Science Without Modernization: China's First Encounter With Useful And Reliable Knowledge From Europe

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Abstract

This paper reviews how recent revisionist scholarship on the history of Chinese science and technology has recast the Jesuit enterprise in China. It argues that the Ming and Qing governments' efforts to control the Jesuit-transmitted knowledge in these fields stimulated ever-more interest among local scholars in Chinese traditions of mathematics and astronomy which culminated in the 18th century 'evidential research' movement. But because the scientific knowledge the Jesuits conveyed was already 'out-of-date' before their arrival in China, local scholars never had the possibility to make a complete reassessment of their own mathematical and astronomical practices. As the primary and -- at times the only -- translators of Western scientific thought to China, the Jesuits had an enormous historical impact on how Chinese scholars became trapped in a pre-Copernican universe where Chinese natural philosophy with its focus on metaphysical interpretations of the natural world remained entrenched until the 19th century.

Introduction: The History of Chinese Science and Technology in Global Perspective and the 'Great Divergence'

In 1603, the famous Chinese intellectual and Christian convert, Xu Guangqi (1562-1633) offered the local magistrate of his native Shanghai county a proposal outlining the methodology to measure the length, width, depth, and water flow of a river. Xu's document (later printed in his collection *Nongzheng quanshu* [Comprehensive Treatise on Agricultural Administration]; comp. 1639) employed conventional surveying practices as well as calculating techniques based on the Pythagorean theorem. Although it is tempting to attribute Xu's achievement here as a direct consequence of his meeting the Jesuit Matteo Ricci (1552-1610) in Nanjing that same year, it is not certain from extant documentation that this encounter with the European was the defining influence on his water study. Growing up in a region of well-connected networks of waterways and extensive wall-building, Xu had already at an early age, acquired an interest in water control and military matters, pursued mathematical study in that regard, and familiarized himself with relevant 16th century Chinese mathematical texts. But it does seem that this proposal, featuring an illustration of a circle divided into 360 degrees, did demonstrate some Western influence. Xu would go on to translate with Ricci the first six books of Christophorus Clavius' edition of Euclid's *Elements*, known in Chinese as *Jihe yuanben* (Geometry by Euclid; 1608), an accomplishment that would earn him distinction and respect among Chinese and European scholars alike (Engelfriet).

Recent modern scholarship on Xu Guangqi has depreciated Eurocentric portraits of this polymath transmitted in the first instance by the Jesuit mission in the 17th and 18th centuries, and conveyed later in 20th century secondary writings as a 'component in the master narrative of the European civilization mission in China' (Brook 2001). Instead, as Timothy Brook advocates, Xu's life should be viewed in a 'Ming-centred approach', with his science and his religion considered integral to 'a knowledge system that prized practical solutions to worldly problems, and a world view that strengthened (Confucian) statecraft concerns with a desire for salvation'. In other words, Xu Guangqi was a man of his times: a talented scholar and a dedicated Confucian official committed to the propagation of agricultural knowledge, the relief of subsistence crises, the encouragement of military defence, and not least, the promotion of free trade between China and Japan as a way of curbing piracy (Brook 2003). According to Brook and other critical scholars, one needs to regard Xu primarily as a member of that stream of late Ming dynasty (circa 1580-1644) thinkers who endorsed concrete solutions to concrete problems, i.e. *shixue* (concrete studies). Thus, in this context, the significance of Xu Guangqi's exploits lies less with what impact Jesuit science had on him, and more with how he may have attempted to solve a number of contemporary problems by utilizing facets of the knowledge bestowed by the Jesuits.

This revisionist scholarship may be judged one more step in overcoming the 'Great Divide' which has castigated the 'scientific West' against the 'exoticised, intuitive East', or in other words, the 'single-minded historical teleology of Western European "success" and non-Western "failure"' (Elman 2002; Zurndorfer 1989a). The preoccupation with the economic, social, and political transformation that constitutes the recent history of Western Europe and North America has frequently indicted other regions, and in particular China, for not fulfilling the potential to modern realizations in the spheres of industrial production or military prowess before the 19th century (e.g. Landes). Invariably, such accounts point to the role of science and scientific-related technologies used in agricultural and industrial production as the West's triumph, and even, rightful privilege. Such thinking has met a provocative challenge with Kenneth Pomeranz's volume *The Great Divergence* in which the role of science in the making of the modern world economy is quietly set aside. Pomeranz has argued persuasively that economic data are sufficient to demonstrate the foundation on which European industrialization was built. He compares the constraints on China's Jiangnan core economy around 1800, i.e. the growing population demand on food, fuel, housing, and handicrafts, that prohibited sustainable growth there with England's situation in the last decades of the 18th century. Because of the geographical accident that provided accessible deposits of coal and iron in England as well as the country's acquisition of colonies in the New World with its wealth of resources, that country was able to overcome similar constraints, and develop an industrial economy.

But this kind of refutation is exceptional, and until the last few decades of the last century, the study of China's path to modern development was an opportunity to cast praise for what Europe developed and possessed, and blame for what China did not, and in particular, science. The positivistic view of science favours the notion that the transmission of science as transparent: since scientific knowledge is positive, how can one resist it? And so, when the first Europeans visiting China expressed how adeptly officialdom supervised practical matters such as salt production, iron manufacture, flood control, and agricultural development, they also voiced surprise that these administrators achieved their responsibilities through an examination system testing moral and literary values. In his letters to Europe, Ricci communicated about this matter and noted that the Chinese were 'trapped' in a humanist civilization that valued literary ideals exclusively. As he commented: 'The study of mathematics and that of medicine were held in low esteem, because they are not fostered by honours as is the study of philosophy, to which students are attracted by the hope of the glory and the rewards attached to it' (Gallagher).

