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China's Catching-Up with Europe in the Field of Cannon Making, 1514-1683

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A master thesis submitted in conformity with the requirements for the degree of Master in China Studies

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1514-1683年中国在火炮制造领域中与欧洲水平的拉近

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【摘要】本文主要探究火药和火药武器，特别是大炮的历史。重点考稽了中国在 1514 年（第一艘来自欧洲的船只在中国靠岸）到 1683 年（清军夺取台湾，至此十七世纪明清交替的动荡过渡期结束）间对欧式大炮的采用。约从 1500 年起，欧洲就有着世界上最先进的火器，火器技术是欧洲最早的领先技术之一，除此之外还有光学技术以及钟表技术。这三项技术是长期以来中国与西方交互占有技术领先地位而相互交换的并非单向过程中的先驱。在十七世纪中国仍然有着更好的铸铁术和更完善的农业技术。火药武器最初在中国诞生，经过改良后又在十六世纪由欧洲传入中国。

首先，本文介绍了火药以及最原始的火药武器，例如火枪、炸弹和火箭，这些都是中国在宋朝（960-1279）时发明的。接着，本文着力探究这项技术在欧洲的传播（发生在十三世纪蒙古对欧亚大陆的远征中）以及发展，比如后膛枪、步枪和改良火药的发明。同时，本文大致介绍了元-明过渡期和明朝（1368-1644）时火器的广泛使用，以及向东南亚的扩散。之后，本文探讨了 1514 年以降中国使用和制造过的、发明于欧洲的后膛装置回旋炮（佛郎机）和步枪，以及十七世纪 20 年代起开始使用的红夷炮。在十六世纪六十年代戚继光对海盗的镇压以及在 1592-1598 年间抗击日本对朝鲜的侵略中，佛郎机炮都发挥了巨大的作用。另外，本文也介绍了皈依基督教的孙元化尝试将欧式火器运用于明朝晚期的军队，传教士为朝廷制造大炮，郑成功在中荷战争（1661-1662）中打败荷兰。通过这些研究，我为本文的论点提供了依据：（1）无论是现在还是过去，人类的技术都不是仅靠一个单一的文明——比如说单一的中国文明或是欧洲文明贡献而来的，而是不同文明共同努力的结果。（2）在 1683 年前，中国积极地并且有能力采用欧洲的火炮技术。中国有能力采用该技术的一个主要原因是频繁的战争，对中国来说，这是采用外国军事技术的一个大的诱因。

在这之后，本文阐述了中国在与英国的第一次鸦片战争（1839-1842）中火炮技术的退步及其原因，其中一个原因是中国经过了一段相对和平的时期，即清帝国治下的和平，而欧洲经过了一段漫长的“战国时代”。 本文还重点指出了尽管在军事和其他方面的技术上的退步，中国在十八世纪前的生活水平比得上甚至超越了欧洲的生活水平。此外，本文简要探讨了紧随其后的“大分流”出现的原因，即欧洲财富和力量的急速膨胀，相关研究包括彭慕兰对欧洲使用矿产资源和开发殖民地的强调，伊懋可对中国陷入“高程度平衡陷阱”不能自拔的理论。然后，本文将中国对欧洲先进天文学的采纳和对欧洲先进大炮的采纳作了比较，并简要阐述了最后中国在两个领域都不能与欧洲抗衡的原因。中国在采纳欧洲先进天文学上失败的一个主要原因是传教士对异端的太阳中心说的抵制，而一直到十八世纪末，传教士都是联系欧洲和中国的主要纽带。

【关键词】火药和火器历史；大炮制造；军事历史；明清过渡；中欧交互；大分流；耶稣会士历法改革

Abstract: This thesis is about the history of gunpowder and gunpowder weapons, especially of cannon. It focuses on China's adoption of European cannon between 1514, the year of the first arrival of a European ship at China's coast, and 1683, the capture of Taiwan by the Qing army, which can be seen as the endpoint of the violent Ming-Qing transition during the 17th century. With Europe having the most advanced firearms in the world since about 1500, firearm technology was among the first technologies in which Europe gained technology leadership, others being the optical and horological technologies. They were fore-runners in the non-monolithic long-lasting exchange process of technology leadership between China and the West from the Middle Age until the Industrial Revolution. China still had more iron casting expertise and a more developed agriculture than Europe during the 17th century. Originally invented in China, improved gunpowder weapons were re-introduced by Europeans to China since the 16th century.

First, I describe when gunpowder and the first gunpowder weapons like fire lances, bombs, rockets and guns were developed in China during the Song dynasty (960-1279). Then, I go into the spread of this technology to Europe in particular, which occurred during the 13th century in combination with the Mongol conquests of wide parts of Eurasia, as well as into further enhancements in Europe such as the invention of breech-loaders, muskets and improved gunpowder. I also sketch the wide use of firearms during the Yuan-Ming transition and the Ming dynasty (1368-1644) as well as their spread to Southeast Asia. After this, I describe how the Chinese used and produced European-derived breech-loading swivel guns (*folangji*) and muskets soon after 1514 and "red barbarian cannon" (*hongyipao*) since the 1620s. The *folangji* played crucial roles during Qi Jiguang's suppression of pirates in the 1560s and during the defeat of the Japanese during their invasions of Korea (1592-1598). Also Christian convert Sun Yuanhua's attempts to integrate European firearms into the late Ming army, the Jesuit's service as cannon makers for the Chinese court and Koxinga's success during the Sino-Dutch War (1661-1662) are described. With these findings, I present evidences for my two theses that (1) the technology of the humanity of today or in the past is not the result of efforts of a single civilization, such as the Chinese or the European one, but rather the result of combined efforts of various civilizations, and that (2) China was in fact eager and capable to adopt European cannon technology until 1683. One major reason for the latter may be frequent warfare in China until 1683 which constituted a great incentive to adopt the foreign military technology.

After this, I go into the fall-back of the Chinese cannon technology until the First Opium War (1839-1842) against Great Britain and discuss its reasons, one of them being a following relatively peaceful time in Qing China, the Pax Manjurica, whereas Europe underwent an extended "Warring States" period. I also stress that China's living standard despite its evolving backwardness in military and other technologies was comparable to or even higher than the European one until the 18th century. After this I shortly discuss answers for the following emergence of the so-called "Great Divergence" which is the following meteoric rise of European wealth and power, including Kenneth Pomeranz' stressing of Europe's access to coal and colonies and Mark Elvin's "high-level equilibrium trap." Then I compare China's adoption of European advanced astronomy with the adoption of European advanced cannon, and shortly discuss why China finally could not compete with Europe in both knowledge fields. A major reason for China's failing adoption of European advanced astronomy was the reluctance of the Jesuits, who were the major intellectual European-Chinese links until the end of the 18th century, to teach the heretic Copernican heliocentric theory.

Keywords: History of Gunpowder and Firearms, Cannon Making, Military History, Ming-Qing Transition, European-Chinese Interaction, Great Divergence, Jesuit Calendar Reform

1. Introduction

The famous "Needham Question", raised by the British China scholar Joseph Needham (1900-1995) who during the second half of the 20th century with his monumental and still unfinished work "Science and Civilisation in China" reminded the West of China's profound contributions to the technology of humanity in the past, asks how it is possible that China over long periods of history was the technologically most advanced civilization in the world in many technology fields but fell far behind the West's or Europe's technology capabilities at the latest from the 19th century. [1] Even though the question's general assumption of China's fall-back in technology affairs may be right, this process was not a monolithic one. It is therefore valuable to investigate in which technology fields this process took place earlier or later – or even never. Moreover, a research about the exchange of technology leadership can shed a light on my first thesis (1) that the technology of the humanity of today or in the past is not the result of efforts of a single civilization, such as the Chinese or the European one, but rather the result of combined efforts of various civilizations. A re-emphasis of this fact could shatter ideologies of the superiority of a certain civilization.

In this thesis I focus on China's adoption of the gradually evolving European technology innovations since the early modern period (roughly 1500-1800) with respect to its cannon technology from 1514 to 1683. These dates refer to the events of the first arrival of a European ship – a Portuguese one – at China's coast in 1514 and to the capture of Taiwan by the Qing forces in 1683 which can be seen as the end of the violent Ming-Qing transition and as the beginning of a relatively peaceful time in Qing China, the "Pax Manjurica". I will search evidence for my second thesis (2) that China was in fact eager and capable to adopt European cannon technology during this time. This is diametrically opposed to the sometimes prevailing view of old China as a country which was closed to outsiders and not ambitious to learn from them which is often supported by the Qianlong Emperor's (r. 1735-1796) quotation of 1793 when he rejected British Lord Macartney's (1737-1806) embassy: "We never have valued ingenious articles, nor do we have the slightest need of your country's manufactures." (Waley-Cohen, p. 1525) However, this eagerness of adopting foreign technologies was probably due to the frequent warfare's incentives.

[1] More correctly, there are two Needham questions: "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 [1564-1642]?" And: "Why, between the first century B.C. and the fifteenth century A.D., Chinese civilization was much more efficient than occidental in applying human natural knowledge to practical human needs?" (Needham 1969, p. 16 and 190)

My thesis starts with a recapitulation of the Chinese invention of gunpowder and its applications on the battlefield like flamethrowers, bombs and guns, for which advanced knowledge of chemistry and metallurgy were required, between the 10th and 13th centuries, its subsequent transmission to Europe by the Mongols and others and a description of the improvement of cannon over there. Then I illustrate the re-import of European cannon technology to China during the 16th and 17th centuries on the basis of the military conflicts of this time, namely the Japanese invasions of Korea (1592-1598), the Manchu conquest of China and Koxinga's Sino-Dutch War (1661-1662). After this I describe the backwardness of the Chinese artillery arsenal during the First Opium War (1839-1842) against Great Britain and discuss how this backwardness could evolve and discuss the reasons for this backwardness. Then I stress that the living standard in China in spite of its more and more evolving technological backwardness was comparably high or even higher than the European one far into the 18th century. I will shortly go into the reasons for this technological backwardness in general and for the emergence of the Great Divergence, the meteoric rise of European wealth and power. Here I mainly illustrate Kenneth Pomeranz' viewpoint. Then I show that in the early modern period the Chinese were also eager to learn in another knowledge field from the Europeans: in astronomy. Also here the late Ming calendar crisis was, similarly to the wars for the cannon technology, an incentive to adopt the new European useful knowledge and to establish a new calendar. But also in this field the knowledge transmission was incomplete, this time mainly due to the incomplete transmission of the Jesuits who regarded the heliocentric theory of the solar system as being heretic. In the end there will follow a conclusion.

