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published in
Explorations in Economic History
2014

DOI (link to publisher)
10.1016/j.eeh.2014.04.001

document version
Publisher's PDF, also known as Version of record

Available online at www.sciencedirect.com

ScienceDirect

Explorations in Economic History 53 (2014) 83 – 100

www.elsevier.com/locate/eeh

Labour productivity and human capital in the European maritime sector of the eighteenth century

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Received 29 August 2012
Available online 18 April 2014

Abstract

Pre-modern growth was to a large extent dependent on processes of commercialization and specialization, based on cheap transport. Seminal interpretations of the process of economic growth before the Industrial Revolution have pointed to the strategic importance of the rise of the Atlantic economy and the growth of cities linked to this, but have not really explained why Europeans were so efficient in organizing large international networks of shipping and trade. Most studies concerning early modern shipping have focused on changes in ship design (capital investments) in explaining long-term performance of European shipping in the pre-1800 period; in this paper we argue that this is only part of the explanation. Human capital – the quality of the labour force employed on ships – mattered as well. We firstly demonstrate that levels of human capital on board European ships were relatively high, and secondly that there were powerful links between the level of labour productivity in shipping and the quality of the workforce. This suggests strongly that shipping was a 'high tech' industry not only employing high quality capital goods, but also, as a complementary input, high quality labour, which was required to operate the increasingly complex ships and their equipment.

JEL classification: J24; N34; N74
Keywords: Human capital; Shipping; Early modern period

1. Introduction

Shipping was a key sector of the economies of Europe before 1800. In the pre-modern period, growth was largely dependent on processes of commercialization and specialization, based on cheap transport within and beyond national borders. Seminal interpretations of economic growth before the Industrial Revolution have pointed to the importance of the rise of the Atlantic economy and the resulting expansion of cities (Acemoglu et al., 2005; Allen, 2009; Wrigley, 1985). But such accounts have not adequately explained why Europeans could so efficiently organise large international networks of shipping and trade. Concerning shipping, there is a more qualitative story to

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http://dx.doi.org/10.1016/j.eeh.2014.04.001

tell about the evolution of shipbuilding, encompassing the major innovations in the High Middle Ages (as a result of the merging of Mediterranean and northern traditions of ship design), the development of the *fluyt* in the sixteenth century, and ultimately the transformative developments in navigation and in ship construction in eighteenth-century England (Unger, 1978; Davids, 2008; Lucassen and Unger, 2011). We argue in this paper that these forms of technological change only partly explain the long-term performance of European shipping in the pre-1800 period. The quality of the labour force employed on ships – their human capital – was also important.

The central thesis of our paper is that not only were such human capital levels aboard European ships exceedingly high, but that labour productivity in shipping was strongly linked to the quality of the workforce. Because shipping was a 'high tech' industry (Rediker, 1989) not only did it employ high-quality capital goods (increasingly efficient ships), but it also needed, as a complementary input, high-quality labour across *different* ranks, which was required to operate the increasingly complex ships and their equipment (Lucassen and Unger, 2011). We explain in this paper that the growth and performance of European shipping was therefore not simply a technological trajectory representing a shifting ratio between capital and labour. 'Raw labour' was improved by both capital goods and *complementary* human capital. The latter point is key for the ongoing discussion about the role of human capital in the pre-1800 economy. Some scholars have argued that the skills of 'common workers' were negligible ingredients of pre-1800 economic growth (Allen, 2009; Mokyr, 2002, 2010), but our findings concerning a major segment of the European labour market (Van Lottum, 2007) suggest that such skills were indeed important.

Eighteenth-century observers were quite aware of the significance of ordinary maritime workers (i.e., not only the officers) and their skills. In his *Wealth of Nations*, Adam Smith observes that common sailors were highly skilled when compared to their peers on land. And yet, 'Though their skill and dexterity are much superior to that of almost all artificers, and though their whole life is one continual scene of hardship and danger, yet for all this dexterity and skill […] they receive scarce any other recompence but the pleasure of exercising the one and of surmounting the other' (Smith, 1778: 134–35). Although Smith does not explicitly link *seamanship* (the term used to describe a wide variety of maritime skills) to performance in the sector, it was common knowledge in the eighteenth century that productivity was greatly affected by the quality of a crew. Take, for example, what we would now call an op-ed piece from April 1791, in the magazine *The Bee* (Anglicus, 1791). The anonymous contributor 'Anglicus' argues that the notion that 'one Englishmen was a match for three of the Gallic race' (176) could in fact be proven by looking at shipping statistics. His jingoism notwithstanding, the author makes some pertinent observations. To prove his point he lists the average burden of English, Swedish, Danish, French, and Spanish ships and compares these to the average number of men serving on board these ships – thereby creating so-called tonnage-per-man ratios, a measure we will also adopt in our analysis. The figures presented (177) show that the French did indeed 'employ three times as many hands' on their ships as the English – the ton-to-man ratio turns out to be three times as low in England. Anglicus then makes the point that this is not (or rather cannot be) a matter of comparing different types of ships. Indeed, he claims he has assessed comparable merchant vessels, and the difference can solely be explained by the quality of the crews: '[the] seamanship [of] one Englishman is literally, and without exaggeration, a match for three Frenchmen' (176).