Thus, beginning with Matteo Ricci's writings, and continuing well into the 18th century with proclamations such as those uttered by the director of the Academy of Sciences in Paris, Jean-Baptiste Dortous de Mairan, or even Voltaire (Adas), there has been a continuous repudiation of China's failure to generate 'science', i.e. a certain kind of mathematical and theoretical reasoning along with systematic experimentation. In this regard, the disavowals made in the first half of the 20th century were particularly vociferous. For example, Bertrand Russell, after a year's lecturing in East Asia, wrote in his 1922 volume *The Problem of China* that until European influence had reached that region, there had been no science nor industrialization. Russell's assertions were repeated twenty years later in the writings of the Yale University philosophy professors Filmer Northrop and Wilmon Sheldon, and a decade after then in a well-known letter written in 1953 by Albert Einstein who communicated his astonishment that the Chinese sages did not make the steps '[to] invent the formal logical system (i.e. Euclidean geometry) nor 'to find out [the] causal relationship by systematic experiment' (quoted in Wright; cf. Hart).

It was against this kind of intellectual disclaimer that Joseph Needham (1900-95) began his *Science and Civilisation in China* project which has culminated in more than thirty volumes documenting China's contributions to mathematics, physics, chemistry, biology, and to mechanical, civil, and nautical engineering (Zurndorfer 1992a). Needham proposed that Chinese attainments in these fields were part of a 'grand titration' in which China was an equal contributor among the tributaries that flowed into the river of modern science (Needham 1963). Instead of a radical civilizational divide between the West and China, Needham emphasized that there had been a radical temporal break between 'primitive science' (originating both in ancient China and ancient Greece) and 'modern science' which he claimed culturally universal but uniquely Western in origin. Over time, his study of this divide became known as the 'Needham problem': Why did modern science, the mathematization of hypotheses about Nature, with all its implications for advanced technology, take its meteoric rise *only* in the West at the time of Galileo? (Needham 1969).

While Needham will always be credited for his most important breakthrough, i.e. to put European inventiveness in a wider perspective, he also attracted critics, and even during his lifetime. Aside from those historians of science such as the late A.C. Crombie or Derek de Solla Price who became even more convinced of science as a uniquely Western accomplishment after familiarizing themselves with Needham's work (Crombie; de Solla Price; cf. Cohen; Elvin), the most important challenge has been the critique by the China scholar Nathan Sivin. On the one hand, Sivin censured 'the excesses' of Needham's rehabilitation of Chinese science, and on the other hand, he doubted the usefulness of attempts to compare the science and technology of civilizations in their entirety (Sivin 1982; 1985). In Sivin's perception, there were many diverse traditions -- 'from techniques, to institutional settings, to views of nature and man's relation to it' -- originating in various locations which 'interacted...continuously until they were replaced by local versions of the modern science that they all helped to form' (Sivin 1990). Moreover, in contrast to Needham who dismissed the contribution of Confucian scholars to science, Sivin has demonstrated the specific achievements of a number of literati (e.g. Wang Xishan [1628-82]) in mathematics and astronomy, and directed attention to the importance of careful analysis of their written works. He views the primary preoccupation of this tiny, educated elite to be the preservation and revivification of its own culture, and in that way, their interest in science and in particular, mathematics, integral to the history of Chinese intellectual development.

Sivin's reproach of Needham has also extended to the matter of his synthesis of science and technology. The second part of the 'Needham problem' asks why between the first century BCE and the 15th century CE, Chinese civilization was much *more* efficient than occidental in applying human natural knowledge to practical human needs. But Sivin discounts the role of science in technology, and argues that during these 1600 years or so science and technology were separate entities (technology *not* being 'applied science'), and that Chinese superiority in technology was not indicative of more advanced science. He believes technology and manufacturing techniques were matters of craft traditions inherited from one generation to the next without written instruction, while science was carried out on the whole by members of the minority of educated people in China, and transmitted in books (Sivin 1982). Thus, the written history of China's agricultural practices and industrial arts such as that illustrated in the *Tiangong kaiwu* (The Exploitation of the Works of Nature; 1637), originated not with those people who fired porcelain or spun cotton and weaved cloth, but from literati observers eager to communicate the achievements of the lower orders.

In that regard, it is interesting to point out the differences between how Qing China and Tokugawa Japan diffused agricultural knowledge (Will 1995). While both regimes printed agricultural handbooks (*nongshu* [Chinese]/*n_sho* [Japanese]), the Japanese aimed these manuals at the educated peasant who would have found the level of technical information comprehensible. In the case of China where official government policy was indeed to encourage agriculture (*quannong*), these books were written by bureaucrats for bureaucrats, and the dissemination of improved agricultural knowledge probably followed the age-old process of person-to-person, word-of-mouth, that paralleled the bureaucrats' communication.

Finally, we should introduce another recent observation of revisionist modern scholarship: that despite the Confucian self-image of a secular and pragmatic society, ironically most of China's most well-known inventions originated in magic and the mantic arts (Smith 1991). 'Writing probably grew from the requirements of divination; printing, from the desire to gain merit by multiplying prayers and chants; magnetism, geology, and the navigator's compass from the geomancer's arts; gunpowder from the use of fireworks to scare off evil spirits; astronomy from astrology, and not least, chemistry from alchemy' (Wilkinson). And as for the latter, it is noteworthy that the world's richest depository of knowledge about chemical reactions and their products up to around the year 1200 may be found in Chinese alchemy *wandan* texts (Sivin 1990).

