

The Needham Question Updated: A Historiographical Survey and Elaboration

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I meditated upon this lack of certitude in traditional mathematics concerning the movements of the spheres and began to be annoyed that philosophers had discovered no sure scheme from . . . the movement of the marching of the world which had been built for us by the Best and Mostly Orderly Workman of All. (Copernicus, 1543)

NEEDHAM'S PUZZLE AND THE GREAT DIVERGENCE: CHINA AND THE WEST

Recent syntheses in comparative global history proclaim that classical views (Smithian, Marxist and Weberian) that narrated the history of China as a history of cumulative economic retardation compared with the economic dynamics of Western Europe from, say, the accession of the Ming (1368) to the Opium War (1839) are no longer tenable.

Two generations of post-colonial historical research on West, South and South-East and, above all, on East Asia have confirmed Marshall Hodgson's percipient observation of 1974 that historical explanations that 'invoke pre-modern seminal traits for the long run economic success of the Occident can be shown to fail under close historical analysis'. Modern revisionists have also published a substantial volume of evidence to support Braudel's insights of 1982 that for, most, if not all, that period, the advanced economic regions of Eurasia are more appositely represented in the words of Ken Pomeranz as 'a world of surprising resemblances'. Revisionism has, moreover, degraded the virtually unsupported assertions from a best-selling polemic from David Landes that 'for the last thousand years Europe (the West) has been the prime mover of development and modernity'.

Montesquieu, Hume, Smith, Malthus, Marx, Weber and their nineteenth and twentieth 'Eurocentric' acolytes – purveying histories of long-term Asian backwardness are now engaged in a scholarly and potentially heuristic debate in global economic history. Furthermore (and unless their Asiatic counterparts happen to be ideologically convinced that histories of anything that might potentially lend support to new

anachronistic narratives of 'Western triumphalism' are politically incorrect), the major discourse in global economic history that remains wide open for both discussion and research is the famous Needham's Puzzle.

According to Needham and his school, for more than a millennium down to and some time after the Accession of the Ming (1338), the locus for most technical, organizational and institutional innovations promoting entirely gradual and, of course, cyclical economic progress (with 'efflorescences' under the Tang and Song dynasties) *can* be located in the East and not in the West of the Eurasian Oikumene.

At some juncture (still under debate) in early modern history, the locus for the generation and application of knowledge behind both process and product innovation shifted from the Orient to the Occident and has remained there down to the present time.

Disagreements over the chronology for what can be represented as a climacteric in the discovery, development and diffusion of useful and reliable knowledge in China followed by the clear emergence of capacities for an accelerated rate of accumulation of such knowledge in Western Europe is probably not resolvable within any degree of precision. Nathan Sivin suggests that 'Chinese civilization was much more efficient in applying natural knowledge to practical human needs' down to the fifteenth century.

Needham himself traced the crossover to the centuries of Europe's classic scientific revolution but finds the antecedents for that revolution (as do modern historians of science) in the writings of natural philosophers, writing as early as the twelfth century. Since Needham launched his great project to integrate the contributions of China into global histories of science and technology, few historians have displayed the temerity to deny Chinese pre-eminence and precedence in the discovery, development and application of useful and reliable knowledge to problems of production and wealth that may have lasted for some 1500 years after the birth of Christ. Thus, Needham's famous question (once again under revived investigation and debate) is when, how and why did the Chinese empire lose its position of scientific and technological superiority to the West?

FLOWS OF USEFUL AND RELIABLE KNOWLEDGE

To clarify and historicize that question, it is necessary by way of a preface to say something about how economists and modern economic historians analyse knowledge as on 'input' into processes of production.

Following classic texts from Schumpeter and Kuznets, they see economic growth ('sustained' rises in standards of living) as emanating from two basic mechanisms: (1) rising productivity of labour employed in agriculture, industry and services and (2) the reallocation of labour from sectors of production (usually agriculture), in which productivity per hour worked is lower, to sectors of production, in which productivity is higher (industry and urban services).

Given this standard framework for the analysis of *changes* in rates of

growth and structures of output, historians proceed to ask: where does useful and reliable knowledge that allows for higher and sustained rises in labour productivity emanate from? Why did some civilizations (China) accumulate and diffuse such knowledge at more impressive rates than others (e.g. Western Europe)? When and why does the locus for the discovery and diffusion of knowledge change?

Two classes of economic theory address these questions and are labelled as endogenous and exogenous. Endogenous growth theory certainly provides historians with a plausible way of explaining the diffusion of knowledge across any industry or economy *once* such knowledge has been perceived to be reliable and commercially profitable. Alas, serious difficulties remain in trying to account historically for the relative achievements of different countries, cultures or civilizations in the *discovery and development* of useful knowledge. Even economic historians (who are educated to explain its accumulation with reference to a tradition of thought drawn from classical, Marxist and neo-classical models in economic theory) remain dissatisfied with narratives that square circles by accounting for Europe's convergence to Chinese levels of scientific and technological efficiency, basically in terms of the outcome of shifts in demand for innovations emanating from higher rates of economic growth in the West. Interestingly, and as a 'Christian Marxist', Needham himself equivocated between endogenous or demand-induced theories of knowledge accumulation and some rather ad hoc speculations that linked the shift in the locus of innovation to clear and profound cultural and theological contrasts between the East and the West in the appreciation, comprehension and manipulation of nature.

