Human Capital, Useful Knowledge, and Long-term Economic growth

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Joel Mokyr
Departments of Economics and History
Northwestern University, Evanston, IL 60208
email: j-mokyr@northwestern.edu

Introduction

Thinking about employment makes one inevitably think about human capital. In the American labor market today, the realization is slowly emerging that without some form of formal education, workers are becoming unemployable. More and more routine operations that once were the responsibility of unskilled workers are carried out by robots or computer-driven automatons of one kind of another. Machines are getting smarter, and if people are still to be gainfully employed, we will need to make sure that they keep ahead of machines. Given that we have no idea of what smart machines will look like a generation from now, it seems foolhardy to predict how workers will interact with them. But it seems that if labor is not to be entirely replaced by capital as in Kurt Vonnegut's dystopian novel *Player Piano* (1976), it can only do so by being smarter, better educated, and more imaginative than the smartest machines.[1]

Was this so in the past? It seems tempting to think so. Literacy and learning are widely regarded as desirable, and so is economic growth. What could be a more reassuring idea than that the two were closely associated? The seminal paper on the matter (Nelson and Phelps, 1966) was published almost half a century ago, and postulated that both technological advance and technological catch-up depended strongly on the level of human capital.[2] In his classic Presidential address, Richard A. Easterlin (1981) posed the basic question: why isn't the whole world developed? His answer was quite unambiguous: modern economic growth depended on the diffusion and absorption of new techniques. But technology has to be learned, and the diffusion of modern technology thus utterly depends on formal schooling. In a more recent paper, Glaeser et al.(2004), criticizing the view that differences in institutions are central to the explanation of differences in economic performance, point to differences in schooling and school attendance as the variable that best explains economic outcomes. In between, a large literature has emerged that views human capital as a central factor in economic growth.[3] Policy-makers have clearly been influenced by this literature.[4]

So how and why can there be any doubt? Some contemporary development economists have expressed the almost heretical view that despite huge investment in education, the response of economic growth to this "education explosion" has been little or none (Easterly, 2001, p. 73). There has been little visible return to the huge amounts invested in education in the 1990s. Moreover, even European countries that had achieved high levels of human capital under communism do not seem

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[1]For an extreme version of such concerns, see for instance Rifkin (1995).

[2]For a recent restatement and elaboration, as well as empirical support, on this view, see Benhabib and Spiegel, 2005.

[3]For a survey see for example Krueger and Lindahl, 2001.

[4]In 1990, the secretary General of Unesco, Federico Mayor, regarded the notion that "the level of education of the overall population determines that country's ability to share in world development" as a "self-evident truth that is no longer in dispute." Cited by Easterly, 2001, p. 72.

to have uniformly been able to take advantage of it. Belarus and Moldova, two of the more economically backward nations in Europe with the weakest institutions, still have respectable educational statistics, but in these countries this investment in human capital has much more difficulty in being transformed into economic success than in Estonia or Poland. Econometric work (Pritchett, 2001) has found little support for a major role for education. Many other issues in the postulated role of human capital in growth suggest that, alas, education or human capital more generally are not the magic formula for rapid economic development.

This literature is mostly written with the past few decades in mind, wondering why some nations have succeeded in building efficient, high-performance economies, and others have not. But the same issues have been and should be raised in a historical context. The endlessly-debated question is the success of the Western world to achieve economic and technological dominance after 1750. Did this achievement rest in some way on human capital? Some models seem to strongly suggest so. The most striking of these are the models known as unified growth models, which try to explain all of long-term history in a single sophisticated model (Galor, 2011). In these models human capital is *the* key ingredient that triggers technological progress, and in turn increases as the returns to education increase.

Historically, human capital, formal education, and schooling have been much more separate than in our own time. Human capital in terms of skills and practical knowledge of artisanal technology were largely acquired directly through apprenticeship. Apprentices typically paid for the service, in part in cash, and in part through their service and assistance to their masters. But the education typically did not involve other skills such as literacy (unless these were needed directly in the occupation). Before the advent of modern compulsory and free universal education, schooling was a complex matter: middle class children went to fee-paying grammar schools, but in many countries, charity schools and various philanthropic and religious organizations provided some measure of education for the children of the poor.[5] Religious organizations were, of course, central to the effort.[6] In some countries, the state intervened directly: in 1763 Prussia made education compulsory for children aged five to thirteen, but actual attendance was low until the early nineteenth century. Even when children went to school, however, it is not clear whether we would think of what they learned as human capital: religion, obedience, loyalty to the state, and respect for those placed higher in the social hierarchy may all have been instrumental in creating a civil society of sorts, but they can hardly be regarded as *skills* or technical knowledge that would be important in production

[5] An example of such education was the work of famous English writer and educator Hannah More (1745-1833) who founded twelve charity schools in Somerset county in the 1780s. The highly religious character of these evangelical schools, and More's insistence that children be taught reading but not writing because of her fear that if children were too skilled they might communicate dissatisfaction with their status in society. Her explicit purpose was to train the lower classes in habits of industry and piety — and here "industry" means diligence

