Knowledge, Enlightenment, and the Industrial Revolution: Reflections on Gifts of Athena

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It is always an honor to have other scholars spend time and thought to reflect on one's work, and all the more so to have four such distinguished and eminent scholars write these essays. Most reassuring of all, however, is that my message seems to have caught on. The main point in writing *Athena* was that the material sphere of technology, production, efficiency in such mundane worlds as cotton mills, coal mines, water mills and shipyards must be understood as closely connected to the sphere of knowledge, ideas, experiments, mathematical proofs, and observation. The connections between these worlds is complex and nuanced, and reasonable scholars will come up with somewhat different views on these matters, but on the fundamental principles there seems to be very little disagreement.

When *Gifts of Athena* was published, I had no illusions that it would be my last word on the topic. Since then, I have published a number of essays, in which subsequent reflections are summarized. One of these was my lengthy paper in the *Journal of Economic History*.[1] In that paper I returned to the concept of *access costs* as a centrally important element in the change in the intellectual landscape of the eighteenth century. Hilaire-Pérez in her paper correctly stresses that my description of the improvements in communication in *Athena* may have been too narrowly focused on a small elite. A good case can be made that the number of agents should be expanded. It remains my view, however, that neither of the two eighteenth-century events I have tried to connect, the Enlightenment and the Industrial Revolution, were the results of massive changes in the knowledge or education of the population at large. Overall literacy rates can hardly have mattered as much as they are believed to in modern economies, given Britain's backwardness in that dimension.[2] The quality of the *average* worker may have mattered much less for the generation and adoption of new and more productive techniques than the quality of the skilled artisans and mechanics that Hilaire-Perez speaks of. Access costs, it should be noted, involved the movement of ideas and knowledge and that often meant the movement of people who came to teach or learn when knowledge could not be codified and had to be seen to be copied. This centrality of *tacit* knowledge, as the late John Harris tirelessly pointed out,

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[1] Joel Mokyr, "The Intellectual Origins of Modern Economic Growth," *Journal of Economic History*, Vol. 65, No. 2 (June 2005), pp. 285-351.

[2] David Mitch, "The Role of Education and Skill in the British Industrial Revolution." In Joel Mokyr, ed., *The British Industrial Revolution: An Economic Perspective,* 2d ed., 1999, pp. 241–79. Boulder, Colo.: Westview Press.

was especially true for the metal and coal industries, but it surely was true across the board.[3]

It is also worth repeating that access costs were important because they governed, so to speak, both vertical and horizontal movements of useful knowledge. By vertical movements I mean the signals sent between those who controlled Ω (propositional knowledge) (the *savants*) and those who dealt in λ (prescriptive knowledge) (the *fabricants*). As I emphasized in *Athena*, the connection between those two spheres is critical to the question posed by Bruland in her essay, namely what segments of Ω will end up being "mapped" into the set of available techniques, that is to say, how does selection on both propositional knowledge and prescriptive knowledge take place? This, indeed, is among the hardest problems in economic history.[4] What is particularly astonishing is that in many cases societies seem to have had technological opportunities that they could have exploited given the knowledge they had, but for one reason or another the mapping does not seem to have taken place. Why, for instance, did the Romans never invent eyeglasses despite their knowledge of glass or optics? Part of the answer must be the point I made above: the communications (or *passerelles* as Hilaire-Perez has called them elsewhere) between those who make things and have a "feel" for what is needed and between those with the mathematical or chemical knowledge to realize how the problem is to be solved needs to be tight and effective for this horizontal signalling.[5] As I have argued repeatedly, this communication is at the heart of the Industrial Enlightenment.

Horizontal access counted just as much. And here Hilaire-Perez's and Berg's emphasis on the importance of artisanal knowledge (very much part of my concept of Ω) points to something important to our understanding of what happened in the eighteenth century. The message of *Athena* here is unambiguous:

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[3]John R. Harris, "Skills, Coal and British Industry in the Eighteenth century," in *Essays in Industry and Technology in the Eighteenth Century.* Ashgate: Variorum, 1992; id*., Industrial Espionage and Technology Transfer*. Aldershot, Eng.: Ashgate 2001.

