INCENTIVES, INSTITUTIONS, AND INDUSTRIALIZATION: A PRELUDE TO MODERN ECONOMIC GROWTH

JOEL MOKYR

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1. *Introduction: an Institutional Puzzle*

Despite some eminent dissenters who have yet to be persuaded, the growing consensus among economic historians today is that «institutions matter» even if they do not necessarily «rule».[1] Following the pioneering work of Douglass North in the 1980s, economists have understood that the incentives and the rules of the economic game – both in terms of the features and nature of governance and in terms of what Greif (2005, p. 8) has called «private order institutions» matter to the economic outcomes and performances. They determine the extent to which society can overcome op-portunistic behavior, reduce transactions costs, and thus make markets work. In addition, they make collective ac-tion possible that creates public goods and organizations. These include the enforcement of property rights and con-tracts and more generally a rule of law and order neces

Joel Mokyr, Departments of Economics and History, Northwestern University; Berglas School of Economics, Tel Aviv University. Email: J-Mokyr@northwestern.edu.

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[1] For a recent critique of institutions as a prime mover see especially Clark (2007) and McCloskey (2010; 2016; 2021). The term «institutions rule» is borrowed from Rodrik, Subramanian and Trebbi (2004).

sary to facilitate exchange and a more efficient allocation of resources.

The puzzle is that institutions as currently understood do not explain modern economic growth as it emerged during and after the British Industrial Revolution. While specialization and more efficient allocations continued to be an important driver of the rising economic performances of Western countries, the *primum movens* of economic growth increasingly became what eighteenth century intellectuals called «useful knowledge». This included what we would call «science» but it was much more than that, such as engineering (Hanlon 2020; Mokyr, Sarid and van der Beek ~~2021~~ 2022), practical mathematics (Kelly and Ó Gráda 2022
~~2021~~) and chemistry (Clow and Clow 1952; Christie 2018), and a large accumulation of what we would call today
artisanal «tacit knowledge». ~~Although~~ ~~such~~ Such tacit knowledge would not qualify by any stretch as «science», yet it stood Britain in good ~~service~~ s t e a d
as
exemplified by relatively poorly educated unscientific «tinkerers» such as George Stephenson, Joseph Bramah, Charles Tennant, and Richard Roberts.

Useful knowledge, both innovation and diffusion, were at the heart of the Industrial Revolution and everything that came after. ~~To repeat: this~~ This is not to say that other factors did not play an important role. But in the absence of continuously expanding knowledge, the other phenomena at play, including a growing international trade sector and rising la-bor mobility would have run into diminishing returns and eventually ground to a halt. In a purely Smithian world, there would have been no Industrial Revolution; the growth in prosperity due to the division of labor and other elements in Smith's idea of what drove growth would have mercilessly fizzled out and the world would have ended up in the sta-tionary state of classical economics.

In what follows, I will raise the question of which institutions were behind the growth in useful knowledge dur-ing the British Industrial Revolution. This is not an issue on which North or Acemoglu-Robinson spent much time. Somehow it was felt that if incentives were aligned, prop-erty rights were enforced, and a country was ruled by an inclusive government that was neither too anarchic nor too despotic, innovations would flow automatically. [2]

Such a con

[2] For a recent restatement in the same spirit, see Aghion, Antonin and Bunel (2021).

clusion is rarely well-supported, much less documented. It seems therefore useful to unpack the institutional elements of technological progress, and ask how instrumental the institutional structure of Britain on the eve of the Industrial Revolution was in facilitating it and how it can help explain the century of British technological and economic leadership.

2. *General Purpose Institutions and the Industrial Revolution*

One could readily extend an argument about the impor-tance of institutions to innovation and economic progress and find institutional elements common to Europe, going back to the Medieval Church, the Reformation, and the Enlightenment. Here I will look only at Britain. It will be useful to make a distinction between what might be called «general-purpose institutions», which ~~set up~~ d e t e r m i n e d the mode of government in Britain and the overall tone of its political environment, and «specific institutions» that may have af-fected primarily particular aspects of the economy and thus may have triggered the Industrial Revolution directly. At a high level of abstraction, innovation needed opportunities and incentives. Institutions set the political and social envi-ronment in which inventors and entrepreneurs operated and in many ways these determined whether innovation would be attempted at all. In highly conservative and repressive societies that encouraged conformism and stability, the environment would be a priori hostile to innovators. The same would be just as true, as Acemoglu and Robinson (2012) pointed out, in highly extractive societies in which ~~any~~ the rents from innovation would be expropriated by greedy rulers.

The seminal paper that related political institutions to the Industrial Revolution was published in 1989 by North and Weingast (1989). The paper is well-known and requires little discussion. It established the view that the Glorious Revolution and the rise of Parliament as the central locus of power in England (later Britain) were the keys to subsequent eco-nomic progress.[3] Parliament became «the place where ab-

[3] **Pincus and Robinson (2014)** expanded this idea and argued that the Glorious Revolution once and for all determined the de facto rules by which political power in Britain was exercised: the emergence of parliamentary sovereignty meant that policy was henceforth set by political parties and thus ministers, and that the Whigs set an agenda of «economic modernization». Gary

solute despotic power, which must in all governments reside somewhere, is entrusted», as Blackstone noted in 1765 (1765-1769, Book 1, Ch. 2, Section III) Parliament became what may be called a «meta-institution».

