Progress, Useful Knowledge and the Origins of the Industrial Revolution

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Introduction

Why and how does culture precisely matter to economic growth? The most obvious channel works through trust, loyalty and what Tabellini calls "general morality" or public-mindedness: individuals contribute to social well-being even if narrow egotism might have suggested otherwise.[1] Suitable attitudes and beliefs about the behavior of others supports markets, the production of public goods, and reduces transactions- and enforcement costs. Culture makes cooperation without third party enforcement easier, and thus may be crucial to the emergence of markets, the division of labor, and the infrastructure that made them possible. In that sense the effect of culture is *indirect*: it affects institutions, either formal or informal, and "cultural beliefs" as defined by Greif (1994, 2005) play a central role in the emergence of markets and commercial development.

Writing about the cultural origins of the Industrial Revolution used to be a risky undertaking in the early days of Cliometrics, when using words like "institutions" and "culture" immediately would brand the speaker as a "soft" sociologist or worse. This was particularly true for the economic history of the Industrial Revolution.[2] The revolution brought about by the work of Douglass North and Avner Greif, have rehabilitated the concept of institutions, and by now it has been embraced by mainstream economists (Zak and Knack, 2001; Acemoglu, Johnson and Robinson, 2005; Acemoglu and Robinson, 2012). If institutions have been rehabilitated, can culture be far behind?[3]

In addition to providing the foundation for markets and exchange, culture could also affect economic activities in a *direct* fashion through determining some of the preferences and attitudes of individuals in the spirit of (among others) Max Weber and David Landes.[4] The argument relies on the assumption that preferences are to a large extent acquired through socialization and not wholly hard-wired. It hardly makes any difference to the economy if individuals prefer spicy to bland food, and (perhaps) only a minor difference if they have a strong preference for alcohol. But the preference for leisure may well determine labor force participation and number of hours worked; time preference will determine the rate of capital formation (including human capital);[5] attitudes

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[1]This finding is supported in the experimental literature as surveyed for example in Bowles (2004, pp. 110–19).

[2]The one scholar who courageously stepped into that breach was Flinn (1966) who dedicated a short chapter to the intellectual and social origins of the Industrial Revolution.

[3]Some economic historians, above all of course David Landes, have maintained all along that culture was central to economic growth. See Landes, 1998, 2000). Among the most notable papers in formal theory is the influential work of Bisin and Verdier (2001). Empirical work includes the work of Tabellini (2008, 2010).

[4]A recent and powerful statement of this kind of cultural change as a fount for economic success is McCloskey (2006).

[5]This is one of the arguments made by Doepke and Zilibotti (2005), who refer to the concept as *patience capital* and explicitly model it as a cultural variable passed on from parents to children, using a model similar to Bisin and Verdier. In similar fashion, they model the preference for leisure as being inculcated by parents through the process of

toward risk (which determined, presumably, the rate of entrepreneurial activity in the economy); and the importance that parents attached to the education of their children, either because they cared about their income or for other (e.g., religious) reasons.

In this essay, I will propose a third and hitherto neglected mechanism through which culture might have affected economic outcomes, and specifically suggest a new way of thinking about the "Great Divergence" between East and West after 1700 or so. This mechanism concerns the cultural (and institutional) underpinnings of technological progress. Technological progress and invention involve certain metaphysical assumptions One component involves the relationship with the natural environment and the role of humans in the creation. As Lynne White and many others have pointed out, technology will advance faster if individuals adhere to a set of anthropocentric notions in which the universe is believed to have been created for the service of mankind. A second component is intelligibility: people are more inclined to manipulate natural forces if the universe is not believed to be beyond our comprehension, even if the entity that supposedly created it may be (Dear, 2006). A third component, and the one I will focus on here, is the belief in progress itself and the capability of science and technology (what I will refer to as "useful knowledge") of bringing it about.

What is the connection between economic growth and a belief in progress? As I have argued in Mokyr (2009a, pp. 33-35), sustained economic progress depended on three factors. First, that progress (of any sort, but specifically material progress driven by growing useful knowledge) was believed to be at all *possible* and that History was capable of producing an upward trend, albeit a non-monotonic one. Second that such a trend was *desirable* and that material progress and economic sophistication would improve some social welfare function, whether utilitarian or other. Third, if the first two are answered in the affirmative, such progress would not happen on its own but depended on a concrete program that would actually bring it about. This account is not quite the teleological model this might seem: the program for economic progress was put forward by a relatively small group of intellectuals, who disagreed heartily among themselves and had to fight for its implementation and in many cases used it as an excuse to advance a fairly narrow interest. The set of beliefs that emerged out of that struggle is what I have called the Industrial Enlightenment and they shared two rather vague principles. One was that material progress could be brought about by the growth and diffusion of science and technology. The other was that economic well-being demanded the reform of social institutions (and they had quite divergent ideas on how to bring these about). But why did the people who held these beliefs emerge triumphant in Europe, and why not elsewhere in a similar form?

Such a victory was far from pre-ordained and resulted from the special circumstances that prevailed in early modern Europe. While in that sense it may have been quite historically contingent, it provides a possible answer to questions about the origins of the Great Divergence. What we should focus on is the competitive market for ideas in which intellectual innovators present their ideas and try to persuade others of their value and validity. This market determined the success or failure of efforts in what we would call today "R&D" in increasing productivity broadly defined. In the past,

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socialization.

arguments about the market for ideas were influenced by the somewhat tired dispute regarding Historical Materialism vs. Idealism: does culture adapt to the material needs of society determined by geography, demography, technology and so on, or is culture an independent actor that controls economic forces and thus determines performance?[6] In more recent years, a new approach has been proposed that seems more fruitful, namely cultural evolution (e.g., Boyd and Richerson, 2005; Mesoudi, 2011). In this approach, culture is seen as a set of beliefs and preferences that is learned rather than hardwired. The default option is always to learn from one's parents, but as additional inputs are encountered during socialization and later life, the individual may abandon the default and pick a different variant.

Cultural choices are not quite like other choices in economics, and hence the concept of a "market for ideas" does not correspond neatly to other markets. Of course, we use the idea of a "market" for other areas in which goods are not bought and sold for a price, such as the "marriage market" and the "political market." But at least in the marriage market, the opportunity cost of picking a partner is well-defined in monogamous societies. In the market for ideas, the opportunity costs are less clear-cut. In some cases, of course, much like the marriage market, the choice is clear: one cannot be a Catholic and a Jew or believe in Ptolemaic and Copernican universe at the same time. But in many other cases buying into a new notion may not crowd out existing beliefs but simply be added to them. In evolutionary terms, this would be equivalent to saying that the selection environment is not very stringent.[7] All the same, what is happening in the market for ideas is that the sellers of ideas try to persuade an audience of the merit of their views and adopt it as part of their beliefs.

The notion of *persuasion* is critical to the operation of the market for ideas. There is no precise equivalent to the concept of a price, but ideas and beliefs are accepted or rejected on the basis of their inherent quality and other environmental parameters. Such persuasion means that people abandon the default option, and are subject to what cultural evolution scholars have called *biases*. I have described these biases in detail elsewhere (Mokyr, 2013). What is meant by bias here is that cultural choices follow certain identifiable patterns that make people "choose" one cultural element over another (Richerson and Boyd, 2005). Biases are a choice procedure that is somewhere half-way between the rational and informed decision-making of neoclassical agents and the mindless evolutionary behavior of Dawkinsian replicators. They guide the infrequent choices made a few times over a lifetime in which people make cultural decisions, such as whether to be conservative or liberal, religious or not, and whether to become a vegetarian or a dog-lover. Because there are often considerable fixed information costs in making such choices, some of the biases are

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[6]For a detailed and insightful discussion of these debates, see Jones (2006).

[7]People might believe that there are natural regularities to which there are exceptions (such as magic). The selection criteria on any kind of cultural belief are contingent, and it is easy to envisage a climate in which the question "but is it true?" can be routinely answered by "sometimes" or "maybe" or "if God wills it." An example is the Jain belief of *syadvada*, which can be summarized to say that "the world of appearances may or may not be real, or both may and may not be real, or may be indescribable, or may be real and indescribable, or unreal and indescribable, or in the end may be real *and* unreal *and* indescribable.*"* Cited by Kaplan (1999), p. 45, emph. added.

determined by those costs. Thus there is a *direct bias*, in which choices are made by individuals following authorities and experts, and there is *conformity* (or frequency-dependence) *bias* in which agents simply choose what the majority of others around them choose assuming that others have acquired the information necessary. These biases then play themselves out in the market for idea, and determine which ideas survive in the struggle for survival in defined social groups.

The outcomes depend to a large extent on the parameters of the "market for ideas." The most important element of the effectiveness of a market is its competitiveness, the ease of entry, and its size, all of which are of course very much related. A critical component of the market for ideas is the ability of incumbents to defend their turf and reduce contestability by declaring some ideas as beyond debate. Concepts such as "heresy" and "apostasy" express the ability of existing ideas to erect barriers to entry and keep others from challenging the ruling conventional wisdom. Doctrinaire historical materialism would stress economic interests as the main determinant of the outcomes. More nuanced approaches would stress not only the structure of the market, but also rhetorical conventions: what counts as a valid argument, what is admissible as evidence, and who is an authority. It also recognizes that there is a certain historical contingency in the outcome of academic and intellectual competition.[8]

The argument I am making below is simple: between 1500 and 1700, the market for ideas changed in dramatic ways in large parts of Europe, preparing the way for the Enlightenment. The changes occurred on all three dimensions: the material interests of an urban mercantile ("capitalist") class became much more prominent; the rules of the market changed, with entry become much more free and the capability of incumbents to suppress "heresy" weakening over time; and the importance of experimental data and systematic observations coupled to more formal methods became a more accepted means of persuasion. None of those were entirely new in 1500, but their impact on the cultural evolution of Europe increased.

