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# AMERICAN SHIPBUILDERS IN THE HEYDAY OF SAIL: ENTREPRENEURS AND THE STATE

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## Introduction

Today, when people conjure up images of the American economy in the nineteenth century, those which come most readily to mind are probably things such as cowboys, cattle barons, Conestoga wagon trains, the transcontinental railroad, the California Gold Rush, the waves of European immigrants, an increasing employment of petroleum and electricity as energy sources, rapid industrialization in the East, and the great farming "breadbasket" of the West. What is so often overlooked is the fact that beginning about 1815, and throughout the remainder of the century, the United States was, with Great Britain, one of the two dominant *seafaring* nations of the world. Indeed, from the mid- 1840s, perhaps even the mid-1830s, until about 1860, this nation could fairly boast of having the best ship designers and builders and the finest and fastest ships that could be found anywhere. Furthermore, although American supremacy on the seas and in the shipyards did decline in the post-Civil War decades, shipping and shipbuilding remained important industries throughout the nineteenth century. If the automobile has been the most influential industrial artifact since about 1930, and if the railroad train dominated the period from 1870 to 1930, then it must not be forgotten that the (wooden) sailing ship in large measure symbolized this Republic from 1789 until about 1870.

The purpose of this essay is to revisit the American shipbuilding industry during that heyday of the sailing ship and to identify some of the reasons (1) why and to what extent American shipbuilders first succeeded and (2) why and to what extent they later retreated from the forefront. This topic is not merely economic in nature. To do it justice, one needs to understand not just economic principles and the general course of economic history. One also needs to be familiar with the technical issues of sailing ship design, construction, and performance. The author meets those criteria, since he is not only a professional economist, but also has long studied maritime history as well as being formally trained in the principles of naval architecture and yacht design.[1] As will be discussed later, the fact that some writers in this field have not possessed such a diversity of knowledge may have led them to certain errors or misunderstandings.

## The Importance of Timber

Throughout the world until the 1860s the overwhelming majority of ocean-going, "square-rigged"[2] sailing vessels were built of wood. Even for the British, the leaders in iron construction, it was not until 1870 that the total tonnage of iron vessels built during the year exceeded that of wooden vessels (Greenhill 1993, 85). Apparently, only twelve square-rigged ships were *ever* built of either iron or steel in the United States (Lubbock 1980, 144, 148-49, 161, 192, 195-96, 203-4). In Germany five were built of iron between 1844 and 1861, with more constructed after 1875; in Holland a mere handful were built in the 1860s (MacGregor 1993a, 21).

One might wonder just how much timber was necessary to construct an ocean-going ship. Bluntly put, as ship sizes increased, it took huge amounts to achieve the necessary structural strength, particularly in the longitudinal dimension (see Crothers 1997 for illustrations). Because a ship was most buoyant "amidships", or in the middle, and least buoyant at the bow and stern, it would sag at the ends, or "hog", if there were insufficient rigidity. And the size of ships did increase dramatically through the first half of the nineteenth century. For example, (1) the *America* was built at Salem, Massachusetts in 1804 and was 114 feet long and measured 331 tons; (2) the *Sheridan* was built at New York in 1836 and measured 157.5 feet in length and 895 tons; (3) the *Sovereign of the Seas* was built at East Boston in 1852 and measured 237.5 feet in length and 2421 tons.

At the upper extreme of wooden shipbuilding one finds the *Great Republic*, built by Donald McKay at East Boston in 1853, which was 335 feet long and measured 4555 tons as built[3]—by a small margin the largest wooden merchant sailing ship ever constructed and by far the largest true clipper ship. This vessel had a keel that consisted of two tiers of wood, each 16 inches by 32 inches in cross-section and over 300 feet long. Her frames varied in cross-section from 15 inches by 22 inches to 8 inches by 11 inches, and her external planking was from 6 to 10 inches thick. Moreover, she had four masts, the tallest of which towered 200 feet above her upper deck. All in all, she required 1,500,000 feet of hard pine, 2056 tons of white oak, 336.5 tons of iron, 56 tons of copper (not including the copper sheathing for that portion of her hull below the waterline), and 50,000 worker-days of labor (Bradlee 1927, 10-13, 19).

The principal species of timber used in such American ships were white oak, live oak, Northern white pine, Southern pitch-pine, hackmatack (or larch), rock maple, and elm (MacGregor 1993a, 25; Hutchins 1941, 78-82). The frames, stem, sternpost, and keel, the key components of the hull structure, were usually white oak, with the hull planking, deck planking, masts, and spars of pine (or, later, of either Baltic fir or Douglas fir). White oak was the pre-eminent shipbuilding wood because it was (a) strong due to its density, 56 pounds per cubic foot versus 35 pounds per cubic foot for white pine (Hall 1882, 249), (b) resistant both to dry rot and to the teredo worms which attacked wooden hulls, and (c) held fastenings very securely. Live oak was even more dense than white oak, at 76 pounds per cubic foot, and did not contain tannic acid—as did white oak—so it did not corrode iron fastenings. Nevertheless, it was used rather little for merchant ships because of its limited availability and substantial expense.[4] British practice, insofar as wooden construction is concerned, differed only in emphasis. First of all, British builders preferred the white oak that grew in southeastern England. In fact, even some Americans agreed that this was superior to the American white oak (Hutchins 1941, 84). Secondly, because the British had access to the forests of the Indian subcontinent, many of the best-quality British vessels were built using teak, which is probably the finest of all shipbuilding woods, being incredibly durable.[5]

Considering the enormous quantities of wood needed to build a large ship, it comes as no surprise that shipbuilding activity was accompanied by a steady but dramatic depletion of the existing forests. Initially, much of the reduction in American forests was due to the British demand for timber. The British desire for both a dominant navy and a large merchant marine fleet had begun seriously to diminish their native forests as early as the seventeenth century. Also, it should not be overlooked that government regulation played a part in this process. That is, since the Corn Laws maintained artificially high prices for many British agricultural products, there was a strong incentive for landowners to clear their land and devote the acreage to farming rather than maintaining the long- standing forests. In 1608, a survey of the Royal Forests of Britain found there to be the equivalent of 234,000 wagon-loads of white oak of a size large enough to be of use in shipbuilding. By 1783, the estimate had declined to only 50,000 wagon-loads (Hutchins 1941, 135).[6] Understandably, the British turned to their American colonies. In 1609 the first shipments of American timber bound for Britain left Virginia. Shipments from New England began in 1634. By 1729, timber of a species, quality, and size appropriate for the construction of ships was placed on the list of "enumerated articles" that American colonists could export *only* to Great Britain (Hutchins 1941, 143).