As is well-known, it was the Chinese who invented firearms around the early 12th century (from a formula for gunpowder first available around the 9th century), but it was the Europeans who perfected fire weapons, and deployed them on a widespread basis (Chase). Techniques for making gunpowder and firearms spread from China to Europe and the Middle East in the early 14th century, and by the 16th century when the Portuguese penetrated East Asian waters, China, Korea, and Japan took up firearms seriously. The Chinese found the Portuguese weapons superior to their own, but in the long term they had no use for them. It was only the Japanese who utilized this kind of weaponry to the fullest extent, and in a major war between Japan and Korea (supported by China) in 1592-98, muskets became the mainstay of the Japanese invaders (Zurndorfer 2004). Although the Ming military did resort to some fire weaponry during this particular clash, in most actions including the defence of the dynasty against the invading Manchus, the Chinese preferred the age-old strategy involving swift mobility of light cavalry formations manned by skilled horsemen capable of shooting, either backwards or forwards, as many as twelve arrows per minute. Centuries of warfare against steppe and desert nomads meant that firearms, however useful for sieges and the defence of urban areas, were incompatible with China's basic military needs until the 19th century. Thus, the history of firearms demonstrates the significance of how the spread of 'useful and reliable knowledge' was not necessarily a one-way affair from West to East.

This brief resume of the history of firearms in-and-out of China helps to underline another facet of this revisionist scholarship of the last decades, ie. the focus on China's 'fertile relations' with other cultures in a global concourse. As Joanna Waley-Cohen has recently demonstrated, China has a long and consistent record of engagement in trade, religion, ideology, and technology with other Asian cultures, and the West since the time of the Silk Road (Waley-Cohen 1999). As she writes, 'the complex network of international exchange that stretched from Syria in the west to Japan in the east and from Korea in the north to Indonesia in the south and, by the 16th century included Europe and the New World' was the arena through which goods and ideas entered and infiltrated China. The foreign influences penetrating China came not only in the form of religion such as Buddhism, and later, Nestorian Christianity and Islam, but also in the realm of ideas extending to philosophy, mathematics, and astronomy: along with Buddhism, came Indian astronomical and mathematical treatises. During the Song (960-1276) and Mongol Yuan (1276-1368) era, China's cosmopolitanism took on new dimensions as sea traffic flourished as never before. The Chinese-built massive ocean-going junks, the technology for which partly drew on Arab models, could undertake long-distance voyages and transport vast cargoes. The extensive Mongol empire facilitated even more the flow of information from South and West Asia. Chinese overland and navigation maps became ever more precise and knowledge of world regions, including South Asia and Africa all the more intricate. By the time of the Ming dynasty (1368-1644), China's naval competence and might were sufficient to dispatch a series of major fleets under the direction of the Muslim eunuch Zheng He over a period of twenty years (from 1405-1431?); these expeditions sailed through the seas of Southeast Asia to India, to Hormuz in the Persian Gulf, and as far as Malindi on the east coast of Africa. In the 16th century, the importation of the New World food plants peanuts, maize, and sweet potatoes via the Philippines helped transform local landscapes in Fujian and Hunan provinces, and culminated in what the historian Ho Ping-ti has called China's 'second agricultural revolution'.

Thus, China can boast about a long-term experience with the world-wide flow of useful and reliable knowledge which sometimes came 'bundled' with foreign religion. 'In the eighth and ninth centuries, when Baghdad was the greatest city in the western world and Chang'an (later Xi'an or Sian) was the greatest in the east, Arab, Persian, and sometimes even Jewish merchants traversed the distance between the two, travelling to India and China from as far away as "Frank-land in the western Mediterranean sea..."' (cited in Lewis). Buddhism originating in India was the most important stimulus in China for printing. The reproduction of identical Buddha images led to the use of wooden blocks to publish Buddhist sutras, and eventually to the printing of the Confucian classics as well as vernacular literature, and the creation of the well-known book industry that flourished from the eleventh century (Chia). And Islam, so closely connected to international trade, brought China in contact with astronomers, mathematicians, and medical doctors of other civilizations.

Unlike both Buddhism and Islam which acquired social and economic functions in China, and thereby integrated into the local life, Christianity was never institutionalized in such ways. The 'useful and reliable knowledge' which the Jesuits transmitted to China remained confined to the relatively small educated elite. The Chinese literati whose own *raison d'être* was entwined with the ideological aims of Confucianism and the political restraints of the imperial court might have mingled, and even worked with the Jesuits (like Xu Guangqi had done), but ultimately the contact between these scholars and the Jesuit missionaries was circumscribed. Governmental control over the mission meant that the Jesuits' primary role was to serve as 'imperial minions' in official bureaucratic agencies where they assisted in calendrical, military, and cartographic duties. Given these circumstances, one may question then whether there is any reason even to consider what kinds of scientific or technical knowledge local scholars did or did not have at their disposal which would have made long-term differences to late imperial China's economic development, such as the employment of new technologies to bolster China's primary industries of silk and tea production, or the promotion of more efficient inland waterway transport systems, or the creation of well-equipped modern arsenals located along China's littoral.

And so, the distinction that Joel Mokyr has recently posed between different layers of knowledge and their applicability to production processes seems irrelevant as one reviews the particular transmission of European science via the Jesuits to China. As we probe into the circumstances of this episode, we may observe both the internal and external conditions which ultimately undermined the usefulness and reliability of knowledge from Europe. In this paper, we will focus on three aspects of the encounter between the

Jesuits and their Chinese interlocutors: how the Chinese authorities accommodated the Jesuit mission for their own purposes; how the Jesuits controlled what 'useful and reliable knowledge' they conveyed to Chinese scholars; and how Chinese intellectuals re-evaluated their own scientific legacies in relation to what the Jesuits communicated with them. In the process, we hope to dispel a number of myths and illusions about Chinese science and mathematics as well as to demonstrate the centrality of politics in late imperial China to the propagation and reproduction of knowledge.

