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Maxine Berg, University of Warwick, UK

The Genesis of 'Useful Knowledge'

Introduction

James Keir, the chemist and Lunar man expressed the consensus of his age in 1789 when he said 'the diffusion of a general knowledge, and of a taste for science, over all classes of men, in every nation of Europe or of European origin, seems to be the characteristic feature of the modern age.'[1] Joel Mokyr's The Gifts of Athena (2002) argues the centrality of 'useful knowledge' to the genesis of Europe's industrialization. Athena features among recent big scope treatments of industrialization, consumption, the rise of the West, and more recently, the new global history.[2] The book and Mokyr's articles that followed[3] generated debate brought historians of science and technology together with economic historians to engage in a new way of looking at the contributions of science and technology to the industrial development from the early modern period to the twentieth century. An early forum for debate on issues raised by the book was the Workshop on 'Useful Knowledge and Technological Practice' held by the University of

[1] Cited in Joel Mokyr, The Gifts of Athena Historical origins of the knowledge economy (Princeton and Oxford, 2002), p. 36

[2] See the AHR review essays: "Explaining European dominance" American historical review, 104 (1999), 1240-57, essays by Mokyr, Guy and Tilly on David Landes, Wealth and poverty of nations: why some are so rich and some so poor; Craig Clunas, Review essay "Modernity global and local: consumption and the rise of the west", American historical review, 104 (1999), pp. 1497-1511 essays on John Brewer and Roy Porter, Consumption and the world of goods (London, 1993); John Brewer and Susan Staves, Early modern conceptions of property (London, 1995) and Ann Bermingham and John Brewer, The consumption of culture (London, 1995); "AHR Forum: Asia and Europe in the world economy", American historical review, 107 (2002), essays by Manning, Pomeranz, Bin Won and Ludden.

[3] Joel Mokyr, "Accounting for the industrial revolution" in Roderick Floud and Paul Johnson, eds., The Cambridge economic history of modern Britain, vol. I, 1-27; Joel Mokyr, "Intellectual origins of modern economic growth", Journal of economic history, 65 (2005, pp.285-351.

Warwick-CNAM, Paris Research Interchange on Cultures of Commerce and Invention. The comments included in this special issue have been selected from those made at that Workshop.[4]

Mokyr in his Gifts of Athena sought to convey to economists the long historical development of the knowledge economy, and the part this has played in economic growth since the eighteenth century. He also sought to engage economic historians to investigate connections between science and technology, and to discover the roots of the industrial revolution in 'useful knowledge'. With these aims in view, Mokyr reached much further than most economists and economic historians are prepared to go; he ventured into the cultural and institutional framework of 'useful knowledge', debating boldly with historians of science, with cultural historians and with historians of the enlightenment. The book puts together 'useful knowledge' and 'enlightenment' to argue the case for an 'industrial enlightenment' that preceded and accompanied the industrial revolution. It takes the role of the knowledge economy further into the second and third industrial revolutions of the nineteenth and twentieth centuries, and it also interrogates the organizational framework of technology, of institutions, politics and resistance. In this issue we deal in depth with only two aspects of Athena – 'useful knowledge and the industrial revolution' and the 'political economy of knowledge'.

Mokyr's position, much disputed, but strongly stated is that the Industrial Revolution belongs to the West, and it does so because there was a 'Western way of knowledge'. The 'great divergence', between the West and the rest of the world, in his

[4] Workshop on 'Useful knowledge and technological practice' University of Warwick Centre in London, 4 July, 2003. Other comments were provided by Ulrich Pfister, Anne Puetz, Nigel Thrift, Luca Molà, Luisa Dolza, Eric Jones, Christine MacLeod, Anna Guagnini, Robert Fox, Patric Bret, Nick Von Tunzelmann, Yves Cohen and Robert Allen.

view, did not arise from differences in resource endowments, but from a 'knowledge revolution' that took place in the West, and not elsewhere. 'Useful knowledge' was developed and used in Europe, he argues, "with an aggressiveness and single mindedness no society had experienced before."[5] Though Europeans adopted and adapted processes taken from others, they used knowledge to create more knowledge and created the institutional environment that facilitated this. Holding 'useful knowledge' to account, above all other factors, not just for the Industrial Revolution, but for the rise of the West, Mokyr must first convince us of the meaning and explanatory value of his concept 'useful knowledge'.