If institutions are the «norms and rules» by which the economic game is played, meta-institutions ~~make~~ create these rules and provide them with legitimacy meaning that even people who are on the losing ends ~~of these rules~~ accept ~~them~~ new rules and follow them. Parliamentary rule became increasingly friendly to what eventually became the Industrial Revolution. Thus,
Dan Bogart and Gary Richardson (2011) have argued that Parliament in the first half of the eighteenth century became more inclined to pass laws and acts that in the views of the ruling Whigs facilitated economic development.[4] British authorities had little patience with resistance to mechanization from workers concerned for their livelihood. When necessary, the government suppressed any resistance, including the draconian Combination Acts of 1799.[5] Above all, however the high degree of legitimacy of Parliamentary rule spared Britain the political upheavals that disrupted political and hence economic life on the Continent for the quarter century between the French Revolution and Waterloo.

Beyond stability and sympathy for industrialists in their confrontations with recalcitrant workers, the British polity was favorable to the Industrial Revolution because it created an environment in which entrepreneurs and innovators were incentivized through the simple mechanism of leaving them with most of their profits if they made any. A state run by what Mancur Olson called «stationary bandits» is in all likelihood prone to killing the proverbial golden-egg-laying

Cox (2017), using different terminology, has similarly argued that the Glorious Revolution established Parliament as the undisputed meta-institution that wrote the rules for taxation, public debt, and royal accountability.

[4] For example, fairly soon after the Glorious Revolution, investment in transportation (especially highways and the improvements of rivers) increased, as regulatory uncertainty was reduced by the unchallenged position of Parliament as the sole meta-institution of England. The enforcement of the charters awarded to private investors who financed transport infrastructure became more secure, and while they always remained regulated by government, the regulatory environment was reasonably effective and new entry into transportation was always sufficient to prevent exorbitant tolls (Bogart 2011; 2019).

[5] There was still plenty of conservatism, neophobic resistance to innovations, and a general suspicion of inventors in Industrial Revolution Britain, but government and most actors who mattered became increasingly pro-innovation, if perhaps not always so much to increase economic welfare as much as out of mercantilist considerations such as the «jealousy of trade» and competitive economic nationalism.

geese. One important element of the decline of extraction and rent-seeking in Britain before and during the Industrial Revolution was the decline of «old corruption». Corruption not only ~~reduces the distortion of~~ distorted the incentives and the allocation of resources in the economy, it also reduces the efficiency of the supply of public goods, which has general-equilibrium effects throughout the economy.[6]

Paradoxically, Britain was, especially during the years of the Industrial Revolution, a heavily taxed country, gainsaying Adam Smith's widely quoted dictum how all that was needed for reaching «the highest state of opulence» was «peace, easy taxes, and a tolerable administration of justice». Taxation was indirect, regressive, and rarely confiscatory, so that the small minority of entrepreneurs and inventors who succeeded were able to acquire significant riches (e.g., Richard Arkwright, James Watt, Josiah Wedgwood, and Charles Tennant) and potential entrepreneurs did not fear that their rents would be taxed away or extracted in some other way. Beyond that, however, British institutions succeeded because they followed the sage counsel of modern economists: «leave me alone, and I'll make you rich» (McCloskey and Carden 2020). While that formula began to break down in the last third of the nineteenth century it worked very well until then.

3. *Specific Institutions: High-powered Incentives and the Patent System*[7]

The European Enlightenment – and the British Enlightenment more than others – believed in the sanctity of property rights. The idea of property rights in ideas – IPR's – was a uniquely Western idea; no such notion can be found for instance in Chinese culture. By the late eighteenth century, it was realized not only that patents were a moral institution – rightly rewarding a successful inventor and recognizing a moral claim on what was deemed to be property – but that it actually stimulated and encouraged innovation and thus economic development.[8] Modern eco-

[6] For a summary of the historical literature on the decline of corruption in Britain, see Mokyr (2009a, pp. 424-428).

[7] Some of the following is adapted from Mokyr (2009b).

[8] Goethe famously wrote that the «clever Englishman» was able to turn ideas into property and sighed that «no wonder they are in every way ahead

nomics has found the idea attractive, as it provided an easy and intuitively powerful connection between institutions and the technological progress that drove modern economic growth (North 1981, pp. 164-165; Aghion, Antonin and Bunel 2021, p. 37). England, after all, had a patent system that predated the Industrial Revolution by over a hundred years, and so this institutional foundation safely predated the Industrial Revolution, ruling out reverse causation. As Adam Smith also believed, it rewarded inventors more or less in proportion to the contribution of their invention, and thus created a high-powered incentive to engage in innovative activity. Or so it seemed.