What interests me here is how this phenomenon can resolve what might be thought of as "the Great Puzzle" of modern European economic growth. The Puzzle is basically this: if we accept the recent near-consensus that institutions are one of the key components of economic performance through the rise of functioning markets, the rule of law, and well-defined property rights, it is hard to explain the Industrial Revolution. After all, the Industrial Revolution marks the rise of the *technological* component of growth, what is often called Schumpeterian Growth. Institutions are the foundation of Smithian Growth: law and order, better markets, more gains from trade and specialization, more efficient allocations, possibly more investment, all of which leads to more growth. But it is difficult to see a systematic difference between Europe and Asia in this regard as late as 1700, and we know that trade within China at that time was highly developed, and that property rights (while quite different than in Europe) were no less effective. But the Industrial Revolution was not about further Smithian growth, it was about useful knowledge and new techniques revolutionizing production and productivity. Whence this advantage?

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[8]For a recent restatement of the orthodox materialist position, see Morris (2010), pp. 423, 476 in which he claims that the best theorists give their age the ideas "it needed" and ask the questions that "social developments force onto them" – a rather oversimplified argument coming from a subtle and learned scholar.

The obvious solution would be that Europe had some kind of institution that encouraged and supported technological change at a higher rate than elsewhere, that is, the Industrial Revolution had deep intellectual and institutional origins (Mokyr,2005, 2008). One institution that seems at first blush the obvious solution to the Great Puzzle is intellectual property rights. In many parts of Europe there was some form of patent system and other forms of incentives in which society encouraged and rewarded technologically creative people who could take credit for some important innovation. Britain had a patent system since 1624, and the Netherlands had their own patent system during the golden age and the eighteenth century. Yet much research has shown that the patent system covered only a small proportion of all relevant inventions, and that its net effects on technological progress are in all likelihood of a second order (Mokyr, 2009b). All the same, there was more to incentivizing inventors than just patents, and rewarding them by recognizing their contribution to society may have been part of the explanation of Europe's success.[9] However, the emergence of IPR's in Europe reflect a deeper phenomenon, namely the success of a *culture of progress* in the European market for ideas. It is that phenomenon I wish to address here.

A Culture of Progress

A prevalent *belief* in the possibility and desirability of progress was probably neither a necessary nor a sufficient condition for it to occur. Yet it was an important element. One interpretation of the idea of progress is that it is logically equivalent to an implied disrespect of previous generations. As Carl Becker noted in his classic work written in the early 1930s, "a Philosopher could not grasp the modern idea of progress ... until he was willing to abandon ancestor worship, until he analyzed away his inferiority complex toward the past, and realized that his own generation was superior to any yet known" (Becker [1932], 2003, p. 131). Seventeenth century Europe already shows quite a few signs of a belief in progress, starting with Bacon and Descartes themselves and their disciples. The young Blaise Pascal, for instance, deeply influenced by Descartes, saw the world of knowledge as if it was a single infinitely-lived individual, "incessantly learning" (cited by Bury, 1955, p. 68). [10]

The notion that progress was an apt description of their own age spread among the British writers of the seventeenth century, including the work of the (non-Puritan) clergyman Joseph Glanvill (1636–1680), who wrote a famous book entitled *Plus ultra, or, The Progress and Advancement of Knowledge since the Days of Aristotle* (1668) in which he proudly listed area by area the advances that science had made since antiquity, much of which he ascribed to the work of the Royal Society and its members. He noted with some exuberance that "a ground of high expectation from Experimental Philosophy is given, by the happy genius of this present Age... and that

[9]Many important innovators in Britain who, for one reason or another, were unable to make use of the patent system, were rewarded by special acts of Parliament. Among them Edward Jenner is the best known, but others include Edmund Cartwright, Samuel Crompton and the Fourdrinier brothers who pioneered continuous paper making in Britain.

[10]In later years, Pascal was converted to Jansenism, a religious creed that was far more contemplative and morally-oriented and he renounced his earlier views and wrote of the "vanity of science" — a good example of how competing religious beliefs, had they prevailed, might have thwarted the progress toward more advanced science and technology.

a ground of expecting considerable things from Experimental Philosophy is given by those things which have been found out by illiterate tradesmen or lighted by chance" (Glanvill, 1668, pp. 104–05).[11] To be sure, not all authors of the late seventeenth and eighteenth century subscribed to a belief that progress was possible or even likely, and doubting Thomases such as Hobbes never quite bought into it, pining for stability more than continuous material improvement. As Israel (2010, p. 4) has recently put it, Enlightenment theories of progress were tempered by a sense of the dangers and challenges facing the attempts to improve society, and their optimism rested on man's ability to create wealth by inventing technologies capable of raising production.

It is the latter that the economic historian should focus on. Material progress depends on the advances made in useful knowledge. The idea of progress, as noted, is inextricably linked to the cultural issue of how one should rate the capabilities and wisdom of one's contemporary generation relative to the wisdom of previous ones. The same age that fostered a belief in progress impudently shed their excessive respect for earlier thinkers, committing to a belief that "we can do better." Such beliefs were strongly resisted, and it is not at all clear that their triumph was pre-ordained or inevitable. Nowhere is this struggle better illustrated than by the famous "battle of the books" which erupted in much of Europe in the late seventeenth century between the "ancients" and the "moderns."[12] Were modern scholars and authors nothing but midgets standing on the shoulders of giants, or were they giants themselves? The debate was widely regarded, then as now, as a tempest in a teapot (Levine, 1981, p. 73).[13] But it was not: it reflected a watershed in cultural evolution that had been two centuries or more in the making (Bury, 1955, ch. IV; Spadafora, 1990, ch. 2). Many of the "ancients" viewed modern science as a possible attack on "learning" and made a point of dismissing the efforts of moderns as futile. Henry Stubbe (1632–76), a pugnacious physician and political pamphleteer dismissed the entire scientific endeavor as futile: "All that is said about the erecting of Mechanical or Sensible Philosophy of Nature is but empty talk. Human nature is not capable of such atchievements" and then accused modern authors ("virtuosi") of being ignorant of Aristotle and other classical writers (Stubbe, 1670, p. 15). As late as 1704, the bookseller's introduction to Jonathan Swift's famous *Battle of the Books*, a satirical essay on the battle of the

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[11]Elsewhere (1665) p. 140 he noted, somewhat insolently, that "that discouraging maxim, *nil dictum quod non dictum prius* hath little room in my estimation. Except Copernicus be in the right, there hath been new under the sun...the last ages have shewn us what antiquity never saw." Furthermore, he believed explicitly that "the Goods of Mankind may be much increased by the Naturalist's insights into trade" — essentially an early statement of one of the central assumptions of the Industrial Enlightenment. Glanvill would, however, not be counted as "enlightened" by our standards — he staunchly defended the existence of witches and spirits and wrote a book vehemently attacking those who doubted their existence.

[12]The literature on this issue is quite substantial. The classic statement remains R.F. Jones (1936). For a recent assessment, see Levine (1981).

[13]There seems to be a certain coyness among modern authors to admit the obvious, which is that the "moderns" had an irrefutable case in terms of useful knowledge, just as their case was unprovable and silly as far as literature and poetry is concerned. Even Nisbet (1979), after describing Georges Sorel's ludicrous characterization of the idea of progress as "a shabby piece of bourgeois trickery" based on circular reasoning, feels the need to admit that "the reasoning was certainly circular". It was not; insofar as progress in science and technology was based on a cumulative process and there was no knowledge "lost" in the course of history, moderns had access to ancient knowledge but not the reverse.

ancients and moderns, concluded that "we cannot learn to which side Victory fell" (Swift [1704], 1720, p. 211).[14] Much of the "battle of the books," of course was about taste, and an argument whether one should prefer Shakespeare to Sophocles or Milton to Virgil seems otiose today. But dismissing R.F. Jones as "whiggish" because he felt sympathy for those who felt that there were good grounds to prefer Galileo to Archimedes or Harvey to Galen seems unproductive. One of the debaters, the linguist and biographer William Wotton (1666–1727), indeed made the crucial distinction between areas that were cumulative (such as science and technology) and those that were not (such as rhetoric and poetry). Swift's pamphlet marks the epilogue of a battle that had been fought for two centuries and and won conclusively. From that point on it was beyond any question that a reference to Aristotle or any other author in the canon, from the Bible down, would not be regarded as sufficient evidence.[15]

By the early seventeenth century, leading European intellectuals were increasingly coming to terms with their break with classical science and philosophy. In the quaint terminology that he invented, Francis Bacon spoke of the "idols of the theatre" by which he meant the defective methodology inherited from Aristotle. He launched a full-fledged attack on classical wisdom (especially in his *Advancement of Learning*) and called for nothing less than to junk classical science and start afresh, using observation and experiment rather than authority. He noted, in a famous remark, that the wisdom of the Greeks was but a wisdom of boys, it can talk but not generate, it was "barren of works."[16] The English physician and physicist William Gilbert in his *De Magnete* (1600), a widely admired and pioneering work in its time, dismissed Ptolemy's astronomy as "now believed only by idiots" and proclaimed that the only avenue to truth was experiment and observation, not

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[14]One cannot help but surmising that the classic Monty Python skit "The Philosophers World Cup" in which Greek and German philosophers compete in an absurd soccer match, was inspired by a paragraph such as "The Moderns were in very warm debates upon the choice of their leaders, and nothing less than the fear impending from their enemies could have kept them from mutinies upon this occasion. The difference was greatest among the horse, where every private trooper pretended to the chief command, from Tasso and Milton to Dryden and Wither. The light horse were commanded by Cowley and Despreaux. There came the bowmen under their valiant leaders, Descartes, Gassendi, and Hobbes, whose strength was such that they could shoot their arrows beyond the atmosphere, never to fall down again, but turn, like that of Evander, into meteors, or, like the cannon ball, into stars. Paracelsus brought a squadron of stinkpot flingers from the snowy mountains of Rhaetia ... The army of the Ancients was much fewer in number, Homer led the horse, and Pindar the light horse, Euclid was chief engineer, Plato and Aristotle commanded the bowmen, Herodotus and Livy the foot, Hippocrates, the dragoons, the allies, led by Vossius and Temple, brought up the rear" Swift [1704], 1720, pp. 228–29.

