Productivity in Swedish merchant shipping, 1470-1820

Johan Söderberg

The ‘big bang’ of globalization and other research issues

There are few issues on which economic historians tend to disagree as much as the conditions of the emergence of the modern world market. One important aspect of this is the long-term trends in sea freight rates and the productivity of merchant shipping.

Some prominent researchers argue that freight rates were substantially reduced only after the introduction of steamship in transoceanic trade after 1820. Kevin O’Rourke and Jeffrey G. Williamson place this issue into a wider context as they maintain that this transition also marks the beginning of globalization. Only with this transport revolution could commodity prices converge worldwide. Before this revolution, long-distance trade was limited to expensive goods such as silk, silver, and exotic spices, which could bear high transport costs. In that world, transoceanic trade had an impact only on the living standards of the very rich who could afford such luxuries. With the steamship, regional markets with different prices melted together into a world market. As international freight rates collapsed, trade volumes increased, particularly in cheap and bulky goods.

According to these authors, globalization is a very modern phenomenon. Moreover, the ‘big bang’ of globalization (to use the expression of O’Rourke and Williamson) can be dated to a short and decisive period, the 1820s.¹

Other scholars have arrived at quite different conclusions from the available evidence. Douglass North has argued that freight rates in Atlantic shipping declined from about 1600 due to improved organization combined with the decline in piracy and privateering, allowing ships to reduce the cost of manpower and armament. Better security was the key to cheaper freights.²

North’s analysis has been questioned by C. Knick Harley. Harley dates the start of the long-term decline in transatlantic freight rates to about 1850, i.e. to an even later date than O’Rourke and Williamson. The decisive factor, according to Harley, was that the advances of the Industrial Revolution were applied to shipping with the introduction of metal hulls and steam propulsion. Harley interprets these results as affirming the primacy of mechanical invention.³

Some researchers observe an increased efficiency in shipping already during the medieval era. Peter Spufford notes that new ship types were developed during the fourteenth century, such as the Hanseatic cog and the carrack in the Mediterranean, which saved on

¹ O’Rourke and Williamson (2002).
² North (1968), pp. 959-960.
³ Harley (1988).
crews compared to previous types of vessels. The sailing ships of Venice, Genoa, and Barcelona grew in size and became cheaper to run. As a result, freight rates for grain and other bulk cargoes dropped. This made possible trade in bulk goods between the Mediterranean and north-western Europe.4

The cost of sea freights can also be related to the question whether or not there was any general tendency towards a relative price decline of knowledge-intensive goods in Europe in the medieval or early modern era. If prices of knowledge-intensive goods declined, this should have been an advantage to Europe gaining world economic dominance, and it may also have been part of creating the prerequisites of the Industrial Revolution. For instance, Hoffman (2006) reports that preliminary data from England, France, and Germany show that the relative price of artillery, handguns, and gunpowder declined between the 14th and the 18th century. Price data thus suggest a potential explanation for why the West developed a comparative advantage in violence over the rest of the world.5

Prices of long-distance sea freights are of great interest in this context as they depended on developments in shipbuilding, on access to information about supply and demand of various goods, as well as on the organization of trade at a high level. Seen from this perspective, the relative price of sea freights can be classified into a broader group of goods (i.e., iron, paper, and books), the production of which required comparatively large amounts of knowledge and capital.6

The seemingly innocent question of productivity in shipping thus turns out to have a bearing on at least three big research issues:

- The view of long-term economic growth as taking off during the Industrial Revolution of the nineteenth century, or the result of a much longer process which may have started already during the medieval era,
- The evolution of relative prices of knowledge-intensive goods and services and their role in the emergence of European economic dominance.
- The prerequisites and timing of globalization.

These issues are obviously important for our understanding of the economic history of the world. All of them can not be addressed in this article, though. Here, focus will be on the evolution of labour productivity in the long term, from about 1470 up to 1820. Two data sets are used. The first and largest one is based on merchant shipping data from Stockholm, while the second refers to the Swedish East India Company from the period 1732-1803.

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A few years ago I came across some sparse data suggesting that the cost of sea freights was falling during the late medieval era in Sweden. I was curious to know if this could be explained by the use of larger ships and asked Jan Glete for his opinion about this. He answered promptly, as always, in an e-mail of 12 January 2006, giving the following information (my translation):

6 Lindert et al (2004),
“I have not seen any research that can give any good clues as to the role of the evolution of ship sizes for transport costs in Swedish foreign trade. What we know is that cargo-ships were built increasingly larger during the late medieval era, and that the technological development of the rig made this possible. But technological progress improved smaller ships as well, and it is evident in a long term perspective that scale advantages in shipping were of rather limited importance until the breakthrough of steamships. Small vessels continued to be competitive, partly because they were more flexible and could bring small cargos to shallow ports, but partly because the advantages of scale were limited with sailing-ships.

Timber and equipment cost about as much for large and small ships, calculated per ton of cargo. The crew also must stand approximately in proportion to the size of the ship, since the handling of sails and anchors was done with muscle power. Some overhead costs could be reduced with a larger cargo, but I find it difficult to see any dramatic difference.