Definitions

Mokyr builds on Michael Polanyi's concepts of 'tacit' and 'codified' knowledge to push beyond the old linear model of the impact of science on technology. He defines 'useful knowledge' as the knowledge of natural phenomena that lend themselves to manipulation, including artefacts, materials, energy, living beings; it encompasses practical and informal knowledge as well as what is traditionally understood to be 'science'. It includes compilations of information about what worked and the knowledge of those who collected data and practices as well as scientific hypotheses. It bridges the traditional division between the history of science and the history of technology; 'useful knowledge' entailed connections and collaborations, or what Liliane Hilaire-Pérez calls 'passerelles', between the 'savants' and the 'fabricants', between natural philosophy and skilled craftsmen. Industrial skill and craft were not, therefore, secret, alchemical, unintelligible except by practitioners in the way that early modern natural philosophers represented them. These could be codified, explained and depicted just as scientific

[5] Mokyr, "Intellectual origins", p. 309

hypotheses could be tested by experimentation. With this more open-ended definition of knowledge it was possible to conceive of an 'open science' and beyond this to what Hilaire-Pérez calls 'open technique'. The key point of this 'useful knowledge' was openness, or access.

The spaces in which useful knowledge developed and became accessible were multicentred. Mokyr builds on 'Cardwell's Law', the argument that societies that have been technologically creative were so for relatively brief periods. Europe, fragmented as it was, provided the "diversity within a wider unity" that allowed technological momentum to pass between various European regions. Technological leadership thus passed from Northern Italy and Southern Germany to Spain and Portugal, and on to the Low Countries, then eventually to Britain.[6] This geographical movement of centres of technological improvement relied on the pre-existing possibilities for original thinkers to move between different regions and spheres of influence. Courts and patrons competed for bearers of knowledge, but an emerging 'open science' fostered the personal connections and webs of ideas. Rapidly expanding print culture: encyclopedias, periodicals, translations, exhibitions, displays and spectacles as well as extensive personal correspondence spread the seeds of innovation. Mokyr emphasises a 'useful knowledge' developed out of the intellectual competition of a multicentred polity. But 'open science' and 'open technique' as developed by Hilaire-Pérez relies to a much greater extent on collectivities and connections, especially among artisans. Those connections were crucial at all levels in the emergence of the Enlightenment, and certainly in that aspect of the enlightenment termed by Mokyr 'the industrial enlightenment'.

[6] Mokyr, Gifts of Athena, pp. 276-278.

The Industrial Enlightenment

Mokyr's definition of the industrial enlightenment is about a trans-European phenomenon. It focuses not on the many, but on the 'vital few'. He argues that the 'open science' and informal scholarly communities that emerged across Europe from the seventeenth century created a scientific culture that was about knowing how as much as about knowing why. A 'critical few' drove forward an ensuing 'knowledge revolution' in the eighteenth century. They were a 'small group of about 1000', a creative community based on the exchange of knowledge'. They were engineers, mechanics, chemists, physicians and natural philosophers, informally connected via personal social contacts, and a print culture of translation, standardization and representation. "Technological advance in the period of the Industrial Revolution was a minority affair…the dynamics of competition are such that in the long run the few drag along the many."[7] Mokyr's enlightenment is not, therefore, about human capital formation, about a general improvement in literacy or education. It is about a 'technical literacy' that became important to a key part of society, and it is about access to knowledge created through an 'industrial public sphere' which included scientific societies, and the coding, storing and transmission of useful knowledge. In his pithy formulation, this was about a social contract between 'knowers' and 'doers'. Its results were lower access costs to knowledge.[8]

Many will dispute this concept of an 'industrial enlightenment'. Is this not just another in a long list of 'enlightenments'? Just what does it add to our understandings of

[7] Mokyr, "Intellectual origins", pp. 301-6.
[8] Mokyr, *ibid*., pp. 297, 318-21.

both Enlightenment and of Industrial Revolution? Is what Mokyr includes here more than the artefacts of the expansion of print culture and of the sociability of polite society? What is the meaning of an 'industrial public sphere?' Where 'public sphere', as defined by Habermas, was about public opinion outside the 'private sphere' of the court and government, it conveyed a political edge, one of dissent and critical thinking. Mokyr's 'industrial public sphere' is the usual amalgam of print culture, societies and informal social contacts, but where is the 'private sphere' (in this case, possibly some kind of 'knowledge enclave') against which it makes its claims? Is it any more than the industrial revolution in print and in talk?

