out in schools. The indicators used in such studies have therefore been either those related to scholastic achievement, e.g. rates of literacy or success in exams, or, alternatively, school enrolment or attendance. The latter, as a rule, is measured by the number and type of years of schooling per individual or the proportion of the population of school age that is registered in educational establishments and would seem more closely related to the aptitude we are trying to assess. On the other hand, it is clear from many accounts that, during the 19th century, labour productivity in manufacturing depended crucially on job-specific skills and that these were learned by young workers on the job. This does not mean, however, that a prior or concurrent schooling of workers of whatever age did not affect productivity too, something that could have happened in a variety of ways. Literacy could have enabled the process of learning on the job skills to be faster and more efficient and it could have made it easier for workers to learn the use of new technologies more readily. It could have made skilled workers that had this capability more effective in their tasks than illiterate ones, as a result of a complementarity between skill and literacy, as Bessen (2003) found in Lowell during the first half of

the 19th century. Finally, the socialisation process undergone by children in the school may have been of such a nature and intensity as to prepare them, once adults, to act more efficiently within the context of large scale, mechanised production, because it rendered them more docile, more punctual and more adaptive to routine.

Strong claims have also been made, on the other hand, for the notion that literacy, numeracy or other cognitive skills had scarce impact on industrial labour's productivity because they had little to do with the acquisition and use of directly productive skills. This contrasts with the main stream view, which fails to consider in any depth what was the precise effect of the cognitive or the non-cognitive skills learned in school, or even whether either of them really contributed to the improvement of workers' productive capacities, particularly to the specific skill required by their jobs (Matthews,1982; Maddison, 1995; Crafts, 1995). According to Mitch (1992 and 1999), the impact of literacy on economic performance during the early industrialisation of Britain was very limited and, consequently, this country greatly over-invested in education and implicitly squandered the resources thus employed. In a less extreme version of this argument and without going into the details of the causal mechanism, O'Rourke and Williamson (1997) have shown that 'good schooling', i.e. both school enrolment and literacy rates, explained only a small part of European convergence during 1870-1910, except in the cases of Spain and Portugal.

In the Portuguese case, the breakdown of perspectives is similar although the issue has received scant attention. Using qualitative sources, Reis (1986) and Rodrigues and Mendes (1999) have argued that human capital shortages were indeed a major stumbling block for Portuguese 19th century industrialisation. This is based mainly on the declarations made by employers and trade unionists during the various industrial enquiries we have referred to above. Mónica (1987), on the other hand, has been sceptical of this on the grounds of lack of convincing evidence that education made workers more productive. One suggestive fact is that they were certainly overachievers, in educational terms, by the standards of the period, and at the same time were paid well above what most workers earned at the time. The data in table 1 amply supports the second of these statements while the first is derived from the 1890 Inquérito. Among adult male industrial workers in Lisbon, the literate were close to 63% of the total. In the population at large, the rate in the same year was 27% and even if we correct this for the difference represented by children and youngsters, who would normally be less literate, the gap between the two groups would still be not less than 20 percentage points.[12]

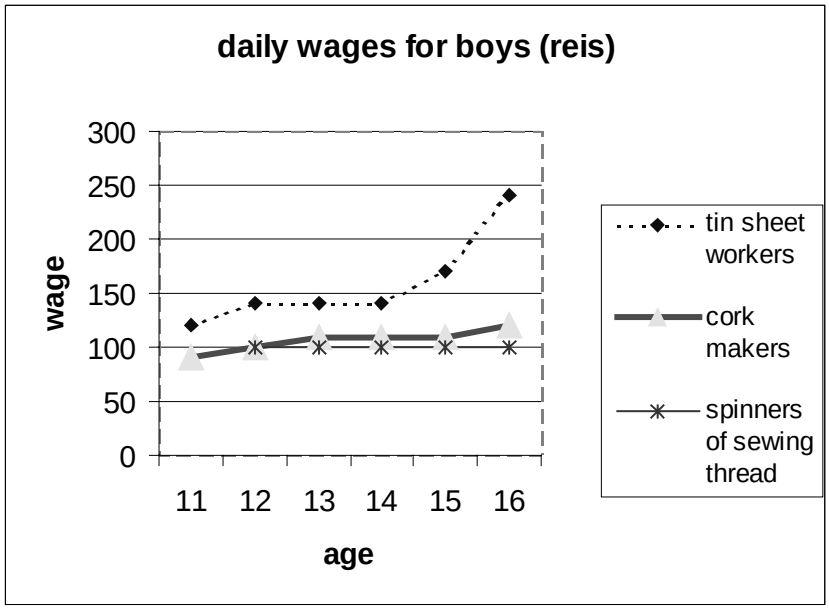
Such data, although interesting, can only point in a certain direction of analysis but hardly warrant a more precise conclusion regarding the causality that we are seeking to explore. In order to shed further light on the matter, two approaches can be followed. On of them consists in establishing a relation between indicators of human capital in the labour force and the output of individual workers. Unfortunately, such studies are difficult to carry out and therefore rare. An important one is that by Bessen (2003) using detailed business records. In it, he has been able to show that literate workers were indeed quicker at learning factory tasks and, moreover, once they had done so, they used the skills thus acquired more effectively than their illiterate counterparts, with the result that they were more productive and earned more. The second approach considers instead what workers were paid for this output and