One reason why bigger ships could be cheaper was that they were less expensive to protect: a large crew was by itself a factor that served to discourage plundering, whereas smaller ships needed a larger crew (or sailing in convoys) to get protection. If heavy weapons were taken aboard for protection, larger ships had a considerable cost advantage relative to smaller vessels. Very small vessels, with little space below deck and with no room for superstructures, cannot have been well suited to long, uninterrupted voyages. The somewhat larger ships, on which the crew could sleep below deck or in a closed superstructure, had a considerable advantage here since they could sail continuously. But a carrying capacity of a few hundred tons was sufficient to accomplish that, and the major part of long-distance trade in Northern and Western Europe probably was carried out with such ships. In the Mediterranean very large ships (carracks) were built, but they were probably primarily designed to provide protection by means of hulls and large crews.

These are just a few thoughts on the matter. Much remains to be done here.”

Jan had an unusual ability to develop an independent point of view in a compact but lucid manner. This article is inspired by his historical vision. It summarizes some evidence on the scale advantages in shipping in Sweden before the advent of the steamship, and presents new results on the evolution of labour productivity in shipping on Stockholm trade as well as in the East Indian trade.

Ship size and cargo up to the mid-sixteenth century

The documentary evidence on Swedish merchant shipping during the medieval era is scanty. Most of the available information refers to cargos rather than to the maximum carrying capacity of the ships. But comparisons of actual loads may be quite as interesting from an economic point of view as data on ship measurements.

Carrying capacity as well as actual loads were expressed in lasts. The composition of cargo is usually not reported in the sources used for this study. A weighted average of three different lasts has been constructed: the iron/copper last, the salt last, and the grain last. This average composite last comprises 1.8 tons for the period 1470-1664 and 2.0 tons for the period 1665-1820 (see Appendix for details).

The Danzig toll books are among the best sources available for the extent and composition of Swedish foreign trade during the late fifteenth century. A total of 57 ships
arrived at Danzig from Stockholm in the three years 1474-1476.\textsuperscript{7} Their average cargo can be estimated at 10 tons per ship, or 11 tons if vessels without any cargo are excluded.\textsuperscript{8} These figures do not inform us about carrying capacity, but they do provide a strong hint that small vessels dominated this trade route.

A few years later, similar information is available for ships leaving Danzig for Stockholm, a total of 27 ships for the years 1490-1492. The average cargo was then higher, 17 tons.\textsuperscript{9} We do not know whether or not the increase since the mid-1470s was due to different mixes of Swedish ships versus presumably larger Hanseatic ships, to a real growth of cargos during the late fifteenth century, or if it can be explained by other factors. At any rate it seems clear that the average cargo was rather small, not exceeding 20 tons.\textsuperscript{10}

Other pieces of information point in the same direction. In a letter from 1507, the Mayor and Council of Stockholm reported that a ship of five lasts had arrived from Lübeck with a cargo of stone and sand. Four boatswains were aboard the vessel.\textsuperscript{11} Assuming that these men were the crew, this corresponds to the very low ton-per-man ratio of 2.25. In 1508, a clergyman in Finland reported that his ship of six lasts (11 tons) had been taken from him outside Tallinn. It carried a cargo of half a last of train oil and two lasts of rye.\textsuperscript{12} Even though this was a small ship, it did not carry a full cargo.

Sources become much richer a few decades later. In 1536, 21 ships arrived at Stockholm from Danzig with an average cargo of about 35 tons. The average cargo of Swedish ships leaving Stockholm was about 60 tons in 1549 as well as in 1560 (in the latter year, ships headed for Danzig carried an average cargo of 78 tons).\textsuperscript{13} These are much higher figures than those noted above for the Stockholm-Danzig trade in the late fifteenth century.

These data suggest a strong increase in actual cargos carried since the late fifteenth century. If we accept the average cargo of 11 tons per ship in the mid-1470s and the 1549 figure of 57 tons, annual growth amounts to an impressive 2.3 percent. Similar comparisons can be made for other points in time. As summarized in Table 1, the average growth rate between the late fifteenth and the late sixteenth century varies between 1.2 and 1.6 percent a year. This appears as an extremely dynamic period in the history of merchant shipping in Sweden.

The growth of cargos is of course linked to the construction of larger ships. In 1536, the biggest domestic ships in the Stockholm trade carried a cargo of 75 tons. This fell far short of the largest ships arriving at Stockholm from Hamburg and Danzig, out of which at least eight carried cargos from about 90 up to 180 tons in the same year. Already by 1549 the situation was quite different. The two largest domestic ships in the Stockholm trade now held a cargo of 575 and 285 tons, respectively, and there were several others exceeding 100 tons.\textsuperscript{14}

\textsuperscript{7} Lauffer (1893), p. 16.
\textsuperscript{8} For an earlier estimate for the year 1474 see Kumlien (1953), p. 275.
\textsuperscript{9} Lauffer (1893), p. 31.
\textsuperscript{10} Even though much larger vessels were used in the Baltic trade, it is clear that they were far from dominating the Stockholm-Danzig route. The ships in the salt trade on Tallinn, for instance, were almost invariably larger than 50 tons during the fifteenth century. Wolf (1986), p. 157; Meronen (2005), p. 112.
\textsuperscript{11} Svenskt Diplomatiums kartotek över medeltidsbrevren (SDhK) 35928. A messenger also was on board, but he is not reckoned as part of the crew in this calculation.
\textsuperscript{12} Diplomatium Fennicum, Finland's medeltidsurkunder, 5336.
\textsuperscript{13} Forssell (1875), pp. 40-42. The cargos reported here take into account that the ton measure used by Forssell corresponds to 0.884 metric tons. His data on average cargos refer to Swedish ships only. Since foreign ships were often larger than domestic vessels, this results in an underestimate of the average cargo in the trade on Stockholm taken as a whole.
\textsuperscript{14} Forssell (1875), p. 40-41.
ability to build large domestic ships had improved much, partly by recruiting skilled shipwrights from abroad. In a few years around the mid-sixteenth century, seven or eight large carriers of around 300 to 600 tons, most of them defensively armed merchantmen, were built at various shipyards in the country. Sweden also purchased ships from Lübeck and the Netherlands, and they could of course be copied.¹⁵