The problem is that a closer look at the British patent system leads to serious reservations on the effect of the British patent system on the Industrial Revolution. The net effect of patents on technological change remains in serious dispute till the present day (Boldrin and Levine 2008), all the more so for the eighteenth century. In a few cases patents have been argued to actually block innovation by the threat of litigation, but perhaps more damaging, the number of actual patents filed was a small fraction of all important inventions. This was demonstrated in devastating detail by Moser (2005; 2021), and while one can question the exact percentages involved, anecdotal evidence strongly supports her findings. ~~For~~ To be sure, for a few inventors, the system worked and they were able to secure a temporary monopoly on a lucrative technological breakthrough. But for many of the most important inventions of the era, the patent system was either not ~~activated~~ utilized or failed to protect the inventor.[9] Until 1851 patenting in Britain was expensive beyond the reach of most middle-class inventors coming from the artisanal class, and legal protection from infringements through

of us» (cited by Klemm 1964, p. 173). In 1795 Chief Justice James Eyre of the court of common pleas observed that many patents existed for new methods of manufactures that were «beyond all calculation important to commercial activity [...] and in my apprehension it is strictly agreeable to the spirit and meaning of the Statute» (cited by Bottomley 2014, p. 152).

[9] Moreover, if it was the patent system that accounted for Britain's leadership, one might wonder why other economies were not more successful earlier. Britain's patent system and its policies encouraging invention were not unique: the Netherlands did have a system of patents awarded by both the Estates General and the provincial estates from the late 1580s on, awarding a peak number of 119 patents in the 1620s. Yet in the eighteenth century, the number of patents dwindled into insignificance (Davids 2008, pp. 400-416). Ancien régime France, too, had a system of rewarding inventors even if it worked quite differently from the English patent system (Hilaire-Pérez 2000).

the courts was weak and unreliable.[10] Incentives came from elsewhere.

In some ways the market system found other ways to reward technological pioneers, above all through the «first-mover advantages» as was famously the case with Richard Arkwright. In a few cases, the political system stepped in directly, with Parliament voting substantial pensions or awards for people whose innovations had been deemed especially useful (most famously the large awards, totaling £ 30,000, awarded to Edward Jenner, the inventor of the smallpox vaccination). The Society of Arts, founded in 1754, awarded medals and small prizes to inventors – provided the invention had not been patented (Howes 2020). In a few cases, inventors could shield their monopoly through secrecy, though it is difficult to see ~~seems unlikely~~ that techniques and formulas could be protected for long from imitation and reverse engineer-ing. Inventors were driven by other motives as well: many of the great engineers wanted to become known as ingenious and creative individuals so as to secure commissions from manufacturers and local authorities. Some inventors who had been trained in formal science absorbed the culture of open science and felt that it was immoral to protect knowledge, which was after all non-rivalrous.[11] Clearly, of course, not all of them were pure altruists: many if not most cared deeply about their reputations among their peers, about membership in the Royal Society, medals, knighthoods and other signaling devices.[12] Institutions, then, encouraged

[10] Because of their dogmatic opposition to monopolies of any kind, judges often decided against patentees. Consequently, patentees who felt their patents were infringed rarely sued: between 1770 and 1850 only 257 patent cases came before the courts out of 11,962 patents granted (Dutton 1984, p. 71).

[11] Michael Faraday only took out one patent in his life and one that had nothing to do with his main line of research, namely a better chimney for the use of lighthouses (which he made over to his brother). His mentor, Humphry Davy, refused to take out a patent for the famous «miner's friend» lamp he invented and claimed repeatedly to be «philosophically» opposed to patents (Ruston 2019).

[12] Economists have long argued that especially in the upper tail of the human capital distribution – the one that matters most the economic development – agents are driven by more than material incentives. As pointed out by Kreps (1997), the distinctions between intrinsic motivation and status incentives can be fairly tricky. Kreps notes that in most employment situations (and that covers the bulk of the citizens of the Republic of Letters) it is hard to detect intrinsic motivation. He notes that «what is called intrinsic motivation may be (at least in part) the worker's response to fuzzy extrinsic motivators, such as fear of discharge, censure by fellow employees, or even the desire for coworkers'

the growth of useful knowledge, but the incentive structure driving innovation was more complex than the simple-minded greed that non-economists attribute to the beliefs of economists (for more details, see Mokyr 2018).

The same holds for the patent system. Human behavior and psychology played just as much a role as income-maximization. Entrepreneurship and invention – and a fortiori patenting – are like unfair gambles or lotteries. Most inventors and innovative entrepreneurs in the Industrial Revolution failed. What ~~makes~~ made the system ~~them~~ work is that a few spectacular and well-publicized successes led others to believe that their odds were better than they really were. Its very existence drove many would-be inventors toward exerting efforts in the hope of securing the kind of riches that James Watt and Charles Tennant had gained from the patent system. This is all the more power-ful precisely because by definition all inventions are in some qualitative dimension different from one another (unlike lot-tery tickets) and a function of the ability of the inventor. It is therefore easier for «gamblers» to persuade themselves that the conditional odds that underlie decisions in this ac-tivity may be systematically higher than the unconditional ones. In other words, would-be inventors overestimated their abilities and thus their chances for a successful patent. The expected rate of return on inventive activity for the *entire* population of inventors was in all likelihood negative, but because of the salient upper tail, the ex ante incentives were powerful. And the social returns of inventive activity exceeded the private return by a large factor. Hence anything that can inflate the perception of private returns is socially beneficial. It is this mechanism that best supports Bottomley's belief that the patent system in Britain «did indeed encourage the development and diffusion of technology during the Industrial Revolution» (Bottomley 2014, p. 174).