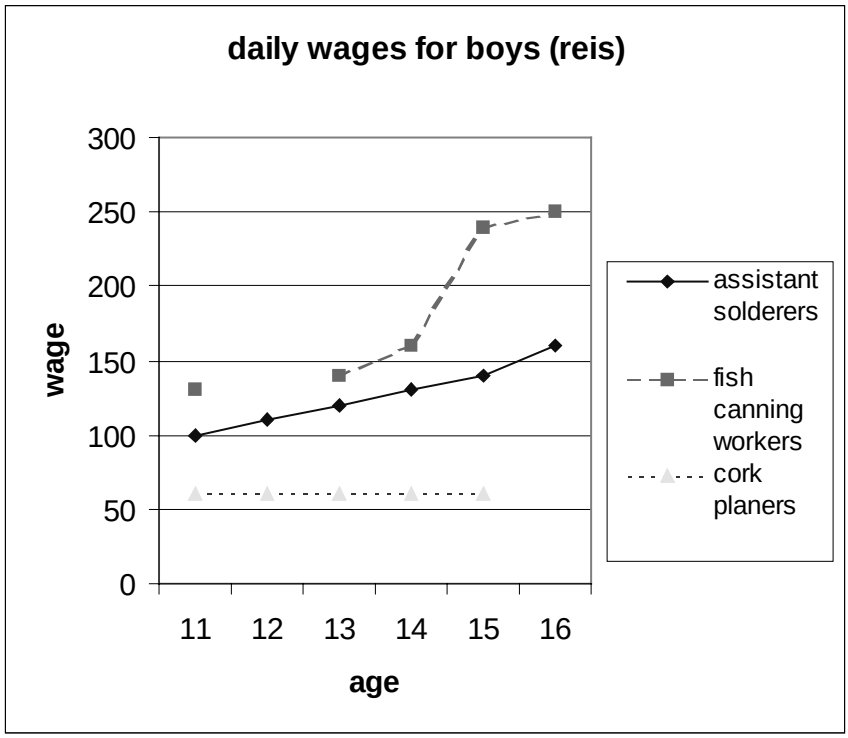
presupposes that the excess over the remuneration of raw labour should be related to their human capital endowment, however measured.

The second methodology is less satisfactory because it assumes that markets are efficient, but it is the only feasible one with the Portuguese Inquérito of 1890. The latter, as seen above, allows us to measure the skill premia with which we have proxied human capital according to the job-specific-skill view that we have been following here. This is the dependent variable of our model, the aim of which is to show in what way the previous accumulation of human capital may have influenced the magnitude of this variable in adult workers. The conjecture is that, when a worker started working as an adult in the over 16 age group singled out by the Inquérito, he brought two basic aptitudes with him. One was literacy, attained as a result of schooling. The other was skills learned on the shop floor during labour as a child or as a teenager.[13] Plausibly, either of these was relevant to the development of the future job-specific skills that would enable him to progress from minimal wage rates, at the start of this career, to the higher rates of pay corresponding to the full development of his capacities, presumably in his 20s or 30s. These are the explanatory variables.