[4]For an attempt to deal with this question, see Joel Mokyr, "Useful Knowledge as an Evolving System: the view from Economic history," in Larry Blume and Steven Durlauf eds., *The Economy as and Evolving Complex System* Vol. III,, Oxford University Press, 2006, pp. 307-337.

[5]Liliane Hilaire-Pérez, *L'Invention Technique au Siècle des Lumières.* Paris: Albin Michel, 2000. Stewart captures the flavor of my argument in his statement that enlightenment thinkers considered the distinctions between scholars and craftsmen downright "to the philosophical enterprise" though they were regarded equally harmful to material progress in general. Count Rumford noted impatiently in 1799 that "there are no two classes of men in society that are more distinct, or that are more separated from each other by a more marked line, than philosophers and those who are engaged in arts and manufactures" and that this prevented "all connection and intercourse between them." Thompson, William Count Rumford. *The Compete Works of Count Rumford*. London: the American Academy of Arts and Sciences, MacMillan & Co., 1876, pp. 743-745.

the vertical and horizontal movements of knowledge were strongly complementary. The former, in the end, was indispensable if macroinventions were to alter technological paradigms; the latter if the knowledge was to diffuse between artisans, improved, adapted, and debugged (through what I have called microinventions) and ultimately raise productivity and introduce new, better, and cheaper goods and services. The belief that improvements in useful knowledge at both levels would eventually benefit society, known as the Baconian program, remained a central theme of the Enlightenment.

Berg, in her emphasis on the importance of artisanal knowledge, and especially its dissemination and mobility within Europe, feels that they may have been short-changed by my earlier work. In *Athena*, rather than treating their knowledge in a "circumspect or suspicious" way, I stressed the importance of artisans through my emphasis on what I call *competence,* that is, the capability of carrying out the instructions contained in prescriptive knowledge.[6] The term "knowledge in action," proposed by Hilaire-Pérez seems to be covering more or less the same ground. Artisans were, as both of them note, the people who actually made things that they did not usually design, not once but over and over. Their role is mentioned in *Athena* but I did not emphasize them as a crucial dynamic element in the Industrial Revolution.

Whether they were or not remains an interesting issue. It is certainly not a self-evident statement, as both Hilaire-Pérez and Berg seems to think, that "an economy of imitation" led to a self-sustaining process of improvement. This argument borders on the inventor-as-tinkerer views of the Industrial Revolution that were one reason why I wrote *Athena*. Artisans normally reproduced *existing* technology (as Epstein has stressed) and in that process an incremental microinventive sequence could lead to some improvements. Many societies we associate with technological stasis were full of highly skilled artisans, not least of all Southern and Eastern Asia. Artisans in the standard sense of the word are an indispensable complement to inventors by building designs to specification and making complex mechanism work; but a purely artisanal-knowledge society will eventually revert to a technological equilibrium in contrast to a society where the

[6]Elsewhere, indeed, I pointed to the competence of British skilled craftsmen as a crucial element of the British Industrial Revolution. See Joel Mokyr, "Technological Change, 1700-1830," in Roderick Floud and D. N. McCloskey, eds., *The Economic History of Britain Since 1700*, 2nd edition, Cambridge University Press, 1994, Vol. I, pp. 12-43 and Joel Mokyr, "Long-term Economic Growth and the History of Technology" In *Handbook of Economic Growth*, Philippe Aghion and Steven Durlauf, eds., Amsterdam: Elsevier, 2005, pp. 1127-29.

world of artisans is constantly shocked with infusions from new knowledge from outsiders.