[15]The late seventeenth century "Battle of the Books" was in fact a rearguard action which shows how strong the position of the "moderns" had become. In the words of one scholar, "to sample a few of Temple's [William Temple, one of Wotton's main opponents] opinions about ancients and moderns gives one a sense of the genteel arrogance the Enlightenment had to put up with and overcome...Temple served up a pastiche of pseudo-intellectual commonplaces. The ancients had said it all; advances in learning and art were unlikely when the originals were so perfect... Where now is the great music of the past when Orpheus could move the stones and tame the beasts? Where today are the ancient arts of magic? How can the fortuitous circumstances that produced such excellences of the past ever come together again in these diminished times? Did Harvey and Copernicus have anything new to say? Who can tell whether it is the sun or the earth that moves?" (Traugott, 1994, pp. 504–05).

[16]Preface to *The Great Instauration.* Repr. in Bacon, 1999, p. 69.

the authority of Greek sages (Jones, 1961 [1936], p. 17). In the first decades of the seventeenth century this rebellion against the "ancients" was taken further.[17] Famously, Galileo wrote in his 1613 letter to Duchess Christina of Florence that "in disputes about natural phenomena, one must begin not with the authority of scriptural passages but with sensory experiences and necessary demonstrations" (cited by Reston (1994), p. 137). Many of the scientists and scholars who rose to prominence in the mid seventeenth century had accepted the critical attitude toward received authority. "Whatever the schoolmen may talk," wrote one of them, "yet Aristotle's Works are not necessarily true and he himself hath by sufficient Arguments proved himself to be liable to error... Learning is Increased by new Experiments and new Discoveries ... we have the advantage of more time than they had and knowledge is the daughter of time...if such great scholars, who were so eminent for their Knowledge in Natural Things, might notwithstanding be grossly mistaken in such Matters as are now evident and certain, why then we have no Reason to depend on their Assertions or Authorities" (Wilkins [1640] 1708, pp. 146-47). The paralyzing respect for the wisdom of previous generations was melting away.

Examples of how traditional learning remained impregnable even in Europe are easy to find. Perhaps no example serves us better than the history of European Jews, an ethnic group that was on average far better educated than their gentile neighbors, and among whom male literacy was close to universal (Botticini and Eckstein, 2012). Although the volume and range of Jewish learning was immense and made considerable progress in many areas, it was conformist and respectful of ancient authority. Within these constraints, there was a great deal of debate and dispute, but violating them was *kfira be'eekar* and could have terrible social consequences as Spinoza found out.[18] 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.[19] When remarkable Jewish intellectuals such as David Ricardo and Moses Mendelsohn did play a role, they typically were alienated from their community. Even

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[17]The best-known writers in this tradition following Bacon and Gilbert was George Hakewill (1578-1649), a Church of England clergyman who strongly denied that a process of decay caused the intellectuals of his generation to be inferior to the ancient classics and the Oxford scholar Nathanael Carpenter (1589-1628), an influential Oxford Scholar who stressed the need to test classical authorities against new evidence.

[18]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.

[19]There were a few exceptions to this rule, such as Jacob ben Immanuel (Bonet) Lates, physician to the late fifteenth century popes and the inventor of an important instrument to measure astronomical altitudes. 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 and helped the Portuguese navigators in computing latitude at sea. 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. See Seed, 2001, pp. 73-82.

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.

In Europe, this battle was won decisively by the "Moderns" and the result was the Enlightenment, in which the "Ancients" were relegated to a polite but irrelevant niche of learning. John Clarke (1687-1734) an enlightened educational reformer who advocated the teaching of mathematics and science, wrote in 1731 that "the antients were indeed but very poor Philosophers. With regard to the Knowledge of Nature the thing is too notorious to admit of any dispute at all" (Clarke, 1737, p. 45). Similarly, Richard Helsham, who held the Erasmus Smith professorship of natural and experimental philosophy at Trinity College Dublin from 1724 to 1738, started his wildly successful textbook in natural philosophy (still taught in Dublin as late as 1849) by disrespectfully stating that "it is a matter of no small surprize to think how inconsiderable a progress the knowledge of nature had made in former ages ... compared with the vast improvements it has received ...of latter times...Philosophers of former ages buried themselves in framing hypotheses ...without any foundation in nature [and] so lame and defective as to not answer those very phaenomena for whose sakes they had been contrived" (Helsham, 1755, p. 1).

It is this kind of cultural change, that explains how and why intellectual innovation became increasingly acceptable in all fields of knowledge, from theology to hydraulics. The more powerful minds of the age realized, much as Pascal (in his pre-Jansenist and more progressive days) noted that it would be unjust to show the "ancients" more respect that they themselves had shown to those who had preceded them, a logical point entirely missed by Jewish theologians (Bury, 1955, p. 68).[20] Progress, the "moderns" (especially Glanvill) stressed, was inevitable because the tools of research had been improved. Galen had no microscope, Ptolemy no telescope, Archimedes no calculus. But more than anything, knowledge was cumulative. Cumulativeness was, of course, itself a variable that society controlled and constructed. Knowledge, it was recognized, could be lost.[21] For that reason Bacon proposed to move the governance of technological knowledge from the individual to the community (i.e., the state). After all, as Keller (2012, p. 242) remarks, "the value of the inventor's knowledge for society was so great that the state could not afford its loss."

The problem with the position of the "moderns" was (and is) that progress was not inevitable or even very likely. While the accumulation of useful knowledge was largely unidirectional, the conditions for its sustained growth are fairly strong, and it took the Age of Enlightenment many decades to figure them out. Enlightenment thinkers disagreed among themselves as to precisely what progress would consist of and how it would be brought about (Israel, 2010), but if there was one

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[20]Auguste Comte noted that "the idea of continuous progress had no scientific consistency, or public regard, till after the memorable controversy at the beginning of the last [i.e., eighteenth] century about the general comparison of the ancients and the moderns ... that solemn discussion constitutes a ripe event in the history of the human mind which thus, for the first time, declared that it had made an irreversible advance" (Comte 1856, p. 441).

[21]One of Bacon's inspirations, the Padua Law Professor Guido Pancirolli, wrote a book entitled *Two Books of Things Lost and Things Found* (1599 and 1602) in which he listed the products and techniques that ancient civilization was believed to possess and subsequently lost.

item on which all but a few retrograde Enlightenment writers could agree on, it was that progress consisted of *material* advances relying on the growth of *useful knowledge*. In other words, science (or "experimental philosophy") and technology ("the useful arts") were the engines of material progress, and evidence was slowly mounting about the huge potential of these forces to change daily material existence of humankind.

The final "triumph of the idea of progress" as Nisbet (1994) has called it was slow in coming, and it was only the triumph of enlightenment thinkers committed to the idea of progress in the eighteenth century that fully explains the sharp turn in European History. Powerful thinkers such as Montesquieu, Hume, Smith, Diderot, and Condorcet each in their own way, had the persuasive power to convince others that indeed material progress could be brought about and the Baconian program was more than a dream.[22] This can be illustrated by showing the sharp increase in words associated with progress in the eighteenth century.

Figures 1 and 2 illustrate the timing of this triumph. It shows the google n-grams of two key concepts of the Industrial Enlightenment. One of them is the concept of "progress" (including its

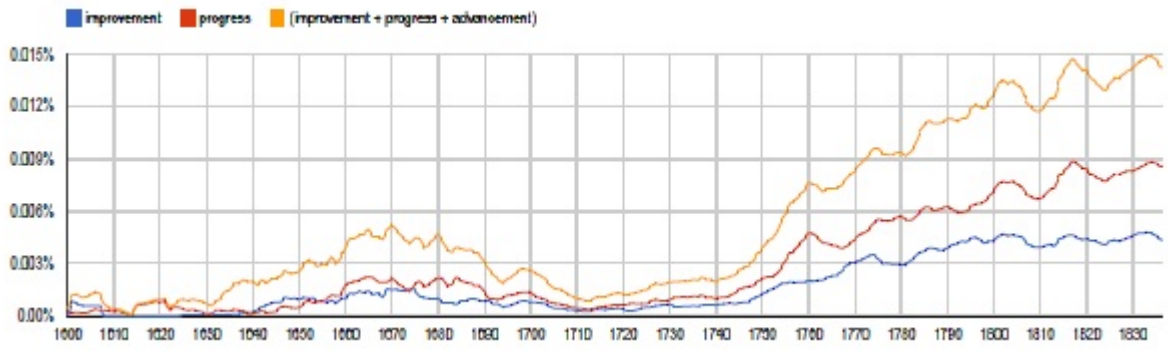

Figure 1: Google n-gram of the concept of progress and related terms, 1600-1830.

related terms of "improvement" and "advancement."