Contemporary testimony confirms that both suppositions are plausible. As regards the first one, several sources indicate that workers under the age of 16 were able, year by year, to improve their wages and that this was the result not only of their increasing strength but also of the stock of human capital they built up through work experience. The factory inspector's report for the districts of Évora, Beja and Faro, in 1907, which provides detailed information on the pay of workers at different ages in a variety of branches of manufacturing, commented that growing 'organic forces', i.e. strength and size, were responsible to some extent for the upward slope of the wage-age profile. But he pointed out in addition that these pay rises were also related to the skills that they were learning on the job. Figure 1 graphically describes these wage-age profiles for six occupations – there are many more in the source that could be used here. It makes it plain that as they entered 'working adulthood', the human capital endowment of youths could already vary immensely and this depended on how advanced was their practical knowledge for the job and how productive were their efforts at work.[14] Some, like tin sheet workers and fish canning workers, had gone far by this stage, while others, such as most cork workers or thread spinners, had barely improved their skills. The latter were 'beginners' who carried out no more than 'elementary operations'.

Figure : Wage-Age Profiles for under 16s in 1906





Source: Boletim do Trabalho Industrial, # 3.
Note: data from the districts of Beja, Evora and Faro.

On the other hand, in the opinion of well-informed contemporaries literacy was also judged to contribute to the productivity of labour. Several employers told the authors of the 1881 industrial enquiry that one of their problems with the labour force was its lack of 'general education' and linked this to its inefficiency (Reis, 1986). It is at least interesting to note, however, that they tended nevertheless to recruit illiterate boys and girls when they entered the factory, typically at around eleven or twelve years of age. It is equally remarkable that quite a number of these youths later in life went to night

school and became literate as grown ups, something that can be seen from the fact that the literacy rate of adult factory operatives was generally higher than that of their younger colleagues below sixteen. In some factories, managers informed that the better-paid jobs were unavailable to illiterates, which may account for this late educational effort and suggests that literacy might indeed be an integral part of the human capital relevant to industrial productivity.[15]

The 1890 Inquérito affords us quantitative evidence on both of these explanatory factors. It has the minimum wage rate for every occupational group, firm by firm, for those over 16 years of age. For each of these groups it also gives us their literacy rate as measured by the ability to read only, a figure that is close to that for full literacy.[16] We employ the latter here as a proxy for the stock of cognitive skills of the labour force. The former serves as a proxy for the possession of initial productive skills by individuals entering the adult work force and therefore before their learning curve began to rise significantly. The principal shortcoming of these data is again that they are not individualised but refer to groups of operatives in the same jobs within firms that we are forced to treat as individual observations. This may produce some distortions. In the estimation below, we have not included, for reasons of difficulty with the data, two other variables which might have some pertinence to the issue. One is the literacy rate of child workers in the same occupation and firm. This would help to establish whether adult workers tended to become literate only when they grew up or whether their selection as youngsters by employers was conditioned already by an earlier acquisition of literacy, as the evidence presented above suggests. The second is the extent to which unskilled labour was present in each firm, and the consequent need for literate workers to act, formally or informally, in a supervisory capacity. It might be argued that the greater the proportion of male to female and child workers, the higher should be the literary qualification of the skilled male labour force given the lesser qualification of the former for skilled jobs.

An OLS treatment is given to these data and the results are displayed in table 2. Two main conclusions can be drawn from it. In the first place, adult literacy did have some effect on the determination of wages by increasing the premium relative to raw labour earned by skilled industrial workers, in Lisbon, in 1890. The coefficient on this variable has the correct positive sign and is statistically significant.[17] In other words, at this stage of technological development, the relevant human capital package that employers sought in their workers already included cognitive or non-cognitive skills of the kind imparted by formal schooling, as most of the international literature claims. It should be noted however that this influence was still very weak – the value of R2 is quite low when the wage premium is regressed on literacy alone (panel A of table 2). Other factors were more important and our second conclusion is that our other independent variable is a case in point. Skills obtained before adulthood made not only a difference but they also made a much greater one to how the degree of human capital acquired on the job during adulthood. The coefficient for the minimum adult wages variable has a positive sign and is highly significant but it increases the size of R2 substantially when it is introduced in the first regression of table 2. This hints at the existence of a path-dependence in the formation of human capital. Childhood capabilities were a good predictor for how far a worker could go in his career, and individuals that got the best jobs tended to be singled out for them already early on in life. How this selection was done cannot be determined with the help of the present data set and we can only speculate regarding the probability that family

links, social networks and the like may have played a role. Our sources are silent on this matter, however. In any case, the impression is that skill premia for most of these workers rose after the age of sixteen as a result of the accumulation of experience and practical knowledge learnt on the job. If formal education impacted so lightly on changes in earning power, one is hard pu to think it could be otherwise. In Portugal it was as Tranter (1981:224) said of human capital in England during the period 1780-1860: 'of far greater importance [than formal education] to the growth of a suitable labour force was the training in new, practical skills disseminated in the home, the workshop and the factory, a training which developed along with the rise of the industrial economy rather than preceded it…'.