In short, Needham suggests that variations across space and time in the accumulation of knowledge could 'in some degree' be exogenous or autonomous – not as fortuitous gifts from Athena, but rather as emanating in significant ways from the social, political and, above all, cultural realms of distinctive civilizations that can be represented as partially but loosely connected in diverse and complex ways to their economic foundations.

Rejecting the insistence by mainstream economists on reifying distinctions between endogenous and exogenous forces, historians continue to recognize 'loops of inter-connections' that are analogous to the components and circuits of the internal combustion engine that play their own particular and indispensable roles in moving economies at various speeds from one to another and superior level of efficiency. Whether the process is endogenous or exogenous or best represented by diagrams displaying arrows of inter-connections, it is not clear how historians might proceed systematically to compare something as amorphous and intangible as the discovery and diffusion of knowledge in China and Western Europe over long spans of time – an evolution that, as they nevertheless recognize, led ultimately to significant differences in the standards of welfare afforded to the populations of these two civilizations.

For a start (and unlike real income, output or other indicators of economic progress), they will never find a way of measuring the

accumulation of knowledge available for production in the East compared with the West. Historians must make do with impressions from scholars who know something about the quality of material life for populations residing at both ends of the Eurasian landmass, who have some understanding of the cultures and institutions that (along with favourable natural endowments) provided generations of Chinese with higher levels of welfare for more than a millennia of time.

Even for those centuries from the accession of the Ming dynasty down to the Opium War (1368–1839), when extensions to the base of knowledge available to the Europeans and Chinese economies supposedly diverged, the knowledge in Needham's prism can neither be added up nor connected in systematic ways to economic progress. Furthermore, it emanated from a *plethora* of sites, sources, institutions, households and individuals ('proto' technologists and scientists) of great variety. Knowledge emerged in numerous forms: explicit and tacit, recorded and unrecorded, written and oral.

In the future, historians may be able to impose some kind of taxonomical, even scalar, order upon the great mass of Chinese and European written and printed material that could be represented as potentially useful and reliable for purposes of production. At present, they can only investigate the contexts or regimes for the discovery, development and diffusion of such knowledge in order to make comparisons across civilizations that might help us to suggest ^{at what} when, why and to what degree the regime evolving in Europe ~~will become~~ ^{will become} more promotional for production than the regime operating in China.

In short and over these centuries when technological progress proceeded gradually, reciprocal comparisons (pace Marc Bloch) are the only method available to ascertain when and why Western economies moved (as many historians assert) up to and along a trajectory that eventually left the Chinese empire economically behind and vulnerable to geopolitical takeover.

Such an exercise in history (involving the comparison of several connected but separable components of regimes for the discovery, development and diffusions of the knowledge upon which the relative economic performances of Europe and China depended) could never be conclusive. The widely shared assumption behind my argument (which is located in a larger narrative on divergence) is that technological innovation mattered for Europe's precocious transition to modern economic growth and that sources for its extension and deepening were contrasting systems or regimes for the production, development and diffusion of useful knowledge.

With a specified comparison in place, I will now proceed to elaborate on connected but separable components of two regimes, but propose to allocate more space to Chinese and European cultures and cosmologies because modern historians assume that observed contrasts between Eastern and Western regimes reside, in some reductionist sense, in their cultural and cosmological foundations.

SITES AND INSTITUTIONS FOR THE GENERATION OF USEFUL KNOWLEDGE**Urban Sites**

Historically, most productive knowledge emerged from urban settings. Maritime towns and cities as nodes or *pôles de croissance* have long been emplotted into histories of slow economic growth in early modern Europe. These narratives and proto-theories from historical sociology represent coastal and riverine *sites* as promotional: (1) for the establishment and maintenance of guilds, professional schools, universities and other institutions for the generation of knowledge, (2) for the exercise of mercantile aristocratic, courtly and ecclesiastical patronage for its formation; (3) for the employment of skilled artisans producing instruments used for the investigation of the natural world; (4) as locations for the embarkation and storage of knowledge imported on sailing ships and embodied in plants, primary products, machines, devices and information from ports along the Mediterranean and Baltic and North Seas surrounding Europe and, increasingly (after 1415), from Africa, Asia and the Americas; and (5) as political spaces offering some protection and toleration and autonomy vis-à-vis the powers of conservative monarchs, seigneurs and bishops to control, tax and even repress potentially dangerous knowledge. Thus, historians of Europe have been educated to look for sites of comparable scale, scope and potential along the rivers, canals and coasts of the Ming and Qing empires. They do find hierarchies and networks of towns and cities all over China. Yet, for reasons that may well be basically political and geopolitical, the extent and depth of urbanization in China, as well as the character of Chinese towns, look relatively less conducive to the accumulation of knowledge than appears to have been the case in Western Europe.