Of course, after 1783, Americans were not compelled to send timber abroad. And yet, much American timber was sold in Europe despite the growing domestic demand. It is ironic that many of the most renowned British vessels were built using considerable quantities of American timber. For example, the very prominent and esteemed Scottish firm of Alexander Stephen & Sons "extensively" utilized American oak around 1810 (Alexander Stephen & Sons 1932, 15). The legendary British tea clippers *Thermopylae*, built in 1868 by Walter Hood of Aberdeen, and *Ariel*, built in 1865 by Robert Steele of Greenock, were both composed partly of American rock elm (MacGregor 1983, 152, 190). And many British vessels had masts and spars made from American white pine or Douglas fir.

The combined foreign and domestic demand severely diminished American forests. By 1860, in the northeastern states—where all the most important shipyards were to be found—only Maine and the interior of New Hampshire still had large stands of white oak and white pine (Hutchins 1941, 277). The primary effect was twofold. Some structural components that had always been oak began to be made of rock elm, rock maple, or hackmatack. Even some decidedly inferior woods like birch and chestnut were employed. Furthermore, the price of white oak rose considerably. In New York, for example, the price of oak timber in the period 1845-1855 increased somewhere between 29% and 42% (Morrison 1909, 153). Secondarily, this and other factors brought about a noteworthy geographical change. In the 1840s, New York; Boston; Baltimore; Philadelphia; Medford, Massachusetts; Mystic, Connecticut; and Portsmouth, New Hampshire were all centers of shipbuilding activity. By the 1870s, large square-rigged sailing ships in any numbers were being produced only at Portsmouth, New Hampshire and in Maine, the latter production being located along the Kennebec River. The last such ship built at New York, for instance, was the *Charles H. Marshall* in 1869 (Dunbaugh and Thomas 1989, 231); the last built at Portsmouth was the *Paul Jones* in 1877 (Brighton 1989, 345); the last built at Mystic was the *Dauntless* in 1869 (Peterson 1989, 177). After about 1880, with a handful of exceptions, Maine alone produced such vessels.

## Shipbuilding Costs

The rising price of shipbuilding timber naturally leads one to inquire as to the total cost of building a ship and to the proportion of total cost represented by the various inputs. Addressing the second issue first, one might consider the ship *Harvest* of 646 tons that was built in Kennebunkport, Maine in the year 1857. She was probably typical of the many vessels of modest size and average quality then being built in Maine.

> *Costs*
> Labor: $9,486 (37.9%)
> Timber for hull and spars: $10,735 (42.9%)
> Iron fastenings, nails, and castings: $1,963 (7.9 %)
> Oakum (used for caulking seams between planks) and paint: $1,652 (6.6%)
> Equipment and tools: $774 (3.1%)
> Miscellaneous: $391 (1.6%)
> *Total Costs: $25,001 (or $38.70 per ton)*
> (does not include suit of sails or copper sheathing for the hull)

If one looks at the cost per ton of this good little ship *Harvest*, which, even including sails and copper sheathing, would probably not exceed $50, and compare it with the much higher contemporaneous prices of many British-built ships, then one is likely to conclude that American shipyards possessed a large cost advantage. And that presumed low-cost advantage is precisely to what some maritime historians have ascribed much of the market success of American shipyards. There are, however, several problems with that train of thought. First of all, *labor* usually represented 30%-50% of the total construction cost (see above example), and wage rates in American shipyards were often almost *twice* those of British shipyards (Hutchins 1941, 297).[7] Thus, at least in terms of labor costs, American shipbuilders may not have had an advantage. Second, when converting British prices in pounds-sterling into American dollars, one should use the actual, or market, exchange rate rather than the official rate. Otherwise, cost comparisons will be biased.

Third, most sailing ships (particularly in the United States) were what today would be called "one-off" designs, that is, rarely were any two ships identical. Even consecutive ships from the same builder's yard might vary significantly with regard to their potential performance under sail, their size, rig, elegance of furnishings, and fitness for a given trade, even though the style and general method of construction would be similar. In modern terminology, sailing ships were relatively *heterogeneous* capital goods, and any comparative analysis should, as far as possible, group vessels by the quality of their design and/or construction. Finally, it is imperative that comparisons in prices per ton be made using *comparable tonnage measurement rules*.

The last point requires some explanation.[8] First of all, merchant ship tonnage was meant to be a measure of cargo carrying capacity, not a measure of the weight of sea water actually displaced by the hull, which is how naval vessels were and are measured. In 1773 the British adopted a tonnage rule that measured only the length and breadth of the hull. If L = length in feet and B = breadth in feet, then tonnage equaled: $0.5[(L - 0.6 B)(B^2)]/94$. The British referred to this as "Old Measurement" tons. This was used in Britain until 1836 when the "New Measurement" rule, which measured several dimensions of the hull instead of just length and breadth, replaced it. That, in turn, was superseded in 1854 by the so-called Moorsom rule. With some modifications, this last remains in effect today. Americans used the "Old Measurement" system (except that the divisor used was 95 instead of 94) from 1789 until 1864, when the Moorsom rule was introduced in the United States.