The development of shipbuilding capacity in Sweden is in turn related to the emerging consolidation of state power. King Gustavus Vasa (1523-1560) has been characterized by Jan Glete as “an innovative fiscal-military entrepreneur”.¹⁶ He held a keen interest in strengthening the navy as well as the merchant fleet. In the course of his reign, the Baltic Sea was for the first time cleared of pirates as the Swedish and Danish navies, competing with each other, managed to uphold a maritime monopoly of violence. This pacification meant that the Scandinavian kings, in Jan Glete’s formulation, were selling protection of shipping in the Baltic Sea for customs duties. The Danish king officially raised the Sound Toll on the ground that it financed his protection of foreign shipping. The Swedish leadership also wanted to bring about more competition among merchants which would lead to lower import prices.¹⁷

For some years in the 1580s, the average size of cargo on ships leaving Stockholm for Danzig has been estimated by Kjell Kumlien at 43 tons (24 lasts), whereas shiploads on the Stockholm-Lübeck route were larger with an average of 63 tons. Kumlien adds important information as he states that the average manpower of a ship comprised six men on both routes.¹⁸ This makes it possible to calculate ton-per-man ratios, which turn out to be 7.2 on the Danzig route and 10.5 on the ships headed for Lübeck. In an international perspective, these are high figures for the period. Labour productivity was clearly higher in the Stockholm trade than in the English merchant fleet, where it was only about five in the 1580s, and similar to the ships of German Hanseatic towns around 1600.¹⁹

The relationship between average size of cargo and maximum carrying capacity is not known. For the mid-sixteenth century, however, geographer Nils Friberg has carried out a thorough study of shipping in Stockholm. He assumes that cargo comprised 80 percent of the carrying capacity on ships in domestic trade arriving at Stockholm from northern Sweden or Finland. He argues that a traditional ship type was commonly used by peasant-traders in sailing from the Finnish province of Österbotten to Stockholm. This type of ship required a crew of five men when crossing the Bothnian Gulf and had a capacity of 11-16 tons.²⁰ The average cargo then was in the range 9 to 13 tons. The ton-per-man ratio, based on carrying capacity, would have been in the range 2.2 to 3.2.

If we accept these calculations, the average cargo carried by the peasant-trader ships in the Österbotten-Stockholm trade in the sixteenth century was about the same as the average shipload in the Stockholm-Danzig trade around 1475. It seems reasonable to expect labour productivity in the latter route to be somewhat higher, due to the probably more frequent use of ship types that were more advanced than those used by the Österbotten peasant-traders, but not widely different from what we have seen in the Österbotten-Stockholm trade around 1550. Allowing for some guesswork, a ton-per-man ratio in the range of 3 to 3.5 appears to be a fairly realistic estimate of the average labour productivity of the Stockholm-Danzig trade in 1475.

¹⁷ Glete (1993), pp. 112-114, 133-139. See also Leos Müller’s essay in this volume.
¹⁸ Kumlien (1953), pp. 290, 298.
Based on these ratios, an estimate of the growth of labour productivity of 1.1 to 1.3 percent a year is obtained for the period from 1475 up to the late 1580s. We may note that Lucassen and Unger, in their broad overview of shipping productivity in Europe, find no case of ton-per-man ratios reaching five before the mid-sixteenth century. Even a somewhat lower ton-per-man ratio of four to five was at the time quite high in an international comparison.\textsuperscript{21}

Table 1. Average annual growth of cargo of ships in the Stockholm trade, 1470s to 1580s

<table>
<thead>
<tr>
<th>Start year</th>
<th>Route</th>
<th>Average cargo, tons</th>
<th>End year</th>
<th>Route</th>
<th>Average cargo, tons</th>
<th>Growth rate, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1474/76</td>
<td>Stockholm-Danzig</td>
<td>11</td>
<td>1549</td>
<td>Swedish ships leaving</td>
<td>57</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stockholm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1474/76</td>
<td>Stockholm-Danzig</td>
<td>11</td>
<td>1560</td>
<td>Swedish ships leaving</td>
<td>62</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stockholm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1490/92</td>
<td>Danzig-Stockholm</td>
<td>17</td>
<td>1536</td>
<td>Danzig-Stockholm</td>
<td>35</td>
<td>1.6</td>
</tr>
<tr>
<td>1490/92</td>
<td>Danzig-Stockholm</td>
<td>17</td>
<td>1549</td>
<td>Swedish ships leaving</td>
<td>57</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stockholm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1474/76</td>
<td>Stockholm-Danzig</td>
<td>11</td>
<td>1560</td>
<td>Stockholm</td>
<td>78</td>
<td>2.3</td>
</tr>
<tr>
<td>1474/76</td>
<td>Stockholm-Danzig</td>
<td>11</td>
<td>1586/88</td>
<td>Stockholm</td>
<td>43</td>
<td>1.2</td>
</tr>
<tr>
<td>1474/76</td>
<td>Stockholm-Danzig</td>
<td>11</td>
<td>1586/88</td>
<td>Stockholm</td>
<td>63</td>
<td>1.6</td>
</tr>
<tr>
<td>1536</td>
<td>Danzig-Stockholm</td>
<td>35</td>
<td>1586/88</td>
<td>Stockholm</td>
<td>43</td>
<td>0.4</td>
</tr>
</tbody>
</table>


**Labour productivity in the trade on Stockholm, 1580-1820**

There are plenty of archival sources available which allow researchers to further explore the evolution of ship size and manning in Sweden during the early modern era.\textsuperscript{22} Starting in the late seventeenth century and continuing up to 1841, captains of ships departing from

\textsuperscript{21} Lucassen and Unger (2000), p. 130.