The Jesuit Scientific Mission in China: Flattery as Strategy

As is well-known, the first Jesuit mission arrived in China in 1583 with the aim of converting the Chinese masses to Christianity. The Jesuits were among the best educated men in 16th century Europe, and as contenders to the Reformation's humanist scholars, 'they made learning, both religious and secular, a major tool in the defence and propagation of Catholicism' (Engelfriet). They established numerous schools and colleges in which they emphasized mathematical skills so as 'to prove that they stood at the frontiers of modern knowledge' (Spence 1984a). The 236 Jesuit colleges scattered around various regions in Southern Europe and Germany as well as in the Spanish and Portuguese colonies in Latin America and Asia made this Order's educational program truly a global enterprise. Although other Catholic orders -- Franciscans, Dominicans, Augustinians, and the secular French Society of Foreign Missions -- also entered China in the 17th and 18th centuries, it was the Society of Jesus that dominated, but with finite success. With a total of some 900 Jesuits working in China during this period, the Society could claim only limited numbers of converts -- probably no more than 200,000 in total over the two centuries (out of a total population of some 300 million) -- and yet, a certain triumph with regard to their contacts with the Chinese elite, and their succession of official appointments to Ming and Qing imperial courts.

It was Ricci who, after having become fluent in written classical Chinese and spoken mandarin, first set the parameters by which the Jesuits established their mission. His strategy consisted of three main principles: propagation from the top down, i.e. focusing on the Chinese literati elite; secondly, maximal 'accommodation' to the life-style of that elite which included a certain tolerant attitude toward the Chinese ritual tradition; and thirdly, 'indirect propagation', i.e. combining the religious message with elements of Western science and technology that should serve to impress educated Chinese with the superiority of Western culture. Interestingly, because the first decades of the Jesuit mission in China coincided with a major Buddhist revival that attracted literati sympathy but official condemnation, the Ming authorities did not halt the Jesuit efforts in their religious propagation to negate Buddhism and, to a lesser degree, Daoism.

But Ricci himself had difficulty with these circumstances. According to the modern scholar Jacques Gernet, Ricci did not understand the stakes involved in the anti-Buddhist reaction of the period which he used to form alliances with educated Chinese. Nor did he comprehend the cosmic mysticism of neo-Confucianism or the philosophical aspects of Buddhism (Gernet 1984). The very first Chinese scholars whom Ricci entertained believed him to be an alchemy wizard who could extract silver from quicksilver (mercury) (Engelfriet; Peterson 1998). But he did not turn these potential converts away, and amused them by demonstrating his prowess in the fields of astronomy, mathematics, cartography, and mechanics. For example, in 1584 he arranged to have a 'mappa mundi' (based on Mercator's 1569 and Ortelius' 1570 maps) issued which showed China at the center of the world and with all the place names transcribed in Chinese. This 'mappa mundi' also attracted imperial attention: the Ming Wanli Emperor (reigned 1573-1620) ordered a gigantic version composed of six panels, each over six feet wide for display in the inner chambers of his Beijing palace (Spence 1984a). Ricci's map went through seven more editions before 1609.

Through extensive discussions with these Chinese literati, Ricci began to perceive what was their knowledge of astronomy, and concluded, as he wrote his Jesuit superiors, the 'absurdities' (*le cose absurde*) of their conceptions. By the time he died in 1610, he had developed a well-versed program for flattering the tastes of the Chinese scholar elite for the science, technology, and arts of Europe while he communicated with his Jesuit brothers 'his opinion...that the Chinese possess the ingenuous trait of preferring that which comes from without to that which they possess themselves, once they realize the superior quality of the foreign product. Their pride, it would seem, arises from an ignorance of the existence of higher things and from the fact that they find themselves far superior to the barbarous nations by which they are surrounded' (Spence 1969). And so, Ricci laid one of the first stones in the vast edifice of European belief that the Chinese were rich, arrogant, and incompetent (Spence 1984b).

One of the goals Ricci had achieved for himself before his death was to gain the right to residence in the capital. There he had further opportunity to convert several high-ranking officials, and not least, to secure permission to bring more Jesuits to Beijing. This second cohort of missionaries also stationed themselves in some of China's leading intellectual centers in the Lower Yangzi region (Nanjing, Hangzhou, Shanghai), and in Fujian and Shaanxi provinces where literati were known to congregate for scholarly exchange and intellectual pleasure. A number of Ricci's successors were expressly recruited by Niklaas Trigualt (1577-1628) for their accomplishments in the calendrical arts. Catholic Europe's own major 1582 calendrical reform which had institutionalized the intercalculating leap year had prepared these missionaries for their work in China, and gave them impetus to gain further acceptance in imperial circles, and thereby the power and opportunity to acquire the faithful, a process which Jonathan Spence has described as 'To God through the Stars' (Spence 1969).

The second cohort, who entered China in the early 17th century (including Adam Schall von Bell [1592-1666]; Johann Terrenz [d.1630], and Giacomo Rho [1590?-1638]), got their breakthrough in 1629 when Xu Guangqi, by then holding the influential office of vice-president of the Board of Ceremonies, arranged a comparison of solar eclipse predictions by the conventional Chinese, Muslim, and newly-introduced European methods. Although the matter of Ming dynasty calendar reform had an extensive history long before Ricci's arrival (Peterson 1986), these previous efforts to eradicate errors had all ended in failure. Because the European method proved to be the only accurate one, imperial approval was granted for reform of the Chinese calendar according to the Westerners' calculating procedures. From then onward, a team of Jesuits and Chinese scholars under Xu's direction began an extensive program of manufacture of instruments and translation of scientific books at court.

In a certain sense, imperial patronage of the Jesuits in this way followed a long-standing convention of appointing foreign 'technicians' for calendrical work. Like the Indian astronomers of the Tang dynasty (618-906), or the Persians and Central Asians recruited by the Mongols during the Yuan dynasty, the Jesuits were utilized by the Chinese because they were outsiders. Since astronomy and calendrical science had great politico-religious importance in China -- with the emperor regarded as the mediator between heaven and earth, and the calendar issued in his name -- it was more prudent to designate foreigners to oversee time-keeping and other calendrical matters than local experts who might use the opportunity to usurp the throne. For their part, i.e. lending their scientific expertise, the Jesuits also expected returns from their Chinese hosts, but such a presumption was not outrageous given the mores of the times. The practice of giving 'scientific marvels' to gain social status and patronage, or to acquire access to a network of communication was common among the learned in the Renaissance courts (Biagioli; Findlen). In that way, the Jesuits were not initiating something new with their behaviour in China.