Higher Education

A high proportion of innovative knowledge produced over these centuries has been 'attributed' to lists of European and Chinese men who received some form of 'higher education'. This component of the two regimes under comparison turns out to be one in which secondary sources allow historians to make some supportable comparisons constructed around several relevant questions, including: (1) ratios of the higher educated to total and to literate populations in Europe and China; (2) the relative openness of political elites to recruitment based upon merit; (3) degrees of centralized political and/or ecclesiastical control exercised over the institutions and the personnel involved with the delivery of all forms of higher education; (4) the scope of the curricula on offer to students at an impressionable stage in their lifecycles; (5) the status accorded to the study of nature; and (6) the encouragement of disputation and debate, both at university and across the cultures at large.

For long stretches of its history and largely for political reasons, the Chinese empire probably offered higher education to a comparable, if not higher, proportion of its male population than Europe and, what is more,

recruited entrants to positions of power and patronage upon a meritocratic basis. From a Euro-centred perspective, the empires and educational institutions emerge, however, as less plural, subject to tighter degrees of central control and offered, for reasons elaborated on below, a more circumscribed curricula for young men interested in the study of the natural world.

Circulation of Knowledge

Knowledge was, however, circulated in cheaper printed form in China several centuries before Europe. It is simply not possible to demonstrate either that the volume of printed natural and technical knowledge available for consultation in China fell below the total volume available in Europe or that the range of potentially useful branches of knowledge covered was more confined in scope or scale in the East. The Needham project's 18-volume compendia of Chinese investigations and analysis of (*shi*) things celestial, terrestrial, botanical, biological, zoological, geographical, optical, mineral, mechanical, chemical, agricultural, industrial, etc. degrades any Eurocentric suggestions of that kind. Furthermore, there seem to be no areas of knowledge in which Chinese publications failed to appear in printed form for year after year during either the Ming or Qing dynasties.

Historians who have the credentials to engage seriously with the history of Chinese science deny the charge that the language is not precise enough for the communication of abstract science and technology. Another negative aspersion that the flow of words printed in China and devoted to yet another round of learned commentaries on Confucian classics in moral philosophy, to lessons in statecraft to exemplary forms of history, to literature, calligraphy and poetry exceeded the flow of useful knowledge by a larger margin than was the case in Europe has not been tested. Although the corollary that the authors of books on 'things' (*gewu*) were not widely regarded within their own culture to be engaged in the promotion of morally and intellectually superior forms of scholarship, it may be the case.

Large volumes of knowledge were, moreover, published in the form of state-sponsored encyclopaedias and manuals that made rather limited inroads into the curricula for higher education. Furthermore, historians of China have not exposed anything approximating to the scope and scale of an 'associational culture' for any sustained discussion of natural philosophy of the kind that emerged across urban Europe in the seventeenth and eighteenth centuries. Indeed, there are suggestions that associations of intellectuals were less tolerated under the Qing (post-1644) than during the closing stages of the Ming dynasty.

To sum up: at present, there is no evidence to show that the share of pages printed and circulated that could be classified as potentially useful and reliable knowledge (compared, say, to the volume of didactic books on religion and moral philosophy) was any higher in the West. Scholars who have surveyed China's fact-based literature leave an impression that it

displays a greater concern with agronomy, hydrology and medicine than with commerce or industry. These 'unquantified' observations are just what one would expect from a physiocratic empire in which leading patrons for books included the state and its mandarinates concerned with *jingshi* or how to manage the age and the empire.

Economic Incentives (Patents, Prizes, Rewards)

How far innovatory knowledge in Europe and China was rewarded and/or protected its progenitors against plagiarism and exploitation by imitators, in order that the search and development for useful knowledge might become profitable for individuals, families or institutions making discoveries, remains another key question to pursue.

Beginning in Venice (1415), European innovators received some (rather inadequate) measures of protection and/or rewards for novel and potentially productive ideas. Europe's state-run systems of protection were, however, neither universal, generous nor effectively enforced, and it could be the case that the maintenance of traditions of secrecy among kinship groups in China might just have provided incentives that were as efficacious as patents and rewards.

CULTURES AND COSMOLOGIES FOR INNOVATION IN EUROPE AND CHINA

Families, Schools and Careers

Mary Douglas defined culture 'as a widely shared cluster of beliefs and values deployed implicitly and explicitly to promote, justify or restrain the collective actions of institutions and the behaviour of individuals'. Cultural historians (now in the ascendant in departments of history) 'reconstruct' cultures in order to 'make sense' of the actions taken by organizations, institutions and people in the past. The goal of cultural history is to recover 'outlooks and dispositions' of peoples as they were experienced, recorded and reflected upon at the time. They are aware that people, then and now, inhabited multiple cultures and that culture should not replace economies as another 'reductionist' category for historical analysis. 'Although' (as Marshal Sahlins observes), 'actions and events are reordered by culture. Culture is also reordered by actions and events'. Cultures as 'durable dispositions' were far more stable and resistant to change in early modern China and Europe than they are today.