\textsuperscript{22} For a brief overview see Johansen (1993), p. 33.
Stockholm had to report their name and residence, the name of the ship and its home port, as well as details of the crew, to the Board of Trade (*Handelskollegium*) of the capital. These lists are called ship protocols (*Skeppsprotokoll*) up to 1741. Each member of the crew was listed by name with information about age, residence, and pay. For many years (though not for most of the first half of the eighteenth century), the size of the ship (in lasts) is also given. There is often information on type of ship (galleon, brigantine, etc.). Some volumes also report the owners of the ship as well as the names of the charterers that paid the freight.

This is a rich source which could be useful for many research agendas. For this study, only data on the ship size, crew size, and homeport (except in 1692) is used. Basic statistics are presented in Table 2 for four cross-sections at 1692, 1750, 1780, and 1820 along with similar data for the 1580s. Very few steamships were in use by 1820, and they are not included in the material used here.

Table 2. Average size and tonnage per man of ships leaving Stockholm in the 1580s, 1692, 1750, 1780, and 1820

<table>
<thead>
<tr>
<th>Variable</th>
<th>1580s</th>
<th>1692</th>
<th>1750</th>
<th>1780</th>
<th>1820</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrying capacity, metric tons</td>
<td>66</td>
<td>142</td>
<td>129</td>
<td>125</td>
<td>130</td>
</tr>
<tr>
<td>Size of crew</td>
<td>6.0</td>
<td>9.4</td>
<td>7.9</td>
<td>7.3</td>
<td>7.1</td>
</tr>
<tr>
<td>Tonnage per man on board</td>
<td>11.0</td>
<td>13.4</td>
<td>14.8</td>
<td>15.4</td>
<td>16.7</td>
</tr>
<tr>
<td>Tonnage per man on board, Swedish ships</td>
<td>14.4</td>
<td>14.6</td>
<td>16.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tonnage per man on board, non-Swedish ships</td>
<td>15.6</td>
<td>18.1</td>
<td>19.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N, all ships</td>
<td>230</td>
<td>437</td>
<td>550</td>
<td>462</td>
<td></td>
</tr>
<tr>
<td>N, Swedish ships</td>
<td>241</td>
<td>429</td>
<td>380</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N, non-Swedish ships</td>
<td>171</td>
<td>121</td>
<td>82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swedish ships, %</td>
<td>42</td>
<td>78</td>
<td>83</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Kumlien (1953), pp. 290, 298; Handelskollegiet, Sjöfolkskontrollen, Skeppsprotokoll (1692) and Skeppsinlagor/manlistor (1750, 1780, and 1820), Stockholms stadsarkiv.

Note: Ships with Swedish homeports (including Finnish ports) are classified as Swedish, others as non-Swedish. The carrying capacity of the 1580s is based on the assumption of a relationship of cargo to carrying capacity of 80 percent.

As seen in Table 2, the mean size of ships departing from Stockholm in 1692 was 142 tons. The median was considerably lower at 100 tons. This difference is due to a small number of large ships influencing the mean but not the median; the biggest ships were rated at 300 lasts (600 tons). The average size thus was twice that of the ships on the Stockholm-Lübeck route in the 1580s, and nearly three times that of ships going to Danzig in the same period.

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23 In 1742, the ship protocols were replaced by a new series labelled *Skeppsinlagor/manlistor* which provides similar information.

24 On the beginnings of steamship traffic in Stockholm see Gustavsson and Hägg (1932).
In other words, a sizeable increase in the size of Stockholm merchant ships had taken place between the late sixteenth and the late seventeenth century. Domestic carvel-built and mounted ships received lower customs dues, since the government wanted them to be used as a naval reserve. The trend towards larger ships was partly driven, then, by the merging of merchant shipping and the early modern military-industrial complex.

The maximum size of Stockholm ships was probably reached already by the mid-seventeenth century, when the average amounted to 274 tons. Aksel E. Christensen, who presents this information, notes that Sweden by then had succeeded in establishing a modern mercantile fleet which could compete with the Dutch traders in the Baltic region. However, this does not necessarily mean that the Swedish merchant ships were built to an optimal size in economic terms. During the latter part of the seventeenth century and the early eighteenth, the average ship size tended to decline.

The average tonnage of ships did not change much between the late seventeenth and the early nineteenth century. It declined slightly from 142 tons in 1692 to 125 tons in 1780, after which year there was a slight increase.

Labour productivity, measured as the ratio of the size of the ship to the size of the crew, increased over time. The average ton-per-man ratio grew steadily from 13.4 in 1692 to about 15 in 1750 and 1780, and further to 16.7 in 1820. This indicates a high productivity in Stockholm shipping as compared to results from several other studies. Christopher French, for instance, finds a ton-per-man ratio of about 11 in the London-Jamaica trade and 12 in the London-Virginia trade at the mid-eighteenth century. North reports much lower figures for ships entering New York, for which the ton-per-man ratio was not more than 4.4 in 1715-19, increasing to 6.9 tons in 1763-64.