Although the Ming authorities allowed the Jesuits to help prepare the calendar, the Europeans remained under the authority of the Muslim-led Directorate of Astronomy. It was only with the collapse of the Ming dynasty that the Jesuits could overcome their subordinate status; in their haste to assume power, the Manchus called upon their expertise in mathematics and astronomy to consolidate their claims to the Mandate of Heaven with an accurate calendar. The new Qing dynasty (1644-1911) accepted the evidence of Adam Schall's superior skills at predicting solar and lunar eclipses, and therefore made him director of the Bureau of Astronomy.

But before Schall ascended to this new position, he had shared with Ming officials another of his talents: his ability to cast cannon. During the last months of the dynasty, in the hope to defend the capital against attack, Ming officials asked the Jesuit to improve the indigenous cannon which were too heavy to wield in rapid deployment. Schall produced more than 500 'forty-pounders' and with a Chinese colleague wrote a work on gunnery, the *Huagong jieyao* (Essentials of Gunnery) (Waley-Cohen 1999). This would not be the first occurrence a European was requested to share 'useful and reliable knowledge' about weaponry, and it would seem that both the Ming and Qing authorities no matter what they thought about Western science and technology, or the general ineffectiveness of firearms in warfare on the steppe, did perceive the advantages of European fire power when the occasion arose (cf. Zurndorfer 2004). By yielding to this 'call to arms', the Jesuits were once again forced to accommodate to their hosts.

In his new position in the Qing government, Schall took advantage by demanding all those working under him in the Bureau would have to convert to Christianity. It was only a matter of time (actually, some twenty years) before his enemies, led by a nativist literatus, Yang Guangxian (1557-1669) would have him vilified and threatened with death for spying, intrigue, and not least, scientific incompetence in 1664 (Zurndorfer 1993). Even after he was proved innocent of the latter accusation, thanks to the help of another Jesuit, the newly arrived Ferdinand Verbiest (1623-88), the other charges were never dropped; Schall died a broken, shattered man, Catholicism became proscribed, and all the missionaries banned to Macao. Schall's Christian foes who too were exiled, circulated the joke 'One Adam having driven us out of Paradise, another has driven us out of China'.

Verbiest spent his early years in China under house arrest but obtained the chance to change his status when the accuracy of the calendar, now under the charge of Schall's successor Yang and the Moslem official Wu Mingxuan, became doubtful. In the same way as Schall proved his astronomical skills in 1644, Verbiest dared to demonstrate to the Manchu authorities the errors of Yang and Wu. The young Kangxi Emperor (reigned 1662-1722) ordered the accuracy of Verbiest's calculations confirmed, and on that basis assigned him in 1664 to the directorship of the Astronomy Bureau. He gained further favor with the throne when he helped cast cannon (like Schall had done in 1644) which helped support the Manchu arsenal. Verbiest also carried on the Jesuit tradition of cartography and produced another world map; it synthesized new knowledge and updated the geographical treatise another Jesuit missionary, Guilio Aleni had produced in 1623.

Verbiest and the Emperor enjoyed a good relationship which culminated in his appointment as personal tutor to the monarch; in that capacity, the Jesuit taught him Euclidean geometry, and later spherical trigonometry, and supervised for him practical experiments in astronomical observation and terrestrial measurement. Nevertheless, the Qing ruler continued to restrict the religious activities of the mission, overcoming any papal attempts to subjugate the missionaries or their converts during the Rites Controversy (1705-07); this

Emperor even claimed personal control over the calendar. Spence sums up Verbiest's years of imperial service as dominated by trivia: 'At the Emperor's request he spent weeks on end perfecting a system of pulleys to lever giant stones over a rickety bridge, making gay sundials and a water clock, building pumps to raise the water in the royal pleasure gardens, and painting tiny trompe d'oeil figures to be viewed through a prismatic tube' (Spence 1969). Nevertheless, to his dying day, Verbiest remained convinced that the monarch in the face of such delights, as well as the insights of Western astronomy, 'would swing to the faith behind the science'.

Neither the Kangxi Emperor's son, the Yongzheng Emperor (reigned 1723-36), nor his grandson, the Qianlong Emperor (1736-95) flaunted much interest in science or mathematics, and both descendants had little patience with the proselytizing activities of the Europeans. The Yongzheng Emperor expelled all foreign missionaries to Macao except those who rendered technical services to the court; and the Qianlong Emperor continued to issue edicts banning Christians in the provinces. It was during the reign of Qianlong that the extent to which the Jesuits had misled Ming and Qing authorities about the true nature of the universe was first revealed. In 1760, the Jesuit Michel Benoist (1715-74) informed the Emperor on the occasion of his fiftieth birthday of the heliostatic world model. Sivin reports the Emperor's reaction as simple, and dismissive: 'In Europe you have your way of explaining the celestial phenomena. As for us, we have ours too, without making the earth rotate' (Sivin 1973).

As missionary influence in China steadily declined, the Society of Jesus also lost support in Europe. In 1773 the pope suppressed the organization around the world.

Thus, by the time the famous Macartney mission from Britain arrived in China in 1793, carrying a fine and sophisticated array of scientific apparatus (including a planetarium, a copy of Herschel's telescope, and other astronomical instruments, as well as a barometer, chronometer, air pump, and even a republica of a steam engine [Cranmer-Byng and Levere 1981]), the Qing court had long ceased any specific fascination for European products (Zurndorfer 1988; Waley-Cohen 1993). Although the purpose of this particular embassy was quite different from that of the Jesuit mission, i.e. to establish 'free trade' relations and a permanent embassy in Beijing, the British strategy here was not all that different from the missionaries. Like the Jesuits, Macartney and his government believed a demonstration of the superiority of the European sciences would access them favour and eventually power in China.