These facts are significant because a ship's tonnage could vary greatly depending upon which measurement rule is used. A swift vessel that rated, say, 1000 tons under the Old Measurement rule, might only be rated at 750-800 tons using the Moorsom system.[9] Consequently, figures for costs per "ton" are quite sensitive to the tonnage rule used.

## Comparative Costs per Ton

The table on this page is a list of 25 American and 27 British ships in chronological order. The basic criterion for selection was that the vessel should have been reputed to be of the highest quality, either with respect to her design and performance and/or her quality of construction. Indeed, the list below includes a number of the most famous sailing ships ever built by the most renowned shipwrights in these two countries. Exchange rates were taken to be $4.566 per pound-sterling up until 1834 and $4.8665 per pound-sterling after that date (Hepburn 1968, 42, 280). For ships listed prior to 1860, both American and British, the tonnage shown is according to the Old Measurement rule. For 1860 and later dates, for both American and British ships, the tonnage shown is according to the Moorsom rule. The symbol (w)

| **American** | **British** |
|---|---|
| 1839, *Roscius*(w), 1009 tons, @$99 | 1840, *Lord Western*(w), 530 tons, @$67 |
| 1845, *Henry Clay*(w), 1207 tons, @$75 | 1845, *Acasta*(w), 327 tons, @$58 |
| 1849, *Oriental*(w), 1003 tons, @$70 | 1847, *North Star*(w), 430 tons, @$88 |
| | 1848, *Reindeer*(w), 328 tons, @$50 |
| | |
| 1850, *White Squall*(w), 1119 tons, @$80 | 1851, *Chrysolite*(w), 570 tons, @$88 |
| 1851, *Challenge*(w), 2006 tons, @$75 | 1853, *Cairngorm*(w), 1246 tons, @$68 |
| 1853, *Young America*(w), 1961 tons, @$71 | 1853, *Hurricane*(i), 1110 tons, @$75 |
| 1853, *Great Republic*(w), 4555 tons, @$66 | 1855, *Schomberg*(w), 2492 tons, @$68 |
| 1853, *Red Jacket*(w), 2305 tons, @$63 | 1856, *Robin Hood*(w), 1166 tons, @$88 |
| 1854, *Lightning*(w), 2084 tons, @$70 | |
| 1854, *Sunny South*(w), 776 tons, @$90 | |
| | |
| 1864, *Mindoro*(w), 1065 tons, @$116 | 1860, *Clyde*(i), 1150 tons, @$88 |
| 1865, *Seminole*(w), 1442 tons, @$87 | 1863, *Black Prince*(c), 751 tons, @$90 |
| 1866, *United States*(w), 1246 tons, @$80 | 1866, *Sobraon*(c), 2131 tons, @$95 |
| 1868, *Highlander*(w), 1352 tons, @$74 | 1866, *Titania*(c), 879 tons, @$88 |
| 1869, *Dauntless*(w), 995 tons, @$84 | 1869, *Cutty Sark*(c), 921 tons, @$83 |
| | 1869, *Patriarch*(i), 1339 tons, @$87 |
| | |
| 1873, *Frank Jones*(w),1453 tons, @$83 | 1870, *Lufra*(c), 704 tons, @$69 |
| 1874, *Western Shore*(w),1178 tons,@$68 | 1873, *British Ambassador*(i), 1794 tons, @$114 |
| 1875, *Continental*(w), 1712 tons, @$65 | 1874, *Calypso*(i), 1061 tons, @$88 |
| 1875, *Brown Brothers*(w), 1420 tons, @$77 | 1874, *Avalanche*(i), 1210 tons, @$80 |
| 1876, *South American*(w), 1694 tons, @$77 | 1875, *Ullock*(i), 815 tons, @$85 |
| | |
| 1882, *St. Frances*(w), 1898 tons, @$56 | 1882, *Port Jackson*(i), 2132 tons, @$66 |
| 1884, *John Rosenfeld*(w), 2268 tons, @$62 | 1882, *Grassendale*(i), 1842 tons, @$62 |
| 1884, *Henry B. Hyde*(w), 2462 tons, @$53 | 1884, *British Isles*(s), 2394 tons, @$102 |
| | 1889, *Ulidia*(i), 2405 tons, @$46 |
| | |
| 1890, *Shenandoah*(w), 3258 tons, @$54 | 1891, *Dalgonar*(s), 2665 tons, @$43 |
| 1892, *Roanoke*(w), 3347 tons, @$52 | 1893, *Bermuda*(s), 2846 tons, @$44 |
| | 1894, *Riversdale*(s), 2206 tons, @$38 |

indicates wood construction, (c) indicates composite construction, that is, wooden planking over iron frames, (i) indicates iron construction, and (s) indicates steel construction. These data were culled from MacGregor (1983, 1988, 1993b), Lubbock (1973, 1975a, 1975b, 1976, 1980), Howe and Matthews (1967), Matthews (1987), Clark (1970), Brighton (1985, 1989), Peterson (1989), Cutler (1984), Stammers (1978), Walker (1986), Dunbaugh and Thomas (1989), and McKay (1969).

From the table, it would appear that American shipbuilders were the lower cost producers during the 1870s and 1880s; British shipbuilders were the lower cost producers prior to 1850 and during the

1890s; while costs per ton were about the same in the two nations during the 1850s and 1860s. Overall, across the six decades, the average for American builders was $73.88 per ton, and the average for the British was $74.74 per ton. Needless to say, averaging of this sort can be very questionable. And it is certainly true that the above are quite small samples, although little more than this may be possible due to the paucity of extant account books that involve such elite vessels. Nevertheless, a *cautious* conclusion may be hazarded: it seems that American ships did not rise to prominence in the world's maritime traffic because of some distinct cost advantage. If that is true, then *why did* American ships achieve such prestige in the antebellum period? Before offering an answer to that question, one must first provide, if only in brief and simplified form, some evidence of this American maritime success.