[6] The National Society, originally known as "The National Society for the Promotion of the Education of the Poor in the Principles of the Established Church" was founded in 1811, and dedicated to teaching the three R's as well as "to provide for the moral and spiritual welfare of the children, by teaching them the "National Religion - Christianity as represented in the Church of England and Wales." http://www.churchofengland.org/education/national-society.aspx, accessed March 19, 2013.

and economic growth. Yet the age of Enlightenment was far from a consensus in recognizing schooling as a source of productive investment. Bernard de Mandeville wrote scathingly that "going to school in comparison to working is idleness, & the longer boys continue this easy sort of life the more unfit they'll be when grown up for downright labour." (Mandeville, 1714, p. 288).[7]

The Industrial Revolution and Human Capital

It is by now well-established that by most measures, Britain did not enjoy advantages in schooling and formal institutions that provided human capital on the eve of and during its Industrial Revolution. The efforts of Hannah More and other charity schools not withstanding, Britain's literacy rates were at best mediocre. Literacy rates were about 60 percent for British males and 40 percent for females around 1800, more or less on a par with Belgium, slightly better than France, but worse than the Netherlands and Germany (Reis, 2005, p. 202). During the Industrial Revolution itself, according to the leading authority on the topic, there was at best sluggish improvement in Literacy in Britain (Mitch, 1999, p.244). Literacy rates, of course, reflect an upper bound of the proportion of children going to school, because many acquired literacy from their parents or private tutors. By 1830, 28 percent of the male population in the age bracket between five and fourteen were enrolled in schools in England and Wales. This figure rises to 50 percent in 1850, significantly less than in Prussia where the percentages were respectively 70 percent in 1830 and 73 percent in 1850, and even behind France (39 percent and 51 percent) (Lindert, 2004, pp. 125–26). As Deirdre McCloskey (2010, p. 162) notes, human capital by itself had little effect: a miner at the coal face may have to be skilled , but the hewer's skill had nothing to do with formal education and book learning. The same was true for skilled textile workers, construction laborers, sailors, and so on.

Yet this view is based on the identification of schools with human capital. In eighteenth century Britain, and much of the nineteenth century as well, the skills necessary for efficient production were acquired through personal contacts. The importance of a successful system in which these skills could be transmitted and acquired cannot be overrated. We should keep in mind that much of useful knowledge imparted on young lads was *tacit* knowledge, that could not be obtained from textbooks or encyclopedias. This was especially true for the coal-using industry such as iron, where experience and what John R. Harris (1992, p. 33) called "unanalyzable pieces of expertise" and "the knacks of the trade" were especially important. But basically apprenticeship was at the core of human capital formation before the Industrial Revolution everywhere. Not all apprenticeships were the same, given that we deal with an institution that survived for centuries in many countries and trades. In some cases apprentices would live with their masters, becoming part of the household and were committed to obey and respect him like a father. The training would be more than technical aptitude, it involved the mysteries and "secrets" of the trade (Farr, 2000, p. 34). The training took

[7]On the other hand, the most famous book written on education in the Age of Enlightenment was Rousseau's *Émile* which, despite being at many levels permeated by anticapitalist Republicanism, actually has some elements that suggest that even he viewed education as useful and productive, and instrumental in the acquisition of skills and the transmission of useful knowledge. But for Rousseau such skills were placed outside a market context as survival skills against hard times, and as such hardly part of what we would see as conducive to economic growth. See Darling (1993) and Gilead (2012).

place through "observation, imitation and practice" over many years, during which acquiring human capital and providing labor services were jointly carried out (Wallis, 2008, p. 849).

An argument can be made that for a variety of reasons this institution functioned better in Britain than elsewhere. It did so despite being largely an informal institution, although it operated "in the shadow of the law" and there was at least the possibility of going to court if all else failed, though these cases were rare. But by and large, this institution worked unusually well in Britain, where guilds were weak but local reputational effects were still important (Humphries, 2003; Mokyr 2008). Moreover, a large number of British lads made use of it: David Mitch (2004) estimated that in 1700, perhaps a quarter of British lads went through some kind of apprenticeship. Needless to say, the apprenticeships varied enormously by quality, by the length needed to complete them, and by the sheer level of technological sophistication involved. This variation, by itself, indicates the flexibility of the institution in Britain. Many apprentices failed to complete their formal apprenticeship, and while there were rules on the books, these were frequently ignored (Wallis, 2008).[8] This institutional flexibility, which served Britain well in many dimensions, also gave it an advantage in the generation of a highly skilled and competent labor force.

As I have argued elsewhere, the successful operation of this institution may have been a key to Britain's early success in the Industrial Revolution. There is little doubt that Britain on the eve of the Industrial Revolution could rely on a larger and better-trained cadre of highly-skilled artisans and engineers than elsewhere, and while its advantage in making original breakthrough inventions was contested by other nations (especially France), there seems to be a clear-cut case that British developers and engineers were vastly superior to anyone else in making the new contraptions actually work, debug and adapt them, adding small but significant cumulative improvements to them, and have the ability to install, operate, maintain, and repair them. Between 1750 and 1850, English and Scottish engineers swarmed all over the European Continent, providing engineering and other industrial expertise to nations whose systems of producing human capital was not quite as effective as Britain's (Henderson, 1954).

