

Masts Like a Forest: Chinese Shipbuilding from the Zheng War to the Opium War (c. 1644-1839)

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■ ABSTRACT

Chinese sailing ships, often called “junks,” were key to both the military and commercial flourishing of Qing China (c. 1644-1912) until the First Opium War (1839-42). Junks were an evolving and flexible technology that could be built with economized materials. During periods of conflict, shipwrights incorporated new designs to maximize speed, maneuverability, and firepower. During periods of peace, they responded to regulatory constraints and limitations in the timber supply to continue regional and international trade. The principal timber, China fir (*Cunninghamia lanceolata*), remained widely available thanks to flourishing plantations. However, shipbuilding put serious pressure on slower-growing tree species, and the demand for timber furthered the colonization of the southwest and Taiwan. The main government response to regional scarcity and rising timber prices was to economize, while many private shipbuilders shifted their operations to Southeast Asia. Catastrophic defeat by the British steamship *Nemesis* signaled the end of junks' military usefulness, although they remained commercially important for another century.

Keywords: junks, shipbuilding, China.

Pals com un bosc: La construcció naval xinesa des de la Guerra de Zheng fins a la Guerra de l'Opi (c. 1644-1839)

■ RESUM

Els velers xinesos, sovint anomenats "juncs", eren una tecnologia flexible que economitava materials, clau per al floriment militar i comercial de la Xina Qing (c. 1644-1912) fins a la Guerra de l'Opi (1839-42). Durant els períodes de conflicte, els constructors navals van incorporar nous dissenys per maximitzar la velocitat, la maniobrabilitat i la potència de foc. Durant els períodes de pau, van respondre a les restriccions reguladores i les limitacions en el subministrament de fusta. La fusta principal, l'avet de la Xina (*Cunninghamia lanceolata*), es va mantenir àmpliament disponible gràcies a les abundats plantacions. No obstant això, la construcció naval va exercir una

forta pressió sobre les espècies arbòries de creixement més lent, i la demanda de fusta va afavorir la colonització del sud-oest i Taiwan. La principal resposta del govern a l'escassetat regional i a l'augment dels preus de la fusta va ser l'economització, mentre que molts constructors navals privats van traslladar les seves operacions al sud-est asiàtic. La derrota catastròfica del vaixell de vapor britànic *Nemesis* va marcar el final del domini militar dels juncos, tot i que van continuar sent importants comercialment durant un segle més.

Paraules clau: juncos, construcció naval, Xina.

Mástiles como un bosque: La construcción naval china desde la Guerra de Zheng hasta la Guerra del Opio (c. 1644-1839)

■ RESUMEN

Los veleros chinos, a menudo llamados "juncos", eran una tecnología flexible que economizaba materiales, clave para el florecimiento militar y comercial de la China Qing (c. 1644-1912) hasta la Guerra del Opio (1839-42). Durante los periodos de conflicto, los constructores navales incorporaron nuevos diseños para maximizar la velocidad, la maniobrabilidad y la potencia de fuego. Durante los periodos de paz, respondían a las restricciones normativas y a las limitaciones en el suministro de madera. La principal madera, el abeto de China (*Cunninghamia lanceolata*), seguía estando ampliamente disponible gracias a las florecientes plantaciones. Sin embargo, la construcción naval ejerció una gran presión sobre las especies arbóreas de crecimiento más lento, y la demanda de madera favoreció la colonización del suroeste y de Taiwán. La principal respuesta del gobierno a la escasez regional y al aumento de los precios de la madera fue economizar, mientras que muchos constructores navales privados trasladaron sus operaciones al sudeste asiático. La catastrófica derrota del buque de vapor británico *Nemesis* marcó el fin del dominio militar de los juncos, aunque siguieron siendo comercialmente importantes durante otro siglo.

Palabras clave: juncos, construcción naval, China.

■ INTRODUCTION

Chinese junks evolved over centuries into a multicultural hybrid technology, incorporating elements from South Asian, Korean, Japanese, Malaysian and European vessels while maintaining traditional construction methods¹. Ships from different regions required idiosyncratic features since there was no scientific naval architectural tradition. Shipwrights mixed and matched useful designs garnered from a spectrum of technologies seen on other ships and created designs that fit local conditions and the needs of merchants. This evolution paralleled three trends in European maritime history discerned by Richard Unger. First, the expansion of maritime commerce gave shipwrights the incentive to create faster, more durable ships. Second, private merchants and seafarers, responding to government regulations, drove this innovation. Third, shipping improvements reoriented insular anti-mercantile cultures towards more cosmopolitan, capitalistic activities².

Junks were ubiquitous. Between 1650 and 1668, the Jesuit Gabriel De Magalhães wrote of the "innumerable vessels" in China: "a man may say there are two empires in China, the one upon the water, and the other upon the land; and as many Venices as there are Cities"³. The encyclopedist Song Yingxing noted in 1637 how integral ships were to economic life and society: "the southerners must rely on the boat and the northerners the cart as the chief forms of transportation... natives of the south never see a mule cart, and those who spend their whole lives in the north never see a large boat."⁴. In 1706, the Russian ambassador Evert Ysbrand Ides cited a Jesuit joke that claimed there were enough ships to make a land-bridge from China to Europe. He saw so many varieties of ships, pleasure boats, house boats, transport barges as to remark that "[the Chinese world seems] like nothing more than a floating city, in which the vessels run together like ants"⁵. Xu Yang's 1759 painting *Gusu Fanhua Tu* which depicts the "resplendent life" in "Prosperous Suzhou," shows four hundred unique ships, from two-man canoes and sampans, to junks and larger passenger ships⁶. Rudolf Hommel as late as the 1930s observed "as

one travels through the country, thousands of years of water-borne traffic were everywhere in evidence”⁷. Chinese shipbuilding was therefore a pillar of the Qing Empire’s infrastructure that enabled the world’s greatest economy to operate⁸.

The timber supply was crucial to these vessels, as a shipbuilder’s proverb expressed in verse: “to build a junk to last for son and grandson: [use] fir, cypress, catalpa, camphor and nanmu.” (*yao zao zisun chuan, shan bai zi zhang nan* 要造子孙船、杉柏樟楠)⁹. All of these species were used to build the ships of southern China. Planks and masts were often cut from sixty-year-old trees, principally conifers like pine (*song* 松/*Pinus*) and China fir (*sha* or *shan* 杉/*Cunninghamia lanceolata*)¹⁰. Chinese foresters expanded the yield and productivity of conifer plantations throughout the early modern period so that the availability of these timbers was never in doubt. Merchants and the state streamlined and standardized the measurement and processing of logs into boards and finished poles, keeping prices down in the face of inflation. Until the eighteenth century, the best ships used nanmu 楠木 (*Phoebe zhennan*) for hull planking, ironwood (*tielimu* 铁力木, *Mesua ferrea*) for rudders, sandalwood (*tan* 檀, *Santalum album*) for tillers, and camphor (*zhang* 樟, *Cinnamomum camphora*) for cabins and railings. Unlike fir and pine, these denser woods did not respond well to cultivation, and they required well over a century to grow to useful sizes. This meant that old-growth logging was the primary, if not exclusive, source of these timbers. In each case, the government developed specialized institutions to ensure their supply.

Timber supply was only one of several factors influencing the design of early modern Chinese ships. Throughout the Qing period (1644-1912), official shipyards struggled with fixed silver budgets that forced managers to economize and respond to inflated prices or military threats. From the 1650s to 1680s, the Qing used a “coastal clearance” policy to try to deny shipbuilding materials to smugglers and raiders. Even after this sea ban was lifted, regulations continued to hold down the size of private ships, to prevent the construction ships that could pose a naval threat. This only further incentivized private merchants and shipbuilders to offshore their

construction, either to nearby islands or to Southeast Asia. To maintain the timber supply, resources within China were economized and further supplies were imported from abroad.

■ BUILDING THE EARLY MODERN CHINESE JUNK

Junks were never a standardized technology. In Chinese, boats were delineated according to their type, place of origin, size, and usage, with the words *zhou* 舟 and *chuan* 船 used for both sail and oared ships, as well as China’s unique tradition of human-powered paddlewheels. The term Europeans used most often to refer to Chinese ships—*junk*—was borrowed the Malay term *djong* which referred to large East and Southeast Asian sailing vessels¹¹. Watertight bulkheads, planks connected with iron and putty, and battened sails were typical of Chinese ships, but these ships were always customized according to the builder’s wishes, producing what H. Warington Smyth called “infinite varieties”¹². Most ships had multiple uses; some were even modular and could be deconstructed and rebuilt for different purposes in different seasons¹³. Premodern sources tell us ships were built at specific dimensions and archeological evidence reinforces our existing understanding of the materials used and structure of ships¹⁴. However, both have limited use in reconstructing a shipbuilding process that was passed down via oral tradition and apprenticeship for generations. For this purpose, no source gives more detail than the records of European and American observers who saw and recorded the process in person and drafted exact schematics starting in the 1830s and continuing into the twentieth century¹⁵. One can almost compare the reconstruction of the history of Chinese shipbuilding to finding instances of species with homologous structures in the fossil record.