### Measures of Success

One obvious and commonly used measure of maritime activity is total national tonnage. In America's case, these numbers reveal a remarkable expansion. In 1774 the aggregate tonnage of shipping found on British registers was 600,000 tons, of which 210,000 tons had been built in the American colonies. After the Revolutionary War the art of shipbuilding prospered, as evidenced by the fact that in 1815 alone 155,579 tons were produced (Hutchins 1941, 155, 188). By 1830, the respective aggregate tonnages of existing vessels for the United States and Great Britain were 1,150,000 and 2,350,000 (MacGregor 1993a, 21). In addition to maintaining a large and growing fleet of domestically-owned ships, Americans built and sold 340,000 tons to a variety of foreign firms over the period from 1815 to 1840 (Hall 1880, 49). The halcyon days for the United States were the 1850s. American *sailing* tonnage increased from 2,900,000 in 1850 to 4,400,000 in 1860; while the comparable figures for the British were 3,400,000 and 4,200,000 ( Greenhill 1993, 84). Regarding such statistics, one must keep in mind that between 1855 and 1865 the rules for measuring ships in "tons" differed between the two countries. Therefore, for that span of time, tonnage figures were biased so as to overstate the size of the American fleet relative to that of the British.

Turning from a quantitative measure to qualitative ones, one cannot overlook the fact that a great many knowledgeable persons, in both the 19th and 20th centuries, have testified to the success and superiority of the American shipbuilders. For instance, it was widely recognized during the 1830s, 1840s, and 1850s that American-built "packet ships" in the trans-Atlantic emigrant trade were among the very finest in the world (Hutchins 1941, 260). And this was a harsh and demanding service in which "speed, weatherliness, durability, and finish....were the primary requirements" (Hutchins 1941, 214). Indeed, several of the most respected builders, such as William H. Webb, Donald McKay, George Raynes, and Samuel Hall, first rose to prominence because of the excellent packet ships they had constructed. These vessels exhibited a pleasing combination of speed, carrying capacity, and strength. Most of the later, more famous, clipper ships[10] evolved from this basic packet ship model (Chapelle 1967, 321-23).

A rather persuasive testimonial to the high contemporaneous esteem for American ships was the decision by two large Liverpool firms, Pilkington & Wilson's White Star Line and James Baines' Black Ball Line, to purchase or charter a number of the larger American vessels for employment in the emigrant trade to Australia and New Zealand (MacGregor 1993b, 117, 124, 148-53; Stammers 1978). Two of those ships, *James Baines* and *Champion of the Seas*, both built by Donald McKay at East Boston, were put on public display at Portsmouth, England in 1857. The evaluations reported in the British press were extremely positive:

> *They are equipped with the latest modern improvements... We have never had any ships in this harbor which have created such interest as these, for they have been visited by the best sailing and gunnery officers of the navy, and all have expressed their admiration and astonishment at their capacious stowage, airy and ample accommodations, and the unprecedented speed chronicled in their logs... For the transport or other service no better ships can be employed and the Thames must look to its laurels.* (quoted

in Stammers 1978, 169-72)

The topic of speed, at least as measured by a vessel's maximum velocity in nautical miles per hour (or "knots")[11], has probably received entirely too much attention.[12] The number of days it took to traverse some long trade route of, say, 15,000 miles, was a much better indicator of a swift vessel as well as being of much greater economic significance. It was often true that one ship whose top speed never exceeded 14 knots would take fewer days on such a passage than another ship which periodically attained 18 knots or more. The rapid transport of cargo or passengers from one port to another required that a ship maintain a high *average* speed under a great variety of wind and sea conditions. However measured, speed had concrete and significant economic value. A perfect example is offered by William G. Low, whose father was one of the partners in A. A. Low & Brothers, a New York firm that owned a fleet of superb clippers [13] that included *Samuel Russell*:

> *I remember Mr. James Banks Taylor, one of A. A. Low & Bros.' agents in China, saying that he had such confidence in the* Samuel Russell's *speed that he could afford, when the new crops of tea came into market, to let others pay the highest price for them, and he, three weeks later, buy them more cheaply, put them in the* Samuel Russell *and get them to New York first. She had the reputation, as I recall it, of being a great money-getter.* (Low 1922, 4)

Fast passages also gained ship-owners high freight rates when transporting someone else's goods as cargo. Once again using the China tea trade as an example, one finds that after *Oriental* arrived in Hong Kong in 1850 at the end of a record passage of 81 days from New York, she was handsomely rewarded by being able to load a tea cargo for London at a freight rate of $29.20 per ton, which was $10-$14 higher than that given any of the British tea clippers (Cutler 1984, 168-69). On her next China passage, *Oriental* received an even higher rate of $34.07 per ton. Similar preferential treatment for American ships was accorded *Surprise* in 1851, *Witch of the Wave* and *Challenge* in 1852 (Cutler 1984, 169-70), and *Swallow* in 1854 (MacGregor 1983, 82).

From the foregoing, one can see why it might plausibly be said that during the 1840s and 1850s the United States "became easily the unrivaled shipbuilding nation of the world" and that "by 1850 American yards were constructing vessels of a size and finish comparable to those of the best European-built ships, and in model and rig they were generally superior" (Hutchins 1941, 275, 289).

## An Hypothesis

If there was no clear *cost* advantage for American shipyards since the forests were fast disappearing and labor was priced higher than in Britain[14], then why were American ships so esteemed? This author suggests that the primary advantage was their superior design. One cannot deny that "material resources are important in any case, but ability to design, construct, and organize better than others has frequently meant the difference between competitive advantage and disadvantage. This was true in shipbuilding" (Hutchins 1941, 112). As Howard I. Chapelle, who was a practicing naval architect as well as an historian, has explained, the evolution of design in Great Britain followed a path distinctly different from that in the United States (Chapelle 1967, 368).