2. The Invention of Gunpowder and Cannon in China

The necessary ingredients of gunpowder (or: black powder) are sulfur, saltpeter and charcoal. The modern and probably best mixture is 75% saltpeter, 15% charcoal and 10% sulfur by weight. The chemical and thermodynamic decomposition reactions anyhow are relatively stable and the exact percentage of the ingredients can vary in a certain range. (Guilmartin, p. 655) While charcoal has been known since long, sulfur and saltpeter were the less well-known ingredients. Nevertheless they already appeared in Chinese texts before the 1st century BC. Early dictionaries ascribed them medical effects. Saltpeter only became known in the West about the 13th century. The early discovery of saltpeter in China is presumably due to its natural occurrence in Chinese soils whereas in Europe this is not the case. (Wang, p. 160-161) Also India possesses natural saltpeter deposits. (Chase, p. 59)

In the third century AD Chinese Taoist alchemists mixed saltpeter and sulfur in the same ratio as it is needed for gunpowder. Finally, after some intermediate steps, in the year 919 a flamethrower working with natural petroleum and probably ignited by gunpowder was used in a battle which indicated the taking-place of the gunpowder's invention being around the beginning of the 10^{th} century. At this time also fireworks were invented in China. In the year 969 fire-arrows containing gunpowder were used. In the year 1000 apparently useful catapults which hurled incendiary projectiles made the large scale-production of gunpowder necessary. The *Wujing Zongyao* (Collection of the Most Important Military Techniques, in Wade-Giles: *Wu Ching Tsung Yao*) of the year 1040 established the term *Huo Yao* for gunpowder. In the year 1231 the first true explosive grenade – the "heaven-shaking thunder bomb" – was shot from catapults. (Wang, p. 177-178) The Chinese developed several types of multiple rocket-arrow launchers where a single fuse ignited more than 50 projectiles and rockets with wings which carried bombs with a bird-like shape for the aerodynamic stability and which resembles the stabilizing wings of modern rockets. They even built two-stage rockets where the second propulsion is ignited when the first stage is in the air. They had stationary and later also mobile rocket launchers. (Needham 1987, p. 472-525)

Finally, after more than three centuries of the military use of gunpowder and during the end of the Southern Song dynasty, the first true barrel-gun appeared in 1288. (Needham 1987, p. 293-294) This weapon possessed all three things which Needham regarded to be basic for a true gun: a barrel made of metal, a high-nitrate gunpowder and a projectile that totally fits the muzzle so that the powder exerts its full potential in propellant effect. (Needham 1987, p. 10) Needham points out that the whole development process to the metal-barrel hand-gun or bombard took place in China before the Europeans had knowledge of gunpowder itself. Besides that gunpowder was also used for mining, quarrying and the building of roads and canals. Anyhow the military inventions could not prevent Song China, the technologically most advanced state of its time, to be conquered by the Mongols who 1276 conquered its capital Lin'an (Hangzhou) and 1279 wiped out the last Song forces in Guangdong.

To summarize the statements made in this chapter, one can say that gunpowder was for the first time produced in China around the beginning of the 10^{th} century. Besides the application of its civilian uses, several weapons that used it such as fire-lances, bombs, rockets and guns were invented in China in the 13^{th} century.

3. Firearms between the Mongol Conquests and 1514

3.1 The spreading of gunpowder technology to Europe

The Mongols in fact created the biggest empire – measured by land area – in world history if one neglects the Soviet Union. It temporarily extended from Korea and Hainan in the east to the Baltic Sea and East Turkey in the west and contained some of the most advanced societies of its time, namely China, Persia and other countries of the Near and Middle East. As the Mongols rampaged through and conquered large parts of Eurasia, they also spread some Chinese inventions. Indeed they mostly were archers on horsebacks who used crossbows. [2] But nevertheless by intensified contacts gunpowder technology and early forms of its military application such as fire-lances and bombs were transmitted to western regions like the Middle East, northwestern India and Europe. Metal-barreled weapons like hand-guns and cannon were not transferred during the first wave of technology transmission as they were not already developed in China during the Mongol's heyday. The Mongols also used the traditional Chinese as well as the advanced Muslim types of trebuchet artillery against fortified cities. (Sun, p. 497-498) For example, Genghis Khan (r. 1206-1227) formed a Chinese catapult specialist unit in 1214 which helped the Mongols in siege warfare in Transoxania in 1220 and in the north Caucasus 1239-1240. (Chase, p. 58) In 1236 the Mongols had reached Europe when Bulgaria was overrun. In 1241 they won the Battle of Liegnitz against forces of the Holy Roman Empire and captured Budapest. But as the message of the death of the Mongol leader Ögedei Khan (r. 1229-1241) [3] reached the Mongols, they had to go back to their capital Karakorum to elect a new Great Khan. After five years Güyük Khan (r. 1246-1248) was elected but the westward push was over. Nevertheless Krakow was still burned in 1259 and Budapest was destroyed in 1285.

[2] But incendiary arrows are also reported. (Needham 1987, p. 572)
[3] Ögedei's predecessor was Tolui Khan (r. 1227-1229).

Joseph Needham suggests that the transmission could have occurred in three separate steps: first, someone brought fire-crackers to the English philosopher and Franciscan Roger Bacon (1214-1294) before he wrote his *Epistola de secretis operibus artiis et naturae* in 1267 where gunpowder and its constituents were mentioned in the European literature for the first time. This was probably done by friars who travelled to the Mongol capital Karakorum since about 30 years ago, for example by the Franciscan monks John of Plano Carpini (voyage 1245-1247) or by William Ruysbroeck (voyage 1252-1256) who personally knew Francis Bacon. Then knowledge of fire-lances, bombs and rockets was perhaps by Arabian military engineers in Chinese service transferred to the Syrian author Hasan al-Rammah who published 107 gunpowder recipes and to the author of the book *Liber Ignium* (Book of Fires), possibly Marcus Graecus, about 1280. Soon thereafter the metal-barrel bombard and hand-gun reached the European military, possibly directly overland via Russia. About the gunpowder inventions it can be said, in Needham's words, that "increasing complexity and effectiveness were thus mirrored in increased speed of transmission." (Needham 1987, p. 570-572)

Striking arguments for the Chinese origin of the early European gunpowder technologies are the initially optimal proportions for the gunpowder ingredients in the European literature, for example the proportion of saltpeter ranging between 66.5% and 75%, whereas the Chinese tried all kinds of chemicals in all kinds of proportions which indicates indigenous experimental achievements. Also the pre-stages flamethrowers, rockets, bombs and mines were barely used before firearms in Europe. Furthermore, the early European hand cannon looked like the Chinese gun of 1288. The earliest records of firearms in Europe seem to originate in the year 1326 when a primitive cannon appeared in an English manuscript and two magistrates of Florence in Italy were given responsibility to acquire firearms for the fortification of their city. Both events indicate a slightly earlier appearance of firearms in Europe. The myth that the German monk Bernhard Schwarz, who allegedly had dealings with the devil, constructed the first firearms and invented the gunpowder in the mid-14th century which was believed until the 19th century proves to be incorrect. [4]

The first firearms in Europe were possibly used at the siege of Cividale (Italy) in 1331 and the first city walls were breached by cannon in Saint-Saveur-le-Vicomte (France) in 1374. Individual handheld firearms were not common at this time. The early firearms were big ones,

[4] And still until the 1970s most historians believed that the gun was a European invention (Chase, p. xiii)

rather immobile and best employed against or behind fortifications. Fortifications were also modified due to these new weapons. The rise of infantry and suppression of cavalry in Europe during the first half of the 14th century anyhow was an independent development and originally not related to the introduction of firearms. The early firearms were of little use on the battlefield. (Chase, p. 58-61)

3.2 European developments

3.2.1 New firearms

Between the 1380s and the 1420s saltpeter plantations in Europe lowered the prize of saltpeter by one-half or even two-thirds. In the early 1400s large, wrought-iron, stone-firing cannon known as bombards appeared in Europe. They were for example used during the Hundred Years' War and during the Spanish conquest of Granada in 1492 which marked the endpoint of the Reconquista. In the late 1400s handheld firearms (arquebuses) appeared; in the early 1500s heavier versions named muskets, fired from Y-shaped supports, followed. Both were muzzle-loaders and used by the infantry. The term musket was used down into the 1800s. While these weapons were shoulder arms, the handheld pistols followed in the mid-1500s. Armor at this time was rated as arquebus-proof or pistol-proof, but there was no musket-proof armor with the logical consequence that armors gradually disappeared from the European battlefields. With cannon and muskets, firearms had begun to do their marks by the late 1400s on both sieges and battles in Europe. (Chase, p. 58-61)

Early firearms were almost entirely muzzle-loading weapons. A diagram of a muzzle-loader is shown in Fig. 1. There the projectile was inserted into the muzzle of the firearm. During the 14th century breech-loading weapons were developed in Burgundy. That means that normally the projectile and the gunpowder were inserted into a breech which again was pushed into the muzzle from backwards. The main advantage of breech-loading is a reduction of the reloading time. It also more precisely hits its target and one can better hide during the time of reloading. But they are not so easy to construct. A difficulty in the construction of breech-loading cannon lies in the sealing of the breech. They only became really widespread during the 19th century.