Table 2: Determinants of workers' skill premia
(linear regression)

Panel A

R Square	0,054785
Adjusted R Square	0,05131
Standard Error	28,32196
Observations	274

R Square	0,479353
Adjusted R Square	0,47551
Standard Error	21,05861
Observations	274

	Coefficients	*Standard Error*	*t Stat*
Intercept	-20,6701	4,115898	-5,02202
Male literacy	6,981767	3,620749	1,928266
Minimum wage for age group over 16.	0,104711	0,007044	14,86572

	Coefficients	*Standard Error*	*t Stat*
Intercept	28,27522	3,321705	8,512261
Male literacy	18,8584	4,749562	3,970555

Panel B

III

The two preceding sections have established that human capital was widely disseminated among the Lisbon industrial work force and that it arose essentially as the result of a process of learning that took place on the shop floor.[18] What these sections do not tell us though is how important was it relative to the other factors of production. This section attempts to provide an answer to this question. It also serves to start the discussion regarding the peculiar way in which capital-skill complementarity may have emerged in the industry of a retarded economy of this period.

The methodology we have adopted for this follows that used by Rosés (1998). The framework is that of a neo-classical production function in which firms use raw

materials, labour, decomposed into raw labour and human capital, and capital. The contribution of these inputs is measured by the market value of the flow of services they provide. The ultimate aim is to estimate their shares in the value added by each firm in our sample, and then to aggregate this to the overall industrial level. In this framework, raw labour, capital and human capital add up to value added, which is is calculated in turn as the difference between gross output and the value of the raw materials required to manufacture it.

The firm's raw labour bill is obtained by multiplying the number of workers by the annual amount of working hours and by the hourly wage of an unskilled and untrained labourer - 40 reis in the case of adult males. In the case of youths under sixteen, we have had to assume that they earned no skill premium and that their actual pay was all on account of their unskilled efforts. This involves an overestimation because part of the sub-adult labour force already had some training on the job. But it is an unavoidable one given the way the wage data are presented in our source and our insufficient knowledge of the price of youth raw labour. Its impact on the result of this exercise should be small, however, since boy and girl workers were only 14 % of the total labour force and their skill premia on the whole were modest. The human capital input of each firm is derived by subtracting this amount from the total payment to the labour force. In other words, human capital is the sum total of the skill premia earned by the firm's employees. The global labour bill itself was calculated by multiplying the number of hours worked by the number of workers in each occupation and by the average hourly wage earned in each one of them. Our source supplies us with information on the value of the stock of fixed and circulating capital but this does not permit and estimation of the value of the services derived from this factor of production. Not only do we lack adequate amortisation schedules and market interest rates with which to compute a realistic rental value of equipment and buildings but the evidence in this respect is too patchy and unreliable to be of much use. The contribution of capital is obtained therefore as a residual, after deducting the value of the raw labour and human capital inputs from total value added of each firm.

The 1890 enquiry provides quantitative information on wages for 260 firms in Lisbon. Unfortunately, for a majority for these the record is not complete and we had to eliminate all but 36 of them in order to obtain a sample in which all the necessary indicators were present.[19] The main reason was the failure of the source to distinguish between the pay of men and women but many other observations had to be ignored because the values of either output or raw materials employed were lacking. Besides being disappointingly small, the group of firms covered in table 3 cannot be claimed to be in any sense representative of the whole. The method of their selection was far from random and introduces some disturbing biases. For example, it discriminates against branches of industry like tobacco or textiles, which were heavy users of female labour. On the other hand, it favours those that preferred men, such as metal working and construction materials. Moreover, we excluded from the sample four fairly large enterprises where, owing to presumed errors, raw labour and human capital together amounted to only 5% or less of value added.[20]

Unlike the study by Rosés (1998), this paper does not aspire to pin down the contribution of human capital to growth over a period of time. Given the lack of time series data, all it can aim to do is to estimate the role that this factor of production may have had in 1890 in comparison with raw labour and capital. The result of the

calculation is shown in table 3 and, initially, may appear surprising. After all, we saw above that the vast majority of occupations involved some remuneration to skill and yet we now see that the share of human capital in the value added of these forty firms is rather small, being lower than 20% and less than the contribution of raw labour. Two downward biases probably account for much of this. In the first place, the composition of our sample seems biased towards activities with a relatively low input of human capital, which means that raw labour's share would rise compared to the full sample of the 260 firms. Secondly, several of the firms observed by chance are within their respective branch among the lightest users of human capital. It is fair to presume that a fully representative sample of firms would have offered a different picture of the balance between factors of production, more favourable to the human capital share and less to that of raw labour. In what follows therefore we must bear in mind that this is a lower bound estimate as regards the role played by human capital in industrial production at this time.