While there was no single form of junk, several characteristics nonetheless distinguish early modern Chinese sailing ships from others. While European sailing ships relied on the hard woods of each plank to resist flexion and longitudinal or transverse stresses, the decks, frames, and the watertight bulkheads in Chinese ships took the brunt of the stresses from the sea¹⁶. Sails were

shot through with planks (battens)¹⁷. Each sail had complex, individualized rigging schemes that could change the wind pressure and navigate the ship, or roll up the sail using gravity¹⁸. Even if only half of a tattered sail remained, the skeleton would still move the ship¹⁹. Chinese rudders were raised and lowered with sandalwood windlasses and tillers. They used two distinct types of oars: rowing oars (*jiang* 桨) used from the sides of the ship much like on Mediterranean galleys, and sculling oars (*lu* 橹 or *yaolu* 摇橹) that used of fulcrums so the plank could swing much more freely on an iron bearing pin²⁰. Chinese ships, as opposed to Southeast Asian ships, used iron nails hammered diagonally into planks instead of wooden dowels and used an excessive amount of putty, but as will be described, the latter was a useful cost cutting measure in the face of Qing-era wood shortages²¹.

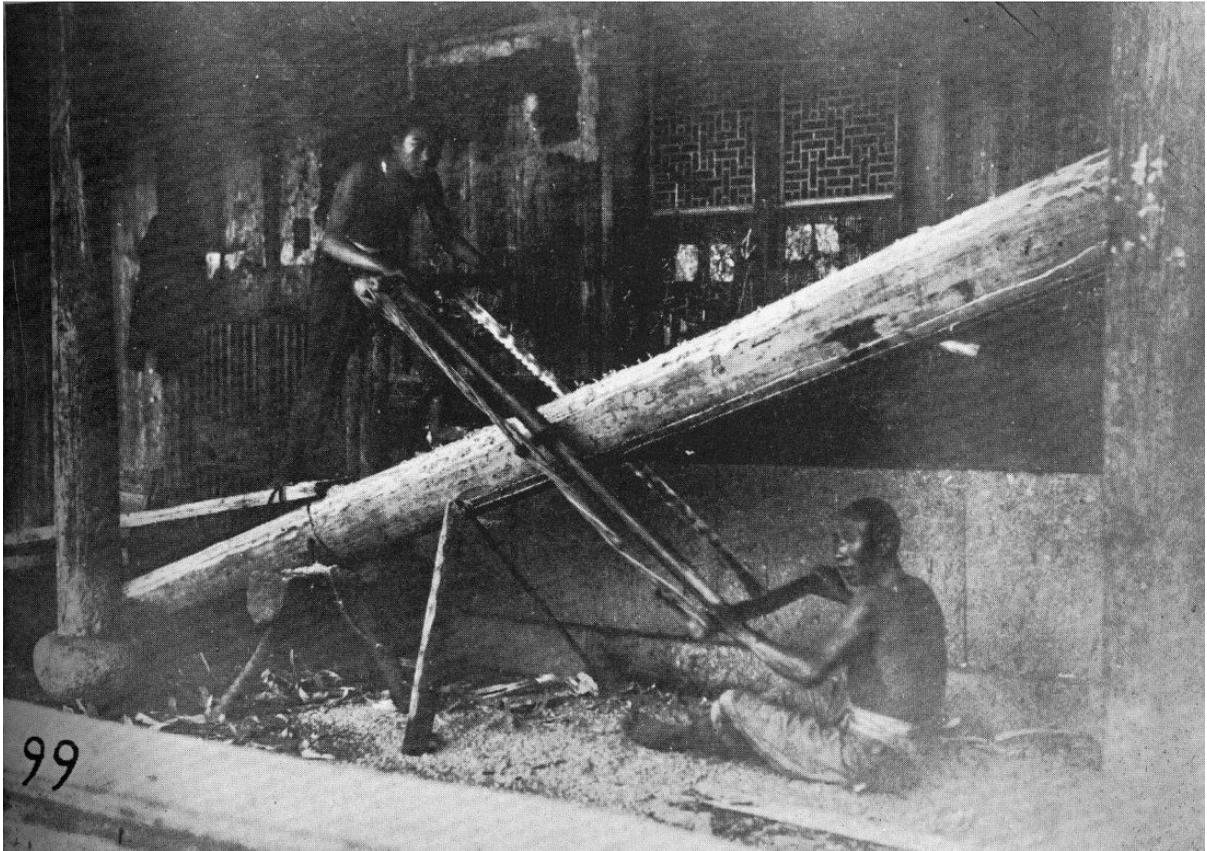
Shipbuilders used the same tools and practices as common carpenters and were often the same people who sailed the ships. Instead of blueprints, private shipbuilding was largely an oral tradition, where apprentices learned by building, guided by proverbs to inculcate how to construct and distinguish ships²². There are passing references to private manuals, but none appear to have survived the Ming and Qing shipbuilding bans. For all but the largest vessels, ships could be made without the need for precise prefabricated materials or blueprints²³. The low overhead and lack of specialized sites or tools meant that ships could be built pretty much anywhere there was a master shipwright, a handful of workers, a beach, and a supply of timber and ancillary materials. One method was for a master architect to construct a detailed tenth scale model, then multiply the model's costs and materials to construct the real thing. The master gathered the experienced men for the job, fed them, and guided their work from dawn to dusk²⁴. These master craftsmen are largely anonymous to history and often illiterate. Their efforts were recorded by scribes who had limited understanding of shipbuilding and focused on defining and labeling parts of ships in illustrations²⁵. Government manuals likewise focus more on the cost of each component than on how it was constructed. Nonetheless, collective financing of shipbuilding may have encouraged more formal group formation.

A few dozen shipbuilding guilds were established by the late 1700s and had increased in number by the early twentieth century²⁶.

Shipbuilding began with obtaining timber, which was felled with axes and ropes or purchased at the riverine markets along the coast and then floated to the work-site. Two-man sawyer teams angled the logs on sawhorses and sliced them into planks with long cutting frames (see figure 1). Craftsmen used adzes to shape the wood and handheld serrated compass saws to bore holes, adding mortises, tenons and rabbeted joints. They turned drills and lathes by hand with a reciprocating motion (figure 2)²⁷. Planks were bent with coal fires and stones and planed with hammers, chisels, and one-man crosscutting saws²⁸.

Ships were built keel first and the hull grew outward and up from this: it was a shell with a skeleton of beams affixed to it, whereas European ships were built in the opposite order. The master architect added mortises and tenons to each plank of the hull and soon-to-be watertight bulkheads and fitted them together like puzzle pieces that would seal without the need for many expensive iron nails. Archeological surveys reveal evidence of long wooden mallets with long cylindrical heads to smash planks together, but the average shipbuilder used the back of an ax reinforced with an iron grommet or buffalo hide²⁹. The planks were reinforced by wooden dowels, then stapled and squeezed together by the occasional iron pin and windlass³⁰. Larger ships layered up to three rabbeted planks together to prevent warping and wood-boring worms³¹. Planks were then caulked with a mixture of calcinated flax powder, tung or fish oil, and lime or ground oyster shells; limestone was preferred for ocean-going ships³². The caulk was shoved into the seams by hand, then by chisel. This brown putty, mixed by pounding the ingredients with mallets in pestles, served as waterproofing pitch and could last up to thirty years, kept out wood-boring worms, and allowed for even bad planks to be trimmed, replaced, and reglued with putty, saving wood³³. Shell plates were attached with wooden nails that dug diagonally into the hull, as an additional layer of protection. After the bulkheads were added, the planks of the upper decks were then squeezed close to

Figure 1. Sawyers cutting planks for construction, c. 1930s. Rudolf Hommel, *China at Work*, 227. Courtesy of MIT University Press.