[22]As Nisbet (1979) has pointed out, even Enlightenment thinkers such as Rousseau who are widely reputed to be critical of material progress, were more objecting to the inequality and injustice that they felt accompanied material progress than to the progress itself.

The diagrams show, interestingly, an early flourishing of the ideas of the Industrial

Figure 2: Google n-gram of "useful knowledge" and related concepts.

Enlightenment during and after the Civil War, possibly related to the rise and decline of Puritanism. The Glorious Revolution, rather than reinforcing this trend, was followed by a period of slow down. Only in the second third of the eighteenth century did these concepts once again start to grab the attention of English-language authors. It seems a bit of a stretch to argue that the onset of inventive activity after 1760 was "caused" by this, but the timing of the two phenomena is at least suggestive.

Progress and Competition

What accounts for this triumph of the culture of progress? It may seem that the rise of an urban merchant and industrial class would infuse intellectual life with a more dynamic and optimistic spirit, but this tempting argument seems to fly in the face of many other highly commercialized societies (such as in India, China, and the Middle East) where which no such "progressive turn" can be detected. Pure materialistic explanations by themselves may not by themselves be persuasive here. Nor is it obvious that the Reformation changed the tone of intellectual discourse, especially because so many of the leading intellectual innovators resided in Catholic countries and some of them, such as the phenomenally versatile Athanasius Kircher (1601–80) were Jesuits. Instead, it seems that the outcome was the result of a series of debates that were played out in a marketplace for ideas in which the field was sufficiently level so that the ideas that appealed the most to intellectuals due to the kind of biases I pointed to earlier won out. Of course, it helped that Renaissance Europe was experiencing in many ways a wave of advances. Those who argued that progress was in fact part of the historical dynamic could point to a huge and growing array of facts that supported them, among them the growth of useful knowledge and technology, but also the successes that Europeans had in reaching and subjugating other parts of the world, the technological advances of the early renaissance, and the progress in areas such as painting, music, and (more controversially) literature. The causality runs not only from a belief in progress to its experience, there is clearly an important channel of reverse causality. Yet earlier successes and even the experience of progress do not guarantee that it can and will be sustained, or become the basis of a set of beliefs anchored in assumptions about improvement. Medieval Islam and Song China, despite centuries of technical and scientific advances, did not experience what

happened in Europe. There were many reasons for this, and I want to focus here on one of them: differences in the market for ideas.

Success in a Schumpeterian market in which entrenched ideas are being challenged by novel ones required an even playing field, and in most societies incumbents made it very difficult for intellectual innovators to challenge the conventional wisdom. It seems rather obvious that novelty is resisted by those whose income and power are based on the status quo. It is far from obvious how and why the transformation took place in Europe. The explanation I am proposing here has nothing to do with a "Eurocentric" view about intrinsic differences and rests on a rather unique constellation of forces that emerged in Europe in the centuries before the Enlightenment, that paved the way for its eventual triumph. On the one hand, the fragmentation of polities in Europe was such that "the states system" (as E.L. Jones referred to it) ensured sufficient competition that permitted intellectual pluralism. At the same time, Europe witnessed the emergence of an institution that actively promoted and enhanced intellectual innovation, even if that was not its intention.

The institution in question was what was known as the "Republic of Letters." The importance of the Republic of Letters in the subsequent economic development of Europe has been underrated in the past even if its importance for intellectual change is well-known.[23] The Republic of Letters was essentially a relatively free and open marketplace for ideas, in which intellectuals and scientists competed with one another for reputation and recognition. Like any other market, the efficiency of the market for ideas depended on its degree of competitiveness and contestability and on the capability of incumbents to block new (and possibly more capable) entrants. It was also transnational, and hence "the extent" of the market was much larger than any single political unit making it more plausible that innovators could cover the "fixed costs" of producing a new idea.

It is here that competition and free entry mattered most. The political fragmentation of Europe became a key to its intellectual development. The dark forces of reaction in the sixteenth century were no less benighted than those of the fourteenth, but it became increasingly difficult for those forces to coordinate and work together, in part because some defenders of the conventional wisdom were Protestant and others Catholic.[24] Authorities could not agree on who was a heretic, and the heretics took fully advantage of this. The unique situation in Europe, then, was that intolerance and the suppression of cultural heterodoxy, long before they fell out of fashion, could not be properly coordinated. Many innovators were able to game the political system to avoid persecution. Hostility between the European powers led to one ruler protecting the gadflies that irritated their

[23]For exceptions, see David, 2004; 2008; Mokyr, 2011-12.

[24]Consider Luther's disciple Philipp Melanchthon's denunciation of Copernicus: 'some think it a distinguished achievement to construct such a crazy thing as that Prussian astronomer who moves the earth and fixes the sun. Verily, wise rulers should tame the unrestraint of men's minds.' Cited by Kesten, 1945, p. 309. Luther himself said caustically of Copernicus, "the fool wishes to turn the entire art of Astronomy on its head" (cited by Merton, 1973, p. 245).

enemies.[25] In other cases, the ability of intellectual innovators to move about the Continent to escape potential persecutors left the incumbents powerless to suppress the innovations, though the causality between mobility and intellectual innovation is of course rather complex.[26] By the eighteenth century, the inability of reactionary forces to suppress innovations had become a bit of charade, and while the more outrageous *philosophes* such as Helvétius and Lamettrie still had to move about when the local authorities became disenchanted with them, they usually found welcoming hosts at other courts.

The Republic of Letters was a *virtual* institution: its operation took place primarily through publication and correspondence. It was an "invisible college" of internationally connected scholars, based on the implicit understanding that knowledge was a non-rivalrous good that was to be shared by the community so that it could be accessed where it could do the most good. It was the embodiment of a "market for ideas" in which experimentalists, philosophers, physicians, and crackpots tried to "sell" their original ideas by persuading others, and in the process acquire the main payoff, which was the recognition and respect of their peers and hopefully the patronage jobs that came with it (David, 2008). The community constituted an elite group of intellectuals and scientists that exchanged and discussed new knowledge. Its operation depended heavily on the printing press and the growth of reliable postal services in Europe. But precisely because of its international character, it provided larger audiences (and more potential patrons) to intellectual innovators.

Like every market institution, the Republic of Letters set up rules and incentives that governed its daily operation. From the point of view of long-term economic impact, what mattered most for the operation of the market of ideas was its international character and free entry. At least in theory, the Republic of Letters practiced a meritocracy, in which neither social class nor nationality mattered. In practice, of course, it was limited to members of the elite, since only they had access to the education resulting from privilege. Yet clearly it could include equally the very rich and aristocratic Robert Boyle and his assistant, the parvenu Robert Hooke, as well as members of an *haute bourgeois* intelligentsia such as Christiaan Huygens and René Descartes. The Republic of Letters fancied itself an autonomous unit with its own rules and institutions and not subject to the norms and values of the rest of society, rising "above the petty concerns of state and church or so at least they claimed" (Goldgar, 1995, p. 3). Pierre Bayle, the French Huguenot philosopher who

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[25]One of the earliest case is Bernardino Ochino (1487-1564), a highly controversial Siennese Franciscan monk and preacher, committed to free inquiry and controversy, and famous for an unusual eloquence. He managed to alienate both the Catholic Church, especially attracting the hostility of the reactionary hardline Cardinal Giovanni-Pietro Caraffa (later Pope Paul IV, 1555-1559). An equal-opportunity gadfly, Ochino also alienated most protestants. He was summoned to appear before the Roman Inquisition established in 1542 (one of the first "heretics" to be so persecuted) and fled to Geneva in 1547, eventually ending up in England, whence he was driven by the ascension of the intolerant Mary Tudor. Returning to Zurich, he was again expelled and ended up in Poland (at that time a relatively tolerant nation) but was banished from it in 1564 at the instigation of the papacy and died in Moravia. Among other things he advocated divorce and was suspected of supporting polygamy (Benrath, 1877, passim).

[26]The most extreme case was without the doubt the celebrated Czech intellectual Jan Amos Comenius (Komensky), whose career was spent moving about between his native Moravia, Poland, Sweden, Hungary, London, and Amsterdam.

lived in exile in Rotterdam and was one of the Republic's early focal points, wrote that "The Common-wealth of learning (Republic of Letters) is a State extremely free... the Empire of Truth and Reason is only acknowledged in it... everybody is both sovereign and under everybody's jurisdiction... the laws of of the society have done no Prejudice to the Independency of the State of Nature as [much as to] Error and Ignorance" (Bayle, 1734, Vol. II, p. 389, essay on *Catius*).

Furthermore, any extant idea should be regarded as contestable. The motto "nullius in verba" (on no one's word) adopted by the Royal Society exemplifies this approach no less than Bayle's well-known restatement of the principle.[27] Many intellectuals regarding themselves as citizens of the Republic of Letters did not shy away from confrontations and sharp critiques of the masters of science.[28] Yet there was also a shared ideology, a sense of common purpose, of being part of a collaborative project of making the world a better place by jointly building a larger knowledge base through the exchange of information that allowed intellectual innovators to build on each other's work after they had verified and tested it.[29] Some of the continued emphasis on "improvement" was no-doubt self-serving, even self-aggrandizing, propaganda by patronage-hungry intellectuals, yet the efforts to add to useful knowledge also counted individuals who demonstrably had no interest in patronage, such as the wealthy aristocrat Robert Boyle or the well-to-do merchant Anthonie van Leeuwenhoek.