Fig. 1: Diagram of a muzzle-loader. (1) Priming charge, (2) Main propellant charge, (3) and (5) Wadding, (4) Projectile (from http://upload.wikimedia.org/wikipedia/commons/9/91/CMM_-_Przekr%C3%B3j_mo%C5%BAdzierza.JPG)

Firearms first had low rates of fire and high rates of malfunction. To compensate these disadvantages the Dutch pioneered the technique of volley fire in the 1590s according to which each rank of musketeers fired in unison and then retired to reload for which a good amount of training and discipline was needed.[5] An advantage of the firearms anyway was the fact that their bullets could pierce armor better than arrows. Also not as much training for musketeers was needed than for archers, so peasants could be more easily recruited. This was one reason why the European armies grew rapidly in the 1600s. Finally muskets displaced longbows. (Chase, p. 74-75)

[5] Anyway the Japanese probably independently had developed such a kind of volley fire before the Dutch did. (Andrade, p. 192) And the Chinese used the volley firing technique before anyone else in a victorious 1388 battle against the Burmese Maw Shan elephantry when the soldiers holding firearms were divided into three rows. (Sun, p. 500)

The monster siege bombards, evolving around the turn of the 15^{th} century, could be made of wrought iron or cast bronze. Originally they threw spherical stone balls. Around the same time another class of wrought-iron breech-loaders with substantially longer barrels evolved. Whereas the bombard design was driven by the desire to maximize the projectile size, the design of these pieces was driven by the desire to maximize the projectile velocity. Some of those could then shoot cast-iron balls. Their advantages compared to the traditional stone balls became soon evident as they were cheaper and had a greater penetrating power. In the last decades of the 15^{th} century some foundries casted bronze muzzle-loaders with similar proportions like the wrought-iron cannon and they fired iron balls. (Guilmartin, p. 657-660)

3.2.2 Gunpowder improvements

If gunpowder is transported or just left in store, its ingredients tended to separate which had the effect that the gunpowder is spoiled. This problem was sometimes solved by carrying the ingredients separately and only mixing them together if they are needed. Moreover charcoal tends to attract water. This was a problem in humid regions as the moisture of gunpowder may not rise above one percent. From this point on gunpowder begins to lose its explosive power. (Garrett, p. 203-206)

In the first half of the 14^{th} century the Europeans discovered that corned powder which was mixed with a liquid, dried in cakes and then crumbled up into powder was stronger (approximately 30%) than the precedent serpentine powder as it develops its propulsive force far more quickly. (Chase, p. 58-61) The spreading of corned powder anyhow was relatively slow because the cannon designed for the serpentine could explode when filled with this new type of powder. (Guilmartin, p. 660)

The Chinese originally got the required saltpeter mainly from calcium nitrate $Ca(NO_3)_2$, with some potassium KNO_3 and manganese nitrates $Mn(NO_3)_2$. This was also the first recipe in Europe. Due to the high deliquescence of calcium nitrate – that means it heavily absorbs atmospheric moisture which makes the gunpowder in too humid regions useless – the naval use of this gunpowder was nearly impossible. [6] Approximately around the year 1400, nevertheless, the Europeans learned to treat aqueous saltpeter with wood ash and to

[6] In China there for example existed different gunpowder formulas for the relatively arid north and the relatively humid south. Besides that, writers emphasized the use of different firearms in north and south China, as well as wagons and cavalry should be used in the north and boats in the south. (Chase, p. 147)

precipitate the calcium and manganese salts until they had a relatively pure low-deliquescent potassium nitrate. Soon thereafter shipboard ordnances became much more common in Europe, heavy ones appeared around the turn of the 16th century on shipboards. (Guilmartin, p. 655-656)

3.3 East Asian developments

But also in China the history did not stand still. Here the earliest metal-barreled artillery was made around the first half of the 14th century and was not called *pao* until the early and especially the middle Ming. According to Sun Laichen the founding of the Ming dynasty in 1368 may be regarded as the starting point of the "military revolution", a concept traditionally attributed to developments in Early Modern Europe, in Chinese and world history. Firearms helped Zhu Yuanzhang, the founder of the Ming dynasty with the era name Hongwu and the temple name Taizu (r. 1368-1398), to overcome the Mongol ruling and his other rivals. After this re-establishment of Han rule, great attention was attached on the production of firearms. During the reign of the Hongwu Emperor around 10% of the army was armed with handguns whereas until 1466 this percentage rose to 33%. The handguns were improved and supplied to the infantry and the navy. Chinese firearms appeared first in naval battles in 1363, and one decade later "bowl-sized muzzle cannon" were installed on warships. The ships additionally had fire-lances and rockets. Also types of "large bronze cannon" (*datongchong*) and "grand general cannon" (*dajiangjunchong*) existed in the 1460s.

This concentration on firearms proved to be successful in military conflicts. The Ming statesman Qiu Jun (1421-1495) reportedly said: "Ever since the appearance of these [firearms] weapons, China has been able to defeat the barbarians in the four directions." (Sun, p. 497-499) Anyway Kenneth Chase states that due to restrictions during the late 14th and the 15th centuries the development of firearms in China was probably slowed down. In the 16th century most restrictions were abolished and it was decided to make greater use of firearms again. (Chase, p. 153 and 198) However, soldiers were required to come regularly to Beijing for gun training during the whole Ming reign, and bureaus to produce firearms were established. (Andrade, p. 189-190)

Gunpowder technology was transmitted to mainland and maritime Southeast Asia from China before the European arrival. For example, Zheng He's (voyages 1405-1433) fleet brought small bronze Chinese handguns to Java in 1421. But firearms had not a military impact on maritime Southeast Asia as they were rather applied for spiritual uses. This was different in mainland Southeast Asia. The Chinese conquered the Vietnamese Đại Việt in today's northern Vietnam and parts of southern China in 1406. One reason among others for this was that their firearms proved to be useful against the Vietnamese war elephants. As the Vietnamese were able to copy the Chinese techniques they were able to push the Ming forces out in 1427 and to defeat their enemy Champa in today's southern Vietnam as they conquered its capital Vijaya in 1471. In summary Sun Laichen suggests that during roughly the time 1350-1450 early Ming China and early Đại Việt in Vietnam as well as early Choson Korea were probably the first "gunpowder empires" in world history. (Sun, p. 514-517)

Indeed the Chinese still possessed a more sophisticated gunpowder fabrication in the early 17th century and accomplished indigenous achievements, but the Europeans could construct the weapons better (Needham 1987, p. 139-141 and 398-407). The Western cannon were lighter and more mobile and could easier be carried over mountains and rivers. (Waley-Cohen) It is generally accepted that European firearms were superior to the Chinese ones since the turn of the 16th century. (Andrade, p. 189)

3.4 Summary

Gunpowder and some of the gunpowder weapons reached Europe, eased by the Pax Mongolica, during the 13th century and the beginning of the 14th century. To cite Joseph Needham, "increasing complexity and effectiveness [of the gunpowder weapons] were thus mirrored in increased speed of transmission". (Needham 1987, p. 570-572) Monster siege bombards and wrought-iron breech-loaders appeared in Europe during the early 15th century, as did arquebuses in the late 1400s and muskets in the early 1500s. Firearms changed war in Europe insofar as they lead to the gradual disappearance of armors and to the design of new fortification models. European gunpowder became stronger and more resistant to humidity during the 15th century. Due to Zhu Yuanzhang's, the founder of the Ming dynasty, strong reliance on firearms during the Yuan-Ming transition and due to the subsequent spread of them, Sun Laichen called early Ming China and its surrounding countries Vietnam and Korea the first "gunpowder empires" in world history. Europe had the most advanced firearms since about 1500.

4. China's Adoption of European Cannon, 1514-1683

4.1 During the 16th century

4.1.1 Adoption of *folangji* and muskets

The first Portuguese ship reached China's southern coast in 1514. (Brook, p. 3) With this event the Europeans encountered a gigantic, technologically refined and numerically superior empire with which trade could be very rewarding. For example, as the silver's value in China was roughly double the value in the rest of the world, the sale of silver in China was a major component in the origination of world trade during the 16th century. (Flynn & Giráldez, p. 214-218) Already around this early time the Chinese attempted to require the more advanced European cannon technology. The police chief of Baisha in Dongguan county He Ru was able to acquire Portuguese knowledge about ship building, gun casting and gunpowder making as he managed Chinese experts who learned it from the Portuguese to defect. (Chase, p. 142) In 1524 he asked the court of the Jiajing Emperor (r. 1522-1526) for permission to study and produce these European cannon in Nanjing and Guangzhou which was granted. (Brook, p. 27)

Portugal sent an ambassador to China in 1517 but China finally rejected to establish formal relations in 1521. In 1519 the Portuguese established a base in Tunmen near Guangzhou without an official permission to do that. After a Chinese attack the Portuguese had to flee back to Melaka in today's Malaysia which they had captured in 1511. In the 1522 Second Battle of Tamao (Tunmen) the Portuguese were again not able to come out on top – instead, Wang Hong was able to present 20 cannon to the court which were captured during the battle. He Ru's first cannon seems to have been completed in 1524. They were called *folangji* (佛郎機). (Chase, p. 142-143) The emperor ordered that for this purpose a bureau was established, and soldiers were trained to use these cannon. (Swope, p. 21)

The *folangji* was a swivel gun which is a small type of cannon which is mounted on a swiveling stand so that it can be moved freely. Swivel guns were originally mostly muzzle-loaders. But during the 16th century breech-loading swivel guns were developed with a breech shaped like a "beer mug", and also the cannon which were named *folangji* by the Chinese were breech-loading swivel guns. In fact the term *folangji* may had two meanings with two different etymologies: it referred to the Portuguese, probably derived from the Franks, as well as to the just mentioned guns, presumably finally derived from the Italian *braga* which means breech.