4. *Specific Institutions (cont'd): The Poor Law and Economic Integration*

Britain was unique in two other aspects that we might consider «institutional» and may have played a role in triggering the Industrial Revolution. One was the English Poor Law, first passed in 1601 (twenty-three years before the

Statute of Monopolies that set up the patent system). No other European country had anything like it. Many cities on the Continent had municipal authorities and charities that looked after the poor, paid for orphanages and hospitals and the like, but they were local in nature. England was unique in making the system nation-wide~~, mandatory~~ and mandatory. It extended ~~extending~~ the system to ~~(and emphasizing)~~ rural poverty to ~~and~~ prevent~~-ing~~ starvation on the countryside. Unlike the Patent office (at least in its ultimate form), it was in no way designed or meant to support economic development and technologi-cal progress. Here, then, was a clear-cut case of unintended consequences.

In a seminal paper, Peter Solar (1995) argued that the Poor Law in England was a form of insurance that was relatively free from the usual banes of insurance markets, moral hazard and adverse selection. It may have reduced the need to own land, and encouraged the emergence of rural wage-labor and cottage industries, which were inherently riskier and more volatile sources of income and thus made more attractive by the existence of some form of social insurance. In that way, the Poor Law helped create a rural wage labor force necessary to create the capitalist, market-oriented farm system that made Britain's agriculture the most productive and efficient in Europe. Cottage industries, in some views, played a role in enhancing industrialization. Solar's work was extended by other scholars who saw a connection be-tween this institution and the rise of the Industrial Revolu-tion.[13] A different approach, but with rather similar impli-cations is taken by Kelly and Ó Gráda (2014) arguing that the English Poor Law effectively terminated the Malthusian «positive check» and placed England in a different demo-graphic regime in which major famines became rare and starvation unusual. While the Poor Law in all likelihood made Britain a different (and arguably a better) economy ~~economy),~~ it affected only the bottom income brackets of the population; much of the action that resulted in the Industrial Revolution

[13] **Greif, Iyigun and Sasson (2013)** ~~**(2011)**~~ extended Solar's idea that the Poor Laws provided a safety net that encouraged people to take more risks. Essentially, it provided a risk-sharing mechanism that may have led to more risk-taking and entrepreneurial behavior. ~~In a similar vein,~~ ~~**Greif, Iyigun and Sasson (2012)**~~ Furthermore, they argued that the Old Poor Law helped foster social order and prevented riots and thus created the relatively peaceful environment needed for economic development and softened the popular resistance to labor-saving innovations thought to destroy the livelihood of workers.

was in the higher (though not the highest) brackets. Something more must have been at play.

One factor that has not been sufficiently emphasized is the economic integration of Great Britain. Many ancien régime continental states still had formidable barriers to the move-ment of goods that impeded internal trade: in Germany and Italy, of course, political fragmentation paired with mercantilist regulations encumbered the ~~prevented~~ free movement of goods and labor. But in France and Spain too, seemingly unified, internal tariffs hampered the free flow of goods, and were one of the early items that the French Revolution targeted for abolition (Dincecco 2010; Grafe 2012). The French Revolution and subsequent upheavals (with its inevitable high costs) were necessary to eliminate an advantage that Britain had enjoyed since the Middle Ages. This institutional advantage was mag-nified by coastal shipping, and an improving highway and canal system. At first blush integration may seem to have benefitted Smithian rather than Schumpeterian growth, but regional specialization meant that the returns to investing in human capital in the regions that had a comparative advan-tage in high-skill production would increase (Kelly, Mokyr and Ó Gráda 2022 ~~2021).~~ Other connections from market integra-tion and better transport to technological progress have been analyzed in detail in Szostak (1991). Beyond Adam Smith's famous advantages of the division of labor, Szostak notes the many other advantages that an integrated market offered, such as quality-standardization, investment in management and marketing, and more intense competition. The full dy-namic gains from trade were just much larger that the «little triangles» of standard static micro-economics and the spill-overs from trade to technology remain an under-researched topic in the economic history of the Industrial Revolution.

Here, too, institutions mattered: Britain was a highly taxed country, but by eschewing internal tariffs as a source of state revenue the British were able to benefit from grow-ing regional specialization and gains from (internal) trade. To the absence of internal trade barriers and an improving transportation infrastructure, we may add the important matter of weights and measures, a major source of com-plaints by enlightenment writers in eighteenth-century con-tinental Europe (and a target by rationalizing policy mak-ers after 1789). Transactions costs were reduced by a uni-fied and reasonably stable currency

weights and measures. It was understood that standardization was desirable, but its introduction in Great Britain was cautious and gradual. As Julian Hoppit notes in his classic essay on the topic, «the survival of non-standard weights and measures is an indication of value systems surrounding exchange which were often locally orientated, customary and traditional» (1993, p. 102). In France, the heavy-handed way in which the metric system was imposed after the revolution generated resistance and it took many decades until it became universal (Alder 2002). In Britain, «Reform was conservative because it wanted to ensure success» (Hoppit 1993, p. 103).