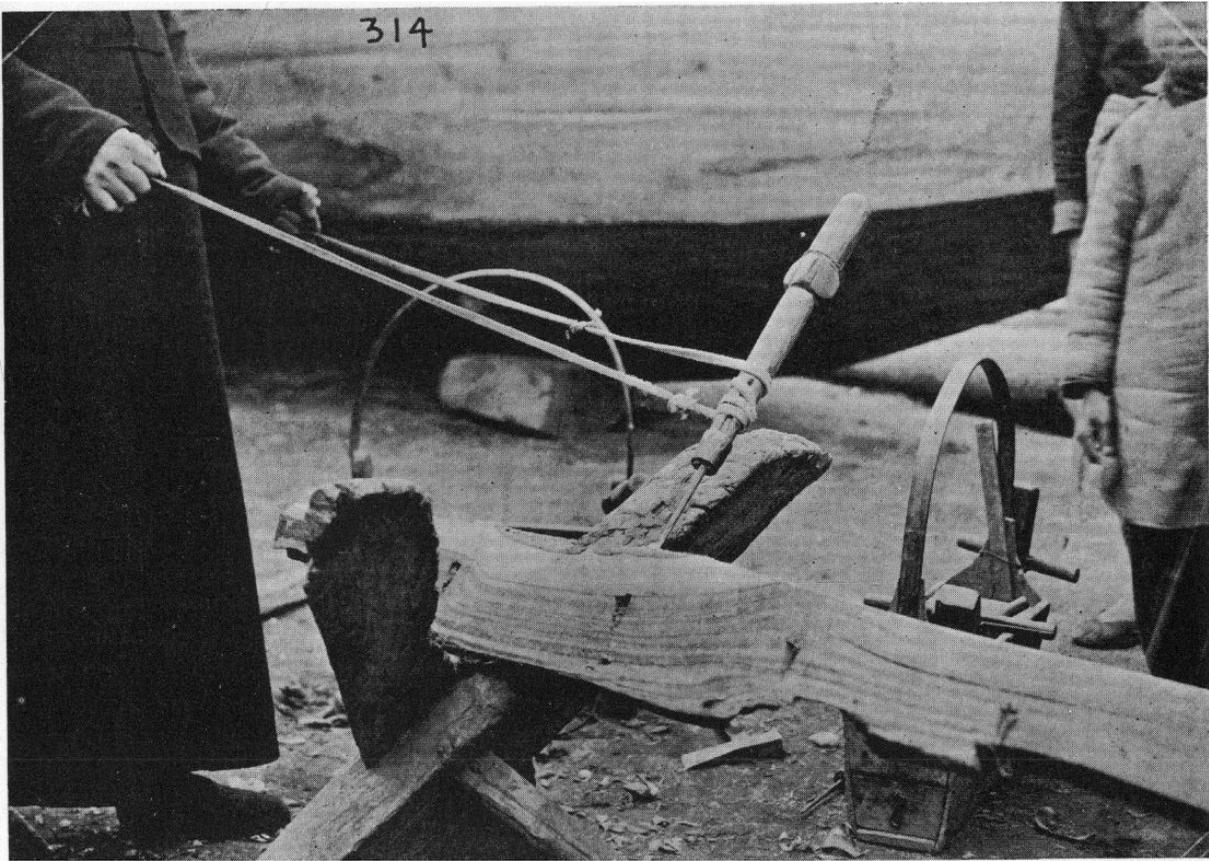


the hull with a windlass³⁴. Long inverted L-shaped iron nails connected the inner wall of board sheathing to the partitions and the beams³⁵.

Other components each had their own specialized materials and manufacturing methods. Highly tensile bamboo fibers were used for anchors chains and tow ropes; hemp rope for sails was waterproofed with pig's blood³⁶. Bamboo was also used to make freshwater tanks and bulwarks for seagoing vessels. Masts were delivered on barges and hoisted in place from horizontal into a block set between two bulkheads. Sails in South China

were made of matting, bamboo or palm coir, and rattan; in North China cotton sails were sewn in cottage industries, often by the shipbuilder's family³⁷. Anchors were usually either stone or dense wood, tied or bolted together; soldered cast-iron anchors use started during the Ming³⁸. Artisans fitted out the ships with decorations and necessities needed for travel, like bells and gongs used to communicate with other ships³⁹. In the Upper Yangzi, new ships were christened with wine and chicken's blood, and feathers were affixed at choice places. Every Chinese ship had giant eyes painted on it so the

Figure 2. Reciprocating Motion with a Shipbuilder's Thong Drill, c. 1930s. Rudolf Hommel, *China at Work*, 331. Courtesy of MIT University Press.



ship could “see.” The painter dipped a large cloth into the bucket and smeared the paint, dyed with coal, cinnabar, gamboge dyes and malachite, all over the hull⁴⁰. Different hull paint helped sailors identify where the ships came from, but they were also painted symbolically for wealth and good luck.

Some features of the early modern junk were in place well before the early modern period. The most important Chinese nautical invention, watertight compartments, were added to these designs quite early, nominally by Lu Xun, rebel governor of Guangzhou in 410 CE⁴¹. Archeologi-

cal finds show that Sui (581-618) and Tang dynasty (618-907) ships were fastened together with iron strips threaded between planks, capped with wood or lead to keep it watertight⁴². First millennium Chinese vessels tended to have large superstructures that were facsimiles of buildings, sometimes with many floors. Arguably the most important policy to enable ocean-going junks was liberalization of trading restrictions in 1070 during the Song Dynasty (960-1279). Before the eleventh century, long-distance trade in the South China Sea was dominated by ships from the Arab-Persian world, peninsular

Figure 3. Hull planks hoisted and squeezed into position by Fujian traditional shipwrights.
Photo by Huang Liang, 2007. Courtesy of UNESCO.



India, and Southeast Asian islands. Thereafter, native merchant shipping from southeastern China began to supersede foreign shipping to Chinese ports⁴³. Circa 1100, ships with iron nails were sealed with limestone putty to make an improved seal. At Yuanmengkou, an early twelfth century wreck provides the first known example of a balanced rudder in the shape of a long scalene triangle^{44v}. Chinese shipwrights began to incorporate other Southeast Asian technologies that enabled ocean travel, such as V-shaped keels and multiple masts⁴⁵. In the Yellow Sea, Korean and Japanese flat-bottomed ships with longitudinal beams built for riverine transit sailed alongside similar Chinese ships with bulkheads. In the East China sea, U-Shaped and V-Shaped hulls that allowed for more distant travel and maneuverability become evident⁴⁶.

Quanzhou, perhaps the most important long-distance seaport in the Song, was commonly called Tung Harbor in there because of the abundance of tung trees (*tong* 桐,

Vernicia), the oil from which made the watertight putty. Quanzhou is also the site of many Song era shipwrecks that reveal the eras innovation. The most famous, a late thirteenth century ship discovered in 1973, had a 17.65 meter tripartite keel connected with tenons and scarfs, could displace up to an estimated 370 tons, and used a mixture of 200 millimeter iron and bamboo nails throughout the hull, though not in the keel⁴⁷. Its hull was built from up to seven longitudinal planks collected into thick bands that were layered halfway on top of one another to produce a series of rabbeted clinker seams that resulted in a hull two planks thick at all points. The planks were built first and sealed with putty and a lath of wood. Archaeologists suggest that the construction did not require heating the wood to bend it; once the initial shape was carved, the rabbeted planks could be snapped in to produce complex shapes. This wreck is also early evidence of limber holes drilled into each bulkhead to allow

Figure 4. Rabbeted Watertight bulkheads on an unfinished Junk made in the traditional style.
Photo by Huang Liang, 2007. Courtesy of UNESCO.



liquid to be stored and drained from each compartment and for compartments to be washed one at a time⁴⁸.

By the Yuan dynasty (1272-1368), Marco Polo reported that Chinese ships employed up to five masts, including port and starboard masts. Ocean going vessels frequently carried thousands of *piculs* of cargo and hundreds of people⁴⁹. Ibn Battuta sailed on a Chinese ship that had six-hundred passengers and four-hundred sailors, “numerous private and public cabins for the merchant passengers, with closets for all kinds of conveniences.” The 1375 Catalan Map of the World by Abraham Cresques, which cribbed details from Marco Polo, showed Chinese ships with larger hulls, five masts, flat bows and sterns and five masts, heavily contrasted with the flat Aragonese Galley with one huge lanteen sail⁵⁰. Wrecks from this period, such as the Shinan wreck from 1322, reveal more complex rabbeting schemes for the planks, grooves carved in the keel to set watertight

bulkheads, and sawtooth mortise and tenon connections between bulkheads and keels. These allowed for sturdier ships on the East Asian and South China seas as well as a design that did not require regular or consistent nail placement⁵¹.

In stark contrast from the relatively open interchange in the Song and Yuan, the Ming dynasty (1368-1644) ordered a strict ban on coastal and ocean-going ships as a defense policy starting in 1371. “Unlicensed construction of large ships with two or more masts” was banned; officially, only single-masted fishing ships were allowed on the ocean⁵². The Ming court also restricted foreign trade to official delegations from other courts, often known as the “tribute system”⁵³.