Kenneth Chase suggests that the Chinese did not invent breech-loaders because the breech-loader was originally a cheap substitute for the muzzle-loader in Europe. Muzzle-loading cannon were cast in one piece. Bronze was several times more expensive than iron and the Europeans lacked the knowledge of producing cast-iron cannon. But there was the alternative of wrought iron. But one could not close off the end of the barrel made of wrought iron, so "the breech was forged as a separate block and fit into place." (Chase, p. 143) The Chinese already did cast-iron cannon in the 1300s. But in fact light breech-loading antipersonnel weapons (against humans) may have been more useful for the Chinese than heavy muzzle-loading siege cannon. Europeans learned then how to produce cast-iron cannon in the mid-1500s. Then "the less powerful breech-loaders fell out of favor" but in China breech-loaders then replaced muzzle-loaders. (Chase, p. 143-144)

The musket or "bird-gun" or "bird-beak-gun" was also transferred to China. Muskets were introduced to Japan in 1542 but Chinese pirates undoubtedly knew them before. Nevertheless probably Turkish muskets came to China in the 1510s, too. Together with swivel guns and muskets also corned gunpowder reached China because those weapons did not work without it. (Chase, p. 144) It was suggested that muskets should be used in south China and a so-called "three-eyed gun" with three barrels in north China. This was the case because in the south Chinese forces mainly had to fight against infantry (of the pirates) whereas in the north they fought against (Mongolian) cavalry. With about one minute, muskets could be reloaded faster and against the fast progressing cavalry one has anyway only one shot. An advancement of the "three-eyed gun" for the cavalry with only one shot because one could not reload, the "winged-tiger gun", was developed as well. (Chase, p. 144-150)

European large-style cannon (Portuguese-type breech-loading cannon, *folangji*) also helped the naval commander Qi Jiguang (1528-1588) when he with his hundreds of ships suppressed the Japanese pirates with their numerous Chinese collaborators at China's south-east coast. He did this at the high point of the pirate attacks in the Ming dynasty in the 1560s. His men were mainly recruited from Yiwu county in Zhejiang. Qi's fleet later joined the Korean navy to resist the Japanese invasion in Korea 1592-1598. (Elman 2005, p. 192)

Shortly before the pirate crisis reached its peak in 1556 when three different groups of pirates, “each said to be ‘several thousand’ in strength”, had landed at China’s coast until even more pirates had attacked and rampaged through Zhejiang. (Chase, p. 156-157)

The repression of the pirates who often were smugglers however was facilitated by a change of trade restrictions in 1567: from then on seafaring was again allowed. Only trade with Japan and the export of saltpeter, sulfur, copper and iron as raw materials for gunpowder and firearms were forbidden. Anyway the trade restrictions were not effectively put into force before that. The Portuguese were officially allowed to settle at and trade via Macau since 1557 as they should keep the Pearl River Delta free from pirates. Nevertheless the Japanese could indirectly trade with China through places like the 1571 founded capital of the Spanish Philippines Manila. (Chase, p. 156-157) The Spaniards began to build a colony on the Philippines in the 1560s. Yet, at the end of the 16th century there were still some pirates at the south-east coast. By the 1600s the Portuguese could move into the vacuum of the China-Japan trade where they made good money with selling Chinese silk in Japan und bringing back Japanese silver to China. (Spence, p. 18-19)

4.1.2 Firearms during the Japanese invasions of Korea

The traditionally stated reasons for the defeat of the Japanese during their invasions of Korea (1592-1598) are the superior number of their Korean and Chinese enemies (but still the number of landing Japanese in 1592 was 150,000) and the death of Japan’s leading warlord Toyotomi Hideyoshi (1536-1598). Anyway, Kenneth Swope argues that the most important cause for the defeat of the Japanese was the deployed military technology by the Chinese. During their invasion the Japanese mainly relied on small Portuguese arquebuses which the Portuguese had brought to East Asia, and which were more reliable than contemporary Chinese arms. Those helped Hideyoshi to bring all of Japan under his control before – they had no big cannon during their invasion – whereas Ming China concentrated on heavy cannon (China regarded this attack as a violation of its tributary system). The latter is perhaps due to the fact that firearms in China were more deployed in defensive and not so much in offensive arrays. These heavy cannon also proved to be useful in the fight against the Mongols. Nevertheless arquebuses were apparent in China. [7] It would not have been so easy for the

[7] For example, already in 1536 about 2,500 arquebuses were supplied to soldiers in Shanxi. (Lorge 2003, p. 125)

Japanese to carry heavy cannon through the hostile and rugged Korean terrain. (Swope, p. 22-25)

The most important artillery pieces in the Ming arsenal at this time were the Portuguese-derived so-called *folangji*. They were mostly mounted on ships. Moreover the Chinese deployed native cannon in their fight against the Japanese, such as the “Grand General Cannon”, the “Great Distance Cannon” and the “Crouching Tiger Cannon”, the last one being very useful in the Battle of Pyongyang 1593. (Swope, p. 27) Swope concludes that during the first stage of the war the Japanese had an advantage of superior technology on land. Whereas the Japanese significantly relied on their muskets, the Koreans used their howbeit famous bows. Nevertheless the Korean with Admiral Yi Sunsin’s (1545-1598) turtleboats and the Chinese with their naval artillery mostly maintained their control over the sea which made the Japanese supply lines very difficult. Later the Chinese supplied the Koreans with superior weapons on land. (Swope, p. 41) Ministers of the Korean king Soryo said: “When the Japanese fire their muskets, you can still hear, even if they fire from all sides. But when the Chinese fire their cannon, the sky and the earth vibrate and the mountains and plains tremble and you can’t even speak.” And: “Military affairs are simple. Big cannons defeat small cannons and many cannon defeat few cannon.” (Swope, p. 37)

4.2 During the Manchu conquest

4.2.1 The loss of Manchuria and “red barbarian cannon”

The Chinese cannon may have worked in Korea. However, the success on the Korean peninsula distracted the Ming from the rise of the Manchus. Those were descendants of the Jurchens who had ruled north China 1127-1234. They were not nomads but preferred to fight on horsebacks. After their surprising attack in May 1618 when Nurhaci (r. 1616-1626) conquered Fushun a Chinese 1619 punitive expedition (the Liaodong campaign) failed near Sarhu. During this campaign firearms and skilled artillerymen were transferred to the Manchus. Alarmed, the Chinese approached the Portuguese in Macau for help in the form of casted cannon. In 1623 a contract with the content of casting iron cannon in Macau was signed. Macau finally also became the chief source of both bronze and iron cannon for the Portuguese outposts between Africa and Japan. For this the Portuguese contributed their advanced expertise for bronze pieces and the Chinese theirs for iron ones whereas both types of cannon followed European designs. (Chase, p. 167-169) The guns manufactured in Macau also served for Macau itself as it just survived a Dutch attack in 1622 and therefore now began to build new fortifications. After initially two Spaniards were in charge, Manuel Tavares Bocarro, son of the gun founder Pedro Dias Bocarro, supervised the gun foundry and powder mill 1625-1645. However, the foundry ceased its operation towards the end of 17th century, perhaps because the stopping of copper supply from Japan in 1639 or because it ran out of orders. In 1717 Macau requested the Portuguese colony Goa in India to send gunpowder and muskets. (Garrett, p. 146-147) The city of Macau may have had a big relevance in cannon making and in other respects but it was still a rather small city. In the beginning of the 17th century 11,000 people lived there of whom about 1,000 were Portuguese. (Huang 2001, p. 242)

The awareness of Fujian and Guangdong officials about European cannon was also increased by pirates and Dutch who harassed the Southeast coast around this time. The pirate and merchant Zheng Zhilong (1595-1661) could finally, using these new weapons, oppose the Dutch and suppress revolts in China. (Huang 2010, Abstract) The Portuguese gave the Chinese cannon which they had dredged up from a Dutch ship in 1621. [8] The Chinese called them "red barbarian cannon" (*hong yi pao*) because they assumed they were Dutch (who were named "Red Haired") cannon but in fact they were English cannon. [9] During this process Jesuits served as intermediaries, supported by a small number of highly influential Christian converts at the court. However there were strong suspicions concerning the Portuguese intentions in the factionalized court of the late Ming period. First the Chinese accepted the four cannon of the Portuguese but not their gunners. However, the Ministry of War then in 1624 requested gunners to come as an additional help. Seven arrived in north China but soon again were sent back. In 1630 "a large contingent of soldiers, advisors and equipment was dispatched from Macau" but soon thereafter most of them were sent back, too.

The Ming emperor had lost its influence in Manchuria since the defeat of Sarhu. However the front line such became shorter and easier to defend. It became harder for the Manchus to break through the heavy Ming fortifications which were equipped with heavy Portuguese cannon. To cross this front line heavy cannon would be useful. For example, the Manchus were hindered to conquer Ningyuan (Liaodong) in 1626 by the firing of a dozen

[8] In total they had dredged up 26 cannon. (Huang 2001, p. 227)

[9] They were about twenty feet in length, weighed over thirty-three hundred pounds and reportedly shook the ground for more than 5 km. (Swope, p. 21)

heavy cannon of which eleven were "red barbarian cannon". Also the Manchu ruler Nurhaci himself was wounded and died shortly thereafter. (Chase, p. 167-169)

4.2.2 Sun Yuanhua's failing military reform

Impressed, the Ming decided to cast more of those cannon. They decided to form a unit with European firearms and with Portuguese help which in the end had 196 cannon of different sizes and 4,000 men with 1,200 muskets. (Chase, p. 167-169) Reportedly the cannon in the battle of Ningyuan were capable of "each cannon-shot killing 100 men". Therefore Sun Yuanhua (1581-1632), a disciple of the famous Christian convert Xu Guangqi (1562-1633) who already after the defeat in the Battle of Sarhu in 1619 started to work for a military reform that would include the use of Western firearms under the motto "be well versed in military affairs", was appointed in 1625 to make more Western cannon. On this military reform Xu Guangqi even spent more energy than on the calendar reform for which he was put in charge in 1629. He soon died in 1633. Moreover Sun Yuanhua strongly suggested using them efficiently: if "they are supported by equipment [i.e. wagons], the use of telescopes, and if measurements are done according to the art of *gougu* [right triangle] […], every shot is a hit. […] One of those weapons is worth a thousand." Also the telescope and the art of triangulation were introduced from Europe to China around this time.