Mokyr's 'industrial enlightenment' develops the case made by Margaret Jacob in Scientific Culture and the Making of the Industrial West for the intellectual origins of the industrial revolution. For Jacob this was about artisan mathematical knowledge and knowledge among people like this of the works of the scientific revolution, of Kepler and Copernicus and especially of Newton. It was about the widespread diffusion of the Newtonian mechanics. Jacob attributes the success of James Watt to this background, and to the context where British engineers and entrepreneurs conversed. A social context which brought together inventors, entrepreneurs, engineers and scientific writers proved conducive to innovation. England's scientific print culture and scientific popular culture provided what Jacob called the 'cultural packaging' of science and the 'mental capital' of the industrial revolution.'[9]

[9] Margaret Jacob, Scientific culture and the making of the industrial west (New York, 1997); Margaret Jacob, "The cultural foundations of early industrialization: a project' in Maxine Berg and Kristine Bruland eds., Technological revolutions in Europe: historical perspectives (Cheltenham, UK, Northhampton, MA, 1998), 67-85.

For Mokyr the industrial enlightenment was about making technological improvement a part of modernity. Experimentation and experience, invention and industrial projects became fashionable among the provincial middling classes and gentry, entrepreneurs and other financial backers. This case has also been made for both France and Britain in Liliane Hilaire-Pérez's pathbreaking, L'invention technique au siècle des lumières (Paris, 2000). The industrial enlightenment created the trajectory from John Smeaton to Richard Trevithick and not just the invention, but the continuous improvement of the steam engine. It created 'useful knowledge' at an accelerating rate.

What part the codification of knowledge and the industrial public sphere actually played in stimulating that relatively confined clustering of technological innovations we have come to associate with the industrial revolution remains debateable. Mokyr's 'useful knowledge' has not solved this old conundrum between cultural or intellectual theories and what Jacob calls the 'tinkerers' theory, that is the economic history of technological change. Now historians of science, such as Larry Stewart, in his piece that follows, 'Experimental spaces and the knowledge economy' are keen to show just how engaged in technological projects and applications were the natural philosophers of the day. John Hadley and Richard Watson, in succession Professors of Chemistry in Cambridge promoted experimental methods and lectured on applications of chemistry to the arts and sciences. Alexander Chisolm, chemist and experimental demonstrator, was employed by Wedgwood at Etruria to conduct experiments on clays, minerals and acids.[10] Or, like Jacob they seek out the scientific knowledge and methodology applied by key inventors and industrial entrepreneurs.[11]

[10] See this issue, Larry Stewart, "Experimental spaces and the knowledge economy", pp. 3-5, 16-19.
[11] Jacob, Scientific culture.

Such 'tinkerers' from David Landes to Robert Allen explained the impetus to technological change, not from the impact of scientific and agricultural treatises, but from supply constraints, demand, input prices, and commercialisation.[12] Extensive collections of agricultural treatises graced the libraries of most English country houses. Indeed we could ask to what extent there was a standard bulk buy in these volumes to secure an identity as 'enlightened landowner'. Likewise collections of commercial dictionaries, encyclopedias, technical manuals, treatises on the arts and manufactures were iconic possessions of the industrial bourgeoisie. Mokyr lists many titles. This was the print and graphic culture of 'useful knowledge'. What part did these titles play? We can ask to what extent this print was at least as much the 'commercialisation of knowledge' as a 'codification'. As commercial paper such knowledge sold. It was not only a repository of practices and theories, it was a domain of consumer culture. From John Brewer's 'consumption of culture' we move to Liliane Hilaire-Pérez on participation in curiosity, in visual please and in demonstration and performace. The workshop and laboratory become the theatre, the encyclopedia and treatise on the arts and manufactures a form of trade catalogue. The codification associated with standardization, regularity and accuracy was not necessarily pursued as *episteme* contributing to *techne*, but as an aesthetic. These were important to the 'quality' of international consumer goods, not 'needs', but possessions.