Table 3: Factor shares of industrial production, Lisbon, 1890
(% shares of total value added)

Nº firms	Nº workers	raw labour	human capital	capital
36	2 462	27.9	17.3	55.8

Source: Inquérito Industrial 1890

A second lesson to draw from table 3 is the distribution of factor shares that it reveals. Capital occupies the first place though labour (the aggregate of raw labour and human capital) is not far behind. In other words, in 1890, the industry of Lisbon appears to have progressed to a considerable extent in terms of using technology and had gone far in replacing labour with it. It was no longer an unmechanised sector relying on the skill and dexterity of its work force.[21] If we take broad capital as our reference (Rebello, 1991), this substitution becomes far more striking. Raw labour accounts for less than one third of value added, while technology and skills together become dominant. On the other hand, despite this progress of innovation, raw labour is still more important than the human capital component in the labour force. These results are similar to those obtained by Rosès (1998) for the Catalan spinning industry in the middle of the 19th century, then a technologically advanced sector in the midst of what was then, by international standards, a dynamic, industrialising economy.[22] At the same time, they contrast with what he found for the more backward, less mechanised cotton weaving industry there, which relied far more heavily on raw labour and traditional skills and had a capital input of less than 20%. Whether much can be inferred about this comparison, given the interval of forty years between the two cases, is unclear. Unfortunately, similar studies using this methodology are scarce and focus on productive skills, rather than literacy, as human capital, which renders it difficult to make a more complete judgement about Lisbon's industry in 1890 in a comparative perspective.

Table 3 raises two further puzzles. The first is why did capital play such an important role in a backward industrial setting characterised by a high cost for this input? In part the answer may derive from the fact that Portugal was not a creator of technology but typically an importer, which obtained it from capital abundant countries in the Western core. With little choice in the matter therefore, Portuguese industry had to adopt this sub-optimal capital-biased factor mix that table 3 brings to light. Also

intriguing, especially for those who believe that technological progress was de-skilling and led to the replacement of human capital by raw labour, is the fact that technological progress did not shift the factor mix towards a greater use of raw labour and away from human capital. This is even more striking if we consider that the skilled-unskilled wage ratio in Portugal was greater than in the core countries and much more like that of other backward latecomers such as Russia.[23] Of itself, this should have discouraged a higher intensity of human capital and therefore seems at variance with the data. One explanation here is that in the places where technology was being developed, human capital was also relatively cheap. As Acemoglu (1998) has pointed out, advanced economies, where human capital is abundant, tend to generate new technologies that favour this factor of production. In this light, it could simply have been again the inevitability of the country's technological external dependency that drove the situation described in table 3, of broadly defined capital's overwhelming presence in the production function.

Another way of equating these problems focuses on the internal conditions of technological choice. It implies considering that, although imported, technology imposed much less of a straight jacket on how inputs were combined than the preceding remarks imply. There was in fact a degree of choice in the matter and this meant that the relation between capital and human capital was not simply externally imposed but depended also on the domestic circumstances that determined cost relatives and factor scarcities. This was even observed by Portuguese textile managers at the time, when they lamented that although they had the best machinery in the world, their weavers could handle no more than two looms each, whereas abroad as much as three and four were operated by one person at a time (Reis, 1986). It is hardly a new idea, however. Already fifty years ago, Gerschenkron (1962 [1952]) noted the paradox that among the late developing economies of the 19th century, where raw labour was abundant and capital expensive, technological choices nevertheless favoured high capital intensity. The reason was the scarcity of suitably skilled labour which could thus have been replaced to an extent by advanced machinery. But this required in turn higher skills in the work force that was to mind these latest vintages of equipment, with the paradoxical result that 'the high skill premium is explained by the generally low level of skill among the growing industrial labour force' (Borodkin and Valetov, 1998: 76). What follows from here then is whether it is not possible to generalize that, under conditions of backwardness, there are good reasons to expect to find traces of that capital-skill complementarity which is supposed to be the mark of today's advanced economies.