The Republic of Letters, then, was the arena in which the battle over the idea of Progress played itself out in the closing decades of the seventeenth century. As I have shown in some detail in my *Enlightened Economy* (2009), this was the foundation of what I have termed the "Industrial Enlightenment." But there was nothing self-evident or inexorable in this victory, and throughout much of early modern Europe supporters of the notion of progress had to struggle with the forces of reaction. Even among Enlightenment thinkers, the idea of commercial-industrial activity and the

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[27]Bayle stressed that "every particular Man has the Right of the Sword and may exercise it without asking leave of those who govern...against Authors who are mistaken...It is true, the Reputation of being a learned man which an author has acquired is sometimes diminished thereby... but if it be done in support of the Cause of Reason and for the interest of the Truth, no Body ought to find fault with it" Bayle, [1697/8] 1734, p. 389.

[28]A good example is the pugnacious Dutch lensmaker, astronomer and embryologist Nicolaas Hartsoeker (1656-1725), who as a sixteen year old had been taught by no less a figure than Leeuwenhoek himself about microscopes, but in his later work did not hesitate to criticize and even ridicule the old man. He also attacked such pillars of science as Newton, Leibniz, and Jakob Bernoulli. Notwithstanding (and perhaps due to) his disputatious reputation, he was offered a number of patronage positions, including one by Czar Peter the Great (which he declined).

[29]In the first issue of the Royal Society's *Transactions,* its secretary Henry Oldenburg (1666) wrote in the best Baconian tradition that " there is nothing more necessary for promoting the improvement of Philosophical Matters, than the communicating to such, as apply their Studies and Endeavours that way, such things as are discovered or put in practise by others ... To the end, that such Productions being clearly and truly communicated, desires after solid and usefull knowledge may be further entertained, ingenious Endeavours and Undertakings cherished, and those, addicted to and conversant in such matters, may be invited and encouraged to search, try, and find out new things, impart their knowledge to one another, and contribute what they can to the Grand design of improving Natural knowledge, and perfecting all Philosophical Arts, and Sciences. All for the Glory of God, the Honour and Advantage of these Kingdoms, and the Universal Good of Mankind."

"useful arts and sciences"as the sites on which the forces of progress converged remained itself contestable — in line with the fundamental principles of the Republic of Letters. In some European countries, the debate ended in a stalemate, and the forces of progress in Europe south of the Alps and Pyrenees encountered more tenacious resistance from religious and political corners. To be sure, enlightened views about the capability of useful knowledge to power economic progress penetrated into every corner of Europe (including, for instance Naples — see John Robertson, 1997), but their impact on the economic institutions and capacity for meaningful innovation differed greatly.

It is this institution that provided the battleground in which the modern idea of progress eventually emerged victorious. Scholars have understandably differed about what kind and whose progress is involved. Nisbet (1994), for instance, distinguishes between "progress as freedom" (which includes material progress) and "progress as power," which we might think of as the emergence of the nation state and institutional change. More controversially, Lasch (1991), dismisses the idea of progress due to human ingenuity and the progress of arts and sciences as "vaporous tributes to the power of reason" produced by "second-rate thinkers." Instead he stresses the demand side of progress, a positive assessment of the proliferation of wants, rising expectations, newly acquired tastes and standards of personal comforts, which he attributes to Hume and Smith.[30] But the idea that stood in the very center of the progress movement was the Baconian program, which purported to increase and disseminate knowledge of nature to benefit 'the useful arts." In the end, anyone purporting to understanding the Industrial Revolution needs to confront its cultural roots.

What accounts for this triumph? On the demand side, the expansion of the economies in Western Europe after 1500 gave rise to an increasingly strong contingent of *homines novi* for whom progress could not mean but economic advantage to themselves. Urban-mercantile classes naturally felt that "progress" meant — however indirectly — more commerce, more urbanization, and greater permeability of the upper classes by *arrivistes*. Yet there was more to it than economic change: the idea of progress proved consonant with Western Christianity in ways that seemed to have eluded Islam and Judaism. Judeo-Christian beliefs in millenarianism provided a sense of a historical dynamic that had an end-point that was recognizably different from current reality. Medieval Europe was suffused with millenarian beliefs of history leading to a "better" world in which a Paradise would be reinstated at the end of history.[31] At the same time, Christianity turned out to be sufficiently flexible and adaptive to accommodate strong commitments to devoutness as well as a

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[30]Lasch, 1991, pp. 45, 52-54. Among the minds that Lasch would have to classify as "second rate" are Descartes, Pascal, Priestley and Condorcet.

[31]One medieval writer who tried to produce a "dynamic" vision of History of the world that led toward some kind of chiliasm was Joachim of Fiore (1135-1202), whose three-stage theory of History (each stage corresponding to one entity of the Holy Trinity) reappeared centuries later in the works of Auguste Comte and Karl Marx (Cohn, 1961, p. 101). Whether this eschatological prophesy was a true theory of progress (as Nisbet believes) or not, it shows that within Christianity such dynamic theories were possible even if they were attacked by St. Thomas and (1263) denounced formally by the Church as heretical.

powerful support for the "moderns" over the ancients, of experimental science over Aristotelian dogma, and of the Baconian application of useful knowledge to production and the "arts."[32]

But such emphasis on the demand side needs to take account of the supply side that depended on the correct incentives for intellectual innovators. These incentives consisted of the increased carrot of patronage and fame in the Republic of Letters, and the reduced stick of less effective resistance and threats of "heresy" accusations by fragmented and uncoordinated incumbents. Above all, it was the power of competition that governed the emergence of the idea of progress. Political units, whether nation states, small duchies, or city states competed with one another for the best minds, the best artists, the best composers, and the best astrologers. Intellectuals competed with one another for reputation and the patronage associated with it. Even religions competed with one another for believers, resulting in some religious reform and improved education — as well as in some of the most destructive violence in the Continent's history.[33]

China, the "Needham Question" and the Market for Ideas

Modern Chinese scholarship has successfully fought the notion that the West's scientific and industrial revolutions implied that China somehow "failed" and denounced it as imposing European norms on a society with very different values and norms. The famous "Needham question" – why Chinese science and technology, after first pulling ahead of Europe were unable to keep pace with Europe's – remains, however, irrepressible (Needham, 1969c, p. 16; Sivin, 1994). A recent issue of *History of Technology* features a number of long essays dedicated to the very question.[34] One conclusion that seems acceptable to all sides in the debate is that there was nothing particularly exceptional about China; the flourishing of science and technology during the Tang and Song dynasties were followed by entrenchment and stagnation during the Ming and Qing dynasties, but there was nothing "unusual" about that retreat. Goldstone's summary statement, that it is typical for

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[32]Nisbet (1994) points to the deep religiosity of some of the major figures of the Enlightenment, such as Priestley and Herder. This is a fortiori true for the seventeenth century. The Merton hypothesis ([1938], 2002)has argued for a strong link between the rise of Puritanism and the development of science in seventeenth century England, and while its emphasis on England is somewhat lopsided, the link has survived much scrutiny. Puritans embraced science, in part because it simultaneously "manifested the Glory of God and enhanced the Good of Man" (Merton, 1973, p. 232). For Puritans, as Webster (1975, p. 505) has added, the ideal life was one that implied an efficient deployment of one's ability for personal advantage and public service and that the glorification of God was exercised by maximizing one's material resources. These two objective were not separable, but complemented one another in ways that took until the end of the seventeenth century to fully work out. Deeply religious men could recognize the deep ethical implication of scientific investigation: the systematic and meticulous study of God's creation was the closest a Calvinist could get to an inscrutable deity that could not be grasped by the "cultivated intellect."

[33]Lawrence Stone, 1969, pp. 81-83 has stressed the positive effect that religious competition between Anglicans and Dissenters had in England, as well as in France between Huguenots and Catholics "in the struggle for men's souls."

[34]It is worth noting that on the Needham question O'Brien (2009, p. 23) can do no better than to return to the old Weberian chestnut that Confucian principles did not account for the world as a rational and explicable work of God, as if this philosophy had prevented science and technology from flourishing under the Song and as if "Confucian" did not refer to a highly diverse and often inconsistent set of principles (Bodde, 1991, p. 344).

science to advance when different cultural and philosophical traditions are allowed to mix, but then for science to stagnate and even be reversed when conflict and disorder occur (Goldstone, 2009, p. 141), is a typical example of the "revisionist" literature. What was exceptional was not what happened in China but what happened in Europe. Not only that the growth of useful knowledge did not run into some kind of barrier that stopped it in its track, but European approaches to how to acquire, vet, and disseminate it spread world-wide and eventually disrupted the equilibrium that had settled in in the Middle East, in China and elsewhere.[35]

As Kenneth Pomeranz and other members of the "California School" have suggested, as late as the middle of the eighteenth century in many dimensions China's economic institutions were not inferior to Europe's. It was commercial, monetized, educated, run by a professional bureaucracy, and was able to generate and accommodate a very substantial population increase after 1680 or so without any obvious Malthusian effects. Yet some European thinkers, who may not have known much about China beyond the accounts of travelers and missionaries, sensed a difference even at that time. David Hume, for one, in his essay on *The Rise of Arts and Sciences* made an argument similar to the one made above. He felt that political fragmentation was the main reason behind European flourishing of useful knowledge. He was well aware of China's past achievements in science and technology and its sophisticated culture ("politeness" in eighteenth century parlance), but in his day he felt that Chinese science was making slow progress compared to Europe. The reason seemed clear to him: In China, he argued, the authority of one teacher was propagated easily from one corner of the Empire to another and "none had the courage to resist the torrent of popular opinion, and posterity was not bold enough to dispute what had been universally received by their ancestors" (Hume, 1742 [1987], p.122).[36]

The idea that European states and religions were in some kind of competitive market while Asia was ruled by large homogeneous Empires is of course overdrawn (Goldstone, 2009, pp. 99-102). Persia, the Ottoman Empire, and the Mughals in Northern India and their nemesis to the South, the Maratha Empire, competed as hard and as bloodily as Louis XIV and Frederick II in Europe, with the great battle of Panipat (north of Delhi) of 1761 being one of the most extensive and bloody clashes of the time. Religious competition, too, was comparable to Europe's with Islam divided between Sunni, Shiite, and other factions, yet competing with Hinduism in southern Asia. In China, the state, dominated by the official religion of Confucianism, suppressed Buddhism, which however

[35]Needham cites (with some disapproval) Einstein's 1953 letter in which he says that "In my opinion one need not be astonished that the Chinese sages did not make these steps [the invention of formal logical systems and the search for causal relationships through controlled experiments]. The astonishing thing is that these discoveries were made at all." (Cited by Needham, 1969c, p. 43).