In order to convey the essence of this hypothesis while minimizing the number of possibly arcane and confusing details, one may think in terms of two concepts found in naval architecture: the Block Coefficient and the Prismatic Coefficient (see the Appendix). The former is a quantitative measure of the displacement of the hull relative to the "block" formed by the three dimensions of length, breadth, and depth and reflects the overall bulk of the immersed hull. The latter is a quantitative measure of the displacement of the hull relative to the "prism" formed by projecting the "midship section" through space for a distance equal to the ship's length (think of the midship section as the shape which would result from vertically cutting the hull at the midpoint of the hull's longitudinal axis) and reflects the degree of sharpness or "fineness" of the hull at bow and stern.

Fast sailing ships almost always possessed either a relatively high Block Coefficient and a relatively low Prismatic Coefficient, or the reverse. The first combination is illustrated by the "Hull of Higher Resistance" in the Appendix and employs (a) a rather full midship section with little "deadrise" (the midship section looks much like the letter "U") and (b) sharp ends at bow and stern that have considerable concavity. Furthermore, the hull is quite broad and deep relative to its length. This was the typical, but not universal, American style. The second design combination was the typical, but again not universal, British style. It is illustrated in the Appendix by the "Hull of Lower Resistance". Here the ship has (a) significant deadrise (the midship section has more of a "V" shape) and (b) sharp ends at bow and stern, but the waterlines are less concave, perhaps even convex.[15] The hull is rather narrow and shallow relative to its length.

The first produces a vessel that combines substantial carrying capacity with good speed, particularly in strong winds. The second produces a vessel with only modest carrying capacity and good speed in light and moderate winds. The first was well suited to the conditions of wind and sea usually found in the packet service, the Australian emigrant trade, and the American trade to California. The second was well suited to the British trade to China and India. Both designs can result in ships that make fast passages, but only the typical American approach also offers large cargo capacity.[16] Once these design elements are considered, it is no surprise that the American ships were highly valued by ship-owners.

One final point must be made regarding these design issues. It has been claimed by certain writers that the fast and successful American designs of the 1840s and 1850s were encouraged by a favorable tonnage measurement rule. As David R. MacGregor (1993b, 24) has explained, the opposite is the truth. The Old Measurement method used in the United States from 1789 until 1864 actually penalized ships with sharp lines relative to those with very full lines. That is, tonnage duties and port usage fees were based on a ship's official tonnage, but her revenue depended on the amount she could actually carry. Typically, a sharply-built ship of, say, 1000 tons (Old Measurement) might carry no more than 1000 tons of cargo, and often much less; while a full-built ship of 1000 tons might carry 1500 tons or more. Both paid the same fees and taxes, but the full-built ship usually produced much more revenue. These American ships were "designed in spite of unfavorable measurement" (MacGregor 1993b, 24).

## An American Tragedy

The decline of American shipbuilding cannot really be blamed on entrepreneurial foolishness, engineering errors, excessive caution, or a Luddite mentality. It is, rather, largely a tale of the harm done whenever the State intervenes in the market process. But before listing the primary acts of government predation, it is essential to recognize how great this decline actually was for the American maritime industries.

In 1827, of all the commerce of the United States, $145 million worth of goods were carried by American vessels and only $14 million worth carried by foreign vessels. By the year 1877, not only were most *imports* carried by foreign ships, but also 83% of American *exports* were similarly transported (Hall 1880, 9, 28). As for total *sailing* tonnage, in 1886 Great Britain led the world with 3.3 million tons (946,000 tons of which was wooden or composite). The United States had fallen from about 4 million tons in 1860 to only 1.6 million tons (essentially all of which was wooden, there being only one square-rigged vessel yet built of iron—*Tillie E. Starbuck* in 1883). Norway had 1.3 million tons and Germany possessed 800,000 tons (Ville 1993, 60-61). By 1910, steamships were utterly dominant, and Great Britain had more-or-less abandoned the idea of merchant sailing ships. In that year, the United States once again had the largest fleet of sail-driven ships: 1.1 million tons (most of which was still wooden), versus 750,000 tons for the British (only 63,000 tons were wooden or composite), 600,000 tons for Norway (175,000 tons were wooden), and 440,000 tons for France (72,000 tons were wooden) (MacGregor 1993a, 23). In only 50 years, the American sailing fleet had diminished by about 75%.

And it must not be supposed that this diminution occurred merely because sail could no longer compete with steam. It is true that by the late nineteenth century the mail, most passengers, and most cargoes that required rapid delivery were transported in steamships. However, bulk cargoes could still be carried profitably by sailing ships right up to 1900 and even somewhat beyond.[17] American ships that carried wheat or timber from the Pacific Northwest or nitrates from Chile survived, and sometimes even prospered. For example, the ship *David Crockett*, built in 1853, did very well for herself. "From 1853 to 1883 she never cost the insurance underwriters a penny, and up to 1876 she made a net profit of nearly $500,000 [about $20 million in today's dollars] over and above the cost of a complete refit and rebuilding in 1869" (Peterson 1989, 177).

### Steamships and Iron Ships

The appearance of the ocean-going steamship did not, contrary to popular belief, immediately drive sailing ships off the seas. It took 50-75 years for that to happen. One reason for that is the fact that steamships were usually far more expensive to build as well as to operate. For example, William H. Webb built two steamships in 1853, the *Knoxville* and the *San Francisco*, whose costs per ton were $161 and $154, respectively (Dunbaugh and Thomas 1989, 193, 195). In 1864 the steamer *General Grant* was built at a cost of $169 per ton (Brighton 1989, 286). Insofar as the American building of sailing ships is concerned, the pivotal event was not merely the appearance of steam, but the *introduction of iron construction*.