It is indeed striking that the most educated parts of Europe were not the ones to climb first on the Industrial Revolution train. In a remarkable paper Sandberg (1979) has referred to Sweden as an "impoverished sophisticate" and pointed out that Sweden had not only a high rate of literacy, but also a level of cutting-edge science and technology far above its paygrade in terms of GDP per capita. This was the nation of Polhem, Celsius, Linnaeus, Scheele, Berzelius, and yet Sweden's industrialization was inexplicably late and cannot have said to be in full swing before the closing decades of the nineteenth century.[9] Sandberg's work suggests that high levels of human capital were

[8] Wallis (2008) also shows that the more or less schematic program in which the apprentice spent the first years of his term learning the tricks of the trade and then repaid his master by working for him is oversimplified, and that the learning and working were for most occurring simultaneously.

[9] According the Maddison's data, Swedish GDP per capita in 1870 was $1,664 in 1990 prices, as compared with Belgium and Switzerland, two of the earlier industrializing nations on the Continent, with $2,202 and $2,697 respectively.

more important in *later* stages of the Industrial Revolution, when the most revolutionary macroinventions of the Industrial Revolution had been adopted and were in place. The second stage, often known as the second Industrial Revolution, required more formal training from engineers and mechanics, and as a result shifted the technological leadership from Britain to Continental countries. This finding was confirmed recently (Becker, Hornung and Woessmann, 2011), studying nineteenth century Prussia. They find that primary education helps explain the technological catch-up of follower nations (the entire world outside Britain). Prussian "educational leadership" translated into technological "catch-up" in nineteenth century Europe.[10] In another paper, Becker and Woessmann argue that Prussia's educational advantage was in part driven by religion, and that Lutheranism stimulated economic development through the human capital channel.

Similar results see to hold for our own time. Krueger and Lindahl (2001) found that while human capital mattered quite a bit for a large and global sample of countries, it did not matter much for a smaller group of developed (OECD) countries. This suggests that countries that are close to the technological frontier (best-practice techniques) benefit little (on the margin) from mass education, whereas countries that are still trying to catch up and adopt the most advanced production methods depend a great deal on more human capital. Modern research has suggested that the total "stock" of human capital is not a sufficient statistic for explaining the growth rate of an economy — in addition we need to know what the composition of the human capital is (highly educated vs. more widespread education), and we need to know how close the economy is to the "world technology frontier" (Aghion and Howitt, 2009, pp. 285–314). Something quite similar was true for Europe between 1750 and 1914, even if we do not have the quality of data that we have for modern-day economies.

It is not easy to say how much of a role formal human capital played in the great innovations that led to the industrialization of Europe; if we use current-day definitions based on formal schooling, the answer must be "not much." But if we include apprenticeship and other personal and informal ways of acquiring human capital, the concept returns with a vengeance. Indeed, as argued by Kelly, Mokyr, and Ó Gráda (2013), the higher quality of Britain's labor force (as reflected among other things by higher wages), may well have been decisive in determining Britain's position of leadership in the Industrial Revolution. These personal channels often provided more education than just technical ability.[11] All the same, Britain's skilled workers were hardly intellectuals, and even some of its most accomplished engineers and inventors often regretted their lack of formal education.[12] James Watt, famously, was educated at a good grammar school but never had a formal

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[10]Oddly enough, this seems to be true for most, but not all manufacturing. The industries that are exceptions were textiles and metal production, which were precisely those sectors in which tacit knowledge and apprenticeship were especially important.

[11]In a seventeenth century Yorkshire family an elderly aunt was responsible for teaching the servants and apprentices to read and she was "very industrious and successful in it" (cited by Lane, 1996, p. 70).

[12]The great engineer George Stephenson, who built the famous "Rocket" locomotive that won the Rainhill Trials that mark the beginning of the railway age in Britain, was entirely self-trained in engineering skills learned to read and write at age eighteen; later in life he employed a secretary to conduct his correspondence because of his poor literacy skills. Many others in this industry, similarly, had at best an informal education: the great mechanical engineer Richard

education beyond that (though he networked with some of the best scientists at Glasgow University). John Smeaton, Watt rival for the position of the best engineer of the age, was also largely self-taught in the art of what was known at the time as "philosophical instruments," though he, too, cultivated friendships and correspondences with people from whom he felt he could learn (Skempton, 2002, p. 619), though he made a number of important scientific contributions. But the kind of brilliant tinkerer with little formal education but with excellent mechanical intuition and a quick mind did not dominate the technological stage for long. By the mid-1800s if not earlier, a training in formal mathematics and science became increasingly essential.

This is not to say that there was a sharp transition from intuition and serendipity-based invention to science-based invention in the nineteenth century. The transition was slow, halting, and involved complex interactions between formal science, practical engineering, and a large of intermediate terrain, in which Fortune favored prepared minds, and inventors studied the work of physicists and mathematicians. It is not always easy how all the ingredients of this human worked together to create the stream of post-1850 inventions that turned technological progress into the chief fountain of human material improvement. Much of this happened outside Britain: the "Big Three Polytechniciens" in France, Gustave-Gaspard Coriolis, Jean-Victor Poncelet, and Louis Navier, made heroic efforts to provide mechanical and civil engineering with a more formal base in the 1820s and 1830s. Some scholars, such as Wengenroth (2002), have expressed doubt whether all this formalization really fed right away into increased productivity, and—with some notable exceptions —the record suggests that most of the economic payoff to formal theory lagged decades behind its development. But eventually, the payoff arrived, and it was huge.