The famous Zheng He voyages (1405-1433) should be seen as an expansion of both the tribute system and the sea ban: to project power abroad, police sea lanes, and invite rulers to pay tribute at his court⁵⁴. These fleets

Figure 5. Caulking tools c. 1930s. Rudolf Hommel, *China at Work*, 333. Courtesy of MIT University Press.



were certainly enormous, with commissions for at least 2,868 ships recorded⁵⁵. However, the sizes and numbers of ships must be reexamined in light of archeological evidence. The traditional dimensions ascribed to Zheng's "treasure ships" (*baochuan* 寶船), 44.4 by 18 *zhang* long (117-134 by 47-55 meters) are from Luo Maodeng's 1597 fantasy novel *Xiyang ji* (*Record of a Journey to the Western Oceans*), a fictionalization of the Zheng He missions. Archeological evidence does suggest the possibility of very large ships. A rudder found in 1962 at the Longjiang Shipyard was large enough to move a ship up to 600 feet,

but the excavated slipways of the Treasure Shipyard are too narrow for a ship of this size. Other large fleets did exist. Between 1370 and 1425, military goods and grain were delivered to the north by sea. In 1396 the emperor ordered at least 80,000 soldiers on at least 1000 ships to Liaodong in the Shandong peninsula, which was the largest sea-borne operation on Earth at the time⁵⁶. Ultimately Zheng He's voyages renewed trading partnerships that had existed for centuries, exhausted the empire's budget, and had no lasting imperial impact. When the fleets were decommissioned in 1433, the Ming was left without an

Figure 6. Ganzeng chuan ("drag-net" ship). *Minsheng shuishi ge biao zhen xie ying zhan shao chuanzhi tushuo*, c. 1730-1800. Staatsbibliothek zu Berlin, Preussischer Kulturbesitz, Orientabteilung, Libri sin. Hirth ms. 5.

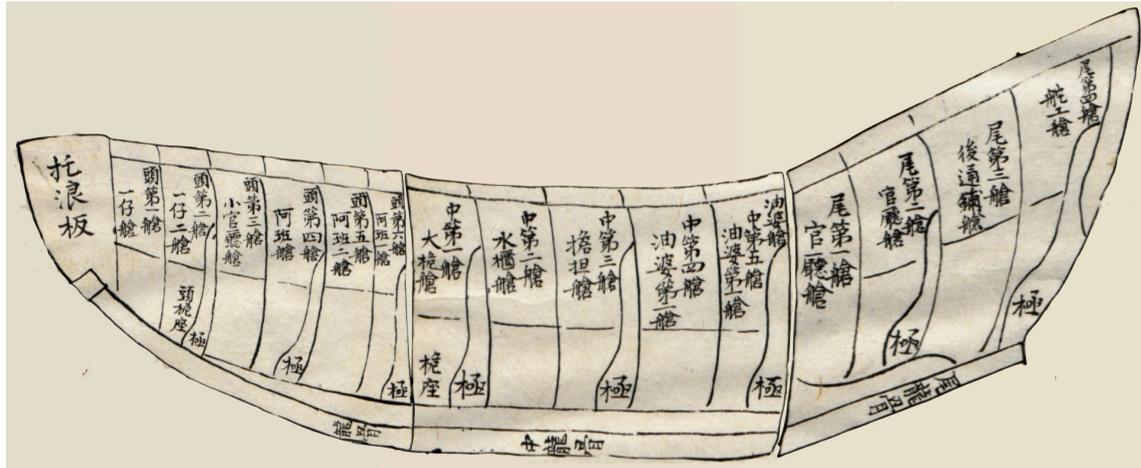


ocean-going navy, and the designs for these enormous ships appear to have been lost.

The decline of large naval fleets and the ban on overseas trade did not spell the end of innovations in Ming shipbuilding, but it did disadvantage them. Ma Huan, the chronicler of Zheng He's voyages, noted how during the Ming maritime bans, many Chinese expatriates fled from Fujian and Guangzhou to Majapahit where food was cheaper and shipping was intensive. Chinese merchants would maintain intercourse in goods there and later in Malacca⁵⁷. In this period, ships from Java and Malaysia dwarfed Chinese ships. According to the Portuguese traveler Tomé Pires in 1512 the Chinese had many hundreds of trading ships but one Javanese one "would rout twenty Chinese junks"⁵⁸. Nonetheless by the early 1500s, Chinese merchants had developed at least three distinct variations of large sailing ship, in blatant violation of the sea ban: heavy ironwood-hulled Guangdong ships (*Guang chuan* 廣船); V-keeled, fir-hulled Fujian ships (*Fu chuan* 福船); and flat-bottomed sand ships (*shachuan* 沙船) used to navigate the sandbars and islets at the mouth of the Yangzi⁵⁹. They also began to incorporate new designs from the Malay world, such as the *prahu* (Chinese: *balahu chuan* 叭喇唬船), a style of multi-oared ship valued for maneuverability when the wind was poor⁶⁰. In the 1550s, in response to the sea ban, the Ming suffered major raids by its own merchants. Ming forces were only able to defeat them in the late 1560s through improvements in military armaments and tactics and a relaxation of the sea ban⁶¹. To match the raiders' ships, imperial shipyards simply took the most maneuverable merchant ships—a mix of large Fujian ships, sand ships, and highly maneuverable oared vessels like the *prahu*—and added "Frankish" guns (*folang ji* 佛朗機), first seen on Portuguese ships in 1522. Within forty years, Chinese ship cannons mixed the best Western and Chinese features⁶².

From the mid-Ming onward, there is far less archeological evidence of shipbuilding, and comparatively more written records. These records focused far more on finance than on shipbuilding technique. The Ming tax system relied on fixed quotas, with each unit of tax directed

Figure 7. Internal structure of an official warship, with individual parts labeled. *Minsheng shuishi ge biao zhen xie ying zhan shao chuanzhi tushuo*, c. 1730-1800. Staatsbibliothek zu Berlin, Preussischer Kulturbesitz, Orientabteilung, Libri sin. Hirth ms. 5. Original modified to combine three diagrams.



towards a specific purpose⁶³. It was therefore poorly equipped to handle even minimal inflation, or to increase ship production in face of a military crisis. To deal with the growing cost of timber, the shipyards worked with nearby customs stations that collected tariffs on timber traffic along rivers to create standard sizes, grades, and prices for timber. They specified precisely how each plank fit into specific ship components⁶⁴. Shipyard manuals demonstrate multiple changes in the specifications of official ships, largely to economize on labor. The Longjiang yards near Nanjing changed standards at least four times—in 1503, 1539, 1551 and 1552—reducing the number of worker-days for a mid-size warship from 1000 to 872⁶⁵. Standards specified the size of boards, number of boards to cut from each log, and prices for logs of each grade of fir and nanmu, ranging from 0.004 taels per *zhang* for a 1.5 foot circumference fir log to 0.3355 taels per *zhang* for a 5.9 foot circumference nanmu log⁶⁶.

Standardizations helped develop the market in plantation-grown fir, which by the end of the Ming stretched across the mountainous regions of at least four provinces: Zhejiang, Jiangxi, Fujian, and the Southern Metropolitan Region (present-day Jiangsu and Anhui)⁶⁷. The shipyards also used nanmu derived from the system of

“timber tribute” originally developed to supply massive timbers for palace-building⁶⁸. But while prices were a constant concern, there is no indication of any major timber shortages through at least the 1550s. In 1552, a mid-size warship used just under 500 standard-sized nanmu poles compared to just under 130 poles of fir and 75 of pine⁶⁹. This suggests that there was still plenty of nanmu sourced from natural growth, which was preferred to fir due to both its superior size and quality.

■ QING DEVELOPMENTS IN SHIPBUILDING

Chinese shipbuilding went through a major transition during a wave of naval violence lasting from the 1620s to 1680s⁷⁰. By the late 1620s, Ming officials already began to suggest reviving restrictions on the shipbuilding industry to combat a rise in smuggling and piracy. With the Qing invasion of Beijing in 1644, one of the most powerful trader-smugglers of the southeast coast, Zheng Chenggong (aka Koxinga, 1624-62), brought hundreds of ships and hundreds of thousands of soldiers and sailors to support the Ming. To defeat him, the Qing pursued a policy comparable to the Ming sea ban, banning large ships in 1655⁷¹. This touched off a period of intense smuggling to

support the Zheng shipbuilding operation. One record from 1657 shows Lin Xingke, a merchant who was caught floating timber down Fujian rivers and hiding it in multiple villages for Zheng's shipwrights, along with iron nails, hemp, and tung oil⁷². At least some of these shipwrights operated at the Zheng base in the Zhoushan Archipelago⁷³. As the conflict intensified in the 1660s, so did the ban, with coastal evacuation edicts (*haiqian ling* 海遷令) ordering tens of thousands of residents to move inland, further denying the Zhengs access to shipbuilding materials and other supplies⁷⁴.