Artisan Knowledge

Mokyr focuses on industrialists, entrepreneurs, inventors as well as the improving landlords, government figures and literary world which contributed to a wider social

[12] David Landes, The unbound Prometheus (Cambridge, 1969); Robert Allen, "Summing up: agriculture and useful knowledge", Warwick-CNAM Workshop on useful knowledge and technological practice, 4 June 2003.

endorsement and public culture of scientific and technological improvement. Mokyr recognizes the place of 'tacit' knowledge, some of which was once covered in the concept of 'learning by doing'[13]. But tacit knowledge much more significantly underpinned Mokyr's earlier concept of 'micro inventions', extensively discussed in his earlier book, The Lever of Riches.[14] Yet in spite of this emphasis on improving technologies as they were used, mainly by their workforces, Mokyr gives little space to the social framework of artisanal knowledge. This is where another 'vital few' made a huge difference, but we do not know how few. J.R. Harris demonstrated the very wide implications of England's invention and wide usage throughout industry and consumer goods production of crucible cast steel. Highly specific skills in using a coal-fuel furnace technology applied across a range of industries, together with skills associated with firelay found in brick making and potting, and turned to the making of crucibles gave the English the critical edge in steel-making over other Europeans. Harris's 'vital few' were not natural philosophers and inventors, but artisans. Harris draws attention to the scientific breakthroughs of Monge, Vandermonde and Berthollet in 1786 who demonstrated that the difference between cast iron, wrought iron and steel was in the carbon content. They may well have aspired to practical results for their scientific theories when they published a 'Notice to iron workers on the production of steel', but this was incomprehensible to all but those who knew the processes already, and it lacked essential detail. They did not provide advice on managing the furnaces or where to find crucible-making skills. Making steel, as Harris argued, depended on a full team of

[13] See the classic account in Kenneth Arrow, "The economic implications of learning by doing", Review of economic studies, 29, 1962, 155-73. See the implications of this for economic history elaborated in Nathan Rosenberg, Perspectives on technology, (Cambridge, 1976).
[14] Joel Mokyr, The lever of riches. Technological creativity and economic progress (New York, Oxford, 1990), especially 292-298

interdependent craftsmen, an interdependence built out of connections across industries and across regions. [15]

Mokyr's engagement with artisan knowledge is circumspect, if not suspicious. His 'doers' and 'makers' are industrialists, engineers and inventors to a much greater extent than they are craftsmen, artisans and workers. He connects craftsmen with apprenticeship and guilds, both of which he regards as rent-seeking constraints on technological change. It is in interrogating the 'personal itineraries' of artisans, their collective capacities, their 'microcommunities', and their hybridity that Liliane Hilaire-Pérez finds not closed societies, but 'open technique'. Artisans travelled across trades and across spaces in Europe; they combined knowledge sets, replicated and reconfigured, building an 'economy of imitation' that led to a self-sustaining process of improvement. Their institutions, including guilds, for example among the Lyon silk workers, created a policy of innovation based on the collective management of invention through copyright, patent rights, public repositories and technical training for artisans. As Hilaire-Pérez argues, '"trade institutions gave way to a public space for technology".[16] As S.R. Epstein has argued, apprenticeship was about making a product that would work; it established expertise and implied an ability to explain. It made 'tacit knowledge' public.[17]

Hilaire-Pérez's close work on regions and localities, as shown here in the case of Lyon demonstrates the fruits of a careful investigation of artisan knowledge. At this local level it is possible to witness the networks and the movements of artisans into and out of