In a recent evaluation of the skill level of maritime workers (Van Lottum and Poulsen, 2011) it was shown for the first time that compared to other sectors of the economy, the maritime sector was generally characterised by relatively high levels of human capital, thus confirming Smith's claim in *The Wealth of Nations*. However, the latter paper looked only at the human capital indicators of numeracy and literacy for seamen according to country of origin, and was limited to the end of the eighteenth century. As such, it could not measure the development of skill levels in national fleets, nor did it allow for an analysis of the possible effect of the two indicators on productivity. Using the same source but constructing a new (and much larger) relational database, containing a variety of data concerning the crews *and* the ships to which they belonged for the beginning and end of the eighteenth century, in the present paper we are for the first time able to analyse the effect of human capital on labour productivity in the European maritime sector.

2. The dataset

The source we use for our analysis is the so-called Prize Paper archive (Van Lottum et al., 2011; van Rossum et al., 2010). The archive consists of documents concerning actions by the Royal Navy taken with regard to privateering, and is part of the extensive archive of the High Court of Admiralty (HCA), which can be found at The National Archives in Kew (TNA). The section of the collection we have used for our analysis is the court's interrogations of crewmembers of captured ships (TNA HCA 32). When a navy vessel or a private man-of-war captured what they suspected was an enemy ship, or if it was believed a ship carried cargo owned by a merchant from an enemy nation, the court needed to establish whether the vessel was in fact a lawful prize. In reality this meant that ships from enemy *and* friendly nations were brought ashore. This was often the only way to determine the origin of the ship; many merchant ships carried several national flags that they could fly in order to fool an enemy (Eyck van Heslinga, 1982). Ships were captured not only in the waters surrounding the United Kingdom, but also near to English interests in the Mediterranean, such as the Canary Islands, Livorno, or Menorca. Other captures were done as far away as the Indian Ocean, in the Bay of Bengal, off the Cape coast and west coast of Africa. However, most captures occurred in the English Channel, from outside Great Yarmouth in the north to Penzance and off the Cornish coast in the south.

Even in times of war, when privateering was the *modus operandus*, the British state tried to protect property rights not only of its own citizens but also of foreigners, and applied strict administrative procedures to that purpose. An essential part of the procedure was the cross-examination of the crews, who were interrogated about all matters relating to the ownership of the ship and its cargo (Van Lottum et al., 2011). Although there are instances in which the entire crew was questioned, the interrogations usually involved three men (the average in the dataset is 2.7 interrogations per ship): in nearly all instances the master, sometimes an officer (such as a mate), and usually one or two common sailors or other ordinary crewmembers.

The interrogations were conducted during the end of the seventeenth century, for different periods of the eighteenth century, and at the beginning of the nineteenth century. In this paper we will focus on two key periods, the first just after the turn of the eighteenth century (1702–1712) and the second several decades later (1777–1801). The data for Period 1 pertains to ships taken in the War of the Spanish Succession (1701–1714); the database contains data for 1702–1712. The second period (Period 2) is based on ships taken in the War of the American Revolution (1776–1783) and the French Revolutionary Wars (1792 until 1802). Here our database contains data for the years 1777 to 1801. As stated above, based on the interrogations, we constructed a relational database consisting of all relevant variables of the merchant ships and its crews. This includes the country of origin of the ship and its crewmembers, along with the ship's destination, age, and information about its ownership, for instance whether or not the master was its owner, in full or in part. Because the database was intended to research various aspects of merchant shipping, all other captured vessels, such as fishing boats, men-of-war, and privateers, were excluded.

To facilitate a diachronic quantitative and qualitative analysis, the data had to undergo series of standardisation and coding rounds. All place-names in the dataset have been standardised and geocoded and to strengthen the robustness of our analysis country group codes have been added to the ships' places of origin. And to help create a meaningful comparison of the individuals' characteristics over time, all occupations of seamen (i.e., their ranks) in the dataset have been standardised using the widely-used HISCO categorisation.[1] Moreover, it was essential to exclude a number of ships (and therefore seamen) from the collected data. The data that was initially extracted from the archive contained a very broad range of ship sizes; the burden of the ships ranged from 2 to 1,500 tons. Moreover, there is wide geographical variation in the journeys undertaken by the vessels; the interrogations cover not only ships sailing between European destinations, but also between Europe and Asia, as well as many transatlantic voyages. Although even within intra-European trade tonnage-per-man ratios could differ – in particular due to the length of the journey (and thus higher mortality rates among the crew) but also the number of canons on board – ton-per-man ratios on ships sailing to the East and West Indies were often quite different from those on intra-European routes (Davis, 1972; Lucassen and Unger, 2011). Therefore, to compare like-for-like vessels as much as possible, the dataset we use in the present study contains data only for ships sailing on intra-European routes and is limited to ships of 50–300 tons burden, thus excluding what are generally regarded as particularly small and large ships (Davis, 1972: 78–80).