When all is said and done, the role of human capital in shifting the technological leadership in Europe from a clear-cut British leadership to a more evenly shared effort was central. This was fully recognized by clear-sighted contemporaries at the time.[13] Yet for much of the nineteenth century, in the words of one scholar, "Britain stood out...for the contrast between its national wealth

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Roberts, the inventor of among many things the self-acting mule, according to Samuel Smiles, "received next to no education, and as soon as he was of fitting age was put to common laboring work. For some time he worked in a quarry near his father's dwelling ; but being of an ingenious turn, he occupied his leisure in making various articles of mechanism, partly for amusement and partly for profit" (Smiles, 1876, p. 321). More recent scholarship has modified this account but still concludes that he was more interested in making things than learning about them" (Hills, 2002, p. 9).

[13]As early as 1851, the chemist and politician Lyon Playfair warned that "a rapid transition is taking place in industry ... industry must in the future be supported, not by a competition of local advantage, but by competition of intellect. All European nations, except England, have recognized this fact" (Tallis, 1852, Vol. 2, p. 194). This may seem unfair, since the ingenuity of a Maudslay or a Richard Roberts represented no less of an intellect than that of a Lord Kelvin. But it was a different kind of intellect. Everywhere but in England, Playfair told his audience, governments have adopted the cultivation of science as a principle of state, and everywhere else there are towns in which schools teach the principles involved in manufacturing. He called for a reform of Britain's educational system devoted to the study of "God's works" (i.e., science and technology) which were more likely to increase the resources of the nation than "the amours of Jupiter or Venus." He complained that science and industry in Britain had not received the respect they deserved despite the fact that the country owed her success to them, mirroring similar complaints voiced twenty years earlier by Charles Babbage (Tallis, Vol. 2, pp. 195–202).

and its educational penury" (Wrigley, 1986, p. 164). Mechanics institutes provided the core of technical education. As late as the 1860s, some of the most prominent industrialists in Britain remained unconvinced that human capital for the masses had a role to play.[14] Yet modern economics has challenged the notion of the initiative for the accumulation human capital coming from the State alone. In an important paper, Galor and Moav (2005) point out that contrary to what many contemporaries were saying, there was a deep complementarity between human capital and physical capital.[15] As a result, it was in the interest of industrialists to invest in the human capital of their workers, simply to maximize their profits. They maintain that the move for mass education was initiated by capitalists before the extension of the franchise to workers. The critical assumption here is that the effectiveness of human capital depends on its expanding on the extensive margin (educating more people) rather than the intensive margins (educating a limited number of workers better).

The difficulty, of course, was that each manufacturer individually could not do this simply because if he spent resources in educating his workers, others would bid them away and benefit from his investment.[16] The source of this market failure, of course, is that the property rights in one's human capital cannot be sold. As a result, the only way for capitalists to increase the amount of human capital in the economy is to have it paid for by the state.

But perhaps the more difficult matter is the assumption that education on the extensive margin is critical to continued technological progress. There are three separate arguments here that could justify that argument, and they are critical to an understanding of the role of human capital in economic progress. The first is that better-educated workers are necessary to operate and maintain more sophisticated equipment. This argument clearly is true for some cases, but not across the board. As I have argued elsewhere (Mokyr, 2002, p. 139), much technological progress takes place by front-loading the ingenuity and scientific knowledge into the equipment and making it simpler to operate while installed. The more sophisticated and deeper the knowledge of the inventors, the greater the gap between the useful knowledge needed to design and build it and the competence to operate it. Driving an automobile and operating a computer were at first tricky activities, but they could be made accessible to millions even if their operators could not repair, let alone design, the artifacts. In the early stages of the Industrial Revolution most machinery was custom-made, demanding in-house

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[14]James Kitson, a Leeds ironmaster, was asked by a parliamentary committee as late as 1868 whether he felt that the rank and file should receive a scientific education much as the managers and foremen. He replied that "as a manufacturer, I should say that it was not. The great need we have is for some superior scientific education for our foremen. It would be useless to give scientific education to the great mass of our workpeople." Great Britain, 1867-68, p. 248.

[15]The concept of capital-skill complementarity is central to the analysis of modern labor markets, but the evidence for its importance before is rather mixed (Goldin and Katz, 1996).

[16]The same Mr. Kitson explained the absence of technical schools in Leeds for managers and foremen by the fact that "individual manufacturers are not able to grapple with it. If they went through the immense trouble to establish schools, they would only be doing it so that others might reap the benefits — and we do not do that in Yorkshire" (Great Britain, 1867-68, p. 248).

expertise and tacit knowledge for operation, repairs, preventive maintenance, and so on. But as many scholars have pointed out, technological progress could be and still is "de-skilling" in that the actual operation may become simpler.[17] Today, of course, machines can actually read and "sense" the environment, and artificial intelligence embodied in robotic devices and automatons has replaced human competence in many activities.