[15] J.R. Harris, Industrial espionage and technology transfer (Aldershot, 1998), pp. 219-21.
[16] Liliane Hilaire-Pérez, "Technology as a public culture in the eighteenth century: the artisans' legacy", this issue, p. 14.
[17] S.R. Epstein, "Craft guilds, apprenticeship and technological change in preindustrial Europe", Journal of economic history, 53 (1998), 684-713; S.R. Epstein, "Transferring technical knowledge and innovating in Europe, c. 1200-1800", Working Paper on The nature of evidence: how well do 'facts'travel?" 01/05, 2005, London School of Economics web site, p. 7

the locality and various branches of the trades. Understanding the 'locality' of knowledge is not about uncovering 'secret' and 'hidden' knowledge, but about discovering knowledge shared within the locality, knowledge shared through combining techniques, copying processes from one material to another and deploying cross-trade skills. And with locality went mobility. Mokyr's 'industrial enlightenment' was European – inventors, natural philosophers, entrepreneurs travelled and translated. Artisans, also on the move, diffused technologies, but also brought their skills to bear on different products and problems across various parts of France, but also across the regions of Europe. Guilds and other artisan institutions sent young journeymen 'on tramp'. Lyon silk-weaving apprentices travelled to Paris for instruction in design. As S.R. Epstein has argued, the migration of skilled labour led the shift of technological leadership from southern to northwestern Europe in the early modern period. The system of apprenticeship and labour mobility, Epstein argues led to a distinctively European technological system from the late seventeenth century. The technological knowledge of pre-modern crafts people and engineers was mainly based in experience, and had to be 'transferred in the flesh'. The movement of technological leadership to new regions in Europe went with the movement of technically-skilled labour. Epstein believes this was easier in Europe because her technicians were not members of ascriptive kin, religion and locality-based communities. [18]

The migration of key workers or key teams of workers may have carried 'tacit' knowledge across Europe's regions, but the question still arises, how did these workers travel, and just how few were 'the vital few'? One of the key ways these artisans moved was with the migration of minority groups. Mass migrations of refugees and dissenters

[18] Epstein, "Transferring technical knowledge", 3.

changed the make up of Europe's cities, and infused these with new industries, skills and knowledge. Venice in the fifteenth century was a city of foreigners – Greeks, Turks, Albanians, Damatians and Germans; likewise a German community of several thousand brought new skills and technology to Renaissance Florence.[19] The Dutch Revolts from 1560-1609 brought 30,000 to England. The 10,000 in London in 1571 alone added to immigrants who made up 10 per cent of the population. London received another wave with the Hugenots in the seventeenth century.[20] These spread to other towns, for example Birmingham, an archetypal town with a reputation of openness to migrants and dissenters. Other cities built on connections with immigrant communities of trade and commerce to bring techniques from other regions. Marseille exploited the expertise of its large community of Armenian traders, and Lyon textile entrepreneurs cultivated their connections in the Levant to bring from the Ottoman Empire techniques of turkey-red dyeing and cotton printing.[21]

The mobility of artisans, not just as part of mass migrations, but as experts travelling between main production centres contributed to webs of knowledge, the networks by which new processes passed from one place to another. This was truly Hilaire-Pérez's 'open technique', and in the case of textile printing and dyeing, it spanned Europe from London to the Netherlands, from Switzerland to Marseille and Barcelona.[22]

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[19] Luca Molà, "Minorities and technical change in early modern Italy", Unpublished paper to the Warwick-CNAM Research Interchange conference on Minorities in Europe, Paris, June, 2004.
[20] Lien Bich Luu, Immigrants and the industries of London 1500-1700 (Aldershot, 2005).
[21] Liliane Hilaire-Pérez, "Culture techniques et pratiques de l'échange, entre Lyon et le Levant: inventions et réseaux au XVIIIe siècle", Revue d'histoire moderne et contemporaine 49 (2002), ….; Olivier Raveux, "Espaces et technologies dans la France méridionale d'ancien regime: l'example de l'indiennage marseillais (1648-1793)", Annales du Midi 116-246 (2004)….
[22] A.-F. Garçon and L. Hilaire-Pérez, "'Open technique' between community and individuality in eighteenth-century France", in F. de Goey and J.W. Veluwenkamp, (eds.), Engrepreneurs and Institutions in Europe and Asia, 1500-2000 (Amsterdam, 2002), pp. 237-56; Giorgio Riello, "The Rise of European

Useful knowledge transmitted across Europe embodied in key craftspeople and technicians did not, however, necessarily 'work'. The success of this 'other vital few' depended heavily on the socio-cultural context of their new environments. Walloons deployed to Swedish or English ironworks might succeed where English steel buttonmakers lured to Paris might 'slack off and do little work', then abscond. Or pulleymakers might be brought to Lorient, but on the way in Calais discover 'the joys of wine' and to be found'drinking fifteen bottles a day'.[23]

How does Knowledge Travel?