It is unclear whether the coastal evacuation did anything to prevent Zheng from obtaining timber. Fir plantations were widespread, and Zheng had a substantial clandestine trading network. Closing off one source did little to prevent obtaining wood from another. In 1662, Zheng seized Taiwan from the Dutch East India Company as a base of operations⁷⁵. His forces controlled their own source of timber on Taiwan, most reliably camphor and bamboo, but large timber probably still came from elsewhere. Nonetheless, as late as 1676, a Qing captain described the Zheng navy as "uncountable, we only saw masts like a forest"⁷⁶. After a brief relaxation, the evacuation policy was reinstated in 1679, this time with a wall running the length of the Fujian coast⁷⁷. It was only in 1683, with a fleet commanded by former Zheng captain Shi Lang, that the Qing were able to defeat the Zheng fleets and take control of Taiwan⁷⁸. The sea ban was lifted in 1684.

To fight Zheng, the Qing navy borrowed the ships used by smugglers fisherfolk along the southeast coast. The two most notable styles to come out of the Qing-Zheng wars were the "drag-net" ship (*ganzeng chuan* 趕纜船) probably derived from a Fujianese fishing trawler; and the "dual-sail" ship (*shuangpeng chuan* 雙篷船 or *ju chuan* 艍船) a ship developed in Zhejiang and used by both smugglers and anti-smuggler patrols. Both were integrated into the Qing navy as standard warship designs⁷⁹. Chinese warships also incorporated more European elements, rivaling Dutch ships in size and armament by the eighteenth century⁸⁰.

After the Qing-Zheng war, both official and private shipbuilding went through further modifications to meet government regulations. In the official shipyards, the first

half of the eighteenth century marked a period of expansion and consolidation, and the second half saw the beginnings of retrenchment⁸¹. Following ad hoc shipbuilding orders in the previous period, in 1725, formal military shipyards were established along the coast at multiple sites in Guangdong, Fujian, Zhejiang, Jiangnan (later Jiangsu), and Shandong⁸². Ten thousand government workers in Jiangnan, the most studied region, repaired and recycled a tenth of the navy's warships and grain ships each year⁸³. The wages for government shipbuilders were fixed at similar wages to soldiers⁸⁴. By the 1740s, the shipyards began to feel timber shortages, as attested by edicts prohibiting shipyard requisitions from disturbing people's livelihoods⁸⁵. The trend at official shipyards was toward economies in use of materials and labor.

In addition to ship dimensions, the Qing standardized timber to control prices and supply. Imperial regulations established standard dimensions for twelve different grades of both the "drag-net" and "dual-sail" ships⁸⁶. The materials and processes for making each of several dozen components for each of these ships are listed with a precision not seen in earlier records. The regulations for building a grade 10 drag-net ship, the most common ship in the fleet, lists construction materials as follows:

The ship's hull uses pine ribs along a single keel divided into three sections, the foreship section is 2 *zhang* long, the midship section joins it with a beam 3.5 *zhang* long, the aft section is 1.5 *zhang* long, totaling 7 *zhang*, uniformly 1 *chi* (~ 30 cm) wide and 8 *cun* (~ 24 cm) thick.... It requires one shipwright to connect these beams in two places. In each place, eight nails are used for each *chi* of length. Along the side, twelve nails are used for each six *chi* of length. In total, it should use:

- Pine boards 1 *chi* wide and 8 *cun* thick, totaling 7.06 *zhang* (further notes detail the loss to sawing)
- 16 1-*chi* (~30 cm) nails
- 24 6-*cun* (~15 cm) nails
- 12.6 shipwright worker-days⁸⁷.

Another text provides diagrams of both drag-net and dual-sail ships and many of their individual components (see Figure 7). These details allowed officials greater scrutiny over their subordinates, even without first-hand experience with shipbuilding. They also reflect the importance of the timber in each component.

For private shipbuilders, the 1680s through the early 1800s was the era of open oceans and free trade. In 1684, customs stations (*haiguan* 海關) were erected at several ports, and opened to trade in 1685 but this did not mean the end to shipyard regulations⁸⁸. By 1703, fishing ships were restricted to a single mast and a beam-width (*liang-tou* 梁頭) of no more than one *zhang* (approximately three meters)⁸⁹. In 1707 a separate decree allowed Fujian transports up to two masts and a somewhat greater size of 1.8 *zhang* beam (approximately five meters), allowing for the need to transport goods to Taiwan. In 1714, this decree was extended to Guangdong⁹⁰. Merchant ships grew longer to maximize storage space under the restrictions on width, while preserving as much maneuverability as possible. Even ships built in Southeast Asia followed the Qing guidelines as much as possible so that they could be registered as domestic traders. Yet size restrictions did not stop shipbuilders from finding loopholes and bribing officials to look the other way. In the early 1800s, nearly all merchant ships conscripted to fight pirates were wider than 1.8 *zhang*, with some up to 2.95 *zhang* (~9 m); the largest reported ship of this era was 3.72 *zhang* (~11 m) wide, while a ship excavated in 1971 was thirteen meters wide, over twice the officially mandated width⁹¹.

A key innovation of this period was the new licensing system for shipbuilding. To obtain a license to build a boat, village heads had to produce a bond of collective responsibility to cover all sailors on board that was stamped with the magistrate's seal. Upon completion of the ship, the bond was examined, and only then was the license to sail granted⁹². Ships were also painted with the name of their owner, serial number, and their home port, a practice confirmed by excavated ships from this era⁹³. After learning of a shipyard constructing hundreds of ships for foreign buyers, the Kangxi emperor ordered a

prohibition on Chinese ships sailing to Southeast Asia in 1717⁹⁴. Shipbuilding restrictions loosened slowly, as emperors devolved responsibility to merchant shipbuilding magnates after the 1750s⁹⁵. Private shipyards operated under relatively free trade, but had to follow restrictions on dimensions and licensing.

■ THE TIMBER SUPPLY

Even as regulations standardized the size of ships and their components, the high demand for timber threatened the supply of certain key tree species. Prior to 1700, the cost of timber was a constant complaint, but the *availability* of wood remained relatively assured. This changed markedly in the eighteenth century. Nanmu, previously a major component of official ships, became increasingly hard to obtain. Ironwood, used for rudders and planking, became downright rare. The Qing even created institutions to manage the supply of camphor in Taiwan to obtain a secondary building material. Official shipyards responded with renewed attempts to economize. Private shipyards, which faced fewer restrictions in terms of their locations or sources of materials, began to import large volumes of timber from Southeast Asia, or to relocate to present-day Vietnam, Thailand, Malaysia, and Indonesia. By the late eighteenth century, Chinese junks were a major industry in Southern Vietnam while Chinese merchants who had transplanted their lives and commercial operations to the Malay Peninsula made up between 15 and 30% of all traders there⁹⁶.

Fir remained the dominant shipbuilding material throughout this period. Grown on largely private plantations, fir was shipped through customs stations along the river and as such, taxed. Nanmu, the preferred shipbuilding timber during the Ming, was cut from natural forests rather than plantations but taxed as well. Fairly complete figures detail revenues derived from these timber customs⁹⁷. Quotas for riverine customs stations more than doubled between 1753 and 1799, suggesting an increase in traffic⁹⁸. Meng Zhang estimates that between 1725 and 1850, an annual average of 5.2 million logs passed through Longjiang customs in Nanjing, with reaching

more than six to seven million in the best years. In the 1880s, 18 million logs passed through the nearby Wuhu customs, which had a somewhat smaller catchment⁹⁹.

A key development that expanded the timber supply was the opening of markets and plantations in the west. The Qing collected timber tribute from the western provinces of Sichuan, Guizhou, and Hunan, an institution inherited from the Ming. However, the Qing “tribute” was actually an elaborate system of official purchase. Competition drove prices for the largest logs well above the official budgets, so timber officials were allowed to conduct private timber trade alongside state business, and effectively asked to subsidize official purchases from their personal profits¹⁰⁰. Large nanmu cut for tribute was increasingly scarce by 1700, and the nanmu supply was now dominated by market logging¹⁰¹. By the late eighteenth century the annual timber tribute quota of 7400 logs per year was probably less than one percent of timber harvested in the west, although the tribute remained an important source of the largest timbers¹⁰².

As natural forests declined, foresters in the former timber tribute regions developed their own fir plantations. In the early 1700s, the Qing warred against the fiercely independent groups of the Miao frontier in Hunan and Guizhou. To prevent further violence between Han and Miao after these wars ended, regulations required merchants to purchase timber through Miao intermediaries. Miao brokers used these agreements to defend their market position well into the nineteenth century¹⁰³. Hunan and Guizhou, along with newly opened plantations in neighboring regions, added significantly to the Yangzi River timber, reaching perhaps 5-15% percent of its total volume¹⁰⁴. By 1800, much of this was plantation-grown fir, although there was still a significant volume of “free-floating” timber (*qingliu* 清流) of various species.