Helping to Make the Earth Stand Still: The Jesuit Agenda and Chinese Priorities

Modern scholars who have examined closely the extensive (and not least, difficult-to-read) Chinese documentation on the Jesuit scientific enterprise in China have disagreed on how to interpret Chinese efforts to master in their own terms what they called Western learning (*Xixue*) in the 16th to 18th centuries. From a broad perspective, the debate falls into two camps. On the one hand, Nathan Sivin has argued that the Jesuits, by withholding the knowledge of the Copernican system, did *not* introduce modern science to China. 'The Church's injunction of 1616 against the teaching of heliocentrism led the Jesuits to present the Tychonic system as the most modern but which in its essentials had not gone beyond the bounds [set] by Ptolemy' (Sivin 1973). According to Sivin, not only did the Jesuits *not* translate any work by Copernicus or Galileo, Kepler or Newton, Descartes or Huygens, they also 'strategically' simplified and rewrote the texts of occidental astronomy to conform much more to their own priorities. 'To the very end of their presence in China, the Jesuits presented the rivalries of cosmologies as that between one astronomical innovator and another, for the most convenient and accurate methods of calculation'. Thus, by the 18th century when Newton's great *Principia*

Mathematica was being popularized throughout Europe, and Newtonian mechanics and continental calculus common foci of scientific study in Europe, the Chinese remained convinced of a pre-Copernican universe. Sivin has also argued that the Jesuit presentation of Western astronomy made it incomprehensible. Chinese mathematics and astronomers who pursued cosmological study found inconsistencies and contradictions (see Zurndorfer 1988). In sum, China's first encounter with modern science from the West was incomplete because of Jesuit distortions.

The other camp of modern experts who too have researched the extensive contemporary record in Chinese born out of Jesuit-transmitted knowledge has laid emphasis on the common and shared concerns of the missionaries and their Chinese interlocutors but the ultimate incompatibility of their world views which inhibited further scientific development in China. The French scholar Jean-Claude Martzloff regards the Jesuits as responsible for stimulating Chinese interest in, and use of European-imported reckoning techniques, calculating instruments, plane and spherical trigonometry, and to a certain level, infinite series (Martzloff 1993-94). In his view, the Europeans and Chinese shared the ideals of a common conception of time and space as measurable and quantifiable elements, and of the validity of astronomical prediction based on the correspondence between calculation and observation.

But this does not mean, as Martzloff makes clear, that the Chinese mathematicians and astronomers appreciated the value of reasoning by discourse in mathematical theorizing. For example, the popular Chinese version of Euclid's *Elements* was expurgated of nearly all the demonstrative discourses. In the eyes of the *shixue* proponents of Euclidean geometry, such discourses were 'reminiscent of religious quibbling, whether Christian or Buddhist...and the root of all evil in view of its uselessness and indulgence'. Martzloff adds that discursive logic did not form a part of the astronomer Wang

Xishan's treatises. In conclusion, Martzloff believes that the Chinese authors of mathematical and astronomical studies acknowledged the utility of European predictive systems but refused at the same time to endorse the conceptual structure on which they were built.

Martzloff's analysis complements Jacques Gernet's well-known argument that late Ming/early Qing China lacked the motives and the peculiar intellectual framework which led to the development of classical science in Europe (Gernet 1982;1985; cf. Goodman and Grafton). His focus on the linguistic barriers between the Europeans and Chinese has a philosophical basis: 'in Chinese, it is so difficult to express how the abstract and the general differ fundamentally, and not just occasionally, from the concrete and the particular'. This means in Gernet's view that the Jesuits could not be expected to penetrate the Chinese (Confucian) unitary vision of man, ethics, politics and the universe. Gernet sums up this divergence with the observation: 'Chinese thought at that time [i.e. 17th century] knew only of one sort of time, which was evolutionary, of one physics, heavenly as well as terrestrial (that of the combinations of *yin* and *yang*), of very long durations in astronomy [and] in [the history of] the earth and of man. It appears modern to us in its independence from any dogma and in the importance it attached to change, but at the same time, devoid of the motifs and of the very peculiar intellectual framework that in Europe allowed for the development of experimental science' (Gernet 1993; cf. Zurndorfer 1995).

These contrasting points of view between Sivin and Martzloff/Gernet are not necessarily exclusive, and other modern contributors have pursued the course of other forms of Jesuit-generated knowledge in China. Richard Smith in his penetrating and provocative studies of Chinese cartography (Smith 1996;1998) has concluded that 'despite a long tradition of sophisticated geographical cartographic scholarship, and an equally long history of foreign exploration (and conquest), the world outside China remained relatively unimportant to the Chinese elite. He argues that unlike the West where the great voyages of discovery ignited flames of interest, Zheng Ho's dramatic naval expeditions met no such reaction. Smith also refers to the surveying techniques first conveyed by Verbiest that enabled the Qing dynasty in the early 18th century to create a far more mathematically 'accurate' map of the empire than had ever been produced: the *Huangyu quanlan tu* (Map of a Comprehensive View of Imperial Territory; 1718) remained the most authoritative atlas of the realm for nearly two centuries. He argues that such cartography was appreciated for its military and strategic value, but had little effect on Chinese mapmaking in the long term. He claims that Chinese mapmakers borrowed little of cartographic substance from the Jesuits, and preferred to arrange foreign locations topologically rather than topographically. Moreover, Chinese scholars saw the various 'mappa mundi' as evidence of the Jesuits' recognition of the centrality of Chinese culture in a universe where everyone paid tribute to the emperor.

The Significance of the First Encounter: Intellectual Dead End?