A second argument for educating all workers is simply to filter in the most talented youngsters and invest further in their education. Such screening mechanisms of mass-education have long been recognized as one of the essential functions of schools, although the matter is quite controversial. It may make *economic* sense to concentrate scarce resources in education on the most talented students, but such policies will accentuate and deepen natural inequalities.[18]

A third argument, and perhaps the one that is most consistent with the Galor-Moav argument, is that mass education is not really about technical skills but about the social conditioning necessary to operate in complex environment with a high degree of division of labor (Bowles and Gintis, 1976). Large-scale team production requires workers to submit to a high degree of discipline and to follow instructions from superiors; it also demands punctuality and a high degree of self control and ability to work with strangers. Such characteristics are exactly what much nineteenth-century (and later) schooling was all about: *drilling* more than *training*. Such skills were a highly non-specific form of human capital since they could easily be transferred from employer to employer, and it was in no employer's interest to invest resources to install docility and obedience in his workers; employees who did not conform to these norms were fired and replaced by others. Yet the worker characteristics that were needed for industrial technology were not hard-wired in individuals, and needed to be acquired through socialization.[19]

Whatever the case, it is clear that between 1850 and 1914 all industrial nations made a strong commitment to education and schooling, and that earlier informal modes of transmission of useful knowledge were slowly receding, though they never quite disappeared. What is important to stress is that not all human capital was accumulated through formal education, and that not all schooling resulted in human capital. What matters is not only how many years of schooling a child receives, but what is taught, and the extent to which the curriculum contributes to future economic

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[17]Marx (1867, 1967, pp. 422-23) stressed this aspect of technological progress, and noted that the workers was becoming "the mere living appendage of the lifeless mechanism" and adds that modern industry brings about "the separation of the intellectual powers of production from the manual labor." Some twentieth century scholars in his tradition have developed this theme (e.g. Braverman, 1974, p. 113).

[18]In the testimony already cited, James Kitson conceded that mass education had value by increasing "the area from which we may draw our foremen and enabling us to advance those who showed any special intelligence or scientific skill" (Great Britain, 1867-68, p. 248).

[19]Mitch (1999, pp. 272-73) criticizes the importance of the socializing effect of formal education before 1850, but admits that "the proposition that schooling has had an important influence on shaping behaviors, attitudes and values remains plausible."

performance. This distinction is especially important when we come to analyze the divergence between the Western world and the rest of the planet brought about by the Industrial Revolution.

Human Capital and the Great Divergence

Notwithstanding a great deal of controversy — or *because of it* — the debate on why in the nineteenth century the Western World — led by Britain — pulled ahead of the “rest” to form a “convergence club” of rich, industrialized, urbanized, and educated nations shows no signs of subsiding.[20] Interestingly enough, with the exception of Galor (2011), most of those scholars have paid little attention to possible differences in human capital and education between East and West in explaining the great divergence. But while it is difficult to compare levels of human capital across such huge geographical and cultural distances, there is very little evidence indeed that by 1700 or so China was, in some sense, less “educated” and “literate” than Europe.

As early as the eleventh century under the Northern Song, China experienced a new emphasis on education, with both government and private schools proliferating. One scholar summarizes this development by noting that “even in the poorest and most remote rural places there gradually appeared lower-level country schoolteachers in the smaller villages...the norms of the higher levels of culture, transmitted through the various kinds of local education, broadly penetrated the level of the ordinary people” (Mote, 1999, pp. 159-60). In their recent survey of Ming-Qing Chinese economic history, three leading scholars have pointed out that poor households sought schooling for their sons, reflecting not only the impact of the Imperial examination system but also the respect and status awarded to men whose educational attainments exceeded the local norm. As a result, both elites and commoners, farmers and craftsmen “all invested in education ... to promote both social standing and economic gain” (Brandt, Ma, and Rawski (2013, p. 47).

Moreover, China was a land of books. Already during the Song era, it had a thriving book trade, but after 1500 there occurred what the leading expert has called an “explosive expansion” of printing. By 1800 “scholarship, book production, and libraries were central to Chinese culture” (Elman, 2006, p. 81). Chinese printers used both xylography (woodprints) and moveable type (which had been known in China since the eleventh century). A variety of books were printed, including novels, almanacs, encyclopedias, as well as the Chinese classics. By the eighteenth century a specially designated street in south Beijing had specialized in the book trade and become the book emporium of China. Lively book markets, however could be found throughout the Yang-zhi delta.

These facts clearly refute any kind of theory based on an obvious human capital advantage that the West had over China.[21] Does this mean that there was no human capital difference between the two cultures and that all differences should be explained by purely exogenous and geographical

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[20]Despite being controversial, the *opera classici* in this literature remain Jones (1981) and Landes (1998). Recent contributions include Goldstone (2009); Ringmar (2007); and Morris (2010).