Hulls built of iron possessed significant advantages: greater strength, lighter weight, larger cargo capacity, lower repair costs, and increased safety, speed, and durability (Ville 1993, 53). Iron hulls were much less prone to leak than wooden ones. Unlike wooden ships, iron sailing ships seemed to last "forever" unless they were wrecked. "Indeed underwriters used to declare that with their thick, heavy plates and splendid riveting, the early iron ships *could not be worn out*" (emphasis added) (Lubbock 1975b, 257). Thus iron ships paid lower insurance premiums than did wooden ships. Although some repair jobs could not be accomplished at sea, it was nevertheless true that an iron hull with iron masts and spars and wire rigging also enjoyed lower overall maintenance costs. And above all, iron ships had greater stowage capacity than wooden ships of the same tonnage. For example, when an iron ship of 1000 tons (Moorsom measure) was compared to an oak-framed ship of the same tonnage as measured by the same rule, the iron ship had 14% greater capacity, which meant 14% more revenue (Greenhill 1993, 81). Iron—and then beginning in the 1880s, steel—construction helped enormously to keep the sailing ship competitive with steam.[18]

### Trade Protectionism

American shipbuilders did not reject iron based on some atavistic impulse. As a matter of fact, the first iron vessel built in the United States, the small steamer *Codorus*, appeared as early as 1825. Several other similar vessels were built for use on the Hudson and Savannah rivers between 1825 and 1845 (Hall 1880, 60). Americans were experimenting with iron as a shipbuilding material early in the nineteenth century and by the 1850s were not unfamiliar with its virtues. It was not ignorance, but protectionism, that kept American sailing ships from being built of iron. As early as 1816 the tariff on hammered bar iron was set at $0.45 per hundredweight, which was 20% of its price. As if this were not bad enough, the tariff was raised to $1.12 per hundredweight in 1828 (Hutchins 1941, 201). In 1830 the shipbuilders in Philadelphia complained to Congress that these iron tariffs added 19% to the $25,000 price of a 500-ton wooden ship (*Memorial of the Shipbuilders of Philadelphia* 1830, 2-3); while the tariff on hemp (used for rigging, of which there were literally miles in a sailing ship) added $720. The tariff on iron was 24% in 1857, 50% in 1861, and 112% in 1864! In that latter year, the legendary Boston builder Donald McKay offered the following estimate of the *additions* to total cost effected by the various tariffs:

> *Cost Additions*
> Iron fittings, nails, chain cables, anchors: $4,145
> Manila, hemp, cotton duck: $1,889
> Salt: $216 (salt was packed between the inner and outer planking to preserve the wood)
> Copper: $1261
> Canadian timber: $1,155
> *Total tariff burden: $8,666 (1000 ton ship)*
> (or an additional 12%-14% added to

> the price of a ship that would otherwise cost around $60,000 to $70,000)

Imagine what the cost of a ship constructed entirely of iron would be at a tariff rate of 112%. Given that the British were the prime source of iron plate at mid-century, the American tariff structure made iron construction prohibitively expensive. "[A]s the importance of iron and other protected articles in shipbuilding increased, and the advantage in timber prices diminished, the [tariff] burden increased until it became a major restrictive force" (Hutchins 1941, 126). Captain Arthur H. Clark, who was himself the commander of several well-known sailing ships, declared in 1910 that

> *the Protective Tariff so increases the cost of living and with it the cost of the labor and materials that... the American shipbuilder cannot produce a steel or iron vessel at anything like a cost that will enable her to compete successfully with a ship of the same class constructed in a European shipyard... the Navigation Laws and Protective Tariff are the millstones between which the American shipowner and ship-builder at present find themselves ground with an ever-receding prospect of escape.* (Clark 1970, 316-17).

## Other Factors

The discovery of petroleum and its many uses may not seem closely related to shipbuilding, but it was. The connecting link was the whaling industry. In 1830 the American whaling fleet totaled 40,000 tons. By 1858 it had grown to 200,000 tons. The building and repair of whaling ships alone kept a good number of American shipbuilders busy. After 1859, as whale oil was used less and less, the construction of such vessels naturally declined precipitously. This chain of events cannot, of course, be blamed entirely on government policies. However, in one sense this too is an example of government failure rather than market failure. The steady depletion of the whaling grounds had stimulated the search for alternative fuel sources. And that depletion was largely due to the absence of any clearly-defined property rights to harvest whales. Thus, the well-known "problem of the commons" as applied to whaling contributed to the decline of shipbuilding.

One event familiar to everyone that certainly had a profound effect on American shipping and shipbuilding was the Civil War. As usual in wartime, all parties to the conflict lost a lot. But perhaps no one lost more than those in the maritime industries. One must remember that most of the important shipping firms and shipbuilders were located in the North. And, despite periodic protestations to the contrary by some, the Southern tactic of attacking the North's merchant fleet on the high seas was very effective. The estimates of the North's shipping losses do vary, however. Hutchins (1941, 323) claims the Confederate commerce raiders destroyed 239 vessels for a total of 105,000 tons. Hearn (1992, xv, 311-317) lists 179 vessels, and 110,000 tons, destroyed. Another 800,000 tons of ships were sold abroad to escape destruction (Hearn 1992, xv). Even those merchants who lost none of their fleet still faced at least two serious problems due to the armed conflict. First of all, it was virtually impossible to obtain insurance on either one's ship or her cargo, and secondly, skilled workmen for the purposes of construction or repair were often extremely scarce because of the demands of the U.S. Navy (Brighton 1989, 269). Any way one tallies the score, American maritime activity suffered a devastating blow.

A secondary effect of the Civil War that is not often mentioned is its impact on the cotton trade. Prior to the war, scores of ships—almost all built in the North—kept busy transporting raw cotton from ports like New Orleans, Mobile, Savannah, and Charleston to textile mills in the North and in Britain. In 1859 alone, 3,535,373 bales were exported (Hutchins 1941, 264). After the devastation of the South, it took a decade or more for cotton exports to rise again to comparable levels. Thus ship-owners who had been involved in the trade were faced with greatly reduced demand for their services for a number of years.

## Conclusion

From a seafaring upstart in 1800, the young republic of the United States rose to challenge and even briefly to surpass the reigning queen of the seas—Great Britain. This was achieved primarily by means of what used to be called "Yankee ingenuity". That is, the key competitive advantage of American shipbuilders in the heyday of sail was not, as so often claimed, access to cheap and abundant resources, but rather their own genius for innovative design and sound construction.