Historians looking for comparisons and contrasts in the dispositions of cultures towards the accumulation of knowledge and innovations should find the cosmologies and clusters of beliefs playing upon the relative propensities of Chinese and Europeans alive between 1368 and 1839 to develop useful and reliable knowledge heuristic to contemplate. Historical evidence will be hard to find and inferences difficult to draw. But, already, the relevant areas for future investigation and research in comparative history have been clearly mapped out by historians and social scientists. For example, innovators are born, raised and socialized within families and networks of kin who inculcate curiosity, desires for the acquisition of

knowledge and attitudes towards risk into children. Secondly, primary schools not only provided the basis of literacy and numeracy required for higher forms of formal education, but reinforced or modified attitudes and aspirations acquired at home. Ambitions formed with families and at school led men towards careers that were selected among privileged minorities, placed to make choices in this matter, basically upon economic grounds, but were also chosen partly in response to cultures of approbation and disapprobation. For example, was it the case, as some historians have suggested, that a disproportionate (sub-optimal share) of young educated men in China, with potential for innovative thought, were attracted into the imperial civil service, in which their prospects for advancement rarely depended on the allocation of time and talent to the study of 'things', let alone the taking of risks for the promotion of novelties? But did this ostensibly unproductive avenue for upward mobility represent really significant contrasts with the courtly, clerical and military careers open to men of ambition and talent in early modern Europe?

All three institutions – families, schools and careers – demand much more rigorous and textured historical research than appears to be available on current bibliographies of comparative histories for the East and West. At present, the extant historiography allows historians to deal in far greater depth with potentially significant contrasts between Eastern and Western cultures at less micro tangible and more general levels, by reconstructing the cosmologies or basic beliefs about the natural world, as comprehended by Chinese and European elites, for, say, four centuries down to the Opium War. Such cosmologies were neither homogeneous nor stable through time, but they are represented by intellectual historians as cultures that prompted relevant political and wealthy elites to formulate policies, construct institutions and offer patronage that either promoted or restrained the accumulation of useful and reliable knowledge.

My reading into the complex and contested histories of early modern European and Chinese developments in science and technology leads me to suggest that the modern bibliography supports Weber's position, namely that, over this period, Western Europeans reordered a traditional Christian cosmology in ways that became discernibly more conducive for the accumulation of knowledge. The maintenance and restoration of an altogether more neutral Confucian cosmology that prevailed under the Ming and Qing dynasties did little or nothing to promote any significant reconfiguration of elite cultures in China until much later in the nineteenth century.

Reconfiguration of European Cosmology 1543–1727

This Weberian hypothesis is framed by dates that refer to the decades between the lives of Copernicus (1473–1543) and Newton (1642–1727) – a period of scientific revolution when increasing shares of Europe's political, ecclesiastical and business elites began to comprehend the natural world in new ways that can be represented as analogous to a gestalt switch. Cultural and intellectual historians (including modern historians of

science) tend to narrate and analyse that switch by way of critical surveys of the protracted, acrimonious and often violent debates between ancients and moderns. The former, as stakeholders in charge of established institutions based upon biblical scriptural and Aristotlean bodies of knowledge, sanctified by religious authority, resisted claims from moderns for the validity of their own more reliable and useful forms of knowledge based upon: (1) systematic observation; (2) Baconian interrogations of nature deploying a variety of reliable and transparent experiments; and (3) above all, the formulation of mathematically rigorous and logically consistent models of how nature depicted as a single coherent system actually worked.

In retrospect and after protracted and unsettled debates among specialists in the history of science, the scientific revolution may still be regarded as a progressive shift in the understanding of how and why phenomena in the celestial, terrestrial and biological spheres of the natural world operated as they did. That evolving comprehension of nature permeated gradually into the mentalities (not of the illiterate masses at large) of Western Europe's educated political and economic elites (including craftsmen) with the powers, means and skills required to favour, sponsor and produce innovations in thought and practice.

Of course, the proclivities of elites to embrace cosmologies favourable to sustained interrogations designed to extend possibilities for the comprehension and manipulation of nature did not change simply as the outcome of an intellectual debate between ancients and moderns. Furthermore, the antecedents and possibly the foundations for that change are to be found in Medieval Christendom. Indeed, evidence has now piled up to undermine ideologically biased histories that left chronologies and impressions of early modern Europe's history as one of pronounced discontinuities with its medieval past. Nevertheless, the four 'Rs' of the period under review for purposes of this narrative in global history, namely the Reconnaissance, the Renaissance, the Reformation and the Revolution in Science, all operated in diverse and interconnected ways to extend and accelerate a pronounced shift in the conceptions held by Europe's elites about the natural world that surrounded and framed their privileged lives on Earth.