Sun Yuanhua had studied firearms and calculation from Xu Guangqi and composed military works like *Jingwu quanbian* and *Xifa shenji*. He then formed a crack regiment in Shandong which mainly relied on Western firearms. Portuguese advisers and Christian converts helped him. However the Liaodong general Kong Youde (1602-1652) with his troops who mainly consisted of Liaodong people started the so-called "Wuqiao military revolt" in Shandong in 1631. As Kong Youde beset Laizhou in eastern Shandong, his rebels possessed 10 "red barbarian cannon" (with a range of 5-6 li) and more than 300 "Grand General" smaller cannon. The defenders were not very experienced in artillery fighting and sometimes used too much powder with the result of exploding cannon. When 6 additional "red barbarian cannon" were supposed to be brought for the defense of Laizhou, they were captured by the rebels. Nevertheless the rebels failed because the city got a backing from outside. In 1632 Kong captured 7,000 troops, 3,000 horses, 10,000 taels worth of provision, 20 large red barbarian cannon and 300 Western cannon, innumerable other firearms and pieces of military equipment from Sun Yuanhua. Regular Ming troops then encircled Kong in

Dengzhou in 1633 but he could escape with parts of his people and his cannon by sea and finally surrendered to the Manchus. (Huang 2001, p. 225-259)

Also the Manchu ruler Hung Taiji in 1629 did a raid and captured Chinese artillerymen at Yongping (Hebei) who were able to cast Portuguese cannon – by February 1631, 40 European pieces had been cast. All Chinese troops of the Manchus were then placed under a separate command whose primary purpose was artillery and siege warfare The siege and capture of Dalinghe in 1631 was then fought almost exclusively with cannon and firearms on both sides. Both sides used Portuguese-style cannon. (Lorge 1999, p. 94-95) Mutinies similar to that of Kong Youde were not uncommon since a drought in north China in 1628. After the rebel leader Li Zicheng (1606-1645) entered the undefended city walls of Beijing in 1644, the Ming general Wu Sangui (1612-1678) who had stationed his army at the Shanhai Pass (Hebei) invited the Manchus to restore the order in China. (Chase, p. 167-169)

During the successful siege of Yangzhou (Jiangsu) in 1645 the Manchu forces had better cannon than the Ming forces. According to the China historian Jonathan Spence the artillery played a "critical role in the Manchu victories" (Spence, p. 29 and 35-36) Later when the Shunzhi Emperor (r. 1644-1661) of the Qing dynasty resided in Beijing, he read the *Xu shi paoyan* (Kitchen sayings of Mr. Xu) which was a collection of memorials on military matters by Xu Guangqi and reportedly said: "If the Ming court had made complete use of his words, what chance would I have of standing here!" (Huang 2001, p. 259) Eventually advanced cannon technology like the red barbarian cannon was transferred from the Europeans to the Ming and from the Ming to the Manchus.

4.2.3 Cannon casting in late Ming and early Qing

The German Jesuit Johann Adam Schall von Bell (1592-1666) casted cannon for the Ming dynasty defense of Beijing since he was asked by the Chongzhen Emperor in 1642 to do so. In fact he was inexperienced but he could guide his workmen. They finally casted 20 pieces which could throw a forty pound shot and which supplemented the already existing Chinese "generalissimo" (dajiangjun) cannon which weighed over 500 kg and were used against attacking cavalry. Bell also casted culverins which were lighter guns with a greater length. (Wakeman, p. 77) He reduced the size of Chinese cannon. With the help of a Chinese colleague he wrote the book *Ze Ku Lu* (Record of Immediate Conquest), also known as *Huo*

Gong Jie Yao (Essentials of Gunnery) which was published in 1643 and reprinted in 1841 during the 1st Opium War. (Waley-Cohen, p. 1530-1533)

In 1620 the Chinese started to cast muzzle-loading smooth bore (that means their barrels are not rifled) bronze cannon which followed European models. The "Dingliao grand general" cannon, manufactured in 1642, and the "Shenwei grand general" cannon, manufactured by Han craftsmen for the Qing dynasty, had iron-bronze composite barrels. According to Huang Yi-long these cannon possessed international leading positions during the 17th century. (Huang 2011, Abstract)

4.3 During the Sino-Dutch War

Portuguese-derived European-style cannon played also a role during the Sino-Dutch War 1661-1662, "Europe's First War with China". In the context of revolt against the newly established Manchu rule General Zheng Chenggong (1624-1662), who is often also referred to as Koxinga [10], whose mother was Japanese and whose wealthy father Zheng Zhilong was a pirate who had a trade network which was spanning between Nagasaki and Macau, attacked Nanjing in 1659 with his followers but failed seriously. His fleets had fought against the Manchus at China's east coast during the 1650s. As Qing forces put pressure on his main base in Amoy (Xiamen, in Fujian) he decided to find a way out in the attack on the Dutch fort Zeelandia in the southwestern part of the island of Taiwan. This fort had been constructed by the Dutch using new fortification models in 1624-1634 to colonize Taiwan. The Dutch had driven out the last Spaniards and Japanese pirates until the 1640s. After a siege of nine months the fortress finally surrendered in February 1662. Koxinga died later in the same year. (Spence, p. 54-56) Before his death Koxinga even prepared to attack the Spanish Philippines. (Andrade, p. 191)

According to Tonio Andrade, Koxinga's and the Dutch cannon may have been of a similar quality, and the Dutch cannon were regarded as very advanced for European standards. Some of Koxinga's cannon were made in Macau but he also possessed advanced indigenous models. The soldier Albrecht Herport who fought for the Dutch expressed his opinion that the Chinese "know how to make very effective guns and cannons, so that it's scarcely possible to

[10] Due to Zheng Chenggong's loyalty the Longwu Emperor (r. 1645-1646) of the Southern Ming dynasty gave him the imperial surname Zhu. Therefore Zheng Chenggong was also called *guoxing ye* (gentleman of the imperial surname) from which the name Koxinga is derived. (Mote, p. 835)

find their equal elsewhere". (Andrade, p. 194) Koxinga's gunners had a great discipline, as had his troops in general. It could compete with the Dutch one which was also regarded as exemplary. European muskets, artillery and discipline seem not to have given the Dutch great advantages, if any, over the Chinese. [11] The Dutch military advantages were more due to their advanced artillery ships and forts built after renaissance fortifications models.

The Dutch big artillery ships were superior in deep water combat and in the ability to sail into the wind. With thirty or more cannon they could carry more cannon than the Chinese war-junks which carried about 8 to 10 cannon and could contend against ten or even twenty of them. Koxinga's few big artillery ships were not used in the naval battle but in the bombardment of land targets. The official history of the Ming history writes about the Dutch artillery ships: "the Dutch base their power on their huge ships and cannons. The ships are three hundred feet long, sixty feet wide, and more than two feet thick. They have five masts, and behind them they have a three-story tower. On the sides are small ports where they place brass cannons. And underneath the masts they have huge twenty-foot-long iron cannons, which, when fired, can blast holes into and destroy stone walls, their thunder resounding for ten miles (several dozen li)." (Andrade,p. 196) The ability of sailing into the wind enabled the Dutch during the siege of Zeelandia to seek help in the capital of the Dutch East Indies Batavia (today's Jakarta), for which they had to sail southwards against the monsoon winds, earlier than expected. (Andrade, p. 194-197) Their new forces were anyhow devastated in a "foolish" attack in shallow water. (Andrade, p. 201)

The second Dutch advantage, the artillery fortress, was first developed by Italians in the 1400s as the better and better cannon shattered traditional city walls. It spread to other European countries in the early 1500s. The walls were now built thicker, sloped to deflect cannon fire and filled with earth, and at the edges of the walls where earlier were turrets now were large angled bastions. One could strategically place cannon crews and musketeers there and hit the advancing enemy with flanking fire. Fortresses like this were used as power bases in the European colonies, and the Dutch who were seen as masters in building these fortresses at this time built the fort Zeelandia according to new models. Koxinga's first attempt to conquer Zeelandia was beaten back by the Dutch flanking fire. Later the defection of a German fortification engineer helped Koxinga to capture Zeelandia. (Andrade, p. 199-200)

[11] Among Koxinga's people for example were also two companies of black soldiers who were former Dutch slaves and who had learned how to use rifles and muskets. (Wakeman, p. 1047)

Fights against the Dutch lingered for some years until they were defeated. The Manchus tried to capture Taiwan from Koxinga's Zheng clan in 1664 and 1665 but failed. Then the Qing administration was distracted by the Revolt of the Three Feudatories 1673-1681 which started in the southern provinces of Fujian, Guangdong and Yunnan. But then, in 1683, Admiral Shi Lang (1621-1696) who commanded 300 war vessels captured Taiwan for the Kangxi Emperor (r. 1661-1722) and put the Zheng rule to an end. (Spence, p. 54-56) With this event Taiwan was incorporated into a Chinese empire for the first time in history.

As a conclusion it can, according to Tonio Andrade, be said that despite the Dutch advantages of artillery ships and renaissance forts, Koxinga's cannon could stand the comparison with the Dutch cannon which were regarded as exemplary in Europe. He argues that "Asian societies were undergoing military modernization along the lines of those in western Europe". (Andrade, p. 185) This indicates an eager adoption of European knowledge as well as a considerable indigenous cannon founding tradition.

4.4 Summary

Fairly direct after the first encounter with European firearms at the beginning of the 16th century European breech-loading swivel guns (*folangji*) were studied and produced in China, as well as the fairly recent invented muskets. The former one, for example, helped Qi Jiguang suppressing the pirates in the 1560s. Firearms played a crucial role during the Japanese invasions of Korea. Oversimplified spoken, the Japanese using Portuguese-derived muskets originally had an advantage over the Koreans using bows. Finally they were driven back by the Chinese using heavy – also naval – artillery. The *folangji* made up a central part in the Chinese arsenal but the Chinese also had indigenous models. The lost Battle of Sarhu in 1619 had two consequences in respect to firearms: (1) firearms and artillerymen were transferred to the Manchus, and (2), alarmed, the Chinese acquired "red barbarian cannon" in 1621 and then obtained cannon of a gun foundry based in Macau. Portuguese gunners were only hesitantly required to come as the Chinese were suspicious of them. The red barbarian cannon were a helpful factor during the victorious Battle of Ningyuan in 1626. Sun Yuanhua then in 1625 was appointed to form a European-style military unit but this project failed in 1631-1632 with the rebellion of Kong Youde who defected to the Manchus with red barbarian cannon, amongst other things. Also Jesuits for the sake of the propagation of the Catholic faith casted cannon for the late Ming and early Qing dynasties. One prominent example of them was Adam Schall von Bell. During the 17th century the Chinese casted cannon had a high quality. Even though the Dutch cannon were regarded as advanced in Europe, Koxinga's cannon were comparably good to the Dutch cannon during the Sino-Dutch War. The Dutch military advantages were rather huge ships and renaissance fortifications – but still they lost.