Hilaire-Pérez emphasizes the innovative capacity of French artisans in their guilds, and the examples she cites are interesting. There can be no doubt that in a purely artisanal world, sequences of microinventions can take place that will lead to considerable technological progress, both product and process innovation. Some of the more interesting "great inventors" of the age — starting with Newcomen and his assistant John Calley and the clockmaker John Harrison — were artisans themselves. Yet artisans, unless they are as unusually gifted and well-educated as Edme Régnier or James Watt, were good at making incremental improvements to existing processes, not in expanding the epistemic base of the techniques they used or applying state of the art knowledge to their craft. Artisans were also not in a well-positioned to rely on the two processes of analogy and recombination, in which technology improves by adopting or imitating tricks and gimmicks from other, unrelated, activities. If all that were needed for the Industrial Revolution had been enlightened artisans, it could have occurred centuries earlier. Artisans, after all, had been around for centuries, and relying on their innovativeness without the infusion of more formalized and systematic useful knowledge for an explanation of the Industrial Revolution would make it difficult to understand why things moved so rapidly after 1750. In textiles, the technical problems were on the whole less complex than in the chemical industry or in power engineering, but even there, as Margaret Jacob shows, mechanical science found its way soon enough to the shopfloor with important consequences for productivity and efficiency.[7] Moreover, France was teeming with skilled artisans, yet for decades it seemed unable to build the steam engines and develop the iron-processing improvements that Britain did on its own. Not all artisans were friendly and conducive to technological progress, as Hilaire-Pérez points out. The armourers' resistance to Honoré Blanc and interchangeable parts in musket making helped derail a potentially promising advance. The Lyon weavers' resistance to the Jacquard loom failed, but innovators needed military protection.

Berg stresses artisanal *mobility* as a dynamic element. But again: artisans had been moving around for a long time before 1700; mercantilist government did their best to attract the most productive ones, but the entire institutional structure encouraged and often forced such "wayfarers" to move about, thus spreading

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[7]See Margaret C. Jacob, "Mechanical Science of the Shopfloor" *History of Science,* 2006, forthcoming.

knowledge.[8] That their movement about helped reduce access costs to knowledge is undeniable. Yet such movements in the sixteenth and seventeenth centuries did not trigger an Industrial Revolution; something was different after 1750. Moreover, their mobility was not sufficiently extensive as to erode the advantages Britain possessed on account of its superior artisans (an advantage she tried to prolong by passing the ineffective prohibition on artisan emigration).[9] As Stewart points out, if we persist of thinking of industry in the Industrial Revolution in terms of purely mechanical dexterity and skills, scientifically-informed engineers and entrepreneurs like Wedgwood, Smeaton, Marshall, and Gott would seem surprising.[10]

What is astonishing, in retrospect, is that the Enlightened belief in the value of useful knowledge survived so long in the face of a lack of success. The world turned out to be more messy and complex than the early and hopeful proponents of the Baconian program realized, as H.F. Cohen has suggested.[11] The natural philosophers on whom so many placed their hopes did not know enough and lacked the tools to solve most of the pressing problems quickly, and many of the early inventions, especially in textiles, were driven by mechanical dexterity, intuition, experience-driven insights, and similar abilities. Yet the belief that somehow the systematic study of nature could yield insights that would eventually enrich and improve industry and agriculture never faded, no matter how remote the chances were. Perhaps nothing illustrates this better than the fascination of the age with electrical phenomena, intensively experimented with in such associations as the Spitalfield Mathematical Society discussed by Larry Stewart. Apart from Franklin's lightning rod and some amusing public displays, the study of electricity did little to advance the economy prior the electromagnetic telegraph in the late 1830s.

The age of Enlightenment set up institutions that signalled to natural philosophers that there were

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[8]Carlo Marco Belfanti, "Guilds, Patents, and the Circulation of Technical Knowledge," *Technology and Culture* 45 (July 2004): pp. 569-89

[9]These difference in competence were clearly understood by contemporaries. Thus Jean Baptiste Say in the early nineteenth century: "the enormous wealth of Britain is less owing to her own advances in scientific acquirements, high as she ranks in that department, as to the wonderful practical skills of her adventurers in the useful application of knowledge and the superiority of her workmen". See, Jean-Baptiste Say, *A Treatise on Political Economy.* 4th ed., Boston: Wells and Lilly 1803 [1821], pp. 32-33.

[10]Jacob, "Mechanical Science of the Shopfloor."