For example, and although this conjecture cannot be quantified, the Renaissance of the *Quartocentro*, which continued during the lifetime of Copernicus, was marked (and more clearly marked after the fall of Constantinople to the Ottomans in 1453) by a faster rate of recovery of classical (particularly Greek) knowledge about the natural world. Recovered, restored and translated texts by Plato, Archimedes, Heron, Democritus and others undermined extant canonical and beatified authorities for higher education derived from Aristotle, Ptolemy and Galen.

Secondly, and what seems to have been seriously quantified by a generation of modern scholarship on the nature of the Reformation, are liberal, Weberian and Mertonian hypotheses that the Vatican resolutely opposed the recovery and assimilation of classical and Islamic knowledge.

The long-established ideological view that the Roman Church (even in Spain) consistently and effectively stamped out investigations into natural phenomena repressed all speculations about the world that might somehow contradict or qualify the rather limited range of references to that natural world as embodied in Christendom's canonical texts, including new and old testaments, scripture, even the writings of Saint Paul and other saints, is no longer held as tenable by ecclesiastical history, let alone histories of science.

All organized religions, Catholic and Protestant alike, remained hostile to the diffusion of 'heretical' cosmological ideas that ecclesiastical authorities deemed to be potentially dangerous to established hierarchies of churches, clerics and their 'sacred books'. For the advance of economies (our key interest), the Reformation left Europe with several institutionalized and competing religions and a multiplication of texts, printed in vernacular languages (mainly moral and theoretical), but containing a plurality of facts and hypothesis about the natural world. As the violence associated with the theological disputes gave way to co-existence, the notion that there could be any single and singular source of authority on the operations of the natural world became less and less credible to educated Christians of all persuasions. Provided their findings and inferences did not explicitly undermine the 'words' of God, as interpreted by several of his chosen churches, natural philosophers as well as theologians became freer to investigate the basis upon which 'their Gods' might have constructed the natural world that shaped the material lives of populations all over Europe.

Finally, and as an outcome of the reconnaissances of the fifteenth century, Europeans established regular contacts and commerce with Africa, Asia and the recently rediscovered Americas. Voyages of discovery followed up by profitable commerce and colonization provided an enormous boost to European confidence. Europeans had acquired the scientific knowledge and technologies required to achieve a dramatic and ultimately profitable conquest over the most awesome parts of nature, namely the winds, tides and seas covering most of the world and surrounding their promontory on the edge of Eurasia. Western Europe's command of the oceans then generated accumulating flows of information about the geographies, peoples, institutions, flora, fauna, artefacts and commodities from all parts of an expanding world that gradually degraded received biblical, clerical and fantastical accounts and conceptions of nature, as it had supposedly operated outside the known, but narrow, geographical and intellectual compass of Western Europe.

In numerous ways, these famous historical conjunctures – the Reconnaissance, Renaissance and Reformation – reordered the culture surrounding urban elites in the West and intensified their ambitions to promote, patronize and participate in systematic investigations of the celestial, terrestrial and biological spheres of the natural world. Despite all the scholarly debate and nuanced interpretations that now surround it, European historians may as well continue to label the programme of

investigation and development in natural philosophy as it proceeded between the times of Copernicus and Newton as a scientific revolution.

The flow, validity and variety of new knowledge about the universe generated by natural philosophers researching with indispensable help from artisans and funded by princely aristocratic, mercantile and even ecclesiastical patrons will be too vast to summarize here. Furthermore, the purpose of the debate is not to reconstruct and evaluate the histories of modern specialized sciences in retrospect. Nor will I be concerned to trace either tangible or indirect connections between the knowledge diffused over this period to particular innovations. Instead, the rather general argument (pursued this far for whatever credence becomes available from an exercise in comparisons with China) makes two points: first, that a loosely connected programme of investigations into the celestial, terrestrial and biological spheres of the natural world was conducted within an otherwise conservative and often hostile social environment of Western Europe, and, secondly, and at propitious times in its early modern history, the knowledge generated by that programme penetrated into, and ultimately undermined, the traditional cosmological predispositions of that continent's political, economic and ecclesiastical elites.

The foundations of elite culture had been based on Europe's conversion to Christianity, a religion that co-existed in tension with the sanctified pagan texts (Aristotle, Ptolemy and Galen), with 'common sense' and with all kinds of heretic fantasies that the clerical establishment did its best to stamp out in favour of a unified view of nature as God's creation. In cultures permeated by monotheistic beliefs, in an afterlife and by heretical fantasies, it is, moreover, not surprising to observe that astronomy played the key historical role in a cosmological reordering of perceptions about the natural world. That 'gestalt switch' could simply be illustrated by detailed investigations into the beliefs held by increasing numbers of educated men about the natural world after, say, the times of Copernicus compared with the comprehension of and attitudes towards nature held by preceding generations for, say, two centuries following the Black Death.