5. Developments until the First Opium War

5.1 China's cannon making backslide

The various military conflicts in China during the 17th century which mainly group around the devastating Ming-Qing transition represented many incentives to develop military technology. The frequent warfare in the 17th century China can, according to Geoffrey Parker, be seen as a part of a global crisis as during the same century, among other crises and state breakdowns, the Polish-Lithuanian Commonwealth collapsed, the Spanish Monarchy, being the first global empire in history, seceded and Middle Europe was plagued by the Thirty Years' War (1618-1648). These widespread crises may again have been fueled by a climate change at this time as a part of the so-called Little Ice Age which lingered during the early modern period. During the Ming-Qing transition there were some disastrous natural phenomena. For example, 1640 was the single-driest year recorded in five centuries in northern China and 1641 was the second-driest year in two centuries in central China. In the latter one the Grand Canal dried up in Shandong for the only recorded time in history. (Parker, p. 1069) The Kangxi Emperor remarked in 1717: "The climate has changed. […] When I was touring in Jiangnan, by the 18th day of the third month new wheat [from the winter wheat crop] was available to eat. Now, even by the middle of the fourth month, wheat has not been harvested … I have also heard that in Fujian, where it never used to snow, since the beginning of our dynasty [1636], it has." (Parker, p. 1063-1064) Anyway from about this moment on the climate began to warm again.

There were fewer than ten major armed uprisings in China in the 1610s, more than seventy in the 1620s and more than eighty in the 1630s. The latter affected 160 counties and involved more than 1 million people. (Parker, p. 1053) Due to harsh natural conditions and warfare the total amount of cultivated land in China fell from 191 million acres in 1602 to 67 million in 1645. The amount recovered only slowly to 90 million in 1661 and 100 million in

1685. The Yongzheng Emperor (r. 1722-1735) estimated that during this time "over half of China's population perished". Parker believes that local data support this view. According to the historian Frederic Wakeman over one million people in Sichuan were killed during this time, and the local gentry was extinguished. [12] One reason for this crisis may also have been overpopulation as during the 1620s, for example, about 20 million people lived in Jiangnan which is an area of 17,000 square miles in the Lower Yangzi Delta. These data result in a population density of about 1,175 people per square mile which is more than the actual population density of the Netherlands with shortly 1,050 people per square mile, and the Netherlands are one of the most densely populated areas of Europe today. (Parker, p. 1059-1060)

The Belgian Jesuit Ferdinand Verbiest (1623-1688) also played a prominent role in the diffusion process of cannon founding technology from Europe to China. On the occasion of the revolt of the Three Feudatories (1673-1681) in south China the Kangxi Emperor forced Verbiest to cast 132 heavy and 320 light cannon. In the end Verbiest alone supervised the casting of more than one half of the 905 cannon being produced during the Kangxi reign until his death in 1688. (Elman 2005, p. 190) Around 1681 he published the now lost "Explanations and Illustrations of [the Cannon Named] Wonderful and Terrible." (*Shenwei Tushuo*) He stressed for example that one should know the weight of the (uniformly heavy) cannonball and the exact distance to the target which made accurate land surveys even more important. His cannon were also used during the Russian campaigns 1685-86. [13] In fact Schall and Verbiest were first reluctant to cast cannon but they were willing to do so as they were faced with the emperor's possibility to execute them and to expel all Christians out from China.

The Chinese still used Verbiest's designs at the time of the 1st Opium War, and the cannon made by Schall and Verbiest remained an important part of the imperial arsenal until the end of the Qing dynasty. Missionaries also helped later the Qianlong Emperor (r. 1735-1796) by offering instructions how to use and to construct firearms. (Waley-Cohen, p. 1530-

[12] According to Wakeman's research China may have had a population of 150 million in the 16th century. In 1661 there may only have lived between 76 and 92 million people whereas in 1700 the population had a 1600 level again. About the year 1700 in England there lived 5 million and in France 20 million people. In 1750 Europe had 150 million and China had 300 million people, approximately. (Wakeman, p. 1054)

[13] The handling of artillery also helped the agrarian empires of Russia and China to partition the Eurasian steppes between themselves during the late 17th century as the archery of the steppe cavalry proved to be ineffective against a well-disciplined infantry. (Wakeman, p. 77-78)

1533) According to Huang Yi-long the Chinese manufactured advanced composite cannon during the 17th century. The technique was forgotten in peaceful times but rediscovered after the shock of the First Opium War. In fact muzzle-loading smooth bore cannon reached their peak in China in the mid-19th century but they were inferior to the new western rifled artillery. (Huang 2011, Abstract)

Tonio Andrade argues that since the arrival of Europeans in China there was a slight divergence in favor of the Europeans in military matters. Only since the Industrial Revolution the divergence evolved to a Great Divergence in military and other affairs. He furthermore argues that the frequent warfare of Europe's very long "Warring States" period precipitated military innovations in Europe whereas the settled states of East Asia enjoyed relatively peaceful times from then on. (Andrade, p. 202-203) Indeed China fought wars in Central Asia against nomadic peoples but the use of firearms was generally not as useful in the fight against nomads as in wars against other settled people. For example, the advantage of firearm bullets being capable of piercing armors was useless against unarmored nomads as they either could not obtain armors or regarded them as too heavy for their horses. Bows and arrows could also do their job. The Chinese fought mostly against nomads while Europeans mostly fought against themselves. (Chase, p. 74-75) Therefore firearm innovations did not seem very rewarding. Moreover frequent sea combats could have helped the Europeans to develop better cannon. Finally the Chinese fought with 17th century cannon against the 19th century British arms during the First Opium War (1839-1842). From this point on it was clear that China needed modernization in military and other affairs.

5.2 China's high living standard and the emergence of the Great Divergence

Sometimes it may be assumed that the European respectively the Western civilization gradually left the world behind it in the areas of science, technology and power politics since the spectacular expeditions of Christopher Columbus, Vasco da Gama and others around 1500. The existence of the lead of the West in itself may be unquestioned as only this can explain the Age of Imperialism around 1900 and the West's exalted status until today. Nevertheless the time of the beginning of this leading era of the West or the beginning of the "Great Divergence", as the time of the West's rapid development is called, is questionable. The Spanish Empire of the 16th to the 18th century with its possessions in Latin America and the Philippines and its other trading posts and islands in Asia and Africa could for the first time in world history truly claim to be an "Empire on which the Sun never sets". Even though this is a respectable fact, if one ignores the inhumanity on which this empire was built, the European seafaring nations were impressed and challenged by the contact with technologically refined civilizations such as the Chinese and the Indian civilizations were.

According to Kenneth Pomeranz, who belongs to the so-called California School, many important variables had similar values for the most advanced regions of Europe (England) and China (the Yangzi Delta and the Pearl River Delta, also called Lingnan) as well as for the whole areas about circa 1750. For example, most estimates of caloric intake in the 18^{th} century are similar between China and Europe. According to Pomeranz, studies suggest that the Chinese birth rates were equal or lower than the European ones throughout 1550-1850 whereas the overall population growth was bigger in China 1550-1750 (!) and roughly similar 1750-1850; this indicates that Chinese death rates were probably lower. Moreover, there are accounts which compare Chinese levels of consumption favorably to that back home. China's horrible deforestation in the late 19^{th} and 20^{th} centuries seems not to be true around 1750 or even 1800, whereas the British Isles already had severe wood shortages before 1650, as did northern Italy. This was also a problem for "fuel-hungry iron forges which often functioned only a few weeks a year for lack of fuel". (Pomeranz, p. 435) In the densely populated Lower Yangzi area the clearing of highlands put not severe ecological pressure until about 1820. Overall, China seems not to have faced more "Malthusian" stress than Europe as of 1800. (Pomeranz, p. 428-435)

Pomeranz argues that the Industrial Revolution appeared in England and not in the advanced regions of China because the coal was better available in England. He points out that as for the main ingredients of the Industrial Revolution only cotton, iron, steel and railways were equally emphasized. As the iron, steel and railway sectors depended on coal, an Industrial Revolution is hardly imaginable without coal. Therefore the better availability of coal in England than in China was a favorable factor for the appearance of the Industrial Revolution in England: "Huge coal stems with visible outcroppings lay relatively close to London […]. By contrast, China's best coal deposits lay in Shaanxi, several hundred landlocked miles from the Yangzi Delta: a bit like if Europe's coal had mostly been under the Carpathian Mountains." (Pomeranz, p. 437) Besides the location of coal deposits their properties were more favorable for England: "British mines needed water pumped out constantly. For this, a coal-fired steam engine, which would later also solve the transport problem, was a great solution. […] By contrast, China's largest coal deposits were in mines where ventilation was a much bigger problem." Soon coal was a significant source of wealth for Britain. In 1820 to annual energy yield from British coal was equivalent to a sustainable 15 or rather 21 million "ghost acres". Also land-intensive overseas imports were useful. In Britain there was not much room to expand the agricultural production with the techniques of 1800, e.g. without synthetic fertilizers. The British and Belgian wood crises were alleviated by the late 18th and 19th century coal boom. The 1750-1900 population and per-capita consumption soared in Europe. On the other hand, the Chinese population growth and per-capita non-grain consumption slowed significantly after 1800. (Pomeranz, p. 433-437) However the very well developed canal system could possibly have helped China to transport coal to where it was needed. Pomeranz' data show that despite the partly existing scientific or technological backwardness which is apparent in the astronomy and artillery sectors, China's living standard was comparably good or even better than the European one far into the 18th century. Only after this time the "Great Divergence", the meteoric rise of European wealth and power, did occur whereas before there were more East-West similarities.