[36]Among the modern economic historians who have squarely blamed Chinese culture for China's falling behind Europe most prominent is David Landes (1998, ch. 21; 2000). Most modern economic historians have taken a skeptical view of his position as "virtually unsupported assertions" (O'Brien, 2009, p. 7) and "essentialist explanations" (Goody, 2010).

flourished in south-east Asia. Within China itself, too, there were attempts to introduce a variety of heterodoxies including critiques of the ruling neo-Confucian orthodoxy.[37]

The fact that competitive markets for ideas existed elsewhere does not mean that these markets operated in the same way they did in Europe. Competition between states is *not* like competition between firms or consumers in that there are no enforceable rules that tame and constrain the competitive process and set the parameters on what forms the competition can take. It could often resort to extreme violence or mindless trade wars and state-sponsored piracy, weakening the economy. But it could also take highly productive forms. In Europe, the competition among rulers to attract the most brilliant minds of the Continent weakened resistance to innovators, thus giving a chance to sixteenth century intellectuals such as Luther, Paracelsus, Vesalius, and Copernicus to successfully launch radical critiques of entrenched knowledge. In Asia, despite continuing warfare in many areas, there are few signs that states competed for the most prestigious scientists and artists.

In China, after its unification by the Ming in 1368, competition for in the market for ideas gradually weakened and intellectual innovation was largely constrained by the limits of accepted philosophical tenets, perpetuated by the neo-Confucian orthodoxy established by Zhu Xi in the twelfth century. If and when this orthodoxy was challenged, it was usually on the basis of alleged inconsistency with the classic teachings. The Mandarin civil service examinations, Needham insisted with some hyperbole, caused the system to "perpetuate itself through ten thousand generations" (Needham, [1964], 1969, p. 202). These examinations, in some opinions remained the instrument through which the ancient texts became "an instrument of repressive conformity" (Huang, 1981, p. 210).[38] European advances in science did filter into China through the activity of Jesuits, but apart from re-calibrating their calendars, their impact was highly selective and not dramatic.[39] Had the

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[37]As De Saeger (2008, p. 81) points out, patronage of scientists existed in China as well, they were limited to mathematics and astronomy (in part for astrological purposes). The main difference remains, however, that in China it was only at the Imperial court that patronage was available, whereas in Europe many rulers competed for the best minds. This meant that in China the Court controlled both the agenda and the contents of intellectual innovation, whereas in Europe they were determined as the result of a more decentralized process. As De Saeger remarks, "patronage had an easier time escaping orthodoxy" (ibid, p. 82).

[38]The effect of the Imperial examination system on Chinese society has been a subject of some debate. but it is telling that in 1713 the Kangxi emperor proscribed questions dealing with natural studies in the civil examinations in an effort to keep divination and portents out of public discussion. Recent works in Qing natural studies and court translation projects on mathematical harmonics and astronomy were off-limits to examiners and examination candidates (Elman, 2005, p. 168). For a discussion of this topic, see De Saeger, 2008.

[39]Deng (2009, p. 62) goes so far as to argue that the European influence on China's "knowledge stock" was hardly noticeable and that China "did not need European knowledge on a large scale." But Nathan Sivin has convincingly argued that China was exposed to European ideas in a heavily filtered way. He notes that "although the Jesuits' Chinese writings at first reflected conservative but open-minded current thinking, they gradually became hopelessly obsolete, out of touch with practice as well as theory. But the constraints under which they wrote, and the lack of competition from lay authors, and that the Jesuits meant that no one acknowledged or corrected crucial misstatements before the mid-nineteenth century" (Sivin [1973] 1995, p. 13). It is worth noting that the Jesuits did not expose China to the heliocentric view of the world till 1760. Needham, 1956, p. 294, notes sarcastically that "one of the

Chinese authorities allowed other gates of entry besides Jesuits, perhaps the new approaches of Galileo and Newton might have made of an inroad. In Qing China there was a market for ideas, but barriers to entry were high, and the competition between incumbents and innovators often biased in favor of the former. This may sound odd in a land where there was no inquisition, and where there was no "index" of prohibited books. But perhaps the emergence of these institutions was a sign that in Europe the intellectual incumbents felt (justly) that they were more under threat. In China the Jesuits were allowed, but were controlled and constrained by the Emperor's goodwill.

What was also missing in China was the ability of intellectuals to move to areas that were not under Chinese control. Consider the example of the seventeenth century Chinese scholar Chu Shun-shui (1600–82), one of the few Chinese intellectuals who can be compared with a European intellectual in his itinerancy. His knowledge was quite broad and extended to fields of practical knowledge such as architecture and crafts. Fleeing from China (he had remained a supporter of the Ming dynasty, overthrown in 1644) first to Annam (Vietnam) and then to Japan, where he had quite a following and eventually became an advisor and mentor to the daimyo Mitsukuni. Chu Shun-shui, in Julia Ching's words, was hardly a purely abstract philosopher, but "the investigation of things referred to less to the metaphysical understanding of principle of material forces, and more to coping with concrete situations. At the same time, the extension of knowledge applied not only to knowledge of the Confucian classics, but also to all that is useful in life" (Ching, 1979, p. 217). This may sound promising, but the fact remains that Chu's work remained unknown in China until his rediscovery in the late nineteenth century. Having left his homeland, he became a non-entity; this, in sharp contrast with Europe where reputations easily crossed boundaries.

The Chinese market for ideas rigidified in late Ming and especially in Qing China, and became increasingly unaccommodating to intellectual innovation. While in Europe the victory of the "moderns" relegated the classical canon to a position in which they were admired and taught but treated with skepticism and doubt, in China the two schools fought to a stalemate. The neo-Confucian annotated "four books" (*Sishu Jizhu*), written in the twelfth century by Zhu Xi, remained as rigid a canon as the West ever had. At times, of course, it was challenged, but contestability largely meant that Neoconfucian doctrine needed to be returned to the original meaning of Confucius and Mencius. The kind of iconoclastic writers such as Ramus, Paracelsus, and Bacon, who completely dismissed and overthrew conventional wisdom in Europe in the sixteenth century never took hold in China. Unlike what happened in Europe, there was little political pluralism that "heretics" and intellectual innovators could exploit to create a more competitive market for ideas. China grew into a meritocracy gone awry. In a society in which public office remained "the most important source of prestige and wealth" (Brandt, Ma and Rawski, 2011, p. 51), the unassailability of these texts remained the most effective bulwark against intellectual innovators.

How did potential intellectual innovators fare in China? An early attempt at intellectual innovation that was more or less contemporaneous with the European growing criticism of the "ancients" can be traced to the writings and career of Li Zhi (1527-1602), a philosopher of heterodox

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ironies of histories is that the Jesuits were proud of introducing to China the correct [Aristotelian] doctrine of the four elements – just half a century before Europe gave it up forever."

inclinations, who actually seems to have felt that one did not have to be a Confucian scholar to be a philosopher, a truly iconoclastic position at the time (Jiang, 2001, p. 13). Certain views that we associate with the European radical enlightenment were expressed by Li, including that self-interest was part of human nature and not to be condemned, and that the pleasures of the flesh might be both virtuous and therapeutic. Huang (1981, p. 204) points out that Li's views were a threat to the Neo-Confucian doctrines of the dominant doctrines of Zhu Xi, and that if it were accepted that individuals could achieve the Great Unity in their own minds, much of the Confucian formal canon could be dispensed with. Such views would constitute a serious threat to the Empire, "the integration of which relied to a large degree on the general acceptance of orthodox teachings by the educated elite." At least in that sense Li might be regarded as potentially as serious a threat as Martin Luther in Europe a generation or two earlier. Yet in China, the battle faced by such potential heretics was far much more uphill. Even the enfeebled late Ming Empire could coordinate the suppression of subversive ideas better than the European states.

Moreover, Li was no Galileo or Bacon. His concern was almost entirely an attempt to reconcile the undeniable private needs and desires of human beings with the obvious constraints of public morality. In any event, his heterodox views were extremely costly to him: following the publication of his heretical book *A Book to Burn* he was arrested by the Emperor's guard, jailed, and committed suicide in prison (Huang, 1981, pp. 189-221). To be sure, it is not entirely clear to what extent Li's heretical writings contributed to his fate, as opposed to his lifestyle and his pugnacious character. His career might be compared to that of his predecessor Wang Yangming (1472-1529). Wang was a successful and influential critic of Zhu Xi's thought, proposing a more idealist philosophy, and there seems to be little evidence that such criticism hurt his career as a general and administrator. For a while the more liberal approaches of Wang and his followers might have seemed to open the door to a more pluralistic approach to knowledge in China, all within the traditions of neo-confucianism.[40] But even in late Ming China, the authorities were able to confine innovative thinkers within the boundaries of what was permissible. Those who stepped outside those boundaries, such as Li Zhi or the populist thinker Ho Hsin-yin (1517 – 1579) died in jail.