The significance of economic integration to the Industrial Revolution is fully elaborated elsewhere (Kelly, Mokyr and Ó Gráda 2022 ~~2021~~). The logic is quite intuitive: in a simple model of regional specialization with endogenous human capital, the return on investment in training in skilled labor will increase with the degree of regional specialization in the region that has a comparative advantage in skilled-labor-intensive manufacturing. Such a region will face higher de-mand and, as a result of finer specialization, it will reduce the production of low-skill products (including agriculture). Hence the supply of high-skilled labor in that region will in-crease, and once it interacts with the flow of new ideas («in-dustrial enlightenment») it opens the floodgates of innova-tion. I shall return to this idea below.

5. *Institutions and technological progress: an Alternative Hypothesis*

As I have argued elsewhere (Mokyr 2008; 2009), by the eighteenth century Britain had become what might best be called a «Civil Economy». Social norms and reputational mechanisms ensured that most economic agents were cooperative and that opportunistic behavior became relatively rare. The quantitative evidence for that view comes in part from fewer court cases (less litigiousness) and in part from the growth of Peter Clark's «associational society» (Clark 2000).[14] The logic, in short, is that cooperative

[14] People needed to send out costly signals that indicated to others that they were reliable and trustworthy because they belonged to a class of reliable and trustworthy agents (see, e.g., Posner 2000). It was important that these signals

(«gentlemanly») behavior became an important norm because reputations became increasingly valuable in a world in which economic and social networks intersected and often determined one's social standing jointly with economic outcomes.[15] Beyond that, Britain was a society of networks and connections, in which individuals interacted and collaborated in a variety of ways that were technologically important. This was strikingly demonstrated by Cookson for one industry, textile machinery, in Yorkshire. In her view, social connections «self-evidently [...] underpin the foundations of engineering in both Leeds and Keighley» (Cookson 2018, p. 10).

How and why did this institutional development matter to the Industrial Revolution? Cooperation and trust mattered at many levels: lower transactions cost, less wasteful litigation, less conflict between partners and between industrialists and the people they dealt with. Here, however, I will concentrate on one aspect, which has been somewhat overlooked, namely the supply of highly skilled labor, the upper tail of the distribution of human capital (UTHC) of craftsmen and engineers. The main reason why this element is so important is what may be called the Great Complementarity: the synergistic relationship between the creativity and originality of the inventors and the skills and dexterity of the artisans who actually built the devices, installed them, scaled them up, maintained and repaired them. These artisans were thus an essential component in the system that implemented new technical ideas and turned them into reality.

There is considerable evidence, both anecdotal and statistical, that Britain's «ingenious mechanics» were far more skilled than those of the Continent. The evidence for this gap is quite strong: beyond the many statements of con-

be costly, so that they could be credible. Such signals were the good manners in dress and language, residential location («a good address»), and the etiquette and manners observed by the British upper classes, and their adoption by the commercial classes. These norms created a stylized ideal of gentlemanly capitalism that resulted in an environment in which bourgeois entrepreneurs could deal with one another and with their subordinates in a cooperative fashion that made commerce and finance work (Sunderland 2007, pp. 15-32).

[15] The economics of behavioral norms is quite intuitive (Spagnolo 1999). If social and economic networks are strongly linked, opportunistic behavior in one sphere can be punished on a much wider front and hence it can become much more costly. The emergence of a world in which middle-class Britons met and interacted in a variety of formal and informal clubs and networks supported the emergence of a more cooperative «civil economy».

temporary economists and businessmen, the most powerful smoking gun is the continuous migration of British artisans to the Continent to install and operate cutting-edge technology in iron, textiles and other industries, and the attempts of a government that still had not fully shaken off the mercantilist state of mind to try to keep these skilled workers in Britain. In a classic of economic history, Henderson (1954) has documented this movement. More modern work has filled in the details on British artisans in France (Bensimon 2011). But things were not different elsewhere on the Continent.[16]

The significance of this superiority has not been stressed enough in the literature of the Industrial Revolution (although see Berg 1994, p. 7). Britain, of course, was an inventive country, and many of the famous and not so famous technological advances were made there. But other nations displayed inventiveness and ingenuity, and many of the most successful inventions of the era were made on the Continent, especially in France (including in the textile industry – one thinks of the invention of chlorine bleaching or the Jacquard loom). Yet astonishingly many of these inventions were first put into practice and perfected in Britain. One reason was that the technical wherewithal to actually make the new idea work, abundant in Britain, was rare on the Continent. So, perhaps, were other factors such as more aggressive entrepreneurs and available finance, though these are harder to demonstrate.

The real question, then, becomes why and how Britain attained this superiority. To unpack the answer, it is useful to stress that artisanal knowledge was reproduced almost exclusively through apprenticeship relations. As Jane Humphries (2003, p. 74) has emphasized in her seminal paper on the topic, skills were learned, not transmitted genetically, and, without a better recognition of the efficiency of the system that produced these skills, we will not fully

[16] For instance in the German-speaking lands, the metallurgical industry in Prussian Silesia was built up by a Scotsman, John Baildon (1772-1846) who left Scotland at age 21 and spent his distinguished engineering career in that Prussian Province, followed by his son William (Szymonowicz 2007). Three skilled British workers set up and supervised the new mules established by a Saxon entrepreneur in Harthau (a suburb of the Saxon city of Chemnitz) in 1798, and another Englishman was placed in charge of another textile mill in Chemnitz a year later. The largest cotton mills on the Continent may have been the one in Pottendorf in Lower Austria, under the leadership of the Manchester mechanical engineer John Thornton (1771-1847) and his brothers.