Modern scholars have also observed that one of the effects of China's first encounter with European scientific knowledge was the genesis of a nativist movement to retrieve the ancient Chinese mathematical and astronomical traditions, and to help revive them (Henderson 1980, 1984; Elman 1984). Benjamin Elman argues that Xu Guangqi inspired a later generation of Ming thinkers associated with the Fushe (Return [to Antiquity] Society) to reject Confucian philosophical speculation, and to reaffirm the original Confucian texts and doctrines. Such intellectual 'purification' in the spirit of 'concrete studies', he claims, became the basis for the *kaozheng* (evidential research) movement of the 18th century which stressed exacting research, rigorous analysis, and the collection of evidence drawn from ancient artefacts and historical documents and texts. According to Elman, 'abstract ideas and a priori rational argumentation gave way as the primary objects of discussion among literati scholars to concrete facts, verifiable institutions and historical events. This research program placed proof and verification at the centre of the organization and analysis of the classical tradition' (Elman 2000). Henderson has suggested that for 17th and 18th century Chinese literati the more accurate astronomy brought by the Jesuits along with geometry became a model for the classical scholarship of phonology, philology, and textual criticism. With these disciplines, scholars now had a way of 'gauging the degree or quality' of their intellectual and moral enlightenment.

The question arises to what extent did Chinese intellectuals re-evaluate their own scientific legacies in relation to what the Jesuits conveyed to them. As we have indicated earlier, mathematics and calendar reform were important concerns among Ming literati before the arrival of the Europeans, and thus, the Jesuits did not 'rescue' Chinese science from 'decline'. Elman's recent study of the Chinese examination system asserts that during the Ming dynasty candidates were expected to demonstrate many of the technicalities of the calendar, astronomy, and music. Questions on methods to measure time, to predict eclipses, or to evaluate mathematical harmonics were common on Ming era examinations (Elman 2000).

While the first Qing rulers banned any focus in the civil exams on astronomical portents and the calendar, probably because they pertained to Qing dynasty legitimacy, they did not dismiss the value of scientific study. The Kangxi Emperor institutionalized mathematical calculation and calendrical studies by creating a special academy where he could converse informally with scholars versed in mathematics and science. In the 'Studio for the Cultivation of Youth' (*Mengyangzhai*) first established in 1712-13 on the model of the Parisian Academy of Sciences, he invited Qing literati and Manchu bannermen only (and thus, not Jesuits, to insure undue foreign influence) to explore Chinese mathematics and sciences, with the goal to promote native talent. In this regard, he also initiated a project to update Ming compendia on mathematics inspired by the Jesuits, and another to issue new compilations which introduced European algebra and logarithms to the base ten, again in the spirit that local scholars could improve their knowledge of both Western and Chinese calculating techniques.

In a certain sense, it was the Kangxi Emperor who 'domesticated' Western learning. He appealed to scholars like Mei Wending (1633-1721), a leading mathematical astronomer who already in 1680 had written a treatise *Zhongxi suanxuetong* (The Synthesis of Chinese and Western Mathematics), to find the correspondences between the orthodox Confucianism (*daoxue*) of the Song dynasty and Jesuit astronomy. In effect, what the emperor did here was to propagate the idea that Western science had Chinese origins (*Xixue Zhongyuan*), a concept which generally became accepted among 18th century scholars. Here again, there was a clear political purpose: by endorsing Western science in this way, the Manchu monarch attempted to convince Han Chinese that he was not advocating something 'foreign' but rather, restoring the most authentic Chinese traditions. He was asking them to consider how the ancients' lack of trigonometry was remediable; he stimulated the literati to reconstruct a new line of transmission from ancient China to contemporary Jesuit astronomy (Hu). Such authorization helped 'civilize' the Jesuit importation of science and mathematics into native status, and with the incorporation of a number of Jesuits into China's first formal collection of 280 life histories (including 37 Europeans) of those well-versed in mathematics and astronomy, the *Chouren zhuan* (Biographies of Mathematicians and Astronomers; 1796-99) by Ruan Yuan (1764-1849), the assimilation of Western science into the Chinese record took on its final formal encapsulation (Bai; Porter).

Such official endorsement of native science also allowed Chinese scholars to question openly the scientific value of what knowledge the Jesuits had conveyed. For example, Xu Guangqi's preface to a study on practical arithmetic translated by Ricci which claimed the superiority of the Western mathematics over earlier Chinese works, was removed and the volume itself *Tongwen suanzhi* (Translations of Guidelines for Practical Arithmetic; 1611?) no longer printed in the 18th century. It was Mei Wending who set the tone of the *Xixue Zhongyuan* movement with complaints about the internal contradictions of European astronomy, many of which later Chinese scholars were to demonstrate emanated from the Jesuits' failure to teach heliocentrism (Zurndorfer 1988). Mei's work was 'followed-up' by Jiang Yong (1681-1762), an intellectual well-versed in the complexities of practical astronomy, who expressed the demerits of Chinese methods of calculation, and the merits of Western computing techniques while he disdained the conceptions upon which they were built. It was men of the following generation, those of Ruan Yuan's time, when the contradictions between the exacting measurements of Western mathematics and astronomy, and Chinese cosmology became central in *kaozheng* discourse. With Ruan, Qian Daxin (1728-1804) helped complete the incorporation of the technical aspects of Western astronomy and mathematics into the Confucian tradition. Qian proclaimed the legitimacy of Western mathematical methodology for the reconstruction of antiquity, revising ancient writings, and broadening the literati tradition, thus reversing centuries of Confucian scholars' focus on moral and philosophical problems. In that way, Qian and his colleagues discouraged any potential to view 'science' as an independent field of inquiry (Elman 1984). Unlike 17th century English practitioners of mathematics, who dedicated their writings especially to artisans, seamen, and craftsmen, Qian and company aimed to elevate and to situate the study of measurement with classical learning. This meant that by the mid-18th century knowledge of mathematics and related disciplines in China would continue to remain the exclusive preserve of a relatively tiny, literate elite (Bai; Horng).