The best generalisation to fit these facts should probably combine therefore the specific features, both external and internal, of late, backward industrializers. Moreover, it should point towards the likelihood that capital-skill complementarity will not only be present in these economies but also be stronger there than among the more advanced economies, owing to the aforementioned 'Gerschenkron effect'. If it could be established empirically, such a finding would be interesting for two reasons. One is that it would broaden the scope of present studies in this field, which suffer from excessive narrowness in both temporal and geographic terms. The other is that it would lead to a better understanding of the underlying mechanism of this complementarity, in particular by stimulating further tests of the current wisdom in this matter. This would help resolve the question we posed initially: is capital-skill complementarity due to certain particular technical features of 20th century industry,

which were absent in earlier periods (Goldin and Katz, 1998); or is it a more general feature of the historic process of industrialisation? The Portuguese and other examples suggest that it is the latter and it is to this subject that we now turn.

IV

Although capital-skill complementarity has enjoyed a vogue in the economics literature of recent years, it has received relatively little attention from economic historians, except in the form of impressionistic analysis. This is particularly true of the Industrial Revolution in Britain, regarding which a strong current has stressed the absence of this relationship. This is a tradition which harks back to Marx although only a small part of it could be called Marxian (Hudson, 1992). Forty years ago, it was forcefully stated by Landes (1969) when he defined the technological revolution as 'the substitution of machines - rapid, regular, precise, tireless - for human skill and effort'. The lack of a detailed and critical analysis of the notion of skill explains perhaps why even now the strength of this current persists. Thus, according to Nicholas and Nicholas (1992: 17) 'the factory deskilled and proletarianised the work force by destroying old skills … and [relied] on power-driven machinery which created jobs that required no formal skills or even rudimentary levels of literacy'. And the same message echoes in a recent article by Feinstein (1998: 651) which claims that 'skilled male craftsmen were displaced or challenged by the introduction of machinery, by change in the organisation of production … and by employing female workers in traditional male occupations'.[24]

Not all have subscribed to this point of view, however. Capital-skill complementarity during the Industrial Revolution has long had its defenders too and this across a broad variety of historiographic traditions than ranges from Mathias (1969) to Raphael Samuel (1977) and to Tranter (1981). Samuel, for example, has argued that 'nineteenth capitalism created many more skills than it destroyed, though they were different in kind from those of the all-round craftsmen, and subject to a wholly new level of exploitation'. In a recent paper, Bessen (2003) has provided one of the most detailed and cogent sets of arguments in its support. Moreover, he makes it clear that capital-skill complementarity is not peculiar to the 20th century but was present many decades before in the West. His claim, based on evidence from the cotton textile industry of Lowell, Massachusetts in the 1830s and 1840s, is that the factory dispensed with certain highly paid skills but generated a demand for other ones that were different but no less costly to employers. The new, mechanised processes required operatives who could work faster and more steadily, given the rhythms imposed by the new sources of power. The factories also needed workers who could take decisions rapidly regarding the use of the machines and, most important of all, who could avoid stoppages and breakdowns. The latter had become costly as never before given the high price of the new equipment relative to other factors of production.

The data at our disposal from the 1890 Inquérito allows us to check what this relationship was like in Portugal at the end of the 19th century. Did the technical progress that raised capital intensity drive a concomitant increase in the value of the package of skills that these new techniques called for? By this time, a fair degree of mechanisation, division of labour and investment in capital had come about in Lisbon's industrial belt but the process was uneven, as was the distribution of skills

across firms. This naturally raises question as to whether any correspondence can be found between the two variables. An OLS regression has been run with the average amount of human capital per worker (HKCAP) as the dependent variable. As earlier, this is measured here too as the average of all wage premia in each firm. The explanatory variable that concerns us here primarily is capital per worker (TOTK). It is derived as a residual in the calculations carried out for the construction of table 3 above, and we should consider the model validated if the sign of its coefficient were positive. In addition, we have included several control variables, which a priori might also have some influence on the dependent variable. Throughput and the speed of operation of machinery could be expected to increase skill requirements, given the importance of being able to deal with speeded up machinery, as pointed out by Bessen (2003). We have proxied the latter with a dummy for the presence of steam engines in the factory (STEAM) or, alternatively, the amount of steam horse power per worker (HPCAP). Throughput, on the other hand, is proxied by the value of gross yearly production per worker. The anticipated signs in both cases are positive. The size of the labour force (LAB) may be usefully included too as it permits the distinction between small, artesanal firms, on the one hand, and large, factory structures on the other. A negative sign here should be expected given that, other things being equal, the former would have quite high inputs of traditional craft skills and a low division of labour but little capital intensity, whereas the opposite should be true regarding large units of production.