Productivity growth was stronger among non-Swedish than among Swedish ships, as Table 2 reports. Non-Swedish ships increased their labour productivity from 15.6 to 19.5 tons between 1750 and 1820. Swedish ships exhibit a weaker growth, from 14.4 to 16.1 tons per man during the same period. The average growth rates amount to 0.32 and 0.16 percent a year, respectively. Several Dutch, British, and American ships appear to have had a high labour productivity.

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25 Carvel-built ships had planks placed edge to edge, unlike traditional clinker building which used overlapping planks. The carvel building technique made for stronger hulls and allowed heavier armament on the decks; Glete (2000), p. 29. In discussions on naval policy in Sweden during the late seventeenth century, carvel-built ships were thought to have twice the lifetime of clinker-built vessels; Gerentz (1951), pp. 166-172.

26 Data for 1648 in Christensen (1941), p. 98. By that time, Stockholm shipping was dominated by Dutch vessels. With an average of 270 tons these were, however, of practically the same size as the Swedish ships at Stockholm.

27 Another high figure was reached in 1667 with an average of 238 tons. It was of a temporary nature, as a number of Dutch merchant ships were sold to Sweden during the Second Anglo-Dutch war. Already in 1670 the average size had declined to 180 tons. Fahlborg (1923), pp. 240, 246, 254, 274 n 1.

28 Similarly, the average tonnage of the Finnish ships employed in foreign trade did not grow during most of the eighteenth century. Kaukiainen (1993), p. 49.

29 These ton-per-man ratios are seemingly lower, but are in fact quite consistent with those reported by Müller (2004), p. 157, for Swedish ships entering Cadiz. For three years during the last quarter of the eighteenth century, Müller estimates this ratio at between 20 and 23 tons per man. With an average tonnage of just above 300 tons, these ships were more than twice as large as the average ship engaged in the Stockholm trade. Ships of 300 tons in the Stockholm trade also display a labour productivity a bit above 20 tons per man (see Figure 3 for the situation in 1780).


31 North (1968), p. 959.
Non-Swedish ships thus exhibit twice the productivity growth of Swedish ships over the period 1750-1820. This difference in productivity growth can be partly explained by the fact that Swedish ships were declining in average tonnage, from 147 tons in 1750 to 124 tons in 1820, whereas non-Swedish ships show the opposite trend, increasing from 107 to 160 tons.

At the same time, Swedish ships became more dominant as a proportion out of total shipping on Stockholm, increasing their share from 55 to 82 percent between 1750 and 1820. Stockholm shipping, then, gives the impression of increasingly being divided into two segments. One was by the end of the period dominated by relatively small, Swedish ships. They were probably sailing shorter distances than the larger, non-Swedish ships of the other segment, which was oriented towards freights to the Western European market.

Labour productivity in Stockholm shipping also increased before the mid-eighteenth century. The average growth of productivity during the periods studied is reported in Table 3. For the period from the 1580s to 1820, annual growth amounted to 0.18 percent.\(^{32}\)

![Table 3. Average annual growth of labour productivity of ships leaving Stockholm, 1580s to 1820](image)

<table>
<thead>
<tr>
<th>Period</th>
<th>Growth rate, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All ships</td>
</tr>
<tr>
<td>1580s-1692</td>
<td>0.08</td>
</tr>
<tr>
<td>1692-1750</td>
<td>0.17</td>
</tr>
<tr>
<td>1750-1780</td>
<td>0.12</td>
</tr>
<tr>
<td>1780-1820</td>
<td>0.20</td>
</tr>
<tr>
<td>1580s-1820</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Sources: Table 1 and Kumlien (1953), pp. 290, 298.

It is important to note, then, that rising labour productivity was not produced by means of taking larger ships into use, but by saving on manpower. Average crew size declined from 9.4 in 1692 to 7.9 in 1750, and further to 7.3 and 7.1 in 1780 and 1820, respectively.

Labour productivity varied systematically according to the size of the ship. A strong association between the size of the ship and the ton-per-man ratio exists for all investigated years (Figures 1 to 3). But we can also discern a tendency towards a levelling-out of productivity among larger ships. Over and above ship sizes of approximately 150 to 200 tons, productivity did not rise and much with increasing size of the ship.

The graphs also reveal interesting differences between the four cross-sections. The most notable is that ships with a very low labour productivity disappeared with time. In 1692, there were quite a number of ships with a labour productivity of less than ten tons per man aboard.

\(^{32}\) The ton-per-man ratio for the 1580s is calculated as the average of 7.2 and 10.5 on the Danzig and Lübeck routes, respectively.
whereas only a few such ships existed in 1820. This of course contributed to a higher average level of productivity. In 1820, the distribution of ship sizes was clearly more compressed compared to 1692. It is remarkable that the productivity changes largely were taking place at the low rather than at the high end of the scale.

Figure 1. Ship size and tonnage per man in 1692.
Figure 2. Ship size and tonnage per man in 1750.