As fir plantations gradually replaced old-growth logging in the west, southern ironwood was nearly extirpated from China entirely. Before 1500, ironwood had been plentiful enough that in Guangdong it was not only used for rudders, but even for ships’ hulls. Ming gazetteers report ironwood available across much of central and western Guangdong, but by the Qing it was in

decline. In the early 1600s, one county reported “lots of ironwood,” but by 1700, only “a little ironwood is found on Mount Dadangwan, but there is none that fills an arm span; if you want larger materials, they can only be found in Guangxi.” Other counties simply claimed “there is no longer any ironwood,” or “ironwood is now rare”¹⁰⁵. More was imported from Southeast Asia. In 1629, officials went to Vietnam to buy just two poles, noting that ironwood was unavailable in Guangdong and Guangxi¹⁰⁶. In 1663, officials were only able to find it on a Dutch ship coming from Southeast Asia¹⁰⁷. In the early 1700s, officials were again dispatched to Vietnam to buy ironwood¹⁰⁸. In the late 1750s, Peter Osbeck reported that Chinese anchors were still made of ironwood, but Guangdong’s famous ironwood hulls had switched to “Saaomock” (i.e. fir)¹⁰⁹. In the twentieth century, shipbuilders used *litchi* or camphor for rudders; in present-day Guangxi, traditional shipbuilders use imported teak¹¹⁰. In 2007, the compilers of *Flora of China* considered ironwood (*Mesua ferrea*) unlikely to be native to southern China¹¹¹.

Meanwhile, in Taiwan, another set of institutions developed to control the camphor supply. In 1725, forty-two years after the Qing conquest of the island, the Qing established the first permanent shipyards in Taiwan. These offices reflected the peculiar conditions at another ethnic frontier. Following an uprising in 1722, the Qing erected 514 stones separating Han and indigenous territory and banned Han logging and settlement east of the line¹¹². With indigenous territory inaccessible, Taiwan did not have enough timber to provide its shipyards and struggled with borderland conflicts. Fir, pine, and iron nails were all imported from the mainland. The one timber with substantial accessible growth on the island was camphor – a secondary shipbuilding timber – but to get it the government had to allow logging east of the Han-Indigenous frontier. The solution was to establish another office, the military works foreman (*jungong jiangshou* 軍工匠首), with exclusive logging rights east of the line¹¹³.

As in the west, providing timber to the state was a money-losing proposition. Not only did the military works foremen supply camphor below market price, they also had to pay an additional fee to the shipyards. To make

this position sustainable, the court allowed official procurers to profit from the sideline trade in forest products. Camphor could be boiled and refined into medicinal crystals. The foremen monopolized this trade¹¹⁴. As one retrospective from 1865 noted, “all the camphor timber produced in [this region] is purchased by the...[military] materials office. Therefore, each furnace household that boils camphor in the mountains of the interior is also controlled by the materials office. For several decades [c. 1825-65], the sale of camphor hearts has been completely controlled by the materials office, and it covers the traces of the outlaws who boil camphor”¹¹⁵. The “outlaws”—Han squatters and “native-born children” (*tusheng zai* 土生子), the offspring of mixed Han-Indigenous couples—were important in securing indigenous permission to log. But they also “lured ‘raw savages’ (*shengfan* 生番, i.e. unacculturated indigenous people) into getting drunk and going out at night and doing great harm to the people [i.e. raiding]. Yet for the state’s shipbuilding the military needs timber, which only grows in the ‘raw savage’ territory. They need to use ‘native-born children’ as guides to get it. This is the one benefit among the hundred harms of the native-born children”¹¹⁶.

The military works foremen also became key middlemen in the Han settlement of eastern Taiwanese lands. Foremen could take up to sixty of their own workers to log the forests east of the Han-Indigenous line. Settlers could also buy “reclamation permits” (*ken zhao* 墾照) allowing them to clear land east of the line, but any trees they cut could only be sold through the military works offices¹¹⁷. The foreman’s unique position in the supply chain allowed them to act as officially licensed brokers in a lawless borderland. To obtain a relatively small amount of a secondary shipbuilding timber, the Qing enabled a large and powerful monopoly on forest products that operated across the Han-Indigenous divide and in the gray area between licit and illicit behavior. Yet despite its abuses, Taiwanese camphor operations were less destructive to forests than ironwood logging. Chen Kuotung’s careful reconstruction suggests that while camphor forests in the middle of the island were overharvested in the late 1760s and 70s, and conflicts over logging rights in the northeast continued in the early 1820s, the depletion of Tai-

wan’s camphor forests was largely the product of the post-1860 era¹¹⁸.

In short, Qing logging depleted large nanmu in the west, ironwood in the far south, and camphor from Taiwan, trees that were only imperfectly replaced by plantation-grown conifers. But how much of this impact can we attribute specifically to the shipyards? Christine Moll-Murata provides a very wide range of estimates the number of large sailing ships in the nineteenth or early twentieth centuries, from 200 thousand to over one million¹¹⁹. Meng Zhang’s estimates for the timber supply is likewise a wide range from 6 to 18 million poles in the Yangzi River market alone¹²⁰. Therefore, any attempt to gauge the shipyards’ impact gives a very wide range that reflects prior assumptions as much as real data¹²¹. Nonetheless, whatever the effect of shipbuilding in general, the demand for specific ship components was a leading cause of the decline of certain trees. Shipyards were a major force behind the process of incorporating forests in new regions into networks of exploitation. Demand for shipbuilding timber led officials to modify existing institutions, and occasionally create new institutions that opened colonization of the southwest and Taiwan. In both cases, the shipyards represented only a fraction of the demand for wood, yet they provided a key justification for the exploitation of the forest.

■ THE NINETEENTH CENTURY AND THE DECLINE OF THE JUNK

The symbolic end of traditional Chinese shipbuilding came during the first Opium War (1839-42) when the British ironclad *Nemesis* trounced Chinese ships at Canton. This was just after the removal of shipbuilding regulations in 1818 which may have allowed greater innovations, but too late for the Qing navy to respond to new European battleships¹²². Nonetheless less than a decade later on March 27, 1848, a massive 165 foot (50 meter) junk, the *Keying*, arrived in Britain on a goodwill mission patronized by Hong Kong businessmen. She was intended to be a museum piece that presented the pinnacle of an ancient technology. The ship was at least fifty years old, purchased illegally, purposed for short range commercial

travel, and filled with random Chinese artifacts to amuse British biases. Still for over fifteen months, it had made the lengthy trip from Hong Kong to London without leaking: the first junk ever to make such a long journey, much further than any of Zheng He's voyages. Yet by 1855 it was left to rot on a beach near Liverpool. Chinese vessels had been interesting to Westerners during the Opium War, but they were no longer a matter to be concerned with²³.

After 1850, Chinese sailors easily transferred to Western "iron planked" ships to make better money. The Self-Strengthening Movement (c. 1861-95) strove to replace all Chinese shipping with better Western-style ironclad steamships to forestall the existential crisis to China as a sovereign force in the world. In December 1874, Li Hongzhang, a leader of the movement, suggested that all war junk construction be discontinued. By the 1894 Sino-Japanese War, only small private junks remained²⁴. Junks were still in use through the 1970s as cargo transports immune to foreign financial controls, as quaint passenger ferries, and as houseboats for fisher folk and some Western enthusiasts. However, the maritime technology that sustained and grew China's economy for a millennium was obsolete. Today, the craft of junk shipbuilding is nearly extinct.

■ CONCLUSION

Chinese sailing ships-junks-were based around several shared technologies, namely keel-up construction, watertight compartments, and batten sails. Beyond this, junks varied enormously depending on their uses, the waters they traversed, the materials used in their construction, and their incorporation of shipbuilding techniques from various parts of China, Korea, Southeast Asia, and Europe. The basic form of the junk was fully mature by the time the Qing dynasty was established in China in 1644. Nonetheless, shipbuilders continued to evolve their designs in response to novel pressures.

Chinese shipbuilding in the late Ming and early Qing eras had the capacity to produce junks for private maritime trade in numbers that dwarfed the Western presence in eastern maritime waters and overtook the previous

dominance of South and Southeast Asian vessels. Yet as the Qing failed to promote their own maritime trade, their shipping concerns became similarly obsolete and became overtaken by Western shipping by the nineteenth century²⁵. The arrival of ironclad steamships signaled the beginning of the end of the junk in the face of a technology that was not as easily grafted onto its ever-flexible design, nor as easily incorporated into existing institutions.

Prior to the Qing, there is little evidence that timber scarcity impacted shipbuilding practices. In the Qing, however, junk evolution responded to rising prices and declining availability of certain tree species. For the official shipyards, the priority was to meet fixed shipbuilding quotas in the face of rising prices. The result was an emphasis on efficiency, standardization, and price controls, rather than on technological innovation. At these tasks, the Qing's official shipyards were successful, standardizing a range of parts and dominating the market for certain preferred timber species - notably ironwood, China fir, nanmu, and (in Taiwan) camphor. In the southwest and Taiwan, the Qing military established institutions of logging and timber purchase that spearheaded colonization of non-Han regions.