understand Britain's leadership. The typical master of any «trade» (that is, occupation) was engaged in classic joint production: he produced the goods or services that he specialized in, and transmitted the knowledge he had to the next generation through apprenticeship.[17] The relationship between apprentice and master was determined by an explicit or implicit contract, which laid out the terms of the exchange between them.[18]

The transaction was far from simple: it was a contract in which two bundles were exchanged. The master provided instruction, as well as the tools and materials for the apprentice to experiment and learn. In addition in many cases he provided room and board, as well as other services (for example teaching the apprentice reading skills).[19] The apprentice paid a fee, provided unskilled labor services at the start and then committed himself to a few years of unpaid or low-wage
labor at the end of his apprenticeship. When concluded between unrelated individuals, such a contract provided endless opportunities for shirking and reneging on promises. It was the mother of all incomplete contracts: non-repeated, riven with unobserved and often unobservable dimensions of the exchange, and many possibilities for opportunistic behavior and disputes.

What made the apprenticeship contract particularly tricky is that the knowledge transmitted was almost entirely *tacit*, to use Polanyi's classic distinction. No one stressed this more in the context of the Industrial Revolution than John R. Harris.[20] Harris noted that in the iron and coal industries what really mattered were «unanalyzable pieces of expertise» and «the knacks of the trade» (Harris 1992, p. 33). The tacitness of the knowledge made verifying the quality of the instruction by the master for all intents and purposes wholly

[17] Some of the following is adapted from De la Croix, Doepke and Mokyr (2018) and Mokyr (2019).

[18] For a more detailed analysis of the economics of apprenticeship, see Smits and Stromback (2001); De la Croix, Doepke and Mokyr (2018); Mokyr (2019).

[19] One historian of apprenticeship has argued that masters transmitted to their apprentices both skills and «values, mores and cultural codes» and served as «surrogate fathers» (De Munck 2007, pp. 4-5).

[20] The tacitness was recognized by contemporary observers. The French chemist and politician, Jean-Antoine Chaptal was one of many who recognized the importance of tacit knowledge in Britain's precociousness when he pointed out that a central part of British know-how was what he called *tours de main* (tricks) and habits that were the soul of industry. Neither he nor his economist compatriot Jean-Baptiste Say ever spelled out how and why it was that Britain could count on the «superiority of its workmen» (as Say put it).

unobservable. Apprentices learned by being inserted ~~«inserted~~ into the production process~~»~~ from the start and in the absence of any serious epistemic base of the techniques in use, learning by doing and emulation were clearly central in the process. Without some ~~form of~~ institutional basis that ~~led to~~ supported trust and the willingness to forego opportunistic behavior on both sides, the institution might well have unraveled.

The many complications of the contract meant in effect that in much of the world apprenticeship relations remained within the family and sons would be taught by their fathers, in which case opportunistic behavior would obviously be minimized. In farming this was generally the case, but in other occupations there were considerable advantages to expand the set from which a master would be chosen. The exact number of sons being taught by their fathers is hard to establish, because within families there was no need to draw up a full (and costly) contract. Yet the evidence indicates that it was common for apprentices to be taught by unrelated masters, thus making the market for human capital more efficient. [21] That fact raises the question of how the contract was enforced and how the inevitable disputes that arose between the parties would be resolved.

As pointed out in detail by S.R. Epstein and others, in providing the solution to these contractual dilemmas, craft guilds played a central role (Epstein 2013, pp. 31-32). In many areas, guilds enforced the contract and could sanction nonperforming masters or recalcitrant apprentices. The degree to which craft guilds exercised this function could vary substantially over time and space. But what is often left out from the discussion is that craft guilds were also social organizations, which mixed collective action with social networking. As such, they were a mechanism of information transmission, through which reputation mechanisms could function. Masters and (presumably) apprentices were ~~fully~~ aware of the reputational costs that misbehavior could entail. In the end, however, guilds provided a means for the system to reproduce skills, but as their rules became more rigid, they tended increasingly to crystallize existing technology (Ogilvie 2019).

[21] One study of medieval Montpellier finds that as early as the fourteenth century, only a minute fraction (c. 5 percent) of all apprentices followed in their father's occupation (Reyerson 1992, p. 357). For other examples of similar findings, see for instance Leunig, Minns and Wallis (2011, p. 423); Prak (2013, p. 153); and, for a similar observation for ancient Rome, see Hawkins (2016, pp. 198-202).

The civil economy that emerged in Britain in the eighteenth century contributed to the effectiveness of a flexible and market-oriented apprenticeship system, in which, the formal legal structures of the 1562 Statute notwithstanding, the system was quite adaptable and produced workers who were – at least comparatively – agile in their competences. Successful entrepreneurs, such as the Yorkshire textile ma-chine makers were hiring well-trained artisans, and were able to make them do things they never did before (Cookson 2018, pp. 106, 126).[22] A quantitative analysis of the re-sponse of British apprenticeship to technological «shocks» fully confirms this view of an adaptable, nimble system in which skills were both sophisticated and protean (Ben Zeev, Mokyr and van der Beek 2017). We know the names only a few hundred of those ingenious mechanics and engineers (Meisenzahl and Mokyr 2012), but right below those who can be traced, there were many more whose skills made the British Industrial Revolution possible.[23]