Another remarkable innovator in late Ming dynasty was Xu Guangqi (1562-1633). Xu's career and views in some ways mirror those of his contemporary Francis Bacon and shared Bacon's belief belief in what is known in China as *shiyong* (the practical application of knowledge in pursuit of social order).[41] His commitment to learning was motivated by the belief that it could be used to save the country, not only by military means, but also by applying science and technology to make the country prosperous and powerful (Qi, 2001, p. 361). In that regard, his beliefs are distinctly reminiscent of Bacon's, despite the obvious differences. Xu was a high-level official in the Imperial administration (at the time of his death he was both deputy prime minister and minister of "rites," roughly culture and education). He was responsible for reforming the Chinese calendar based on

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[40]Needham compares Wang's views to those of such giants of western philosophy as Berkeley and Kant, but adds that "unfortunately all this, sublime as it was, could hardly be sympathetic to the development of natural science...Wang could never understand the basic principle of scientific method."

[41]This term is proposed by Bray and Métailié (2001), p. 323.

more accurate astronomical data he learned from the Jesuits, who had access to the work of Brahe and Kepler. Remarkably, he converted to Christianity in 1603 (subsequently becoming known as "Dr Paul,") and was a close collaborator of the Jesuit missionary Father Matteo Ricci, with whom he translated Euclid's *Elements of Geometry*. Perhaps his most astonishing contribution was his monumental *Nongzheng quanshu,* an agricultural treatise published posthumously in 1639 that summarized much existing knowledge of Chinese agriculture, but also illustrated his firm belief in the importance of experimentation in augmenting knowledge in farming. The book was vast, containing 700,000 Chinese characters (Bray, 1984, p. 66). It was, by the standards of that time on any continent, full of progressive ideas. Xu reported a great deal of agricultural experimentation, at least some of which he carried out himself. He also advocated the new crops that were being introduced into China from the new world, and condemned conservative farmers reluctant to adopt new crops such as sweet potatoes because of their mistaken belief that crops will only grow well where they originated (Bray and Métailié, 2001, p. 341). He was a practical intellect, who endorsed concrete studies (*shixue*) and perhaps serves as an indication of where Chinese intellectual innovators could have gone had they lived in a different polity (Zurndorfer, 2009, p. 82). Yet unlike Diderot's Encyclopedia, Xu's work was not widely disseminated, and one widely-traveled early Qing scholar, Lio Xanting (1648–95) complained that in ten years search he had not been able to find a single copy (Bray and Métailié, p. 355).[42] No new edition appeared for two centuries. The comparison with the rapid diffusion of eighteenth century Encyclopedias in Europe is perhaps emblematic of the difference between the Chinese and European environments.

None of the late Ming writers directly challenged and refuted the basic canon of Chinese metaphysics. All the same, De Bary (1975, p. 5) and Jiang (2001) are correct in noting that the various modernizing and innovative views of the world thrived in a limited way in the late Ming period.[43] What was decisive was that these tendencies could not survive what de Bary calls "Manchu suppression." If it is true, as Jami (2012) and others have suggested that the rise of the Qing dynasty was decisive to the fate of the development of science in China, it underlines the difference with Europe: there were repressive and reactionary regimes in Europe, but the high level of interstate competitiveness constrained their ability to enforce a specific orthodoxy, both because such an orthodoxy would have negative effects on their military capability and political prestige, and because it might deprive them of some of their most useful citizens. If all rulers had been rational, therefore, we would never have seen any suppression in Europe. In fact, such events did occur, the most notorious being the revocation of the edict of Nantes in 1685 in France. But in Europe's institutional environment, all such decisions did was to shift around *where* intellectual innovation would occur, but it could not stop it altogether.

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[42]Bray also notes (1984, p. 70) that Xu's detailed program of reforming agricultural administration were never put into practice.

[43]All the same, commenting on the death of Li Zhi, Ho Hsin-yin and a similar fate that befell another heterodox writer of his age, Tzu-po Ta-kuan (1544-1604), a contemporary noted that "if anyone behaved like a heretic, he will of course be killed. Li Zhi and Ta-kuan are good object lessons" (cited by Kengo, 1975, p. 60).

Nothing like the open and competitive "Republic of Letters" emerged in China. That is not to say that Chinese intellectual life was lacking in dynamics. The Chinese attempt at Enlightenment in the seventeenth and eighteenth centuries was known as the school of *kaozheng* or "evidentiary research." In this school, abstract ideas and moral values gave way as subjects for discussion to concrete facts, documented institutions and historical events (Elman, 2001, p. 4). Chinese scholarship of this period was "not inherently antipathetic to scientific study or resistant to new ideas" (De Bary, 1975, p. 205). It was based on rigorous research, demanded proof and evidence for statements, and shunned away from leaps of faith and speculation. It all sounded quite promising, but in the end these scholars were primarily interested in philology, linguistics, and historical studies "confident that these would lead to greater certainty about what the true words and intentions of China's ancient sages had been and, hence, to a better understanding of how to live in the present" (Spence, 1990, p. 103). Equally significantly, unlike the European Enlightenment, the *kaozheng* movement remained of, by and for the mandarinate, the ruling Confucian elite, which by most accounts had little interest in material progress.

The literature about the "Chinese Enlightenment" may have overstated its bias toward literary and philological topics. There was considerable interest in astronomy and mathematics, and Chinese scholars carefully examined useful knowledge that seeped in from the West. Scholars such as Mei Wending (1633-1721) carefully compared Western mathematics and astronomy to Chinese knowledge, and pointed to the advances that the West had made. Chinese scholars, however, often made an effort to try to show that this knowledge had already existed in ancient China, indicating the difficulty they had in ridding themselves of the burden of the "ancients." Mei convinced the Kangxi emperor that European learning was derivative from the Chinese and that the only source of reliable knowledge was the ancient learning of China (Elman, 2005, p. 236). Yet Mei's rhetoric in his book *Lixue yiwen* (Doubts Concerning the Study of Astronomy, 1693) illustrates the fundamental constraints that the accumulation and application of useful knowledge in China was subject to. First, in Mei's work the moderns are in no way superior to the ancients, and there is no progress in history; indeed "the accumulation of human knowledge is merely a token of the ancients' superior merit" (Jami, 2012, p. 220). Second, he argued that the new astronomical knowledge such as the rotundity of the earth, while in its current version originating in Europe, had been present in China all along and thus was not foreign at all. Thus, Chinese sources invalidated in his view the claim of Westerners that they knew better (id., p. 222). It was in this direction that Kaozheng scholarship was increasingly applied. No such need to assert their originality seems to have been present in Europe. They borrowed useful knowledge freely from their ancestors and from foreign civilizations, acknowledging these as needed, and then went on to improve the techniques.

Unlike Europe, then, China found it difficult to shake loose from the iron grasp of the past. Mathematics, medicine, and most other forms of useful knowledge were studied and reflected on, but remained a branch of classical studies. Attempts to apply this knowledge to practical uses were taking place, and when new ideas or products appeared, the Chinese were not averse to them. But it never got to the point that natural philosophy made material progress through its applications one of its raisons d'être. The wholesale shredding of the wisdom of earlier writers, at times quite impudently so, that was characteristic of many European writers of the sixteenth and seventeenth centuries did not catch on in China. The weight of past knowledge kept burdening and constraining

original scholarship. Even Xu Guangqi massive treatise on agriculture was backward-looking: it was based for over 90 percent on citations of earlier writers (Bray and Métailié, 2001, p. 337).[44] The work of Gu Yanwu (1613–82), one of the founding intellectuals of the *kaozheng* school is revealing. Sometimes pictured as a kind of Chinese version of Arthur Young (e.g., Morris, 2010, p. 473), Gu's work is emblematic of the new Chinese scholarship: it was far more rigorous, and rational, and based on extensive traveling in China, where he acquired first-hand information. But it was mostly information based on philology, archaeology, and the careful analysis of early works.[45] Gu's interests were mostly historical and textual studies and politics.

A likely member of the kaozheng school to introduce a new spirit of investigation into useful knowledge may have been Fang Yizhi (1611-1671). Fang published a book meaningfully entitled *Small Encyclopedia of the Principles of Things*, which discussed potentially useful forms of propositional knowledge such as meteorology and geography. He was familiar with Western writings and quite influential in the Kaozheng school of the eighteenth century. Peterson (1974, p. 401) has gone so far as to suggest that Fang was representative of the possibility in the seventeenth century that the realm of "things" to be investigated would center on physical objects, technology and natural phenomena. He argued that Fang's work paralleled the secularization of science in Europe. The real question, then becomes, what was different about China and the West that Fang did not become a figure comparable to Bacon, and that his new ideas remained a only "possibility."[46]

Another suggestive example of the Chinese market for ideas is the scholar and philosopher Dai Zhen (or Tai Chen, 1724–1777). Dai Zhen was one of the dominant figures in the *kaozheng* movement, and his insistence on evidence and his mathematical capabilities would appear to make him comparable to European contemporaries. One historian described him as someone who was "a truly scientific spirit ... whose principles hardly differed from those which in the West made possible the progress of the exact sciences (Gernet, 1982, p. 513). " Yet by "evidence" he did not mean anything that Newton or Boyle would have been interested in — for him the focus of research was philology and phonology, exegesizing the writings of earlier generations. As such, he reinterpreted the writings of Confucius and tried to reconcile the teachings of two of Confucius' most illustrious followers, Mencius and his opponent Xunzi, and opposed the neo-Confucian philosophy of the Song era. As such, he did criticize the writings of earlier authorities such as the Zhu Xi, but largely on the

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[44]Nathan Sivin (1975, p. 161) notes that "in China the new tools were used to rediscover and recast the lost mathematical astronomy of the past and thus to perpetuate traditional values rather than to replace them."