Finally, a few words should be said about the particular environment in which Chinese intellectuals communicated with each other, and the implications thereof. As mentioned above, the Kangxi Emperor favoured academies as a vehicle for intellectual communication, and consequently, he encouraged provincial officials to establish local institutions in which literati could exchange information and participate in the massive literary projects he initiated, and which his grandson the Qianlong Emperor would continue. Both the gigantic officially-sponsored compilations *Qinding gujin tushujicheng* (Imperially Approved Synthesis of Books and Illustrations Past and Present, 1726-28) (consisting of 852,408 pages divided into 6,109 sub-sections), and the *Siku quanshu* (The Complete Library of the Four Branches of Literature; 1783) (incorporating 2.3 million [hand-written] pages), encouraged literati to commit to 'evidential research', and to do so in the flood of academies that emerged by the mid-18th century. Academies became the framework in which textual scholarship was debated, deliberated, and discussed.

Although academies were located all over the empire, the regions of the Lower Yangzi and the southeast coast (Fujian and Guangdong provinces) where a flourishing commercialized economy sustained intellectual life, had the highest concentration of these institutions (Zurndorfer 1992b). And, interestingly, the native place of many of the intellectual giants (including some of those named above) who attended these academies in the Lower Yangzi area was one particular region, i.e. Huizhou. Huizhou was a locale famous for its merchants and their far-reaching empire-wide trading and business activities (Zurndorfer 1989b). The extended families of Huizhou literati, commonly organized in corporate lineages, were known to mobilize their economic and cultural resources to support academies, libraries, book production, and special learning institutes with the result that the major forms of knowledge production and reproduction in 18th century China were in the hands of this relatively small group of people who were bounded together through marriage, patronage, and friendship.

It would not be until the mid-19th century when the intellectual transformation of China's second encounter with 'useful and reliable knowledge' through Protestant missionaries would exceed the intellectual boundaries of textual scholarship, and China's 'intellectual map [would be] redrawn' (Reynolds). In the process, the narrow confines of the small Chinese intellectual elite would dismantle, but the institutional structure for the creation of modern science would still await the 20th century, and the 'third encounter' with Western science. Moreover, the transfer of Western technology did not fare much better in China during the first half of the 19th century. On the one hand, Europeans would still seek the technological secrets for silk production, textile weaving, porcelain making, and large-scale tea production from the Chinese (Elman 2002). As late as 1849, another of Xu Guangqi's most important studies, his compendium on silk manufacture and the cultivation of the mulberry tree, was still being translated into French and English. And, on the other hand, Westerners tried, but without much success in the mid-19th century, to convince Chinese manufacturers of the advantages of machines (Zurndorfer 1994). After 1861 when the British import-export firm of Jardine, Matheson and Co. established a steam-powered silk-reeling filature in Shanghai, Chinese entrepreneurs and silk guild leaders would shut the foreign plant down after a few years by making sure the foreigners had an inadequate supply of silk cocoons, and thereby protecting their own industry from encroachment. Similar Chinese organizational efforts curtailed foreign intrusion into the soybean packing industry in north China in the 1870s.

Some Further Observations

In this paper, we have reviewed the conditions in which China first experienced 'useful and reliable knowledge' from the West. Although China had for centuries incorporated technological and scientific discoveries from other regions into its material and intellectual well-being, the Jesuit transmission of European science only really confirmed that there existed alien ways of thinking. A deliberately incomplete transmission of European astronomy, mathematics, and other scientific information coupled with a foreign religion which lacked a certain appeal, and which ignited repulsion by the imperial authorities (despite their tolerance of the creed up to a point), formed the background to this encounter. The Ming and Qing governments treated the Jesuit missionaries like they did all foreign 'technicians', as minions to serve the court and to support the astronomical, military, and geographical needs of the regime. And, in a political environment where the manipulation of scholarship was the norm, it was only a question of time before native scholars would incorporate the Jesuit-conveyed 'useful and reliable knowledge' into the corpus of local learning, and thereby exclude the possibility of European science becoming freed from the entrenchment of Chinese metaphysics. Finally, we have tried to elucidate the limitations of the knowledge discourses that preoccupied Chinese intellectuals on the eve of the Great Divergence.

The question remains how can we evaluate this encounter between Europe and China in the context of contemporary global and local developments? One answer to this question may be found in the observations of the modern scholar P.E. Will who views China in the 18th century experiencing modernization 'but without science'. Will proposes that in the more dynamic regions of the empire then, there were certain conditions that hinted of transformation, places where 'we have something not unlike what certain historians, dealing with early modern Western Europe, have termed 'Smithian growth'...a multifaceted process including market expansion, more complex and more efficient trade organizations, regional specialization of production, and increased monetization of social relations -- a process which does not necessarily entail any scientific breakthroughs, or even any significant increase in per-worker or per-acre activity' (Will 1994, 1995; cf. Zurndorfer 1996). Will also points to the efficacy of the 18th century Sino-Manchu state's fiscal and bureaucratic reforms 'to construct a better integrated, more efficient, and more productive society'. Moreover, this state did not discourage individual initiative, that is the efforts by ambitious peasants, landowners, or merchants to promote crop specialization, expand handicraft production, or generate new market organizations. Ironically, he suggests, it may have been the very success of this state flexibility and wide-spread integration that made more problematic a dismantling of traditional social and economic relations in the 19th century. Certainly, in the matter of China absorbing the transfer of European technology up to the 20th century, as mentioned above, the problem of 'success' seems paramount.

In other words, Will's presentation leaves us with the thought that there is sufficient evidence to argue the framework of China's indigenous modernization before the 19th century, but without the abstract reasoning so often associated with the speculative sciences of the West. While the best Chinese minds did use European mathematical science to revitalize their own traditions, they could not see its potential for other uses, except calendrical calculation.

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