6. *Institutions and the Enlightenment*

To sum up the argument so far, there were many links between the quality of institutions and the economic and technological advances between 1760 and 1830 that we call the Industrial Revolution. Yet there is far more to the story. In the final knowledge we need to recognize the role played by what we call today «science» – essentially for-mal knowledge («natural philosophy») practiced largely by well-educated intellectuals, most of them with a knack for practical questions. The vast bulk of important scien-tists of the eighteenth century were concerned with prac-tical questions, none more so than Jean T. Desaguliers, Stephen Hales, Joseph Black, William Irvine, and Joseph Priestley. Some professional engineers were scientifically informed, such as John Smeaton or William Strutt. Some

[22] The most telling evidence for this agility was that a full one-third of the list of innovators compiled by Anton Howes made inventions that were quite different from the specialized training and skill of the inventor and invented in a range of seemingly unrelated fields (Howes 2017, p. 36). High-level skills did not yet imply high levels of specialization. As Howes put it, «mechanical training could be applied to anything, from textile machinery to agricultural machinery to coachbuilding» (p. 24).

[23] A comprehensive compilation of the engineers of the age is Skempton (2002). For an analysis, see Meisenzahl and Mokyr (2012).

industrialists, similarly, ~~had good~~ possessed considerable scientific knowledge or kept close connections with scientists.[24] A market for scientific consultants developed in the eighteenth century.[25] The bridges between those who made things and those who knew things were getting wider and easier to travel; that, in short, was the essence of what I have called elsewhere the Industrial Enlightenment (Mokyr 2009a).[26] These, too, should be seen as part of the institutional background of the Industrial Revolution.

While at its base the Industrial Enlightenment was a cultural phenomenon reflecting a belief in material progress and ideas on how to bring it about, it had deep institutional roots. The «associational society» that Peter Clark described so well included formal and informal networks of what is known as public science, in which scientific and philosophical societies organized meetings, lectures, and public experiments (Stewart 1992). Masonic lodges were another common meeting place of the educated elite. It was in these networks that much of the interaction between producers and natural philosophers occurred. For the Great Complementarity between ideas and practice to occur, the practitioners on both sides had to connect. The famed «Lunar Society» was only the tip of the iceberg here: less regular (and less high-powered) meetings occurred in taverns, private salons, and provincial societies.

Why did this matter?[27] Historically, one of the great sources of technological stagnation had been the social divide between those who knew things (*savants*) and those

[24] For example, the Manchester cotton spinner George A. Lee, the owner of the first industrial mill to introduce gas lighting, was described by none other than Robert Owen as «one of the most scientific men of his age» (cited by Musson and Robinson 1969, p. 99). Josiah Wedgwood, of course, was a Fellow of the Royal Society, an amateur geologist, and a close friend of both Priestley and Erasmus Darwin. Thomas Bentley, Wedgwood's partner, was a genuine intellectual who spoke fluent French and Italian and was a founder and trustee of the celebrated Warrington dissenting academy.

[25] Among the most successful of these consultants were the clockmaker John Whitehurst, a member of the Lunar society, and the Cornish applied mathematician Davies Giddy (Gilbert). Whether this activity, while lucrative, actually yielded on average any tangible net benefits to those who hired consultants is no more obvious in the eighteenth century than it is today. For more details, see Mokyr (2009a, pp. 57-59).

[26] For a more detailed argument regarding the role of science, see the classic Musson and Robinson (1969) and more recently **Jacob (2014)**. The notion of the Enlightenment as a movement toward the practical improvement of material life through useful knowledge – the essence of modern economic growth – has found its expression in titles such as Peter Jones (2016) and earlier in Porter (1982) and Cunningham and French (2006).

[27] Some of the following is adapted from Mokyr (2005).

who made things (*fabricants*).[28] The importance of establishing connections between these two groups ~~this connection~~ was first pointed out by the sociologist Edward Zilsel (1942), who emphasized the importance of the relationship between artisans and intellectuals for subsequent economic development. To construct pipelines or *passerelles* as Hilaire-Pérez (2000) has called them, through which ~~those two groups~~ t h e y could communicate was at the core of the Industrial Enlightenment project. The commu-nications ran in both directions: practical people with spe-cific technical problems to solve could access and absorb whatever best-practice p r o p o s i t i o n a l knowledge had to offer – which, of course, at most times was rather little. At the same time, the needs of crafts and manufactures could influence the research agenda of the scientists. The close connections be-tween James Watt and his Scottish academic friends John Robison and Joseph Black are a prime example. So was the growing demand for scientifically informed consultants by progressive industrialists.

The Industrial Enlightenment, interestingly enough, was to some extent a provincial affair. London, of course, re-mained the cultural center of the country ~~where~~ in which a large number of skilled artisans catered to the local market. But in provincial towns such as Manchester, Liverpool, Newcas-tle, and Leeds, we find as J.H. Plumb (1972, p p . 2 3 - 2 4) memorably put it, «knots of enlightened men with a passionate regard for empirical knowledge, secular in their intellectual attitudes, although often muddled, uncertain and tentative, with [...] rational and irrational beliefs combined in the same man». Their interests, unlike many of the great *philosophes* on the Continent, were not in deep political issues, but in practical and pragmatic ones such as pistons, pumps, and pulleys.