[11]H. Floris Cohen, "Inside Newcomen's Fire Engine: the Scientific Revolution and the Rise of the Modern World." *History of Technology* 25 (2004), pp. 111-132, quotation on p. 123.

problems to be solved, there might be money or honor to be gained from doing so (usually more the latter, given the institutional structure of the scientific community), and to focus their efforts on searching within the available body of propositional knowledge for solutions to real-world problems. The Royal Society, at least in its early days, was deeply conscious of this responsibility.[12] From the determination of longitude at sea to the needs to bleach textiles to the desperate attempts to cure or prevent smallpox, the eighteenth century looked increasingly at propositional knowledge for solutions to its most pressing problems. The institutions in charge of this established involved a large number of perceived payoffs to inventors, and monetary rewards through patents or grants and pensions awarded by a Parliamentary or Académie Royale committee were only part of the story. The Society of Arts, for instance, played an important role in focusing the minds of potential innovators to what was needed in the economy. Eighteenth century science was different from science in our own time, and that much of the growth in Ω was heavily descriptive and consisted of the three C's (counting, cataloguing, classifying) is well-known. Yet it was widely believed that such descriptions in themselves would help producers be more efficient and productive.

That the Industrial Enlightenment was a milestone in this improvement in communications seems by now too obvious to mention. Indeed, the entire Enlightenment project has been interpreted by some scholars in the Habermas tradition as being primarily about communication. The channels of communication, roughly, divide into those that transmitted codified and formal knowledge (books and articles), those that transmitted tacit knowledge (travelling artisans and industrial spies), and those that did a little of both (exhibitions, museums, correspondence). The tale of James Cox and the Mechanical Museum he opened in 1772 in Spring Gardens near Charing Cross mentioned by Hilaire-Pérez is instructive here. Clearly it indicates the huge demand for mechanical knowledge at the time. It bears noting that the mechanical part was actually managed by a Belgian named John Joseph Merlin, illustrating the international nature of the flows of mechanical knowledge. It might also be noted that Cox's museum was a financial failure, like so many other endeavors of the Industrial Enlightenment. There was nothing linear or self-evident about technological progress; the engineers and mechanics of the time stumbled and fumbled their way toward things that worked

[12]Michael Hunter, *Establishing the New Science : the Experience of the Early Royal Society.* Woodbridge, Suffolk, and Wolfeboro, N.H.: Boydell Press,1989.

a little better. Equally likely is the possibility that the actual agents that advanced useful social knowledge were not able themselves to catch much of the social surplus they created.

But, as Larry Stewart stresses, content mattered a great deal. It was not just that knowledge accumulated: the Industrial Enlightenment changed the research agenda. Peter Burke has argued that the eighteenth century saw the rise of "the idea of research" and the sense that this knowledge could contribute to economic and social reform.[13] The change in the pace of progress of knowledge after 1680 was indebted to the triumph of Newtonianism in the first half of the eighteenth century. There was perhaps little in Newton's cosmology or optics that would be of much direct use to engineers and inventors, but the increase in the prestige of a particular kind of science that combined careful observation with rigorous reasoning without too much concern about the metaphysical implications, were part and parcel of Newtonianism and informed other areas of investigation.

How and when this growth in the prestige of formal science led to technological improvements is still not quite clear, but Newton's triumph coupled with the "focusing devices" that emerged in the eighteenth century changed the agenda of research. The rather concrete needs of manufacturers, sea captains, physicians, and farmers signalled to the natural philosophers and increasingly affected their choice of subject matter. The "business of science," John T. Desaguliers noted in the 1730s, was "to make Art and Nature subservient to the Necessities of Life in joining proper Causes to produce the most useful Effects."[14] The greatest minds of the age did not hesitate to get dirt under their fingernails and work on problems that were pragmatic and mundane. Leonhard Euler, the most talented mathematician of the age, was concerned with ship design, lenses, the buckling of beams, and (with his less famous son Johann) contributed a great deal to hydraulics. Colin MacLaurin found an ingenious solution (1735) to the problem of measuring the quantity of molasses in irregularly shaped barrels by the use of classical geometry. René Reaumur was another great scientists deeply interested in pragmatic issues, assembling huge amounts of information on metallurgy, ceramics, entomology, the design of workshops and machinery. The great Antoine Lavoisier himself worked as a young

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[13]Peter Burke, 2000. *A Social History of Knowledge.* Cambridge: Polity Press, p. 44.