Up for debate is the historical background to and representation of a scientific revolution as a 'cosmological reordering' that led European elites (including skilled artisans) and eventually majorities among populations in the West to believe and expect that everything in the world can be explained rationally, demonstrated empirically and manipulated technologically.

Cultures and Cosmologies for Innovation in the East

Research to establish plausibility for a historical narrative about the possible significance of changes to the cosmological basis for the discovery and diffusion of useful knowledge around Western Europe can only be taken further by following Marc Bloch's advice to engage in reciprocal comparisons with China – the West's leading contender for technological leadership – then and, again, today. This strategy for the construction of global economic history upon a comparative basis bypasses 'orientalist'

objections that Chinese culture is *sui generis* and the empire's regime for the accumulation of such knowledge had successfully proceeded along a trajectory, all of its own, for at least 1,000 years. Historians must also perforce ignore assertions that comparisons of this kind can be dismissed as 'Eurocentric'.

Several tentative and under-researched suggestions as to why the regime evolving in Western Europe may, in retrospect, be perceived as being on a relatively more efficient trajectory have appeared in print. Furthermore, an extensive historical literature on the rise and decline of national economies in the West has already documented the penalties (institutional and cultural constraints) attached to the early starts and temporary positions of technological leadership held by the Italian, Dutch, British and, latterly, the American economies, which could well apply to China before 1800.

Until well into the eighteenth century, many features of the economics and societies of the Ming and Qing empires continued to be widely admired by enlightened European intellectuals of the day. At that time, the scale and scope of information about China that filtered into European perceptions through reports from Catholic missionaries (mainly Jesuits), travellers' tales and accounts from merchants were neither voluminous, representative nor accurate. Today, these valuable accounts are but a part of a much wider and deeper historiography written in Chinese, Japanese and European languages, concerned to ascertain with reference to primary sources what institutional or cultural capacities the empire possessed (or lacked) to sustain technological leadership when confronted by dimly perceived, but retrospectively clear, challenges from the West.

Historians, with help from a far greater volume of evidence than contemporaries had at their disposal, have revisited seventeenth and eighteenth-century European debates that deal with representations of China as a model culture, polity and economy. Several have reaffirmed the objections raised by Montesquieu, Hume and Adam Smith, who disputed more favourable interpretations of the oriental empire by Montaigne, Barros, Bayle, Voltaire, Leibniz, Quesnay and others. This famous enlightenment discourse resonates into modern investigations into knowledge formation and innovation across different civilizations, including institutionalized incentives and scope for the operation of multiple sources and centres for state and private patronage for investigations into the natural world and the circulation of knowledge. In short and taking a lead from anthropology, modern historians have taken up Needham's suggestions to expose and analyse contrasts in cultures and cosmologies, playing upon the missions of Chinese institutions (including the imperial state) as well as the dispositions of China's educated and wealthy elites to support and patronize the development of potentially productive forms of knowledge.

As wily Jesuits missionaries to China discovered, the differences between (Confucian) and Western (Christian) cultures as moral philosophies were neither profound nor (in their ultimately mistaken view) unbridgeable.

Both cultures supported hierarchy, patriarchy, filial piety and proclaimed in favour of righteous, just, frugal and patient behaviour, although Christian practice had probably come further along the way towards an accommodation with the avaricious tendencies of those with sufficient wealth and power to lead more autonomous lives and display individualistic patterns of conduct. That contrast came about because Christianity had risen to a position of ideological hegemony in Europe as a functional component of the Roman Empire and as a quasi autonomous hierarchical organization with pretensions to a universal mission after the fall of Rome. Christian churches and their congregations existed under the benign protection of diverse and competitive secular authorities, kings, aristocracies and oligarchies to whom they offered the promise of compliant subjects. That promise was not idle. As parishioners, most Europeans believed that obedience to moral codes propagated by priests and participation in the rituals performed by the Church accorded to the will of a divine creator would secure their places in Heaven.

In China, the political institutions of an empire that survived as a political unit and claimed sovereignty over populations and territory greater in scale, extent and complexity than Western Europe also rested on principles designed to maintain hierarchy, internal stability, external security and obedience, coupled with more commendable concerns for social welfare. These Confucian principles never evolved in a Western sense into religions that were expressions of a divine order interpreted by a universal church that, for centuries, sustained claims for a sphere of authority sanctified by God and separated from the secular power exercised by hereditary rulers of realms, republics and cities. In China, the principles underpinning the institutions of the empire (including families, farms, firms, merchant networks, guilds, schools, higher forms of education, the organizations of local, urban, regional and imperial governance) were all derived from a set of canonical texts as revised, interpreted and implemented by an elite of officials, recruited along meritocratic lines, operating in the name of successive dynasties of emperors, with mandates from Heaven. The Chinese recognized no god and provided no space for the authority of a church separated from the state. Power in the Chinese empire depended more heavily for the implementation of rules, policies and decrees emanating from emperors and their officials upon ideological persuasion than upon coercive, more costly forms of power deployed by rulers of Europe's smaller but more manageable set of warring polities. Under the Ming and Qing dynasties, Confucianism and the institutions and personnel most actively involved in the refinement, revision and diffusion of that all pervasive and effective moral code evolved into an extraordinarily powerful and relatively *cheap* way of obtaining compliance for the governance of a vast, heterogeneous complex and expanding empire.