[45]His magnum opus, *Ri-zhi-lu* or Jih-chih lu (Daily Accumulation of Knowledge) is a treasure of information, but is definitely stronger on Confucian classics, history, ceremony and administration than on matters of great practical knowledge. See Peterson, 1968, 1969 for details.

[46]Sivin (1975, p. 166) is far more skeptical of Fang's abilities and has compared him with European medieval scholasticism, feeling that his work was "antiquated." He points out that Fang's ideal research methodology depended on hearsay and books, not on experiment, and that "in short, the scientific revolution in seventeenth-century China was in the main a response to outmoded knowledge that gave little attention to, and consistently misrepresented, the significance of developments in the direction of modern science." Needham, 1986, p. 137 refers to Fang as "slightly muddle-headed."

grounds that the latter had misinterpreted earlier and more authoritative sages, not on the basis of observation or experiment. The Chinese were unable to entirely liberate themselves from the shackles of their ancient classical learning.[47]

The *kaozheng* medical literature had its own debate of "Ancients vs. Moderns," but ironically it differs from Europe's in critical dimensions: first, the "ancients" were the classical writers of the Han dynasty, and the "moderns" were the writers of the Song era (still three of four centuries past); and second, that the "innovative" scholars favored the earlier writers (Elman, 2005, pp. 232–36). There were no Chinese equivalents of Paracelsus and Vesalius, who threw all caution to the winds and trusted only what they (believed they) saw in the concrete evidence. Little wonder, then that the verdict of historians has been that "this scientific spirit was applied almost exclusively to the investigation of the past" (Gernet, 1982, p. 513).

What, then, explains the Needham puzzle? One tantalizing clue is a famous remark by Nathan Sivin that China has sciences but no Science (Sivin, 1994, p. 533). In this view, China paradoxically lacked a unifying single coordinating mind, whose commanding authority imposed a set of assumptions and methods that were respected by all other agents competing in the market for ideas. In Europe, despite the political fragmentation, the market for ideas worked well enough to allow such intellectual entrepreneurs to flourish, even if they were rare and far in between. Such a "focal point" in a market for ideas, as long as it does not degenerate into an uncontestable authority figure, is a sign of a well-working market (comparable in some ways to a single price). Isaac Newton played exactly that role, as did Descartes, Galileo, Lavoisier and a few others (Mokyr, 2013) . What made such entrepreneurs possible was that in Europe sacred cows were increasingly being led to the slaughterhouse. What Europe did to Aristotle, Ptolemy, and Galen, Chinese intellectuals could not do onto Confucius, Mencius and Xunzi.

The market for ideas and the Industrial Revolution

How does all this relate to economic history? The "Great Puzzle" cannot be resolved unless we recognize how culture affected the institutions that unleashed the avalanche of useful knowledge

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[47]A telling example is the adoption of the telescope, clearly a European invention, to the study of astronomy (Huff , 2011, pp. 110–14). The telescope was introduced into China by the Jesuit missionaries, but their star catalogues were not expanded at a rate similar to that achieved by telescope-equipped European astronomers such as John Flamsteed. Huff attributes this difference to a "curiosity deficit" in China, but one cannot understand this difference without a deeper examination of the institutional and political environment in which the accumulation of useful knowledge operated. Mathematicians such as Mei Wending (1633-1721) carefully compared Western mathematics and astronomy to Chinese knowledge, and pointed to the advances that the West had made, though he and other Chinese scholars made an effort to show that this knowledge had already existed in ancient China. These efforts are illustrative and indicate the difficulty they had in ridding themselves of the burden of the "ancients." Mei convinced the Kangxi emperor that European learning was derivative from the Chinese and that the only source of reliable knowledge was the ancient learning of China (Elman, 2005, p. 236). Mei's rhetoric in his book *Lixue yiwen* (Doubts Concerning the Study of Astronomy, 1693) illustrates the fundamental constraints that the accumulation and application of useful knowledge in China was subject to. In Mei's view the moderns are in no way superior to the ancients, and there is no progress in history; indeed "the accumulation of human knowledge is merely a token of the ancients' superior merit" (Jami, 2012, p. 220).

that eventually fueled the European Industrial Revolution. Despite the beliefs of David Landes and Max Weber, there was nothing *inherently* different about European culture that made it inevitably more innovative. A Judeo-Christian tradition, the legacy of Classical Civilization, or the heritage of Feudalism (to cite just three historical differences) all make little sense. What made the difference were the unintended consequences of institutions such as the Republic of Letters and an intellectual ferment that arose as the result of historical contingencies and as the by-product of largely unrelated phenomena. Christianity, the belief in a personal God, and many other supposed metaphysical differences mattered insofar as they affected the outcomes in the market for ideas. Metaphysical beliefs may have prepared some minds for the ideas of economic progress through useful knowledge, but they might just as well have ended in a repressive and reactionary world of intellectual stagnation, in which intellectual innovators were strongly discouraged from proposing new ideas or never had a chance to enter the market for ideas.

The main novel insight that gained a large following in Enlightenment Europe, that economic and social progress could and should be attained by the accumulation of useful knowledge, was certainly not in direct contradiction with Chinese culture and as we saw, some Ming and Qing intellectuals moved in that direction. But because the market for ideas was insufficiently competitive, innovators were insufficiently incentivized and protected, and the few radical intellectual innovators lost out. It was not until the late nineteenth century that China was sufficiently shocked by a sequence of political disasters that its institutions were dramatically revamped to change how useful knowledge was deployed.

Such a commitment to past knowledge may seem more surprising in a society such as China's, without institutionalized religion and without an organized caste of priests, rabbis, or mullahs who interpreted the sacred writings of the past. One explanation may be the huge investment of human capital in the classical writings of the past in the hope of passing the Ming Civil Service examination. The vast bulk of candidates failed these exams in local competitions, and large reservoirs of classically trained men who were still looking for ways to extract some rents from their human capital. These people also constituted a vast audience for the books published at the time. The first three Qing emperors, who ruled for more than a century, sought to appropriate the classical legacy to "establish their dynamic prestige and political legitimacy" (Elman, 2005, p. 238). But more generally, the often disrespectful scepticism toward the formerly sacrosanct knowledge of earlier generations that awoke in Europe when more and more beliefs of ancient authorities were questioned, tested, and found wanting by European scientists and physicians, was rarely allowed to arise in China.[48]

Was there no concept of "progress" among Chinese intellectuals? In a long essay, Needham (1969a, p. 280) reacted to Edgar Zilsel's (1945, p. 325) remark that the idea of progress in useful knowledge had never occurred to Brahman, Muslim, Confucian or Latin scholars by remarking that "he would have done better to leave Confucian scholars out of it." Needham argued that the "idea

[48]Even Jack Goody, who goes out of his way to condemn "essentialist" interpretations of Chinese history, writes that "characteristic of the cultural history of China has been a constant looking back to the Confucian classics, to 'Antiquity', providing a continuous point of reference for both conservatives and reformers" (2009, p. 238).

of cumulative disinterested cooperative enterprise in amassing scientific information was much more customary in medieval China than anywhere in the pre-Renaissance West."[49] Other experts have disagreed: it was pointed out that Taoist thought felt overall that if there was a trend in history, it led from paradise to corruption; it was argued that the decline only began after early sage-kings had completed their "civilizing work" on society and that while both "cyclical" and "linear" dynamics can be found in Chinese reflections on history, the cyclical element clearly dominated (Bodde, 1991, pp. 122-33). In general, most Chinese thinkers, insofar that they recognized a trend, felt that the past was better than the present or that at worst history was a cyclical but stationary process. Strikingly, Needham's evidence for belief in progress is entirely taken from pre-Ming China, and the idea shrank and withered in China just as it was emerging triumphant in parts of Europe. Needham concedes that the effects of innovation in China were never quite as profound as in Europe and that the same innovations that dramatically altered the course of history in Europe "left Chinese society relatively unmoved" (Needham, 1969a, p. 284).[50]

The modern idea of progress was largely a European invention, and despite some precursors, clearly emerged triumphant only in the eighteenth century. It was (and still is) seriously contested in Europe, and there is no a priori reason for it to have triumphed ineluctably. The outcomes in market for ideas eventually changed the institutions in which intellectual innovation functioned. In early modern Europe stronger incentives for such innovators emerged, from intellectual property rights to a variety of rewards and patronage positions. The economic significance of the victory of the idea of progress for the Industrial Enlightenment and the subsequent economic development of Europe is hard to quantify, but seems undeniable. After all, it was one thing to formulate a theory of progress; it was quite another to devise a detailed program of institutional change that would actually bring it about. The result was that in the eighteenth century, especially after 1760, western Europe entered a regime of accelerated innovation that ended up changing the world.

The Industrial Revolution had many complex causes (Mokyr, 1999), but at its foundation was a cultural belief in Progress of a particular kind. Progress was to be achieved not by the perfection of morals or the attainment of freedom or even by the reform of political institutions (though these mattered as well), but above all by mastery over nature and the ensuing technological improvements. That such progress was possible and how it was to be achieved was decided in the market for ideas, and studying that market is an important task for economic history.

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[49]Needham adds (1969, p. 277) that "no mathematician or astronomer in any Chinese century would have dreamed of denying a continual progress and improvement in the sciences they professed."

[50]Compare this with the more recent statement of Frederic Mote: "self-renovating change was constant and gradual, no sudden and disruptive and always justified by reference to past models...[China] presents the fascinating enigma of archaism serving the cause of renovating change" (1999, p. 966).

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