Figure 3. Ship size and tonnage per man in 1780.
Labour productivity in the Swedish East India trade, 1732-1803

The outlier at the very right-hand in Figure 2 requires a comment. This ship was Prins Carl of 930 tons, belonging to the Swedish East India Company. It was built in Stockholm in 1750 and left the capital for Gothenburg, the usual port of departure for voyages to China. It had a crew of 104 men, much more than other large merchant ships at the time, and consequently a low ton-per-man ratio. Prins Carl was designed for an even larger crew of 140 men when sailing to East India, which would bring down the tonnage per man even further. It carried 30 cannons, which was normal for the Swedish East India Company ships by the mid-eighteenth century.\(^{33}\)

This low ton-per-man ratio was a typical feature of the ships of the Swedish East India Company. Heavy armament and large crews were considered necessary for security during this long journey, and the high value of the cargo brought home was calculated to pay for the cost of protection.\(^{34}\) Prins Carl made a handsome profit of 40 per cent on its first voyage. Profits of the order of 30 to 40 percent were common among the ships of the Swedish East India Company by the mid-eighteenth century.\(^{35}\)

The different risks on the trade routes are reflected in the marine insurance premiums. These were quite low at the mid-eighteenth century for ships from Stockholm to destinations in the Baltic or the North Sea (1 percent of the value of the cargo to Lübeck, 2 per cent to

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\(^{34}\) This applies to the East India trade of other European nations as well. Jan Glete notes that only the large East Indiamen still carried heavy armament towards the end of the eighteenth century, when piracy in the European and American waters had been largely suppressed. Armed ships with large crews were feasible from an economic point of view due to the high value of their cargo. Glete (1993), p. 53.

London), but clearly higher on Mediterranean destinations (5 per cent to Alicante and Marseilles), and even higher for the China ships (11 per cent for the two-year voyage Cadiz-Canton-Gothenburg). These were peacetime premiums. During wartime the cost of insurance increased dramatically. This was the case after the outbreak of the Russo-Swedish war in 1788 when, according to the directors, insurance against capture could not be acquired even for premiums of 70 to 80 percent of the cargo.

There was, however, room for considerable productivity growth among the Swedish East India Company ships. The first ship of the Company began its journey in 1732. Over time, the tonnage of the ships increased while the number of cannons was reduced. It seems that none of the cannons on any of the ships were ever fired in battle, though they were made ready in a few threatening situations. This experience may have facilitated the transition towards more lightly armed ships. Average crew size remained approximately constant at about 125 men.

As a consequence of these changes, the ton-per-man ratio increased step by step over time, as is seen in Figure 5. It approximately doubled from not more than five at the start of the series to 10 around 1800. The average productivity growth over the period 1732-1803 was 0.8 per cent per year. This is a much higher figure than those reported in the previous section for ships departing from Stockholm.

![Figure 5. Labour productivity of ships of the Swedish East India Company, 1732-1803](image)

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39 The results reported here are based on a total of 35 ships. Koninckx has calculated the number of crew per ton and year on the East India ships for the period 1732-1765, which as expected gives a significant downward trend; Koninckx (1980), pp. 304, 472.
This fits well into Douglass North’s observation that ton-per-man ratios were consistently lower on routes where there was a threat from pirates, such as the East Indies, than on routes that had become pacified (the Baltic, North Europe, and North Atlantic). As the perceived risk of piracy diminished, substantial productivity growth could be achieved by investing less in defence measures.

Despite this productivity growth, East India voyages became unprofitable towards the end of the eighteenth century. A large part of the profits of the Swedish East India Company was based on the tea trade in Britain and The Netherlands. These markets became practically closed for the Swedish East India Company during the 1780s and 1790s, due to changing toll and import regulations. At the same time American ships began to sail to East India, successfully taking over a great part of the market. The directors of the Swedish East India Company maintained that American shipping benefited by several circumstances such as a more favourable geographical location, low cost shipbuilding, and cheap access to silver from Spanish America.

Concluding discussion

This study has shown that the labour productivity of merchant shipping in Stockholm grew over time during the late medieval and early modern period. This was initially primarily an effect of increasing size of ships. Later, from the late seventeenth century onwards, the productivity gains stemmed from falling crew sizes. As a result, the average ton-per-man ratio rose from about 11 in the 1580s to 13.4 in 1692 and further to 16.7 in 1820.

Why, then, did ship sizes not increase over time after the mid-seventeenth century? Research on Dutch shipping has shown that the ships employed on the Baltic route were increasingly confined to a standard range of tonnages. Even though the Dutch could build large ships of up to 800 tons in the early seventeenth century, these were not used in the Baltic trade. After a period of experimentation with various types and sizes of ships, the range of tonnages narrowed, and by the 1630s vessels of 200-240 tons had become dominating. This seems to have been the optimal size for this route. Using larger ships apparently had disadvantages, such as long waiting periods before a ship could acquire a full cargo.

The Stockholm data examined here encompasses a variety of routes, and we should of course not expect to find any strong tendency towards a single optimal ship size. Yet, it is worth noting that the choice of ship size was the subject of considerable controversy in Sweden. An interesting debate took place in the early 1720s, shortly after the end of the Great Northern War. Some of the large Stockholm merchants argued that ships should be of at least 150 lasts (300 tons) in order to bring about the lowest possible freight price. Only the large ships were capable of bringing Swedish goods to distant countries and bring home their products, above all salt which was regarded as the most essential imported good.