Their triumph was fairly short-lived, however. In the 1840s and 1850s American ships were widely acknowledged to be the best in the world. By 1865, due mainly to the Civil War and the stifling effects of trade protectionism, American shipbuilding began a long, slow decline from which, in many ways, it has never recovered.

## Notes

(1) The author has nearly finished a manuscript on the performances and characteristics of some 900 nineteenth-century merchant sailing ships, is a member of the International Maritime Economic History Association, Mystic Seaport Museum, and the National Maritime Historical Society, and has received formal training from the Westlawn School of Yacht Design in Stamford, Connecticut.

(2) "Square-rigged" means a vessel rigged either as a "ship", with rectangular sails set on "yards" perpendicular to the longitudinal axis of the hull on all its three or more masts, or as a "bark" ("barque" to the British and French), which is rigged like a ship except that the aftermost mast—variously referred to as the "mizzen", "jigger", or "spanker" mast—has only fore-and-aft sails, that is, sails set parallel to the longitudinal axis.

(3) *Great Republic* fell victim to a fire while docked in New York before her first voyage and was rebuilt as a smaller vessel of 3357 tons (Old Measurement).

(4) Live oak was expensive to shipbuilders because it was heavy and thus costly to transport and because it grew only in certain coastal regions of the South far from the principal shipbuilding centers.

(5) The famous *Cutty Sark* (whose name means short skirt or chemise in Scottish), which is preserved today in dry-dock at Greenwich, England and was launched in November 1869, has survived in part because she was built with *teak* planking over iron frames (so- called composite construction).

(6) By 1886, near the end of the sailing ship era, only 5% of England and 4% of Scotland was still forested (Hutchins 1941, 135).

(7) On the other hand, some believed that the American shipyard workers were more efficient (a higher marginal product?), so it is possible that the American workers added less to average costs than did their British counterparts. In the absence of detailed data on productivity it is impossible to reach a firm conclusion.

(8) See MacGregor (1993b, 24; 1983, 32-33, 87-88; 1988, 271-73) for more details.

(9) The figures in the table on this page for some selected ships that were renowned for fast passages will give some idea of the contrast between the Old Measurement rule and the Moorsom rule.

| Name of Ship | Year | O.M. Tons | Moorsom | % Difference |
|---|---|---|---|---|
| **American Ships** | | | | |
| *Maury* | 1855 | 594 | 518 | 12.8 |
| *Sovereign of the Seas* | 1852 | 2421 | 1461 | 39.7 |
| *Blue Jacket* | 1854 | 1790 | 1403 | 21.6 |
| *Defiance* | 1852 | 2026 | 1695 | 16.3 |
| *Ino* | 1851 | 895 | 673 | 24.8 |
| *Golden Gate* | 1851 | 1349 | 945 | 29.9 |
| *Flying Cloud* | 1851 | 1782 | 1098 | 38.4 |
| *Nightingale* | 1851 | 1060 | 722 | 31.9 |
| *Red Jacket* | 1853 | 2305 | 1597 | 30.7 |
| *Panama* | 1853 | 1139 | 867 | 23.9 |
| **British Ships** | | | | |
| *Robin Hood* | 1856 | 1166 | 853 | 26.8 |
| *Gauntlet* | 1853 | 784 | 667 | 14.9 |
| *Fiery Cross* | 1860 | 864 | 695 | 19.6 |

(10) The term "clipper ship" has always suffered from a certain degree of imprecision. In general, any sailing vessel that exhibited above-average speed was likely to be placed in this category. From the standpoint of naval architecture, clippers were vessels whose hulls were rather sleek

("sharp") and less burdensome than more conventional ships, so that potentially the wind could drive them through the sea at a high rate of speed. However, to what extent such speeds were actually achieved also depended on the skill of her commanding officer, the vessel's sail area, and the prevailing sea conditions.

(11) The nautical mile, or knot, equals 6080 feet as opposed to the land mile of 5280 feet. The highest speeds in knots ever attained by sailing ships appear to have been 22 knots by *Sovereign of the Seas* in 1854 and 21 knots by *James Baines* in 1856.

(12) A basic tenet of naval architecture is that speed is a function of the square root of a vessel's waterline length. Thus, one should compare not the absolute speeds of different ships, but what is called their "speed-to-length ratios", which is equal to the top speed of a ship divided by the square root of the ship's length along her designed waterline. Two of the highest speed-to-length ratios among cargo vessels were those of the American bark *Maury* and the American ship *Sovereign of the Seas*, both of which reached a ratio of 1.450.

(13) The Low fleet consisted of *N. B. Palmer*, *Houqua*, *Surprise*, *Maury*, *Contest*, *Jacob Bell*, *Oriental*, *Great Republic*, *David Brown*, *Golden State*, *Penguin*, *Benefactor*, and *Osaca* in addition to *Samuel Russell*. The offices of A. A. Low & Brothers are preserved today as part of the South Street Seaport Museum in New York.

(14) The further, and substantial, burden of import duties will be discussed later.

(15) To get a mental image of "waterlines" one may think of slicing a hull into several sections by cutting horizontally, that is, in a plane parallel to the level of the water. The outer edges of those sections are the waterlines.

(16) The clipper ships of the 1840s and 1850s have gotten most of the attention, but perhaps the perfect examples of this approach were the so-called "Down Easters" of the post-Civil War period. They were capable of passage times that rivaled the best achieved by the clippers, but were burdensome carriers that could produce excellent profits.

(17) See Kahre (1977) and Rohrbach, Piening, and Schmidt (1957) for details about how the Norwegian firm of Erikson and the German firm of Laeisz maintained profitable sailing fleets even into the 1920s and 1930s.