[14]John T. Desaguliers, *A Course of Experimental Philosophy,* third edition, London, 1763, vol. 1, p. iii.

man on the chemistry of gypsum and the problems of street lighting. His students Monge, Berthollet, and Vandermonde published in 1786 a famous paper, which nailed down the chemical properties of steel.[15] It is almost immaterial to what extent these efforts contributed significantly to GDP or the technological practices of the day. What mattered was the growing belief that the agenda of scientific research, at least in part, should be guided by the material needs of society. It seems misleading to exaggerate the dichotomy between Britain and the Continent in this regard. Elsewhere, Larry Stewart has argued that in Britain "being enlightened meant being industrious as well as being technologically au courant." Surely this is but a part of the British Enlightenment, and not one that they monopolized. Voltaire and Helvétius are part of the French Enlightenment, as Stewart has noted elsewhere, but they do not "symbolize it" as he would have it.[16] One could make an equally compelling case for a pragmatic side of the French Enlightenment symbolized by Reaumur, Duhamel de Monceau, François Rozier, Chaptal, Berthollet, and many others. There *were* differences between national styles, because the Enlightenment in each country was exposed to a different institutional environment and faced different constraints. But the differences tended to be eroded and dissolved over time, as intellectuals across national boundaries corresponded, visited one another, read each others' books and papers, and compared notes.

Bruland in her essay stresses the importance of political economy, but feels that resistance to new technology does not invariably leads to inferior outcomes. In particular cases, her argument seems attractive as I have argued at length elsewhere.[17] It is not just that some technological innovations may lead to inferior

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[15]Charles C. Gillispie, *Science and Polity in France at the end of the Old Regime*. Princeton: Princeton University Press, 1980, pp. 438-44.It is indeed interesting that Berg cites John Harris's somewhat dismissive remark about the discovery of the properties of steel by Berthollet, Monge, and Vandermonde in 1786. Without the knowledge that carbon content determined the characteristics of steel, it would have been rather hard to make progress in this industry — though it took many years from that paper to Henry Bessemer and Robert Mushet. The knowledge, however, had clearly diffused to Britain by the 1820s, and was cited in widely available sources (e.g. *The Repertory of Arts, Manufactures and Agriculture* London: J. Wyatt, 1821, p. 369; Edward James Wilson, *The Artist's and Mechanic's Encyclopaedia,* Vol. 2,, Newcastle upon Tyne: Mackenzie and Dent, 1830, p. 67). In France, the Committee for Public Safety instructed the three scientists to write a 34-page pamphlet depicting how to make steel and distributed fifteen thousand copies. See Jeff Horn, *The Path not Taken: French Industrialization in the Age of Revolution*. Cambridge, MA, MIT Press, 2006, pp. 147-48.

[16]Larry Stewart, "A Meaning for Machines: Modernity, Utility, and the Eighteenth-century British Public," *Journal of Modern History* 70, no. 2 (1998), p. 264.

[17]See Joel Mokyr, "The Political Economy of Technological Change: Resistance and Innovation in Economic history" in Maxine Berg and Kristin Bruland, eds., *Technological Revolutions in Europe*, Cheltenham: Edward Elgar Publishers, 1998, pp. 39-64.

outcomes because not all their social or ecological consequences are understood from the outset. It is also surely the case that in the absence of any resistance to change, a dynamic system would become totally unstable, with a huge degree of experimentation leading to costly chaos. Yet, clearly, past institutions were more likely to favor the status quo over the novel, and while many cases of what seems like technological conservatism turn out to have been sensible, on the whole it cannot be disputed that most resistance to new technology was self-serving and costly to progress. Had it triumphed, Europe might have experienced an experience more similar to China, that is, become an economy that was commercialized, monetized, and in which economic organization is conducted at a fairly sophisticated level, but one largely devoid of the inherent capability to generate the technological momentum to break out of the stationary state.