[21]In this regard the non-western world is quite diverse: in the Islamic world, for mostly religious reasons, printing and publishing was delayed by centuries.

variables? As McCloskey points out, education can be counterproductive, when it is overly focused on venerable but antiquated knowledge, and producing a "rote-learning bureaucracy hostile to innovation." Without the appropriate values, which she feels are embodied in a "bourgeois rhetoric" education becomes a desirable human ornament, not the way to riches (McCloskey, 2010, pp. 162–63). One key element, clearly, were the Chinese Imperial examinations. Studying for these examinations represented a huge investment of human capital in the learning of the past. The vast bulk of candidates failed these exams in local competitions, and there were large reservoirs of classically-trained men who had failed their exams and were still looking for ways to extract some rents from their human capital. These people also constituted a large audience for the books published at the time.

The Mandarin civil service as it evolved in Ming and Q'ing China, became the instrument through which the ancient texts became "an instrument of repressive conformity" (Huang, 1981, p. 210). The neo-Confucian annotated "four books" (*Sishu Jizhu*)were written in the twelfth century by the great neo-Confucian scholar Zhu Xi (1130-1200). His writings mark the *summa theologica* of neo-Confucianism and evolved to be as rigid a canon as the West ever had. What China was short of, though they were never quite absent altogether, were the kind of iconoclastic writers such as Petrus Ramus and Paracelsus who insolently overthrew conventional wisdom in Europe in the sixteenth century. Unlike what happened in Europe, there was no political pluralism that heretics and intellectual innovators could exploit to create an open market for ideas. China turned into a meritocracy gone awry: the system of the imperial examination, which tested candidates on their knowledge of the classical canon was a powerful tool to defend incumbents against the threat of heterodox cultural entrepreneurs who threatened the political power of incumbents and the value of their human capital. In a society in which public office remained "the most important source of prestige and wealth" (Brandt, Ma and Rawski, 2013, p. 47), the unassailability of these texts remained the most effective bulwark against intellectual innovators. Neo-confucianism, which emerged during the Song dynasty, became in the following centuries a state-sponsored orthodoxy, since the imperial examinations were entirely based on them and they thus became the subject matter of most human capital accumulation.

Human capital, then, was available in large quantities in China, but arguably it was seriously misallocated. Chinese scientists, up to a point, treasured contact with the West.[22] For much of the seventeenth century Jesuit mathematicians and astronomers taught the Chinese literati a great deal (Elman, 2005).[23] But in the end it all depended on the good will and patronage of the Emperor and

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[22] Even Landes (1998, p. 341–42) who stresses that the rejection of foreign technology was all the more serious because China itself had slipped into a "technological and scientific torpor" concedes that "intellectual xenophobia did not apply to all Chinese."

[23]Mote (1999, p. 959) goes so far as to assert that the quality of the Jesuits at the Chinese court was as good as anything that European learning could offer anywhere. This may have been partially true for the years that the ingenious Belgian Jesuit Ferdinand Verbiest was at the early Qing court (1659-1688), although even Verbiest was constrained by his Jesuit commitments to a Tychonic world view and by the 1650s both the instrumentation and the theory they deployed in China were obsolete. While he managed to convince the Kangxi Emperor in 1670 to prefer his calendar to that of the

his court and despite the demonstrable superiority the Westerners could demonstrate in improving the calendar and making astronomical predictions, the Chinese remained suspicious of the Jesuits' religious objectives. After 1670, their knowledge was no longer at the cutting edge (ibid., pp. 105, 148). In 1704 the Pope sent an emissary to China to look into the activities of the Jesuits there, and clashed with the Kangxi Emperor, seriously damaging the continued dissemination of Western science into China. Although there were still thin trickles of this knowledge, the damage was done. The Jesuits in China had come to spread Catholicism, not to disseminate best-practice Western science and technology and in 1717 the Kangxi emperor (ruled 1661-1722) prohibited all further missionary work. Western knowledge was deemed to be part and parcel of Europe's religious and political objectives, and by the early eighteenth century a reaction set in. Kangxi went as far as to ban all questions on natural studies from the civil service examination and his successor, the Yongzheng emperor began a closed door policy that lasted until after the Opium Wars in the 1840s (ibid., p. 168). Their relationship with the Jesuits illustrates the basic issue with Chinese importation of Western culture: it had to be controlled, filtered, and sorted and subjugated to Chinese authority. For a while, the narrow transmission channel of Jesuit missionaries suited the Chinese well, but also limited what they could learn.

It seems absurd to argue that Confucianism, as such, was in any way inconsistent with the growth of science and technology.[24] What happened, however, was that the explosion of a diverse and abundant scholarship that occurred in the later Song, Yuan, and Ming was largely focused toward the reinterpretation of classical scholarship. It was not reactionary as such, but neo-Confucianism as embodied in the writings of Zhu Xi and his followers in the Song era evolved over time into something quite different from the intentions of its founders, an intense emphasis on individualistic self-cultivation and in the Q'ing period it crystalized into "a conservative scholasticism devoid of philosophical vitality" (Hucker, 1975, p. 364). This statement may seem overly harsh; the study of past wisdom can be enlightening and lead to progress if this study is based on criticism and skepticism that eventually lead to innovation. Human capital, then, expanded a great deal, in China, but it did not lead to the explosive expansion of useful knowledge we see in eighteenth century Europe.