(18) There were two major problems that did arise in the early years of iron construction: (1) hulls were "highly susceptible to coatings of weeds and shells, particularly when traveling through tropical waters", which slowed the vessel considerably and (2) the "hammering and vibration experienced by a ship under construction was responsible for the development of a permanent and complex magnetic field", which made ships' compasses unreliable and brought about several disasters (Ville 1993, 56-57). However, by the 1860s solutions to both problems seem to have been found (Ville 1993, 57; Greenhill 1993, 76-77). Effective anti-fouling paints were developed to deal with the first problem, and to cope with the second, magnets were placed near the compass, which was housed in a deck fitting called the "binnacle", so as to negate the effects of the hull's magnetic field.

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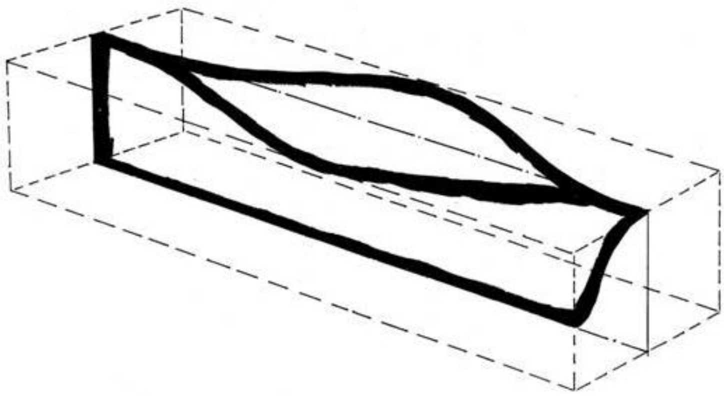
**Appendix**

(1) The Block Coefficient

(2) The Prismatic Coefficient

(3) Waterlines and Buttock-Bow Lines of Typical American Design (Best in High Winds)

(4) Waterlines and Buttock-Bow Lines of Typical British Design (Best in Moderate Winds)



"Block" formed by multiplying the breadth at the Designed Waterline by the Mean Draft by the Designed Waterline Length

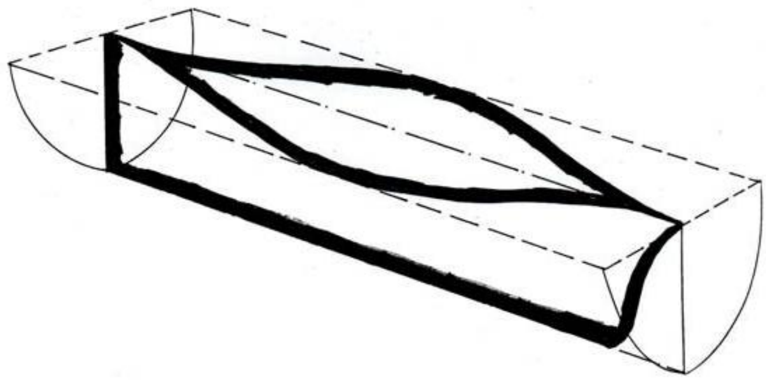
**Block Coefficient**

The Block Coefficient is the ratio of the displacement of the hull below the Designed Waterline to the displacement represented by the "block"

Illustration by the author

**(1) The Block Coefficient**

**(2) The Prismatic Coefficient**

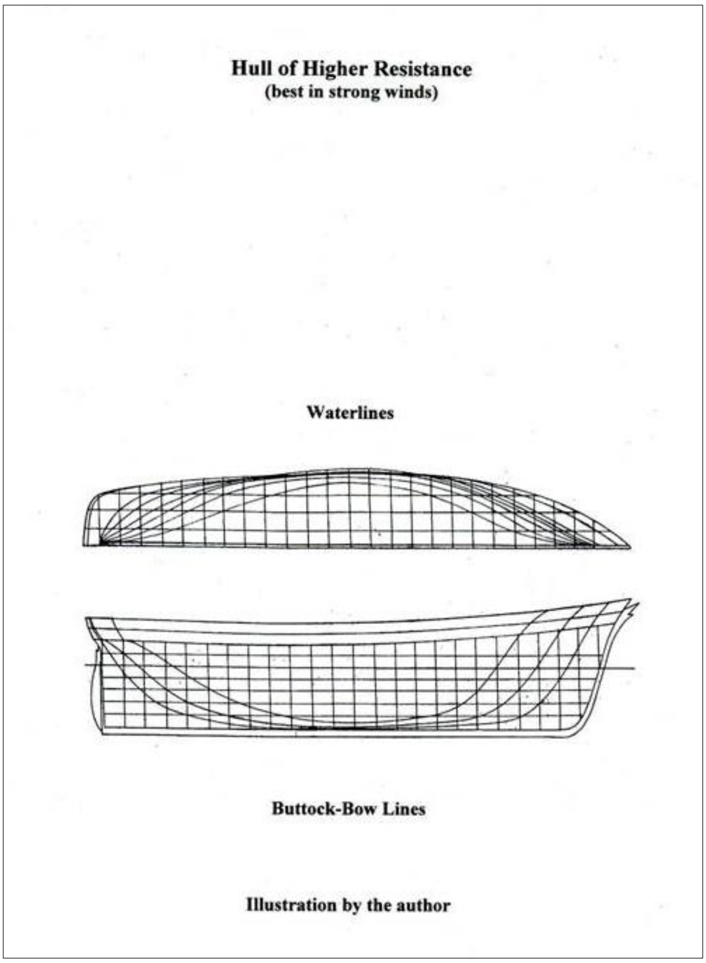


"Prism" formed by that portion of the Midship Section below the Designed Waterline multiplied by the Designed Waterline Length

**Prismatic Coefficient**

The Prismatic Coefficient is the ratio of the displacement of the hull below the Designed Waterline to the displacement represented by the "Prism"

Illustration by the author




**(3) Waterlines and Buttock-Bow Lines of Typical American Design (Best in High Winds)**

**(4) Waterlines and Buttock-Bow Lines of Typical British Design (Best in Moderate Winds)**