Much of the history of the Industrial Revolution is, as Bruland points out, should be about the political and social institutions that stimulated and enhanced technological progress and determined not only which techniques were selected but also which institutions helped to write the menu of techniques. Governments played an important role in this process, although perhaps less so during the critical years of the Industrial Revolution than in our own time or in Song China. Specifically, we need to know much more about what institutions help determine the agenda of investigation, what areas are high priority, what areas are taboo, and which are in between. My recent research has looked into the political and ideological background of the agenda in Europe in the centuries before the Industrial Revolution.[18] Economists, of course, are fond of pointing to those institutions that provided the "correct" incentives to innovate, and which induce the direction of innovation in a particular direction. During the Industrial Revolution, Britain provided many such incentives. Even when inventors were failed by the patent system, some of the more notable ones were voted pensions and grants by parliament and others maintained serious hopes that such compensation would be forthcoming. The Society of Arts awarded small prizes to successful inventors who had not secured patents, and other rewards were handed out or petitioned for by grateful colleagues to inventors who made

[18] Joel Mokyr, "The Market for Ideas and the Origins of Economic Growth in Eighteenth Century Europe," [Heineken Lecture], in *Tijdschrift voor Sociale en Economische Geschiedenis* 2007, forthcoming.

unusual contributions to a particular industry.[19] Some well-known prize contests challenged the best and the brightest to resolve technological bottlenecks, of which the Board of Longitude and the 1825 Rainhill competition are the best known.[20] What mattered further to would-be innovators were access to credit and markets to turn ideas into business ventures, both of which were especially strong in Britain. It is also clear, however, that not all inventors were as patent-hungry as Boulton and Watt who lobbied long and hard for the extension of their patent until 1800. Many of the important inventions were made by scientists whose culture was much more like open-source in our day, and who were interested in credit, not profit. Greed was only one motive for the innovators of the Industrial Revolution: ambition, altruism, and curiosity also played roles.

Beyond that, however, what was needed for a rapidly growing economy is the kind of polity that discourages rent-seeking and diverts the energies and initiatives of the most resourceful individuals toward technology and production and not toward lobbying and redistribution. It is this aspect of the Enlightenment which *Athena* underemphasizes, and on which I have tried to set the record straight subsequently.[21] The Enlightenment placed the old mercantilist mentality under severe pressure, and inspired reforms that reduced the amount of rent-seeking and redistribution in the economy. Economists have long realized that such reforms are necessary if economic growth is to take off in a serious way.[22] Among the *ancien régime* institutions that were in the crosshairs of the eighteenth century *philosophes* were the craft guilds, long reputedly an obstacle to technological advances and a more effective allocation of resources. Hilaire-Pérez invokes the

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[19]An example is Nicolas-Joseph Cugnot, widely believed to be the true inventor of the steam car, whose *fardier à vapeur* of 1769 was a steam-propelled vehicle. The research was funded by the French military and was discontinued in 1772, but he was awarded an annual pension by Louis XV in recognition of his efforts.

[20]The example cited by Stewart, the Society of Arts's promised prize for the best imitation of Chinaware from British raw materials, is another case in point.

[21]Joel Mokyr, "Mercantilism, the Enlightenment, and the Industrial Revolution," Presented to the Conference in Honor of Eli F. Heckscher, Stockholm, May 2003. Forthcoming in Ronald Findlay, Rolf Henriksson, Håkan Lindgren and Mats Lundahl (eds), *Eli F. Heckscher (1879-1952): A Celebratory Symposium.* Cambridge, MA: MIT Press, 2006, pp. 269-303. Id., "The Great Synergy: the European Enlightenment as a factor in Modern Economic Growth", in Wilfred Dolfsma and Luc Soete (eds), *Understanding the Dynamics of a Knowledge Economy*. Cheltenham: Edward Elgar (2006), pp. 7-41.

[22]William Baumol,. *The Free-Market Innovation Machine: Analyzing the Growth Miracle of Capitalism*. Princeton, NJ: Princeton University Press 2002. Andrei Shleifer, and Robert Vishny, *The Grabbing Hand : Government Pathologies and their Cures. Cambridge, MA: Harvard University Press 1998.*

work of Stephan Epstein and his colleagues who have made an attempt to set the record straight on the role of guilds in impeding technological progress.[23] The final verdict on the guilds's role in technological change is not quite in, and it is likely that their net effect on technology differed over time and space. Yet by the mid eighteenth century they had been become a conservative force in most of Europe, and a main tool of rent-seeking both by their members and the taxing authorities who utilized them.[24] That some guilds were more innovative than others, as Hilaire-Pérez argues, is quite obvious. Yet there can be little doubt that in Britain the weakness of the guild system removed a serious impediment to the acceptance of technological progress, and there is little evidence to date that conservative guild traditions being turned more innovative was a nation-wide phenomenon. In Lyon, Hilaire-Pérez's own data show that thirty years after the invention of the Falcon loom, less than one per cent of its weavers utilized it — hardly a stellar example of technological diffusion.