Moving objects, tools and machines, treatises and translations and even artisans was not always enough to kickstart new regions of technological ascendancy across Europe. Epstein emphasises connections between urbanisation and technological change over the long pre-modern period. Skills and technologies were passed not just between regions and states, but between creative cities.[24] Venice's glassmakers and Nuremberg's metalworkers, despite attempts by guilds and city authorities to restrict their crafts, 'leaked' outside the region. Ascendancy in scientific and timekeeping instruments moved from Italy through Paris to London. Fundamentally, 'useful knowledge' moved among towns and cities. The period between 1650 and 1750 saw England emerge from a

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calico printing and dyeing and the influence of Asia in the seventeenth and eighteenth centuries", Unpublished paper presented to Gehn conference on Textiles, Pune, India, 2005.

[23] Göran Rydén and Chris Evans, "Kinship and the transmission of skills: bar iron production in Britain and Sweden 1500-1860", in Maxine Berg and Kristine Bruland, eds., Technological revolutions in Europe: historical perspectives (Cheltenham, UK and Northampton, Mass., 1998); Kristine Bruland, ed., Technology transfer and Scandinavian industrialisation (New York, Oxford, 1991); J.R. Harris, Industrial espionage and technology transfer. Britain and France in the eighteenth century (Aldershot, 1998), pp. 199, 441.

[24] For an earlier discussion of these shifting poles of technological creativity across Europe see K.A. Davids, "Shifts of technological leadership in early modern Europe", in J. Lucassen and K. Davids (eds.), A miracle mirrored. The Dutch Republic in European perspective. (Cambridge, 1995), 338-66.

"technological and under-urbanised periphery to the most technologically innovative and urbanised country in the West." Concentrations of skilled workers in towns stimulated the growth of the crucial intermediate goods industries and the knowledge transfers and sharing among these.[25] This is why the 'locality' of knowledge matters so much. The connections across very different industries in a city like Lyon, as set out here by Hilaire-Pérez, or a town like Birmingham, a place where inventors came to find the skills and tools to develop prototypes and entrepreneurs came to invest in their projects were what made these creative and inventive cities. To understand 'industrial enlightenment' and 'useful knowledge' as *European* rather than *English* phenomena we need to understand how these cities worked as creative nodes and how artisans and skills as well as inventors, natural philosophers and entrepreneurs traversed the spaces between these. Hilaire-Pérez points to the place of subcontracting and commercial networks, not just within a locality, but between towns and regions. Harris's 'Le Turc' observed the role of workmen in transferring technology, but even more significantly, their embeddedness in the English subdivision of labour.

> "There is no country where labour is so divided as here. No country, consequently, where the whole of a trade is so difficult to seize hold of. No workers can explain to you the chain of operations, being perpetually occupied with…a small part; listen to him on anything outside that and you will be burdened with error.[26]

Nevertheless, technologies did move, and not just processes and codifications of knowledge, but 'tacit' knowledge. State and court competition for luxury goods, for

[25] S.R. Epstein, "Transferring technical knowledge", p. 31.
[26] Hilaire-Pérez, "Technology as a public culture", p. 15; Harris, Industrial espionage, p. 451.

improved manufactures and for the latest military equipment and infrastructure fostered an international market for knowledge; European warfare pushed larger groups of skilled workers away from localities to stimulate surges of technological innovation elsewhere. Where Mokyr emphasises the multicentrism of European knowledge as carried by Europe's original thinkers and inventors, Epstein and Hilaire-Pérez base Europe's unusual technological momentum in the mobility of its skilled labour. This is what we need to more about in the eighteenth century: the movement of skilled technicians and labour as products and processes sold across borders, the attraction of skilled labour as print culture expanded and codified knowledge, standardized, regularized and translated communicated across borders, and finally the movement of key workforces in train with religious and political dissent.