Table 4
Capital-Skill Complementarity

Dependent Variable: HKCAP
Method: Least Squares
Included observations: 40 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic
C	33.47655	15.40159	2.173578
TOTK	0.002670	0.000864	3.090086
LAB	-0.141018	0.096077	-1.467752
HPCAP	-0.590716	0.267025	-2.212208
OUTP	3.17E-05	0.000152	0.207925

R-squared	0.261729	Mean dependent var	42.27500
Adjusted R-squared	0.177355	S.D. dependent var	60.97288
S.E. of regression	55.30225	Akaike info criterion	10.97997
Sum squared resid	107041.9	Schwarz criterion	11.19108
Log likelihood	-214.5995	F-statistic	3.102018
Durbin-Watson stat	1.859665	Prob(F-statistic)	0.027570

Variables:
HKCAP: human capital per worker
TOTK: capital per worker in each firm
LAB: number of workers in each firm
HPCAP: horsepower of motors per worker
OUTP: value of gross production of each firm per worker
STEAM: dummy for the presence of steam engines (=1) or their absence (=0)

The result of the regression, in table 4, is on the whole satisfactory. The main objective is met in the sense that human capital endowment was positively and significantly related to technical progress. The only other significant variable is steam

power but its sign is wrong in both versions (it is presented here only as horsepower per worker but the result is practically identical with the dummy). This is probably due to multicollinearity and is not surprising given the association between the use of machinery and the presence and power of steam engines in the factory. Size (LAB) has the right sign but is mildly significant. Throughput, on the other hand, yields a non-significant result although it has the right sign too. This may be ascribable to a erroneous specification of the variable, which is quantified by the value of output rather than its physical volume, which would have been more appropriate but is not available.

These findings prompt two final remarks. One is a note of caution regarding the peculiarity of the underlying data. The most important aspect of this is the presumable bias caused by only using firms that employed male labour entirely, the consequence of which is the exclusion of a number of firms that were modern, highly mechanised and employed a considerable amount of female labour in conjunction with male workers. The second and more substantive comment is to underline the importance of establishing that capital-skill complementarity can be identified in a period well before the time alleged for its onset in the more recent literature. Moreover, in the Portuguese case, it was present in an impoverished and late industrialising economy that was hardly on the cutting edge of technological progress. This suggests that capital-skill complementarity is a much more enduring and widely spread feature of industrialisation than has been supposed. It did not have to wait for electrification, batch production and high throughputs to make itself felt because the machines of the classic steam era already generated an intense demand for new skills and abilities.

V

Several conclusions emerge from this paper which are of interest not only for the study of the role of human capital in Portuguese industrialization but in a wider context too. The first is that human capital, as measured by the premium of skill over the remuneration to raw labour, had a significant and wide-spread presence throughout Lisbon's manufacturing branches at the end of the 19th century, despite the appearance of backwardness which the latter displayed at this time. In the second place, we have established that practical, on the job learning of skills by industrial workers was responsible for the most valuable part of human capital in this context. Formal educational skills contributed as well but to a small extent only. A third finding is quantification of the relative importance of human capital as a production factor. It has been shown that, despite its wide diffusion, it was much less important than fixed capital and somewhat less than raw labour. By 1890, raw labour, however, had been replaced by ‘broad capital’ to a very considerable extent, a fact that points to a greater degree of technological progress than has been supposed to date. A fourth conclusion, with broader implications than the last two, concerns the presence of capital-skill complementarity in Lisbon's industrial structure. Linear regression analysis shows that this existed even though the sector was still far from achieving the levels of technological and structural sophistication that have been considered in the literature as indispensable to this development. It also confirms that capital-skill complementarity was a thing of the first and not only of the second or of the third industrial revolutions and can be located in quite backward economies.

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[2] For a detailed survey of earlier efforts of the kind, see Matos (1991).

[3] Our count of workers actually surveyed differs slightly from that of Mata (1999), which provides two figures: one of 14,557 on p.132 and one of 18,476 on p. 137.