For private shipbuilders, potential profits were offset by strict regulations on the size and outfitting of ships even after the strictest "sea bans" were lifted in 1684. The result was innovation within specifications that restricted the width and number of masts. In the early 1800s, these restrictions were also lifted, but by then Chinese shipbuilding had already evolved toward long, narrow, navigable ships rather than working to build the best-performing ships overall. Nonetheless, private innovations outpaced official ones, and the Qing navy repeatedly borrowed ship designs from merchants, smugglers, and deep-sea fishing fleets. As shipbuilding timber grew in price and scarcity within China, a significant proportion of private shipbuilding simply moved to Southeast Asia.

The ships themselves increased their capabilities as well. In the twelfth and thirteenth centuries, sturdier ocean-worthy hulls were adapted from Southeast Asian, Korean, and Japanese templates. In the sixteenth century, European cannons were added to improved merchant ships and *prahu* from the Malay world. In the

seventeenth and eighteenth centuries, builders added idiosyncratic bulkhead schemes and other features useful for commodity trading in the South China sea. In the nineteenth, standing rigging and capstans were added, as well as more modern navigation technology. Finally, in the twentieth century, junks featured motors to maneuver and travel against the current¹²⁶. But without the pressure of major wars, designs remained the same for almost the entire eighteenth century, leaving Chinese warships several generations behind the European competitors—and even behind private shipbuilding in China itself.

Ultimately, the junk deserves a reappraisal, both in comparison to European shipbuilding and in its context in China. Compared to European ships, the junk held its own as both a warship and transport well into the Qing, an era that many commentators have argued signaled its stagnation and demise. Within China, the importance of these varied and numerous ships can hardly be overstated: without them, China's fishing, overseas trade, commuting and internal shipment of vital materials like grain, salt, and timber would have been impossible. Without more detailed figures, we cannot conclusively determine what proportion of China's timber supply was claimed by its shipyards. Nonetheless, the impact of shipbuilding on China's forests was clearly significant, especially on species such as nanmu and ironwood. China's formal expansion to the southwest and Taiwan, and its informal expansion to Southeast Asia, was keyed in part by the need for shipbuilding timber. While guided by different institutions and priorities, this paralleled early modern European colonialism driven in part by the search for new timber supplies.

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■ NOTES

1 Watson, *Transport in Transition*, 4.

2 Unger, ed., *Shipping and Economic Growth*, 3-4 and Unger, *The Ship in the Medieval Economy, 600-1600*, 18-28; Brook, "Communications and Commerce," 579.

3 Magalhães, *A New History of China*, 129, 131.

4 Song, *T'ien-kung k'ai Wu*, 171, 185.

5 Ides, *Three Years Travels*, 163n1, 163-164.

6 Xu Yang, *Prosperous Suzhou, 1759*, Liaoning Provincial Museum, Shenyang, https://commons.wikimedia.org/wiki/File:Prosperous_Suzhou.jpg (accessed June 1, 2022); Ding Ding et al., "The Evolution of the Living Environment in Suzhou in the Ming and Qing Dynasties Based on Historical Paintings" *Journal of Computer Culture and Heritage* 14:2, Article 20, <https://doi.org/10.1145/3430700> (accessed June 1, 2022).

7 Hommel, *China At Work*, 330.

8 Blaut noted it is often forgotten that Asian and African empires had complex and robust infrastructures to produce the commodities that they traded. Blaut, *The Colonizer's Model of the World*, 169-172.

9 Worcester, *Junks and Sampans*, 30.

10 China fir is not a true fir (*Abies* sp.) but a distant relative in the cypress family (*Cupressaceae*). Like other trees such as Douglass fir (*Pseudotsuga menziesii*) or Riga fir (*Pinus sylvestris*), its common name expresses its morphological similarity to *Abies*. Throughout this article, fir refers to *Cunninhamia*.

11 Pierre-Yves Manguin, "Trading Ships of the South China Sea," 204.

12 Smyth, *Mast and Sail*, 401.

13 Gould and Foster, *Junks*, 51.

14 Kimura, *Archaeology of East Asian Shipbuilding*, 130-177.

15 Kimura, *Archaeology of East Asian Shipbuilding*, 4; Maitland, *Setting Sails*, 61. Master shipwrights are a dying breed. In 2009 UNESCO reported on the last three in Fujian who made a junk called the *Princess Taiping* that successfully reached San Francisco. Their techniques had been passed down for generations, but in a world where their craft was obsolete, they supported

themselves by making ship models. Huang, "Watertight-bulkhead technology of Chinese junks." G. R. G. Worcester and Louis Aude-mard are the most comprehensive compilers of late Qing era Junks, itemized by region. One of the first were Admiral Edmond Pâris (published in 1843) and contributors to British *Chinese Repository* journal (1832-1851).

16 Gould and Foster, *Junks*, 2-7.

17 Smyth, *Mast and Sail*, 407.

18 Osamu, *Books and Boats*, 256-7.

19 Worcester, *Junks and Sampans*, 57-86.

20 Song, *T'ien-kung k'ai Wu*, 175.

21 Flecker, "The South-China-Sea Tradition: the Hybrid Hulls of South-East Asia", *International Journal of Nautical Archaeology* 36.1 (2007): 82.

22 Worcester, *Junks and Sampans*, 30.

23 Gould and Foster, *Junks*, 15-16.

24 Needham, et al. *Civil Engineering and Nautics*, 409.

25 Needham, et al. *Civil Engineering and Nautics*, 382, 402-3. Some examples are the Japanese scroll paintings in the eighteenth century *Tōsen No Zu*, held in the Matsura Historical Museum.

26 See Li, *Jiangnan de zaoqi gongyehua*.

27 Hommel, *China At Work*, 224-259.

28 Needham, et al. *Civil Engineering and Nautics*, 413.

29 *Baochuanchang yi zhi*, Black and White Plates XIII-XV.

30 Hommel, *China At Work*, 255-7.

31 Xi, ed, *Illustrated Shipbuilding History*, 138.

32 Song, *T'ien-kung k'ai Wu*, 202.

33 Gong et al., "Ancient putty."

34 Gould and Foster, *Junks*, 32.

35 Hommel, *China At Work*, 22.

36 Song, *T'ien-kung k'ai Wu*, 176; Hommel, *China At Work*, 334.

37 Worcester, *Junks and Sampans*, 57-86; Kimura, *Archaeology of Shipbuilding*, 98.

38 Xi, *Illustrated Shipbuilding History*, 68-69.

39 Worcester, *Junks and Sampans*, 118-119, 123.

40 Rudolf P. Hommel, *China At Work*, 334; Rieth, *Voiliers et Pirogues*, 86.

41 Kimura, *Shipwreck ASIA*, 26.

42 Xi, *Illustrated Shipbuilding History*, 31.

43 Chaffee, *Muslim Merchants of Premodern China*; Sen, *Buddhism, Diplomacy, and Trade*; So, *Prosperity, Region, and Institutions*; Schottenhammer, "China's Emergence as a Maritime Power."