To repeat: the eighteenth century was pivotal. Larry Stewart is quite correct in pointing to the many ways in which this century witnessed ways in which natural philosophy and industry were brought face to face. "Useful knowledge" of course included a lot ore than formal science. Tables, compendia, and catalogs classified and described natural phenomena in the hope that some regularities would emerge that could improve production processes. The same was true for agriculture, and while a term such as "agricultural enlightenment" sounds mildly oxymoronic, there can be little doubt that the idea that even in farming — maybe especially in farming — more knowledge would yield significant results. Like all other aspects of the Enlightenment, it was not confined to the British Isles, the French coining the phrase *agromanie* and Empress Catherine the Great invited the noted German agronomist J.C. Schubart to Russia to help spread his ideas of improved farming. The great practical writers of the era, whom everyone interested in enlightened farming read and admired were predominantly British. What is striking about them is the increasingly tight connections they sought with natural philosophers. Arthur Young himself sought the help of the leading

[23]S. R. Epstein, "Craft Guilds, Apprenticeships, and Technological Change in Pre-industrial Europe." *Journal of Economic History* 58, no. 3 (Sept.1998) pp. 684–713. Id., "Knowledge-Sharing and Technological Transfer in Premodern Europe, C. 1200 - C. 1800." Unpublished manuscript, presented to the EHA Annual Conference, San Jose, 2004.

[24]Sheilagh Ogilvie,. "Guilds, Efficiency, and Social Capital: Evidence from German proto-industry." *Economic History Review* 57, no. 2, 2004, pp. 286-333.

British scientist of the 1780s, Joseph Priestley, in setting up his experiments. Many leading scientists were deeply interested in farming. The eminent chemist Humphry Davy was commissioned to give a series of lectures on soil chemistry resulting in his *Elements of Agricultural Chemistry* (1813), which became the standard text until replaced by Von Liebig's work in 1840. The creative and original Scottish chemist Archibald Cochrane, the ninth earl of Dundonald, published in 1795 a treatise *Shewing the Intimate connection that Subsists between Agriculture and Chemistry*. Most of these writings were empirical or instructional in nature. Davy had to admit that the field was "still in its infancy" and his work was largely empirical. A few, however, actually tried to provide the readers with some systematic analysis of the principles at work. As so often, much of this work was done in Scotland. One of those was Francis Home's *Principles of Agriculture and Vegetation* (1756). Another was Lord Kames's *The Gentleman Farmer: being an Attempt to Improve Agriculture by subjecting it to the test of Rational Principles* (1776).

Whether this literature affected productivity in the short run is very much in doubt. It tells us perhaps as much about the demand as about the supply side of useful knowledge in the eighteenth century Western European economy. It reflects what people believed: they had persuaded themselves that "useful knowledge" could increase and improve their living standards. The "enlightened economy" was not confined to the "modern sector" in manufacturing, transportation, or mining. It extended, at least in intent, to sectors where its success was rather limited because the foundations of the natural processes were so poorly understood. Yet the hope that knowledge would improve material welfare was widespread, and the niggardliness of nature was attacked on a much wider front than is often realized. The first breaches in that front were made where the problems were less difficult by comparison and where progress could be secured even without a wide epistemic base.

Although economic growth properly speaking did not take off until the nineteenth century, the preparatory work for the Great Divergence occurred in the century after 1680. Pomeranz and his fellow Californians may well be correct that measurable living standards in Western Europe did not differ much from those in the Yangzhi valley around 1750; but underneath the surface the tectonics plates in Europe were moving relentlessly toward the growth explosion of the nineteenth century. It seems hard to dispute that in this era Europe had an Enlightenment — whatever precise definition we may want to attach to the word —

and the rest of the world did not. Indeed, in key European societies, the Enlightenment was resisted for many decades and failed to make much of an impact; whether accidental or not, these countries (one thinks of Spain and Russia, as well as much of Eastern Europe) were slow to join the "convergence club" of 1914. Pomeranz, in particular, avoids science and technology, or even institutions in general, as possible explanations of the Great Divergence. No doubt geography mattered as well. All the same, ideology and "beliefs" mattered a great deal, since they were the foundation of institutional change. Can one even imagine the American and French revolutions without the impact of the Enlightenment?