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40 North (1968), p. 960. Jan Luiten van Zanden and Milja van Tielhof make the same point with regard to Dutch shipping; where the routes to Norway and the Baltic used small crews compared to the heavily manned voyages to the Mediterranean and Asia; Zanden and Tielhof (2009), p. 391.
42 Paul Casseburg, a functionary in Estonia, stated in 1684 that the grain trade with the Dutch was unprofitable with small ships of about 30 lasts. Only ships of 150-200 lasts (300 to 400 tons) could gain from this trade; Soom (1961), p. 227. This is a higher figure than the optimal size of the 1630s referred to here, but Casseburg was taking the low Dutch grain prices of the time into account.
43 Heckscher (1922), pp. 171-175; Boëthius (1943), pp. 97-99; Gerentz (1951), pp. 166-172.
The Stockholm merchants were, however, strongly divided on the issue. The majority spoke in favour of small and medium-sized ships. They were easier to charter, could load and unload quicker and were able to sail faster. In the Mediterranean trade, swift small ships (labelled frigates) therefore stood a better chance of avoiding pirates. All foreign ports could not receive large ships and did not ask for their cargo of up to 1,000 tons of iron. Other arguments were that imports of the products of the European industrial countries did not require a large tonnage, and that big ships suffered from an overcapacity when visiting medium-sized or small ports. The majority conceded that the small ships were proportionately more expensive to fit out, but argued that no one would use big or small ships for their own sake, but because they were suited to the particular purpose of the trade.

The Board of Commerce (Kommerskollegium) recommended lower toll fees (helfrihet) for all carvel-built ships of at least 50 lasts (100 tons) that had been constructed in Sweden, as well as for all ships that sailed beyond the Channel, regardless of size. The government accepted this proposal.

In other words, the advocates of small and medium-sized ships emerged victorious from the debate. This was in contrast to policies pursued before and during the Great Northern War, when large ships had been favoured. The notion that it always made economic sense to use as large ships as possible was questioned, and there was a growing scepticism towards regarding large ships as the optimum in the late seventeenth and early eighteenth century.

* These results to a certain extent parallel those of North in his study of Atlantic shipping. According to North, the average ship size increased very slowly, if at all, until 1800. Yet, labour productivity increased substantially due to declining crew size. More efficient manned thus was the key to rising labour productivity in Atlantic shipping. This seems to apply to Stockholm shipping as well during the late seventeenth and eighteenth century.

The results diverge, however, in another respect. The average size of ships in the Stockholm trade increased substantially before the mid-seventeenth century. A transition from small to middle-sized ships was taking place between the late medieval period and the late sixteenth century. Whereas North disregards productivity advances before 1600, this study underscores them. A key period took place approximately between 1475 and the mid-sixteenth century, when average cargo grew by about 2 per cent a year.

There was a tendency towards weaker productivity growth in the trade on Stockholm during the eighteenth century. This did not apply to all Swedish shipping, however. The Swedish East India Company offers an example of a relatively strong growth of labour productivity of about 0.8 percent a year during the period 1732-1803. This clearly outdistanced the merchant ships trading on Stockholm where the corresponding figure was not more than 0.1 to 0.2 percent during the same period.

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44 On the contrast between frigates and the heavy warships with hundreds of men on board see Barber (1930), p. 261 n 1.
45 Boëthius (1943), pp. 97-99. Already in 1663, the Board of Commerce was critical of the large ships, regarding them as difficult to navigate. The Board feared that the Dutch, using cheaper and lighter ships, would outstrip the Swedes. Fahlborg (1923), p. 216. In another debate around 1680, many Stockholm merchants regarded the smaller ships to be advantageous since the building or purchase of these did not require foreign loans at a high interest. Gerentz (1951), p. 131.
The sources of productivity advance thus varied across periods and the type of shipping. In the dramatic growth phase ca 1475-1560, the major gains in the Stockholm trade seem to have been in terms of the size of cargo per ship, which was connected to the use of larger ships. After the late seventeenth century, the trend was another as crews were substantially reduced while ships declined somewhat in tonnage. Yet another trend appeared in the East India trade as ships grew in tonnage over time, whereas crew sizes did not decline. Lower cost of protection seems to have been decisive in the productivity growth on the East India route. This supports North’s emphasis on the importance of protection costs in productivity change. The results also highlight the versatility of productivity advance in shipping: if one road forward was blocked, another could be found and exploited.

Two different methods have been used above for estimating productivity growth. The first one, employed for the period up to the 1580s, is based on comparisons of actual shiploads carried. The other method, used for the period from the 1580s up to 1820, relies on data on the ratio between carrying capacity and crew size, and does not take not actual loads into account. The results for the two periods can been linked, using certain assumptions, in order to obtain an estimate of long-term productivity growth. Disregarding the pitfalls, labour productivity growth was estimated at 1.1 to 1.3 percent a year for the period from the mid-1470s up to the 1580s. This is a much stronger growth than that for the period from the 1580s up to 1820, when it was only about 0.2 percent a year. For the whole period of investigation, from the 1470s up to 1820, labour productivity growth amounts to about 0.5 percent a year.47

Three main results emerge from this study of Swedish shipping. The first is that productivity growth shows a long continuity, covering several centuries. While the transition from sail to steam certainly was a breakthrough, the long evolution of the technology and economics of shipping also was of great significance. It laid the groundwork for the transformation of the nineteenth century.

The second main result is that the major phases of growth are found quite early in the process, from the 1470s up to the seventeenth century. Jan Glete was right in emphasizing the importance of improved safety for the expansion of seaborne trade in the Baltic after about 1570.48 There was, however, also an earlier phase of remarkable growth with regard to the size of ships and cargoes from about 1475 up to the mid-sixteenth century. This growth can not be the result of pacification of the Baltic, which by then had not occurred. Apparently, ship sizes and labour productivity could grow despite the existence of piracy, privateering, and wars. Two factors may have been of particular importance in explaining this. One is the entry of the Dutch in the Baltic trade, offering low-cost competition with the Hansards. Late medieval Swedish rulers strived for increased trade with the Dutch, noting that their presence in the Baltic served to reduce prices. One result of this was increased salt imports to Stockholm from Amsterdam.49 Another factor, pointed out by Jan in his letter quoted above, is that larger ships could carry heavier armament which, together with the size of the crew itself, should have deterred pirates. Low safety, in other words, encouraged the construction and use of larger ships.