- 44 Kimura, *Archaeology of East Asian Shipbuilding*, 50-52.
- 45 Manguin, "Trading Ships of the South China Sea," 269-272.
- 46 Kimura, *Archaeology of East Asian Shipbuilding*, 79-80.
- 47 Kimura, *Archaeology of East Asian Shipbuilding*, 79-80.
- 48 Jeremy Green and Nick Burningham, "The Ship from Quanzhou, Fujian Province, People's Republic of China," *International Journal of Nautical Archaeology* 27.4 (1998): 277-301; Needham, et al. *Civil Engineering and Nautics*, 431.
- 49 Xi, *Illustrated Shipbuilding History*, 82.
- 50 Edson, *The World Map*, 85-86; Worcester, *Junks and Sampans*, 18; Abraham Cresques, *Catalan Atlas*, 1375, Bibliothèque Nationale de France, https://commons.wikimedia.org/wiki/File:1375_Atlas_Catalan_Abraham_Cresques.jpg (accessed June 1, 2022).
- 51 Kimura, *Archaeology of East Asian Shipbuilding*, 110-136.
- 52 *Ming lü jijie fuli* 15b.
- 53 Brook, "Communications and Commerce," 615; Nakajima, "Ming Tribute Trade System;" Hamashita, *China, East Asia and the Global Economy*, Chapter 2; Lim, "Haijin to kaihai," 6-8.
- 54 Of the voluminous literature on Zheng He, the most valuable is Dryer, *Zheng He*.
- 55 Dreyer, *Zheng He*, 116-17.
- 56 There is limited textual or pictorial evidence. Despite umpteen popular illustrations, no contemporary image of Zheng He's ships exist. Song, *T'ien-kung k'ai Wu*, 172, 186n2; Dreyer, *Zheng He*, 102-6; Kimura, ed. *Shipwreck ASIA*, 33-36. The ships dwindled in number in later periods. Guang, *Rupture, Evolution, and Continuity*, 22-3, 155-159; Li, *The Ming Maritime Policy in Transition*, 169.
- 57 Ma Huan, *Ying-yai sheng-lan. 'The overall survey of the ocean's shores' [1433]*, trans. by J. V. G. Mills (London: Hakluyt Society, 1970), 89, 93; Anthony Reid, *Charting the Shape of Early Modern Southeast Asia* (Chiang Mai, Thailand: Silkworm Books, 1999), 71.
- 58 Tomé Pires, *The Suma Oriental of Tomé Pires*, trans. by Armando Cortesão (London: Hakluyt Society, 1944), 122-3
- 59 Tan, *Linghai fanying*, 18-19, 25-26.
- 60 Tan, *Linghai fanying*, 35-6. "Balahu chuan," *Wubei zhi* 116.
- 61 Geiss, "The Chia Ching Reign," 490; Chonlaworn, "Rebel with a Cause," 189; Lim, "From haijin to kaihai": 1-5, 14-22; Andrade and Hang, *Sea Rovers, Silver, and Samurai*, 8-9; Sim, *The Maritime Defense of China*.
- 62 Andrade, *The Gunpowder Age*, 141-3.
- 63 Huang, *Taxation and Governmental Finance*.
- 64 See Miller, *Fir and Empire*, Chapters 5-6.
- 65 "Quotas" (*zhi'e*), *Longjiang chuanchang zhi*, 2.
- 66 "Wood prices," (*mujia*), *Longjiang changchang zhi*, 5.7a-8a. Fir was only listed from 1.5 to 3.4 feet circumference and nanmu from 3 to 5.9 feet. In the range where they overlap, nanmu was roughly twice as expensive as fir.
- 67 Miller, *Fir and Empire*, Chapter 2.
- 68 Miller, *Fir and Empire*, Chapter 7.
- 69 "Quotas" (*zhi'e*), *Longjiang chuanchang zhi*, 2.
- 70 Antony, *Like Froth Floating on the Sea; Andrade and Hang, Sea Rovers, Silver, and Samurai*.
- 71 Yang, "Government Registration," 37.
- 72 *Zhengshi shiliao xubian* 5.198, 226.
- 73 We have a rare list of twenty-one names. *Zhengshi shiliao xubian* 5.212.
- 74 Hang, *Conflict and Commerce*, 160.
- 75 See Andrade, *Lost Colony*.
- 76 *Zhengshi shiliao sanbian* 40.
- 77 Hang, *Conflict and Commerce*, 169, 218.
- 78 See Hang, *Conflict and Commerce*.
- 79 Tan, *Linghai fanying*, 76-82. "Shipbuilding administration" [*chuanzheng*], *Qinding Da Qing huidian zeli* 135. Fishing trawlers were noted as early as the mid-1500s, in groups of 8-10. Tan, *Linghai fanying*, 47.
- 80 Marshall, "Western Arms in Maritime Asia," 52-55.
- 81 Moll-Murata, *State and Crafts*, 134-5.
- 82 "Shipbuilding administration" [*chuanzheng*], *Qinding Da Qing huidian zeli* 135
- 83 See Li, *Jiangnan de zaoqi gongyehua*.
- 84 Moll-Murata, *State and Crafts*, 188-9.
- 85 *Qinding Da Qing huidian zeli* 135.
- 86 *Qinding Fujiansheng waihai zhanchuan zeli*. Tan Yuhua dates this text to 1688 and Christine Moll-Murata to 1769. The latter is correct.
- 87 Worker days were likely twelve hours. *Qinding Fujiansheng waihai zhanchuan zeli* 11.1a-2a; Sally K. Church, "Nanjing's Longjiang Shipyard Treatise and our knowledge of Ming ships," 46.
- 88 Schottenhammer, "Characteristics of Qing Maritime Trade Policies," 126 and *passim*.
- 89 Tan, *Linghai fanying*, 83; *Qinding Da Qing huidian zeli* v. 629 entry for "haijin."
- 90 Yang, "Government Registration," 38-41.
- 91 Tan, *Linghai fanying*, 88.
- 92 Yang Peina, "Government Registration," 39.

- 93 Tan, *Linghai fanying*, 88.
- 94 Schottenhammer, "Characteristics," 108. Citing *Qing Shengzu shilu* 270.14b-16a.
- 95 Moll-Murata, *State and Crafts*, 170.
- 96 Geoff Wade and James K. Chin, eds., *China and Southeast Asia: Historical Interactions* (New York: Routledge, 2019), 7, 245-8.
- 97 Zhang, *Timber and Forestry*, Chapter 2
- 98 Zhang, *Timber and Forestry*, 51, Table 2.1
- 99 Zhang, *Timber and Forestry*, 58, 184.
- 100 Zhang, *Timber and Forestry*, Chapter 1.
- 101 Miller, *Fir and Empire*, Chapter 7.
- 102 Chen customs in Hunan had a quota of approximately 780 thousand logs, 15% of the Longjiang quota of around 5.2 million. Figures from Zhang, *Timber and Forestry*, 51, 58, 184.
- 103 See Zhang, "Frontier Timber;" Zhang, *Mucai zhi liudong*.
- 104 Three western stations received ~5-7.5% of total tariff revenue. If we assume that downstream customs derived only 50% of revenue from timber, western customs account for ~12-15% of timber revenue. Figures from Zhang, *Timber and Forestry*, 51, Table 2.1.
- 105 Huang and Zhong, "Ming-Qing Guangdong zhenxi shuzhong," 11. Our translation.
- 106 Tan, *Linghai fanying*, 148.
- 107 Zhang Xueli, *Shi liuqiu ji*; See also Tan, *Linghai fanying* 148.
- 108 "Sea ships" [*haichuan*], in Huang Shujing, *Taihai shichai lu* 1. See also Tan, *Linghai fanying*, 148.
- 109 Osbeck, *Voyage to China and the East Indies*, 196. Tan Yuhua (148) incorrectly interprets "saaomock" as *shaomu* 梢木 which may refer to *Dipterocarps*. E. Bretschneider makes clear that Osbeck's *saaomock* was *sha-muk*, the Cantonese pronunciation of *shanmu* 杉木 - i.e. *Cunninghamia*. See Bretschneider, "Early European Researches into the Flora of China," 90, 109.
- 110 Tan, *Linghai fanying*, 148-9.
- 111 Wu et al, *Flora of China*, 38.
- 112 The boundary was completed in 1761, by which point much land to the east was already cultivated by Han settlers and acculturated indigenous people. A second line was established further east in 1790, designating the region between as a zone of acculturation. Chen, "Jungong jiangshou," 126-7.
- 113 Chen, "Jungong jiangshou," 129-32.
- 114 Chen, "Jungong jiangshou," 130-133, 147.
- 115 "Camphor management" (*zhang li*), *Danshui tingzhi* 4. Wikisource.
- 116 Tang Zangun, "Native-born children" (*tusheng zai*), *Taiyang jianwen lu* 2.
- 117 Chen, "Jungong jiangshou," 130-32.
- 118 Chen, "Jungong jiangshou," 135-146.
- 119 Moll-Murata, *State and Crafts*, 16.
- 120 Zhang, *Timber and Forestry*, 58, 184.
- 121 A very rough estimate: if these ships were replaced every ten years and required an average of 20 poles of timber to replace (<10% of the largest ships), this would require 400 thousand to 2 million poles per year. At an average of 50 poles/ship, the figure reaches 1 to 5 million poles.
- 122 Moll-Murata, *State and Crafts*, 116; Tan, *Linghai fanying*, 89.
- 123 *The Standard* (London), May 19, 1848, 3; Davies, *East Sails West*, 17-57.
- 124 Chu and Lu, *Li Hung-chang and China's Early Modernization*, 57, 60, 65, 198.
- 125 Geoff Wade and James K. Chin, eds., *China and Southeast Asia: Historical Interactions* (New York: Routledge, 2019), 235; Yang Hanqiu, "The Rise and Fall of the Sino-Western and Trading Forces from the 15th to 17th Centuries" (*Lishi Yanjiu* 歷史研究 5 1982): 93-105.
- 126 Flecker, 82; Gould, 66; Matsuura Akira, "The Activities of Chinese Junks on East Asian Seas from the Seventeenth to the Nineteenth Centuries: Mainly Based on Sand Junks and Bird Junks," *Mariner's Mirror* 94 (January 2008): 150-159.