However, there are other explanations for the lack of China's industrialization respectively its technical enhancements. Mark Elvin's "high-level equilibrium trap" suggests that China's labor force in recent times was just too big as there could have been good incentives for a further mechanization. In fact up to the 12th century many more labor-saving agricultural techniques were developed in China than afterwards. On the other hand, as Justin Yifu Lin argues, labor shortages always existed during the peak seasons. (Lin, p. 271-274) Last but not least the time-consuming learning of the classics for the imperial examinations extracted talents from careers as a technician. Officials were highly respected. The Confucian classics in total had 431,286 characters which required 6 years of memorization with a rate of 200 per day. (Lin, p. 285) It was also argued by some scholars that the foreignness of the Manchu rule prevented the Chinese from achieving an industrial revolution.

5.3 Summary

Chinese cannon did not improve much until the First Opium War. The cannon of Schall and Verbiest then still were an important part of the arsenal. Finally the British fought with rifled 19th century cannon against Chinese 17th century cannon. Whereas the quality difference from Chinese to European cannon was still relatively small until at least the end of the 17th century, the European cannon of the 19th century were already much superior. One explanation for the European dynamics and the Chinese stagnation, among others, may be the one that China enjoyed relatively peaceful times (the Pax Manjurica) whereas Europe underwent an extended "Warring States" period. Moreover, the use of firearms against nomads who were the main Chinese enemies during that time is not as effective as against other settled civilizations. Nevertheless the Chinese still enjoyed a high living standard until far into the 18th century. The Great Divergence, the meteoric rise of the west, seems not to have taken place before. Among the explanations for Europe's rise are the suggestions of Pomeranz that Europe had a better access to coal and land-intensive overseas imports and Mark Elvin's "high-level equilibrium trap" model that regards China's overpopulation as a barrier for further mechanization, which significantly helped Europe to gain power, among others.

6. A Comparison to the Adoption of European Astronomy

6.1 The calendar crisis and the arrival of the Jesuits

Cannon founding was not the only knowledge field in which the Europeans possessed advantages compared to the Chinese during the 16th and 17th century. Also the European astronomy was on a high level, for example. It may therefore be valuable to compare China's adoption of European astronomy with the one of European canonry and to ask why, finally, China could not compete with Europe in both knowledge fields. As the European-Chinese contact intensified when the first European ships reached China's coast and especially when the Jesuit China Mission was started by the Italian Jesuit Michele Ruggieri who had reached China in 1579 as the first Jesuit the Chinese intelligentsia came in contact with new Western astronomical thoughts. The "Society of Jesus" was founded in 1539 by the Spanish soldier Ignatius of Loyola to defend and propagate the Catholic faith in the context of the Protestant challenge. The Jesuits had a rather military spirit and had to follow a strict discipline. They were well-trained scholars in scientific and practical matters. Already in 1540 the first Jesuits went to the Portuguese Goa in India to spread their faith. (Sharma, p. 346) Their calculation was to serve the Chinese elite in practical matters to spread the Catholic faith and to increase the Pope's power.

In fact knowledge of the Jesuits was needed in China as during the 16th century a calendar crisis was eminent in China. The Yuan dynasty had established the lunisolar Season Granting astronomy system (*Shoushi Li*) in 1280 which in principle also already used the Ptolemaic system. It was quite successful and was re-promulgated by the first Ming emperor in 1368 but he called it the Grand Concordance astronomy system (*Datong Li*). Even though it was occasionally slightly modified, after 300 years the Yuan-Ming calendar was off for one whole day. This was especially a problem because the beginning of a month was fixed by the calendar to the day of a Sun-Moon conjuncture when the Moon was not visible. With the high error solar eclipses could now occur at another day than the first of a month to which numerous ceremonies were tied. The ceremonial dates could therefore not be calculated correctly.

Michele Ruggiere was soon joined by his compatriot Matteo Ricci (he came in 1601 to Beijing) in Macau in 1583. They soon understood that their mission in China could be more successful if they would succeed to solve the Ming calendar crisis. In fact they also had had a mathematical schooling. Ricci for example had studied mathematical astronomy under the German Jesuit Christoph Clavius in Rome who also worked for the Gregorian calendar reform of the West in 1582. Their initially conversions were "via the door of mathematics". (Elman 2005, p. 64-70) The Jesuits introduced the full Ptolemaic theory of epicycles (of Ptolemy, 90-168 AD) to China. For this, Euclidian geometry (of Euclid, about 300 BC) was necessary. Euclid's geometry had already reached China about the year 1275 and was according to Needham probably translated into Chinese. Nevertheless Euclid had not an impact on Chinese thinking until the 17th century. (Needham 1959, p. 148) Matteo Ricci and the convert Xu Guangqi completed the translation of the first six books of Euclid's *Elements of Geometry* into Chinese in 1607. (Elman 2005, p. 90-91) With the adoption of the Ptolemaic system geometry and trigonometry became more important for the Chinese than their traditional numerical and algebraic techniques. (Sivin, p. 18)

6.2 Jesuit eclipse prediction successes and reform efforts

The Jesuits got respect from the Chinese because of their more accurate eclipse predictions. The Astro-calendric Bureau was responsible for the calendar of the Chinese empire and belonged to the Ministry of Rites. The time of its prediction for the solar eclipse of December 1610 was approximately 30 minutes too late whereas the Spanish Jesuit Diego de Pantoja who was in China since 1599 had made a more accurate prediction. The supervising Ministry of Rites therefore called two times for an imperial approval to study the reform of China's astronomical system but the Wanli Emperor's (r. 1572-1620) court did not act according to this advice. The Ministry also suggested to translate Western astronomical texts and referred to a 1382 translation of Muslim works to support its advice. The scholar-official Xing Yunlu had also called for a calendar reform in 1597. The translation was then done by the converts Xu Guangqi and Li Zizhao. Both were palace degree holders (*jinshi*) in the imperial examination system (1604 and 1598). They were baptized in 1603 respectively in 1610. The emperor tolerated those translations and reform discussions but did nothing to support them until 1619. Due to a lack of more useful textbooks and instruments these efforts first were not too successful anyhow.

This problem was already foreseen by Ricci as he asked in a letter to Rome in 1605 to send more Jesuits with mathematical and astronomical knowledge as well as specialized books and instruments to China. In 1612 the Belgian Jesuit Nicholas Trigault was sent from China to Rome. After his 1613-1614 stay in Rome he returned in 1621 with about 7,000 new works to China. Many of these works had a scientific content and were published in the 1610s but nevertheless they mainly had a Ptolemaic that means geocentric orientation. With him also the German Johann Adam Schall von Bell and the Italian Giacomo Rho, both specialists in mathematical astronomy, arrived. The convert Li Zizhao used several of these books to compile the "Collection of Celestial Studies" (*Tianxue Chuhan*) which was the last real Ptolemaic work in China. In the 1630s Schall and Rho introduced the geoheliocentric system of Tycho Brahe (1546-1601) in China. This was an agreement between the antiquated Ptolemaic geocentric and the heretical Copernican heliocentric astronomic systems. In fact the Jesuits had different views concerning the new Copernican theory which was published in Nicolaus Copernicus' year of death in 1543 until the Pope officially condemned Copernicanism and set his book "On the Revolution of the Heavenly Spheres" (*De revolutionibus orbium coelestium*) on the index in 1616 when the Copernican heliocentric controversy climaxed in Europe – where it officially remained until 1758. Another condemnation followed in 1632. To the degree to which the Jesuits now served the astronomical and other needs of China's imperial court they now – besides the Pope – also served the Chinese emperor.

The whole translation and reform efforts got a backlash as the vice-minister of the Ministry of Rites Shen Que accused the Jesuits in 1616 of "staining the minds of the people" and opposed any Jesuit cooperation in the calendar reform. Shen arrested Jesuits and their converts in Nanjing where he also lived. They were finally sent to Macau. Other Jesuits in Beijing got an exile in Hangzhou. As Elman points out, "after 1616, most of the fourteen Jesuits remaining in China studied Chinese texts and language in seclusion in Hangzhou". Shen renewed an attack from 1621 to 1627 but at this time already some Jesuits were in Beijing again to serve as military experts.

In June 1629 there was also a solar eclipse prediction competition and the Jesuits prediction was more accurate than the Chinese and the Muslim one. Xu Guangqi, now a senior vice-president of the Ministry of Rites, again called for a calendar reform. The establishment of a formal astronomical reform system by Xu Guangqi, Li Zizhao and Jesuits was now approved by the Chongzhen Emperor's (r. 1628-1644) court and the suggested reforms, mainly worked out by Giacomo Rho and Schall von Bell, were gradually presented between 1631 and 1635. Xu was allowed to set the Tychonic astronomical system as the basis. However, despite the new system proved to be satisfying in 1642 the astronomical reform did not come into effect before the collapse of the Ming dynasty in 1644, which might also be due to the death of Xu Guangqi in 1635. (Elman 2005, p. 89-94)

6.3 The calendar reform

It was then the Shunzhi Emperor (r. 1644-1661), the first emperor of the Manchurian Qing dynasty, who appointed Schall to be the head of the Astro-calendric bureau and who put the calendar reform into force. [14] A Jesuit would finally be at the head of the bureau until 1775. In this year the information that the Pope had abolished the Jesuit order reached China. Anyway there already had existed a tradition of foreign experts in the bureau as there were Indian experts during the Tang dynasty and Muslim experts during the Yuan dynasty and beyond. Schall was criticized as he willingly served whoever just had the power as he served the succeeding Qing dynasty and even the anti-Ming rebel leader Li Zicheng who captured Beijing for a short time in 1644.