Third, an average annual labour productivity growth of 0.5 percent over a 350 year period is an impressive achievement of the pre-industrial economy. Though such a growth rate may seem low by to modern standards, it clearly surpasses what most economic activities

47 Above, the ton-per-man ratio in 1475 was assumed to be in the range 3 to 3.5. This results in a growth rate of 0.5 percent a year for the period 1475-1820 regardless of whether the calculation is based on the lower or upper point is this interval.
48 Glete (2000), pp. 125-126; see also Leos Müller’s article in this volume.
before the Industrial Revolution can show evidence of. Real income per capita in Holland, for example, is likely to have grown by about 0.1 per cent a year during the same period. Had Dutch per capita growth been 0.5 percent rather than 0.1 percent during the period 1475-1820, real income by 1820 would have been more than four times higher than it actually were.\(^{50}\)

In contrast to the assertion of O’Rourke and Williamson, long-distance trade before the introduction of the steamship was not limited to luxuries such as silk and exotic spices which affected only the living standards of the very rich. Trade in cheap and bulky goods, e.g., grains and timber, was possible in the Baltic for centuries before the early nineteenth century, and contributed towards price convergence between markets at quite a distance from each other. Globalization is, after all, not a very modern phenomenon. Neither is productivity advance in shipping.

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Was Jan on the right track, then, in his conjectures about the conditions of pre-industrial shipping? Was his scepticism regarding scale advantages well-founded?

In the very long run, scale advantages did have an impact. The smallest vessel in the 1820 cross-section of Stockholm shipping was at 22 tons, which may well have exceeded the average ship size of the 1470s. There is no doubt that larger ships generally saved on labour. But the cost of labour was after all only one component in total cost. The early modern trade on Stockholm offers a complexity which brings Jan’s discussion of the interplay between technological progress, flexibility and size into mind. The very small ships, which were frequent in the late seventeenth century, were unable to survive over time. At the same time it is clear that the average ship size did not grow during the period 1692-1820. There was an upper limit to scale advantages, just as Jan thought there would be in general. Not only middle-sized ships but also many small vessels continued to be competitive.

The advantages of scale are more evident in the Swedish trade on East India. This very long-distance trade used increasingly large ships which saved on labour. The China trade also benefited from reduced costs of protection, as fewer cannons were taken aboard in the course of the eighteenth century. These ships were nevertheless unable to compete with American ships towards the end of the century. Once more, scale advantages did exist, but they are not necessarily the key to the understanding of the problem.

Jan thought that the history of Swedish shipping in the pre-industrial era has not received the attention that it would deserve. This state is likely to remain for some time. But potential researchers will always be able to find inspiration in Jan’s fascinating writings in the field of maritime history.

**Appendix: The size of the last**

Before 1726, when the last was standardized to 2,448 tons, there were several different lasts in use in Sweden. A mathematics textbook from 1693 distinguishes between a small last of 12 barrels, a medium last of 18 barrels, and a large last of 24 barrels.\(^{51}\) In addition, the size of the last differed between goods. The weight of the fifteenth-century grain last in Stockholm can

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\(^{50}\) Calculated from data in Broadberry et al. (2010), p. 60.

\(^{51}\) Anderson (1945-1946), p. 60.
be estimated to about $2\frac{1}{3}$ tons due to the fact that its relation to the Lübeck grain measure, the Schepel, is known.\textsuperscript{52}

The iron last was lighter than the grain last. It is considered to have corresponded to 12 ship pounds of 133 kg in Stockholm from the mid-sixteenth century up to 1634, when it increased to 136 kg.\textsuperscript{53} This makes a 12-barrel iron last of 1.596 tons up to 1634 and 1.632 tons thereafter.

The salt last varied in size. There are examples of a last of 12 barrels, but also of 16 and 18 barrels. The Stockholm authorities decided in 1478 that imported Bay salt should have the weight of 15 lispund excluding the weight of the barrel itself.\textsuperscript{54} If we assume that a lispund of 6.65 kg and a weight of the empty barrel of 1 lispund, this gives a salt barrel of 106.4 kg, amounting to a 16-barrel salt last of 1.702 tons. This weight is here assumed to have applied for the period up to 1600. To further complicate things, the weight of the lispund increased over time. For the period from 1665 up to the mid-nineteenth century it is assumed to have comprised 8.5 kg.\textsuperscript{55} The weight of the salt barrel of 16 lispund would then have been 136.0 kg, corresponding to a 16-barrel salt last of 2.176 tons.

A weighted average of the various lasts has been constructed based on these data. Iron and salt were more important than grains in the Stockholm trade. If the iron and salt lasts are given twice the weight of grains, the average composite last is 1.8 tons for the period 1470-1664 and 2.0 tons for the period 1665-1820.

\textsuperscript{52} Jansson (1945-1946), pp. 38-40.
\textsuperscript{53} Morell (1988), pp. 10-11, 30.
\textsuperscript{54} Stockholms stads tänkeböcker 1474-1483 (1917), p. 182.
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