Mokyr situates 'useful knowledge' in the West. Were all the factors he packs into useful knowledge enough to explain why a knowledge revolution happened in the West but not the East. If invention is about reconfiguring existing stores of knowledge, codified in journals, manuals or scientific treatises and adapting the tacit knowledge transmitted through artisan skill, then this invention must extend to responses to interchanges with Eastern objects and processes. For some industries – textiles, dyeing, printing, the Mediterranean was but a European lake. For others, expanding trade with China and India brought objects, fine porcelain and lacquerware, or high quality printed textiles. The challenge to innovation was in the object: learning through observing, handling, taking apart, analysing those things that had not yet been made in the West.[27]

[27] Maxine Berg, "In pursuit of luxury: global origins of British consumer goods in the eighteenth century", Past and Present, 182 (2004), 85-142, pp. 125-130.

As Epstein has put it, "Imported Chinese porcelain could prove that something thought impossible could be done."[28]

The Gifts of Athena, however, leaves us with a 'western useful knowledge'. Connections with the East are little explored. Were Eastern knowledge systems similarly codified in scientific treatises, encyclopedias and manuals, or did different traditions of codification prevail? Was there dialogue between 'savants' and 'fabricants' in the way described by Mokyr, Jacob and Stewart? As whole communities of craftsmen were transferred by rulers across parts of the Ottoman empire, or between Mughal courts in India were new conduits of knowledge opened, or did these communities remain enclaves? Where so much of the transfer of knowledge in Europe was about the market in goods, print culture and in techniques, were different institutional arrangements in the Ottoman Empire, Mughal India and Ming China the constraints that ossified technologies?[29]

Debates on East-West comparisons and connections lead into the part played by political institutions. As Kristine Bruland argues in "Technology selection and useful knowledge", her paper contributed here, discussions of political economy usually end up with contrasts between an allegedly dynamic West and an allegedly stagnant East. Looking at the part played by political institutions within Western economies undergoing technological change, she emphasises not the constraints of political economy, but how institutions modulate or shape the path of development of knowledge. "Even if we look at

[28] Epstein, "Transferring technical knowledge", 28.
[29] These issues were discussed in the Global economic history network conference on Useful and Reliable Knowledge, Leiden, September, 2004. See especially papers by William Gervase Clarence-Smith, "Science and technology in early modern Islam, c1450-c.1850"; Roy Bin Wong, "Useful knowledge and economic change: what are we explaining?"; and Floris Cohen, "The coming-into-being of our modern world: what science and technology had to do with it".

the West as a whole, it is not simply a matter of 'where does its dynamism come from?', but rather of 'why does this dynamism take the forms it does'?" Political processes, she argues, play a significant part not just in the selection of innovation, but in its very genesis. Taking this point to early modern China, we find cases of knowledge in modular units, combined in different ways, and conveyed to peasants by government officials in local contexts, as in agriculture and adapted to local conditions.[30]

The Gifts of Athena brings together the types of knowledge, formerly studied in separate domains, that could be deployed to technological and economic improvement. The ways in which these different knowledge spheres met and combined did lead, as Mokyr powerfully argues, to an altogether new phase of growth that was also self-sustaining. Whether the roots of this lay in a peculiarly European industrial enlightenment or in newly intensive artisan mobility and interaction arising out of greater commercialisation and higher living standards among this group remain major areas of debate. The challenge now raised by Athena is to discover the questions, categories, and concepts to lead to a more global history of 'useful knowledge.' Mokyr needs to take up the statement of David Hartley, the Newtonian writer on physiology and the mind, whom he cites: "the diffusion of knowledge to all ranks and orders of men, to all nations, kindred and tongues and peoples…cannot be stopped but proceeds with an ever accelerating velocity."[31]

[30] Kristine Bruland, "Technology selection and useful knowledge: a comment", this issue, p. 4; Wong, "Useful knowledge", p. 9. On modular knowledge see Lothar Ledderose, Ten thousand things: module and mass production in Chinese art (Princeton, 2000).
[31] Mokyr, "Intellectual origins", p. 326.