Confucianism's status as a primary source of power utilized by emperors, mandarins, local officials and patriarchs to exercise authority emerged clearly during crises of internal order and interludes of dynastic

change when China's ruling elites turned again and again to purification of Confucian values to restore peace, harmony and stability to an empire that had, by the time of the Qing dynasty, survived for more than two millennia. As an ideology, designed and refined to maintain a common identity, cohesion, obedience and effective rule, Confucianism became of greater concern for the political authorities of China than religions (either Catholic or Protestant) ever became for the dynasties, aristocracies and oligarchies, governing polities of smaller scale and lower complexity in Europe.

Apart from rituals of ancestor worship, deference towards age and greater veneration for ancient texts (all of which could be functionally conservative in their operation), the major contrast between Eastern and Western cosmologies resides in the more stable and coherent cluster of beliefs and perceptions that the majority of a well educated Chinese elite held about the natural world and the study of nature over the centuries between the accession of the Ming dynasty (1368) and the Opium War (1839).

Both Christian and Confucian cosmologies can be depicted as anthropocentric in the sense that they reaffirmed and continually refined a foundational belief, namely that all institutions and personnel exercising power over the subjects of hereditary rulers should act in accordance with immutable moral-cum-spiritual precepts. Prescriptions for all forms of human behaviour in the spheres of familial, interpersonal, social, economic and political relations were pretty clear for both Chinese and European rulers and their subjects. One salient difference was that rulers of China, unlike their counterparts of the West, had refrained from embodying these principles (as expressed on their policies and decrees) into codes of law reinforced by precedents that applied across the empire.

Law usually operates to constrain custom and the discretion of local officials to take personal and particular contexts into account. In their adjudications over all spheres of private and social behaviour, including the economic spheres, the Chinese managed without applicable reference to any universally applied system of imperial law.

Both cosmologies also recognized that men not only interacted with others, but were also intensely preoccupied with the natural world that surrounded, sustained and *afflicted* their daily lives. Yet, the attention devoted and resources allocated to the systematic study of nature were neither a top priority nor accorded high status, either in China or Europe. Nevertheless, the historical record suggests that the Chinese accumulated a more impressive stock of useful and reliable knowledge down to some indeterminate period, marked by a climacteric that probably occurred under Ming emperors, when Confucian priorities for the conceptions and comprehension of nature and the methods used by Savants to investigate all natural phenomena (including the human body) seem (in retrospect) to have continued along a trajectory that accumulated useful and reliable knowledge at a low, rather traditional rate of advance compared to Western Europe.

In this, our Europe mirror, Chinese savants neither envisaged nor institutionalized a separated quasi autonomous sphere for the study of nature, whereas Christian cosmology (with its felicitous origins in the Roman Empire) accommodated its theology, teaching and institutions to take in knowledge inherited from classical times. In forging that particular fusion, the 'Roman' Catholic hierarchy left no space at all beyond its parameters and perimeters for alternative moral philosophies or interpretations of the words and commands of God. But the Church certainly encouraged the circumscribed study of an (albeit inferior) branch of pagan knowledge and learning, namely natural philosophy, concerned with systemic investigations into nature as a whole, but always as a reflection of the creation and works of God.

For centuries in the West, natural philosophy as represented in the 'expurgated' works of Aristotle, Ptolemy, Galen and a limited range of other pagan and Islamic texts existed within a tolerated but uneasy position of subordination with Christian theology, concerned with its own sanctified set of Latin texts and scriptures dealing with God and principles of moral behaviour.

Unlike Christianity (or Islam), Chinese cosmology displayed no comparable divisions or tensions. Confucians never separated moral from natural philosophy. They formulated their overall view of the world as an integrated whole, embodying human behaviour, all socially and politically constructed institutions (especially the state) conceived to be organically related to the celestial, terrestrial and biological spheres of the natural world.