The data for the beginning of the eighteenth century (Period 1) consists of a relatively large group of small vessels. Between Period 1 and 2, however, ship size increased substantially. Fig. 1, which shows kernel density plots for the two periods in the dataset, demonstrates that during the eighteenth century, many of the smaller ships were replaced by bigger ones. As a result, in Period 2 the distribution of ship sizes becomes more evenly spread.

The shift in scale size is confirmed by the descriptive statistics of the two periods. Table 1 reveals that in Period 1 the mean was 102 tons, with a median of 80. During the eighteenth century the mean ship size rose to 133 tons, while the median increased to 120 tons. The

[1] The HISCO (Historical International Classification of Occupations) coding can be found at http://historyofwork.iisg.nl/.

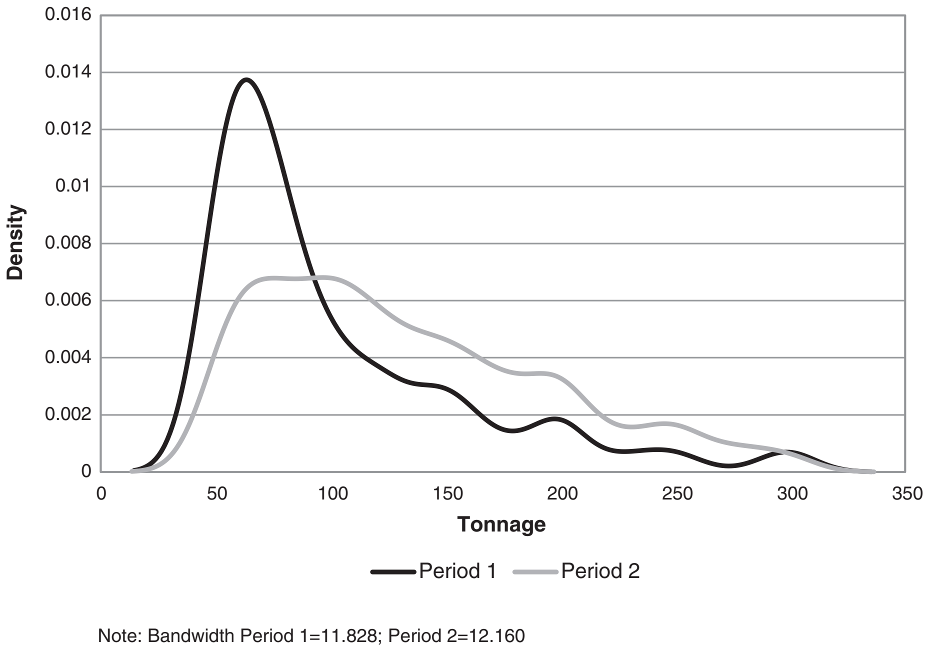


Fig. 1. Kernel density plot of the ships in Period 1 (1702–1712) and Period 2 (1777–1801).

dataset also indicates that there were regional differences with regard to size. In our dataset the ships from the countries north of France were larger than their southern counterparts. In Period 1 the mean ship size in the north was 108 tons, with a median of 80; in the south the mean size was 93 tons, with 70 tons as the median. In both regions the size of the ships increased substantially over the eighteenth century – though with a greater increase in ship size in the north. The northern ships in Period 2 averaged a tonnage of 138 (median: 124); in the south the average was 110 tons (with a median of 90 tons).

The Prize Paper archive covers all parts of the world, and in addition to European ships includes many North American vessels (in particular from New England). However, because of the two criteria mentioned above, the dataset used in this study consists exclusively of European ships, mostly from northwestern Europe and France.[2] Fig. 2 shows the ships' places of origin.

A striking feature of the map is that English (or British) ships feature in our dataset – they were captors, after all, not captives. But these ships show up here because of the common practise of interrogating the crews of English vessels that had been captured by privateers and subsequently recaptured by the English. This was done to corroborate what the captured privateers had told them and to investigate whether other crew members had been in league with the privateers.