Such a ~~bilateral~~ bi-directional interchange between formal science and technology seems natural to us in the twenty-first century. In eighteenth-century Europe, however, such interactions were slow and gradual to develop and grow, resisted by social inertia and snobbery. Yet in the longer run they proved as inexorable as they were crucial to the continuing progress of technology. The Enlightenment in Britain, which by com-

[28] In one of his most perceptive essays, Needham (1969, p. 27) pointed out that in Imperial China real work in engineering was «always done by illiterate or

parison was more practical and focused on material issues, was consonant with the growth of communications between natural philosophers and the more progressive industrialists of the time (Porter 1981).

7. *Conclusions*

Institutions, in the sense of setting incentives and creating both opportunities and the rewards for taking advantage of them, have become a major theme in economic history. Yet oddly enough, with some exceptions, they have not been systematically explored in trying to understand why the Industrial Revolution occurred first in Britain.[29] What is needed above all, is an explanation of the impact of institutions on innovation and technological creativity in an eighteenth-century context. In other words, to understand the Industrial Revolution, we need to lay bare why innovation occurred at all, as most societies that existed before 1750 were far less innovative than eighteenth-century Britain. An examination of the various institutional aspects shows, first and foremost, that political institutions and the other institutions that determined the distribution of power and authority in Britain were important, but so were private-order institutions. What is now needed above all are measurement and testing of the impact of institutions as much as possible; in this debate an ounce of data is worth ~~more than~~ a pound of theory.[30]

The deeper question, and one that the neo-institutional literature has struggled to answer, is why some economies have institutions that are more conducive to technological progress than others and therefore become technological leaders, if only for limited periods. Are institutions themselves endogenous to economic and material factors as Marxian orthodoxy maintained? Or are they wholly determined by what people value and believe, as recently argued by McCloskey (2021b)? I have ~~made a similar argument~~ discussed the issue at considerable length in **Mokyr (2016)**.[31] It seems reasonable

[29] For earlier surveys see Kapás (2012) and Mokyr (2008; 2021).

[30] A pioneering attempt to test some of the alternative hypotheses is Dowey (2016); see also Kelly, Mokyr and Ó Gráda (2021).

[31] There is a somewhat pedantic debate on whether the word «culture» is an appropriate term. McCloskey (2021b) feels that «'culture' is merely the vague way in which economists talk when they have not actually taken on board the exact

to argue that rather than one «driving» the other, they co-evolved, affecting one another. Furthermore, both were ~~but also both~~ affected by exogenous shocks and events. History, however, is rich with examples in which institutions were not ~~in any way~~ chosen by societies, but imposed through raw political and military power.

The exact way in which culture affects institutions is a topic that still awaits full incorporation in economic history, and will be a project large enough to keep an entire generation of scholars busy (Alesina and Giuliano 2015). But proof of the notion that any single cultural factor is either necessary or sufficient to create the kinds of institutions needed for technological progress seems so far elusive. In many cases institutions were created for one reason and led to unintended consequences. In other cases, fairly small events led to contingent institutional outcomes with far-reaching implications for innovation and economic prog-ress. Neither the Poor Law of 1601 nor the Patent system ~~Office~~ of 1624 were created by people with an Industrial Revolu-tion in mind. Moreover, disequilibria can persist between what people want and like and the kind of institutions they actually experience. After all, political revolutions can occur quite abruptly, and it seems implausible that Russian cul-ture was completely turned upside down between 1985 and 1991 or Iranian culture changed dramatically between 1978 and 1980. Closer to the topic at hand here, McCloskey ar-gues that an ideology of liberalism and individual freedom led to «a liberal releasing of opportunity» and was the key to growth. In fact, however, eighteenth century Britain was hardly the liberal (in the classical sense) *laissez faire* society it was to become in the second quarter of the nineteenth century. It was a highly regulated and protectionist state in which rent-seeking and mercantilist ideas ~~constrained~~ encumbered and distorted many markets. Moreover, non-liberal institutions can, under the right kind of government, generate innovation and technological progress, even if it is perhaps less sustainable and welfare-enhancing as free-market pluralist societies.

and gigantic literature about ideas, myths, stories, rhetoric, ideology, metaphors, ceremonies, and the like since the Greeks, the Talmudists, or the Sanskrit grammarians». Basically, however, the standard definitions of culture as the «unions of the sets of shared beliefs and values in a society» as proposed by **Boyd and Richerson (1985**, p. 2) in their pioneering work on cultural evolution seems perfectly adequate for the purpose at hand.

Furthermore, anyone arguing for the primacy of culture over institutions owes us – no mean requirement – some kind of theory of where ideas come from and why they become prevalent, that is, why they triumph in the market place for ideas. To complicate matters further: institutions in turn can successfully bring about cultural change by successful propaganda and steering education and social conditioning in one direction or another.[32] In the absence of a more general theory explaining the coevolution of culture and institutions, we have to be satisfied with the (only slightly) more modest project of finding how institutions helped bring about the Great Enrichment.

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[32] Of the many examples that illustrate this point, a striking one is the success of Nazi educational policies to install antisemitic ideas in German youngsters, a culture that survived into the post-war period. See Voigtländer and Voth (2015).

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