The difference between the Chinese and the European systems of human capital cannot be summarized in a teleological fashion by noting that the European political system and its underlying somehow were conducive to technological progress and the formation of human capital and the Chinese was not. Europeans spent no less than China on educational activities that were unproductive investment, including poring over the writings of the classics in dead languages and various forms of mystical and occultist writings. Many of its most prominent educational institutions,

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Chinese astronomer Yang Guangxian (Elman, 2005, p. 103).

[24]Landes, 1998, p. 344 for instance, feels that Confucianism had an "easy disdain for scientific research," which it disparaged as "interventionist and superficial."

including universities, had at best a mixed records in educating youngsters.[25] The difference was that China was a single entity where education was governed and coordinated by a single administration, and hence there was little pluralism and competition in the system. In Europe, the accumulation of human capital, like so much else, was governed by the macro-competition among the states and the need to keep ahead of others. This constant concern with international politics, whether actually accompanied by armed conflict or not, was a major motive in the founding of some of the most productive institutions in human capital generation, such as the École Polytechnique founded in France in 1794 at the height of the revolutionary wars. Scotland prided itself on having some of the best higher educational systems of eighteenth-century Europe, and produced far more human capital than its small economy could absorb. Many Scottish engineers and chemists found a place in the rapidly growing English manufacturing sector. The Prussian reforms of its educational system (following the defeat of the country by Napoleon in 1806) was designed by the justly celebrated Wilhelm von Humboldt. These were largely motivated by the urge of Prussia to remain a leading political power in Europe.

But macro-competition in Europe went beyond the struggles between Kings and Emperors, it extended to the competition between religions as well as that between different regions and towns. The competition between different religions after the Western Christian Church lost its monopoly position in the West is particularly relevant here. Following the challenge of the reformation, this position was contested and the resulting response create a large boost to the formation of human capital. The role of the Jesuits, an order established explicitly to defend Catholicism from competing Christian faiths in the formation of human capital in the West and elsewhere, is too well-known to need elaboration here. There can be no question that one of the main instruments they relied on was education. What is striking, however, that Jesuit education contained not just religious and moral teaching, but insisted on the inclusion of useful knowledge such as mathematics and physics, into the curricula.[26] The inclusion of mathematics in curricula was supported strongly by the great Jesuit mathematician Christopher Clavius (1538-1612), best-known for being the moving spirit in the calendar reform that led to the Gregorian Calendar.[27] Religious competition was also an important factor in Britain, where the Church of England had to contend with dissenters, who founded the

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[25]Adam Smith ([1776], 1976, Vol. 2, p. 284) remarked sarcastically that at Oxford the dons had "long ago given up all pretence of teaching" and the great Enlightenment scientist and philosopher Joseph Priestley (1787, p. 32) compared the mainstream colleges (from which dissenters such as himself were excluded) to "pools of stagnant water."

[26]In his recent magisterial work on the rise of modern science, Cohen (2012, pp. 146-47) points out that the education of Europe's elites in order to strengthen the counter-reformation was one of the main objectives of the Jesuits and that the Jesuits made a supreme effort to reconcile the Aristotelian system with what Cohen calls "mixed mathematics" by which he means "applied mathematics," which was used in astronomy, calendar calculation, the analysis of music and so on. In the end, Cohen concludes, Jesuits were constrained by the preconceived notions imposed on the Jesuit intellectuals (ibid., p. 495).

[27]The best example of the wide-ranging and diverse scholarship that Jesuits contributed to European culture is the work of Athanasius Kircher (1601–80), a German-born polymath of prodigious scholarly productivity who wrote important books on topics as different as natural history, mathematics, geology, and the history of ancient Egypt. See Findlen, 2004.

"dissenting academies." These were high-quality schools, that taught geography, mathematics, chemistry, languages and useful skills in addition to heterodox religion. Among the more celebrated teachers in these academies were the great scientists Joseph Priestley and John Dalton.

The impact of education and human capital, to repeat, depends a great deal on what is deemed important by the intellectual elite in society and what is being taught to students. It is here that metaphysics and religion become central to the story. Perhaps the best illustration of that argument is the strange role of the European Jews in the history of science and technology. For many centuries, the Jews represented a highly literate minority in a large uneducated world (Slezkine, 2004, p. 29). In their pathbreaking work on the history of the Jews before 1500, Botticini and Eckstein (2012) point to the religious origins of the accumulation of human capital among Jews and note that this explains the occupational structure of the Jewish minorities in Europe and the Middle East and their specialization in handicraft and service industries. Religious worship for the Jews became identified with learning: the very word for the Jewish synagogue was *shul* — derived from the German word for school. Yet it is striking how little effect this had on the generation of the kind of useful knowledge that eventually led to the technologically-driven economic expansion of Europe in the nineteenth century.