[4] In the tin trades, the comment was 'when the worker is no longer of use, he is sacked' (p.222); 'lathe workers receive a variable daily wage, according to their aptitudes' (p.234); in cotton textiles, 'workers are kept on as long as they are necessary, and are sacked without notice, when they are not' (p.268).

[5] The testimony given by trade unions in 1909 presents a harsher picture of the length of working days than the Inquérito of 1890. See Cabral (1977).

[6] The real (plural, reis) was the Portuguese monetary unit of account. In 1890, before the financial crisis of 1891, 4,500 reis were equivalent to one pound sterling.

[7] This dividing line is taken from our current research on Lisbon wages between 1800 and 1900 based on the archive of the royal palaces. It is equivalent to a daily wage of 400 reis, the usual remuneration of men engaged in heavy but unskilled work in gardens or on construction sites.

[8] This is based on family budgets in Lisbon for around 1910 compiled by Martel (1911). The trade union inquiry of 1909 (Cabral, 1977) presents similar cost of living levels for a family of five. For a family living decently with a single bread winner, its implicit estimate was that the hourly wage should be in the 74-120 reis range. It should be noted that the Lisbon cost of living in 1890 was 10% lower than in 1910. This picture is confirmed by Poinsard (1910), who researched into the living conditions of the working class in 1909.

[9] As a consequence of the methodology followed, we have been unable to situate properly three important industries of this period since they usually paid by the piece and not by the day. These are cork, fish canning and textiles.

[10] Madureira (2001) argues that as a result of the de-skilling caused by mechanisation, there was a spread of occupational designations that no longer related to the tasks performed but rather to the way in which workers were paid, e.g. 'day worker', 'operative' , 'subcontractor', and so on. In fact, these categories were relatively insignificant, as we can see.

[11] For an interesting discussion of this problem regarding French 19th century industry, see Cox and Nye (1989).

[12] The census does not give us literacy per age group and we have therefore calculated the most unfavourable cenario for our argument. This assumes that all people under 16 were all illiterate and that those registered as literate were all over sixteen. The rate would be about 42%.

[13] Madureira (2001)'s description of jobs in the textile industry makes it clear that their associated skills were typically learned at work, and rarely, if ever, by means of technical education. The principal exception seem to have been the schools for women who were to become spinners and which were set up, for a few decades, towards the end of the 18th century (pp .47-8)

[14] The 1909 report on the conditions of the working class repeatedly states that the earnings of apprentices were closely related to the extent of their skills, whatever the task they were engaged in (Cabral, 1977: p.307).

[15] See, for example, the interview with the manager of the Xabregas tobacco factory in Lisbon in vol.1, part 2 of the 1881 Inquérito, p.336.

[16] Portuguese literacy statistics from the 1890 population census show, for the Lisbon district, that this group exceeded that comprising those who could both read and write by 3% only. Already in 1852, a survey of Lisbon industrial workers shows that these two rates were close and respectively 20.4 and 25.4%. See Relatório (1857: 11).

[17] Mata (1999: 136 and 138) also finds a positive relationship between literacy and technical skill, on the one hand, and the use of machinery, on the other. This conclusion is not reached, however, by regression analysis but by visual comparison of thirteen broad industrial categories, which lump together quite a variety of jobs and of manufacturing branches.

[18] This is made abundantly clear in Madureira (2001) whose detailed descriptions of occupations in the textile industry show the importance of the practical learning of skills.

[19] Even so some interpolation was necessary, as when the number of working days per year had to be interpolated from other firms in the sector.

[20] They are the state canon foundry, the state's printing works and two private firms.

[21] If we accept installed horse power per worker as a proxy for technological development, it is worth noting then that the value for this indicator in Lisbon in 1890 was 0.13, while in 1906 it was 0.45 for the whole of France and 0.79 for Britain (Dormois, 1997).

[22] His results on average for 1831-61 are 15 % for human capital, 29 % for raw labour and 56 % for capital. For 1861, they are 22 % for raw labour, 19 % for human capital and 59 % for capital.
[23] In the US at the time it was in the 1.7-1.8:1 range, while in Britain it was also less than 2:1 (Lindert and Williamson, 1980; McIvor, 2001). In the Netherlands, it was even lower, according to Smiths and Van Zanden (1998). On the other hand, in Portugal it varied between 2.4 and 2.8:1 and in Russia between 2.6 and and 3.1:1 (Borodkin and Valetov, 1998).
[24] For similar views regarding the Portuguese situation, see Mónica (1979).