Finally, I would like to dwell briefly on the matter of why Europe had an Enlightenment at all.[25] There appear few persuasive explanations beyond the usual ruminations about religion and the rise of a commercial bourgeoisie. One way of thinking about it is that rather than asking why it occurred at all, we may ask why it was successful in Europe, allowing for the possibility that it had stood a chance elsewhere but failed to overcome the resistance to it.[26] The Enlightenment, in this view, was the result of a triumph in a competitive "market for ideas" in which ideas competed in a Dawkinsian world for "selection."[27] Just as techniques and scientific hypotheses are selected by people who attach credence to them on the basis of whatever the rhetorical standards of the time are, thus the entire notion of the Enlightenment, was on the whole persuasive to most eighteenth century intellectuals. In part, of course, this was because Locke, Diderot, Hume, Voltaire and others told their audiences what they wanted to hear. In part it was because many of these intellectuals were articulate, eloquent, and smart. In part it was because they were in many ways part of the "establishment." Many of the leading lights of the eighteenth century philosophes and political economists were well-born and politically well-connected. Even when they ran afoul of the regime, the relations rarely degenerated into hostility. This "cosy fraternizing with the enemy," as Peter Gay calls it did

[25]For a more detailed analysis, see my "The Market for Ideas and the Origins of Economic Growth in Eighteenth Century Europe," [Heineken Lecture], in *Tijdschrift voor Sociale en Economische Geschiedenis* 2007, forthcoming.

[26]For a brief discussion of the Chinese *KaoZhen*g movement in the late seventeenth century and how it failed to turn into anything that would affect economic performance, see Mokyr, "Synergy."

[27]Joel Mokyr, "Mobility, Creativity, and Technological Development: David Hume, Immanuel Kant and the Economic Development of Europe". In G. Abel, ed., *Kolloquiumsband of the XX. Deutschen Kongresses für Philosophie*, Berlin 2006, pp. 1131-1161.

not come without a price, but it allowed the *philosophes* to be politically effective without necessarily threatening the status quo.[28]

But above all, we should not forget how difficult it had become to suppress *any* kind of heterodoxy or apostasy in Europe after 1500. Effective suppression, in the European environment, would have required a close coordination of many rulers and officials, spread over different political and religious regions. Such coordination became very hard to attain in early modern Europe. Enlightenment figures often played the great powers brilliantly against one another, and if necessary, simply moved about. By 1700, in fact, the peripatetic character of European intellectuals and their cleverness in exploiting the limits to power and geographical boundaries made any suppression of new ideas quite unlikely.[29] The failure of centralized and coordinated suppression gave the European Enlightenment a chance it did not have elsewhere. At the same time, political fragmentation was accompanied by a coherent community of knowledge, the "Republic of Letters," an informal but powerful network which European scientists, mathematicians, and philosophers belonged to, disregarding national and language boundaries.[30] This happy coincidence created a set of circumstances in which innovation and creativity had the opportunity to flourish as nowhere before and nowhere else. Inevitably, such a flourishing would end up affecting the economy and society in ways that no one at the time could have anticipated.

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[28]Peter Gay, *The Enlightenment: an Interpretation. The Rise of Modern Paganism.* New York: W.W. Norton, 1966, p. 24.

[29]A good example is the location of Voltaire's Ferney estate, just over the Swiss border. It had to be located in France to avoid Geneva's rule against having a private theatre, but close enough so that *in extremis* he could make a quick escape, which, given that this layout was common knowledge, was in fact never necessary.

[30]An elaborate argument on the growth of useful knowledge thanks to the changing dynamics of these networks can be found in Randall Collins, *The Sociology of Philosophies: a Global Theory of Intellectual Change*. Cambridge, MA: Harvard University Press, 1998, ch. 10.