[14] Schall also introduced 360 degrees in a circle rather than the old 365.25 du and the day was now divided in 96 parts rather than before 100. (Elman, p. 103)

The Tychonic system was first presented in Li and Schall's book "On the Farseeing Optic Glasses" (*Yuanjing shuo*) of 1626. [15] This system was presented by the Danish astronomer Tycho Brahe (1546-1601) in the late 16th century. He in fact possessed Europe's most advanced astronomical instruments of his time and his data were the basis for Johannes Kepler's (1571-1630) later findings of the laws of planetary motion. In Brahe's "geo-heliocentric" system the five known planets orbited the Sun whereas the Sun and the Moon orbited the nonorbiting and nonrotating earth. However, in the Tychonic system, contrary to the Ptolemaic system, ancient Greek philosopher Aristotle's (384-322 BC) incorrect crystalline spheres were abolished. Before that the "vaulted heavens" (*gaitian*) cosmology where the heavens were a "hemispherical dome, an umbrella-like canopy, over a flat earth" and the later during the Eastern Han dynasty arising alternative of the "spherical heavens" (*huntian*) were important. (Elman 2005, p. 95-98)

In 1658 the astronomer and literati Yang Guangxian (1597-1669) criticized Schall for the date chosen for the burial of an infant prince as being wrong. He accused Schall to purposely select an inauspicious day to cast a deadly spell on the emperor and empress as the parents. In fact the Jesuits were a little bit unhappy with their responsibility for determining auspicious days as this was regarded as unchristian astrology. Yang furthermore charged that the Jesuits plotted rebellion and spread heterodox doctrines among the people. He tied some recent inauspicious deaths in the imperial family to Schall's divination to determine burial sites. [16] Schall, Verbiest and their Chinese colleagues were sentenced to death in 1665 but discharged due to an earthquake. Schall died one year later in Macau and Verbiest became the Jesuit's chief spokesman. Verbiest also became the administrator of the calendar and codirector of the bureau in 1670 and the Jesuit's preeminence in the Astro-calendric Bureau was restored. (Elman 2005, p. 136-144)

6.4 Limits of the knowledge transmission concerning Copernican theories

The Jesuits brought valuable astronomic and related knowledge to China. In the context of the Ptolemaic world view they for example introduced the doctrine of a spherical earth whose surface can be divided by meridians and parallels. They helped to improve the

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[15] The first telescope was brought to China by the German Jesuit Johann Schreck in 1618. One telescope was presented to the emperor in 1634 and also refinements as the cross-hair and the micrometer were brought. (Needham 1959, p. 438)

[16] Also the Jesuit claim that the Chinese descended from biblical Noah's son Sem caused significant trouble at that time. (Elman, p. 27)

Chinese calendar. But they also introduced some false or confusing elements. For example, they first introduced the incorrect Ptolemaic-Aristotelian geocentric universe of solid concentric crystalline spheres. Such were “the elements of superiority in European science at the turn of the 16th and 17th centuries imposing a fundamentally wrong world-picture, that of the solid spheres, on the fundamentally right one which had come down from the Hsüan Yeh school, of stars floating in infinite empty space.” (Needham 1959, p. 439) However, the spheres were abolished again since the introduction of Brahe’s geoheliocentric universe in the 1630s. The Jesuits also first imposed the antiquated and unpractical Greek ecliptic coordinates upon Chinese astronomy despite the Chinese already had the more satisfactory equatorial coordinates and despite Tycho Brahe also recently had introduced equatorial coordinates in Europe. Needham states that the Jesuits “completely failed to appreciate the equatorial and polar character of traditional Chinese astronomy” (Needham 1959, p. 438) The Jesuit leadership in European natural studies was also declining during the early modern period. (Elman 2002, p. 210) For example, they were excluded from the French Academy of Sciences, formed in 1666, as they were not regarded as worthy members anymore in 1699. (Elman 2005, p. 23)

But the most distracting issue from a Chinese point of view is the not carried out transmission of the full Copernican heliocentric theory. Instead the Jesuits trapped the Chinese thinkers into a not updated geoheliocentric world view. In fact the Jesuits who first were more anti-Aristotelian than anti-Ptolemaic described the heliocentric theory for a short time before the Church’s ban in 1616. But due to the Pope’s censorship the Copernican conflict in China finally lasted until the 18th century. (Needham 1959, p. 437-445) The French Jesuit Michel Benoist introduced the Copernican theory to the court in the 1760s, shortly after the end of the Church’s ban. (Elman 2005, p. 150) But the manager of the Summer Palace waterworks failed as the Chinese criticized his demonstration as having inconsistencies with the former astronomy, taught by Western scholars. (Schaffer, p. 228) It was not easy for Benoist to argue against the up to then evolved new classicism which was an amalgam of the European Copernicanism and rediscovered traditional Chinese thoughts. (Sivin, p. 18) The Copernican theory was not fully established in China until the 19th century with the teachings of the Protestant missionaries as Joseph Edkins, Alex Wylie and John Fryer. Japan’s first modern observatory which was founded in 1725 for example already fully used the Copernican theory. (Needham 1959, p. 447) Moreover, the Jesuit astronomical teachings were in some cases not even new for China. In Needham’s words: “In some cases, the Jesuits were really only reminding the Chinese of things which they themselves had developed long before, but which the degenerate science of the Ming had forgotten." (Needham 1959, p. 437) It could appear strange that the old Ptolemaic theory could improve the Chinese calendar but still, as Nathan Sivin points out, the mathematic-astronomical knowledge of the Chinese by its last high point about 1300 did never quite reach the one which Ptolemy achieved 1100 years earlier. (Sivin, p. 3) The Ptolemaic theory communicated a false world view but worked quite well.

6.5 Summary and comparison

Due to the calendar crisis as an emergency situation the Chinese were willing to accept European astronomy via the early Qing calendar reform, similar to the frequent warfare for the adoption of European cannon. Nevertheless, similar to their final failure in cannon making, the Chinese in the end were only partly capable to adopt European astronomy and calendar making, being other techniques in which Europe possessed leading positions. Whereas peace may have been a major reason for a lacking adoption of cannon, here the reason for the lacking adoption was the reluctance of the Jesuits to teach the heliocentric theory. Their misinformation trapped the Chinese thinkers into a geoheliocentric world view. Finally the Chinese were not able to fully catch up with the European advanced canonry and astronomy which means that also in this field the knowledge transmission was incomplete. Copernicanism was not really established in China before the 19th century.

7. Conclusion

This thesis was supposed to provide more knowledge about the scientific-technological exchange between Europe and China during the 16th and 17th century, especially about the transfer of European cannon making expertise to China, to the reader. Moreover it contains information about the spread of European astronomy, for example.

The evidences for my first thesis (1), the various civilizations' contributions to cannon making technology in particular, are highly visible, as the Chinese invented gunpowder and various gunpowder weapons including guns and the European developed better gunpowder formulas, breech-loaders and muskets. Also the Muslims, for example, contributed to the trebuchet technology, and the Turks were well-known for their cannon for a long time. Despite their earlier leadership in the usage of firearms the Chinese around 1500 had fallen behind the Europeans with their now increased speed of innovations.

As for my second thesis (2), which states that China was eager and capable to adopt European cannon technology between 1514 and 1683, I find evidences. China soon after the first encounter with European ships and cannon in 1514 adopted and produced the *folangji* and later, despite the suspiciously attitudes of some Chinese officials concerning the new Western technologies and the political agendas of their transmitters, the "red barbarian cannon" in the 1620s. Sun Yuanhua attempted to adopt European weapons, and there was a wide usage of them in wars. The European-derived cannon were central elements of the Chinese arsenal. Also the Jesuits served the Chinese court as cannon-makers. Koxinga's success against the Dutch militates in favor of an active and successful adoption of European cannon technology. The various military conflicts were great incentives to adopt the useful European knowledge. However, possibly due to peace and to the occasional fight against unfavorable enemies for firearm development the Chinese still fought with 17th century cannon against British 19th century cannon during the First Opium War.

Anyway, to return to my initial thought in the introduction, the exchange of technology leadership between Europe and China was not a monolithic process. Firearm together with optical (eyeglasses) and horological technology (clocks) belonged to the first technology fields where the Europeans already enjoyed worldwide leadership since around 1500. (Chase, p. 8) On the other hand, it was shown that the Chinese reeling machines for spinning hemp threads, agricultural techniques in general (Lin, p. 270) as well as the iron casting techniques were superior to the European ones in the 17th century. Robert Temple, who summarized Needham's findings, even states that "indeed, until two centuries ago, the West was so backward in agriculture compared to China, that the West was the Underdeveloped World in comparison to the Chinese Developed World." (Temple, p. 12) Europe and China both were superior and inferior, depending on the just investigated technology. According to Benjamin Elman "by 1600 Europe was already ahead of Asia in producing basic machines such as clocks, screws, levers, and pulleys that would be applied increasingly to the mechanization of agricultural and industrial production. China in the period from 1600 to 1800 did not 'possess optical lens makers, horological gear-wheel cutters, and men who could make accurate micrometer screws.' […] In the seventeenth and eighteenth century, however, Europeans still sought the technological secrets for silk production, textile weaving, porcelain making, and large-scale tea production from the Chinese. Chinese literati in turn, before 1800, borrowed from Europe new algebraic notations (of Hindu-Arabic origins), Tychonic cosmology, Euclidean geometry, spherical trigonometry, and arithmetic and trigonometric logarithms.” (Elman 2002, p.228-229) For example, a Jesuit, usually a Swiss, looked after the emperor’s clock collection during the Qing dynasty. (Elman 2005, p. 103)

Also in mechanics the technological exchange was reciprocal. [17] Joseph Needham states: “When traditional Chinese technology came into confrontation with that of the aspiring Renaissance West, it had very little to be ashamed of so far as fundamental principles were concerned.” (Needham 1965, p. 222-225) Nathan Sivin again modifies the Chinese technological superiority in the Middle Age as he points out that the European and Chinese medical practices were comparable to each other in their effect up to 1850. (Sivin, p. 3)

Finally, one can conclude that the intensified European-Chinese contact during the early modern period accelerated the technology development and helped to form the basis of the technology today. These technological developments may have been advantageous for the humanity. However, they are a mixed blessing. Especially the invention of firearms put great harms on many people. The modern science put nuclear bombs in the hands of humanity, and new technologies are able to threaten the livelihood of the humanity and to affect the climate. It is therefore the task of the humanity to apply its knowledge and power in a responsible way.

[17] For example, the Archimedean screw was introduced to China and the rotary fan winnowing-machine was introduced to Europe, the latter one probably under the guidance of the Jesuits at the beginning of the 18th century.

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