For centuries, Chinese savants contemplated, studied and added impressively to the world's stock of knowledge about natural things (*shixue*), including stars, water, plants, animals, minerals, colours, medicines, topography, magnetism, optics, etc., etc. Their epistemological tradition accorded no credence, however, to speculations, let alone theories, about the operations of nature (*li*) as a cosmic realm detached from man, society or from emperors with their mandates from the heavens to rule over a large and successful empire. Nature, as a whole, seemed too multifaceted and alien an idea to grasp, let alone produce general theories about. It was perceived to display nothing more challenging and useful than harmonies and balances (*ying* and *yang*). As part of nature, men were advised by sages to go with and not against its grain. Furthermore, it would have been inept and dangerous for savants, employed by the state, to publicize speculations that questioned or undermined the harmonious cosmological foundations of the empire. Not only was it politically prudent and profitable to stay with mainstream moral philosophy, but the curious minority of educated Chinese who strayed into speculations about nature concentrated upon the classification of natural phenomena, detecting patterns and correlations and/or investigating problems of clear and immediate practical import. After all, their successful civilization flourished on this basis for more than a 1,000 years.

As systems of belief that weave diverse perceptions of the universe into

some kind of coherent whole, there were similarities but also discernible contrasts between European and Chinese cosmologies and it is arguably the case that the wedge into Western cosmology that widened between the times of Copernicus and Newton placed investigations into the comprehension and manipulation of the natural world upon a more systemic and efficient basis for technological innovation.

This 'hypothesis', currently under debate among historians of science, cannot be construed to suggest that the accumulation of useful knowledge in China had been restrained from the beginnings of the Empire. Clearly (as Needham and his school have demonstrated), that had not been the case. And, as Mark Elvin observed, the Chinese were nothing other than almost entirely cognizant of (if not familiar with) the several methods and styles of investigation adopted for the study of natural phenomena in the West.

Furthermore, only historians of particular problems or proto-sciences could detect and somehow sum up changes at frontiers of knowledge where Chinese levels of comprehension and potential for advance really lagged behind the West. The list of extant examples (which includes geometry, cartography, anatomy, astronomy and the use of scientific instruments) was never that long. On the basis of an established cosmology and indigenous institutions and traditions for enquiry, the Chinese continued to add to their own and the world's stock of useful and reliable knowledge. Neither intellectual stasis nor any deep-seated cultural antipathy to learn from and adapt advanced Western knowledge (offered to the Chinese state as part of a culturally unacceptable package of religious moral and natural philosophy by Jesuit missionaries) can be represented as an incontrovertible or highly significant part of scholarly answers to Needham's important question of why. China failed to keep up with the pace set by the West for the accumulation of knowledge from the times of Copernicus onwards.

Tim Brooke, Dennis Twitchett, Jonathan Spence and Jean Genet, Ben Elman, John Henderson and other historians of Chinese intellectual traditions are currently constructing a narrative to suggest that 'promising' developments in Confucian thought in both moral and natural philosophy occurred in the late Ming period, and may well have been cut short by the prolonged and protracted takeover of the empire by Manchu armies after 1644. They and other global historians are suggesting that decline of the East allowed for the rise of the West. Certainly, there seems to have been widespread destruction during this dynastic takeover by the Qing regime and sufficient and cultural repression for some time thereafter to provide support for the thesis of a lost cosmological moment in the long history of the empire.

Needham's Unanswered Question

Eurocentric and other historians from backgrounds in comparative history may remain more impressed with Needham's view that 'China was overtaken by the exponential growth of modern science' and by Mary

Wright's classical study and its conclusion that 'obstacles to the adaption to the modern world was not imperialist aggression or the accidents of history, but nothing less than the constituent elements of the Confucian system itself'.

From several perspectives (which are shared by many Chinese scholars) is the view that what counted against China in its always difficult endeavours at unpropitious times to move onto a learning curve for the accumulation of knowledge comparable to the West was China's long tradition of success as an empire, reinforced by a set of cosmological-cum-political constraints that can be ranked for discussion and future research under the heading of Needham's Puzzle. At the top of that agenda for historical research must be the Chinese stance of incredulity towards the paradigm that had gripped the imagination of European natural philosophy, namely that all natural phenomena, including the human body, could be investigated, comprehended and interrogated as cases or instances of universal laws of nature. Furthermore, these laws (which explained how and why things operated as they did) were the manifestations of the intelligent designs of a divine creator. They could be exposed by transparent experimental methods and explicated rigorously in mathematical language. Natural laws that could be represented as divine in origin provided the West with a cosmology and a culture for elites of aristocrats, merchants, industrialists and craftsmen that rested on an acceptable, unproveable, but ultimately progressive supposition that God created a natural world that was rational and explicable, that its tendencies to afflict the lives of people's everywhere could be fixed or ameliorated and that matter could be manipulated to provide technologies to raise the productivities of labour.

Confucian cosmology neither restrained nor promoted the interrogation of nature or the search for technological solutions to problems of production. What it did not provide for, even during the continued economic advance of the Qing empire, was that powerful promotional confidence that entered into the cultures of Western elites of a natural world that was the rational and explicable work of their God. As Needham observed, 'there was no confidence that the codes of nature could be read because there was no assurance that a divine being had formulated a code capable of being read'. His point is intact and remains open for research and discussion.

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HISTORY OF TECHNOLOGY