Although the volume and range of Jewish learning was immense, it was always conformist and respectful of ancient authority. Within given constraints, there was a great deal of debate and dispute, but violating these constraints was *kfira be'eekar* and had terrible social consequences as Spinoza found out.[28] The outcome was that despite their disproportionate number of intellectuals and learned individuals, the great scientific and technological revolutions of the seventeenth and eighteenth centuries did not draw on much learning from Jews, and when remarkable Jewish intellectuals such as David Ricardo and Moses Mendelsohn did play a role, they typically were alienated from their community. Even in medicine, in which Jews had specialized for centuries, their impact was rather disappointing until the nineteenth century. The great innovators of medicine before Pasteur, from Vesalius to Sydenham, from Harvey to Jenner, were not Jewish. Beyond that, there were few major Jewish mathematicians, despite the fact that Jews, of whom many were engaged in commerce and finance had to be numerate as well as literate (Botticini and Eckstein, 2012, pp. 134-35). Yet apart from an elaborate numerology in which meanings were attached to words according to the values associated with their letters, it is hard to find important Jewish mathematicians before the nineteenth century. Such mathematicians did exist (they helped the Portuguese navigators in

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[28]Even an original thinker such as Maimonides (Rambam) discussed heresy at length in his *Mishneh Torah* and judges them severely. All Jewish evildoers will still be "part of the next world." Not so those who questioned religious authority. He distinguished between three types of them: *minim* (heretics– those who question the essence of the Jewish God), *epikursim* (apostates), and those who deny the Torah (*Mishneh Torah, Sefer Mada, hilchot Teshuva* (repentance), ch. 3, pp. 108–110. The penalty was to be that they would not become a part "of the next world" but in ch. 8 of the same it is quite clear that the biblical penalty of *karet* would be applied to anyone who seriously questioned the scriptures, which is most likely equivalent to ostracism.Some translations misinterpret *minim* as atheists (e.g. Russell and Weinberg, see Maimonides, 1983, p. 116). Although atheists are mentioned ("those who say there is no God and the world has no leader") but so are heretics ("those who say there is a God, but he has a body and an image.") All translations mine. Later texts such as the celebrated *Shulchan Aruch* (sixteenth century) are even harsher on heretics.

computing latitude at sea),[29] but the great advances in mathematics between 1600 and 1750 do not count many Jewish names.

Conclusions

Economic models suggest that human capital can play an important, perhaps even central role in economic development. But a look at its actual role in economic history suggests that this role should be modified in important ways. Much like physical capital, investment in human capital can be massively misallocated and even have a negative impact on economic performance as McCloskey (2010, p. 162) points out. Investing in the training of youths in the art of hacking others to pieces, as was the custom in Sparta as well as in much of medieval Europe, cannot have added much to productivity. More seriously, educational systems could steer societies, and especially intellectual elites, toward a reverential but sterile exegesis of obsolete texts or purposeless scholastic debates. What confounds this argument is that education is acquired for many other reasons beside raising the person's future earnings. In that sense, human capital is not like physical capital: nobody would erect a steel plant for purely aesthetic reasons. But education is a consumption good as well, both for the person being educated and for his or her parents. Investing many years in poring over the *Four Books* or the Talmud may not be the key to an Industrial Revolution, but that was never their intention. Education, may however, simply enrich a person's life, or in economic terms, be complementary to consumption: it is hard to imagine someone enjoying the writings of James Joyce or the music of Arnold Schoenberg without some prior investment.

A second problem with the effect of increasing human capital is whether it should be allocated on the extensive margin (expanding the coverage and educating the masses) or the intensive margin (deepening the education of those who are already being educated). If we believe that modern economic growth is propelled by breakthroughs in science and technological progress, there can be little doubt that it is carried by a small minority of technically talented and imaginative workers. In that regard, investing in the education of the best and the brightest may be a superior strategy. But, as I already noted, we do not know ex ante who the best and brightest are, and unless we provide schooling to everyone, we may lose most diamonds in the rough. Moreover, the required skills and attitudes needed for adapting to the new techniques often depended on educating a new generation of workers, which often required state intervention. These skills have usually been thought of as being associated with formal education in schools, but they can be produced by informal contacts as well.

Finally, the human capital needed to generate radically new ideas and techniques (that is to improve *best practice* technology), and the human capital needed to adopt techniques that are already in use (increase *average practice* technology) appear to be quite different. For the former what is required is a highly competitive, diverse, pluralistic, and tolerant system in which thinking "outside

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[29] See Seed, 2001, pp. 73-82. The best-known of those astronomer-mathematicians was Abraham Zacuto (1452-1515), the inventor of a new and improved astrolabe to measure latitude at sea, and the compiler of detailed astronomical tables for ocean navigation.

the box" is not discouraged. It is important that in such systems the market for ideas be always contestable, so that conventional wisdom is continuously challenged (Mokyr, 2007). Such systems, of course, generate a lot of *bad* ideas that are generally discarded. At times, the winnowing mechanism also throws out some good ideas, which seems inevitable.

Despite these complications, it is worth recalling the wisdom of the old gag that states that "if you think that literacy is overrated, try the alternative." While I have concluded above that high investment in human capital may not have been either a *necessary* nor a *sufficient* condition for economic growth to take place, it is surely correlated with it. Illiterate and uneducated societies *are* capable of substantial technological progress, provided it is nothing too complex. Early medieval Europe, despite its low levels of literacy and poor education system, was able to produce an astonishing stream of innovation. All the same, to release them from the constraints of a subsistence, agricultural economy, more was needed.

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