Because the sample size of the various fleets (and hence their crews) differed, in the analysis we use (clustered) country groups (see Table 2). This makes a more geographically balanced comparison possible and increases the robustness of the data analysis. Ships from the Netherlands and the Southern (or Habsburg) Netherlands are clustered into a group aptly called 'The Netherlands'; the country group of 'Scandinavia' comprises ships from Sweden, Denmark, Norway, and Finland; English, Scottish, and Irish ships are clustered in a group called the 'British Isles', and all German states and cities are grouped into the country group 'Germany'. Northern Europe thus refers to all countries north of the Southern Netherlands; southern Europe consists of France, Italy, Spain, and Portugal. Because they provide

Table 1
Descriptive statistics of the ships in Period 1 (1702–1712) and Period 2 (1777–1801).

	Period 1			Period 2		
	N	Mean	Median	N	Mean	Median
Northern Europe	275	108	80	1,779	138	124
Southern Europe	184	93	70	339	110	90
All	459	*102*	*80*	*2,118*	*133*	*120*

[2] The few American ships sailing on intra-European routes have been excluded from the dataset.

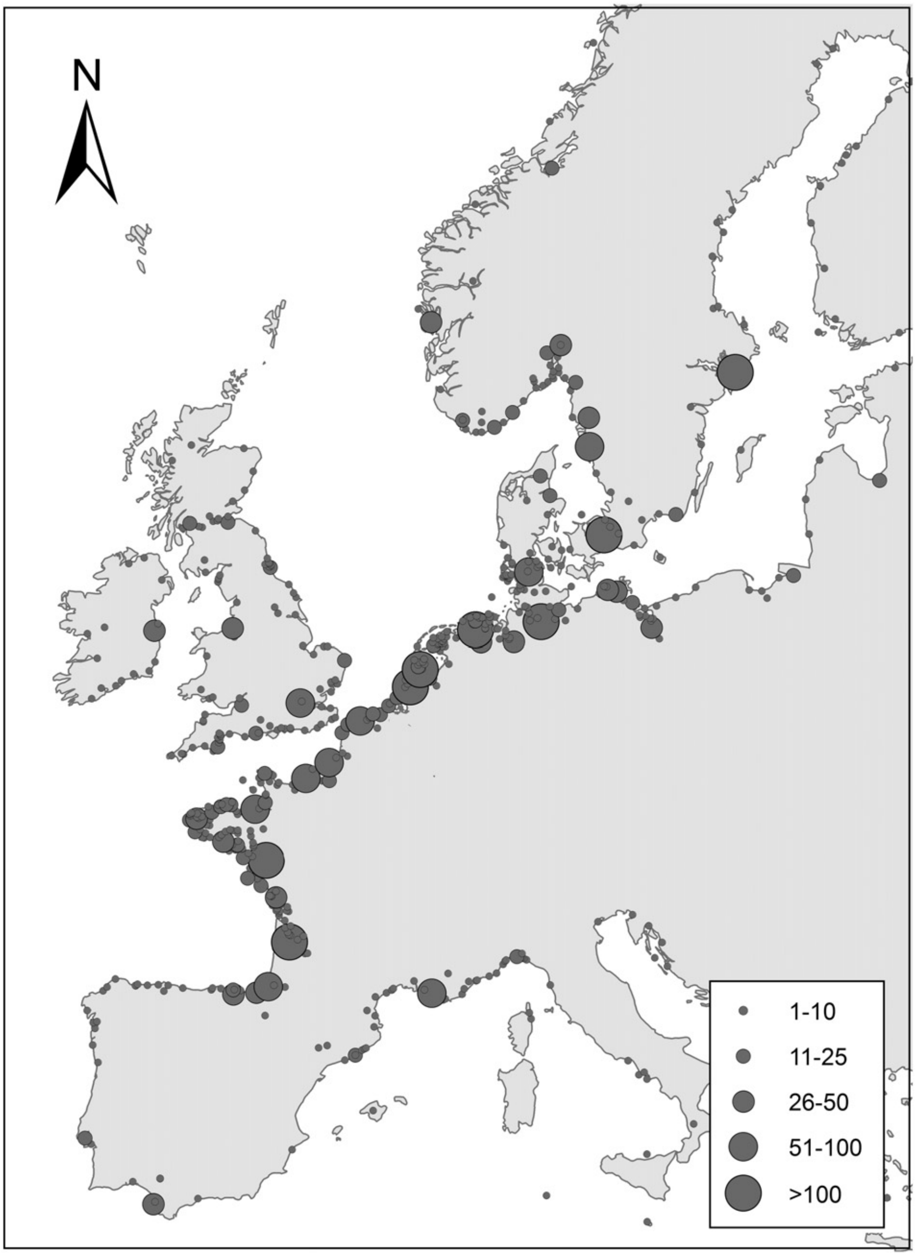


Fig. 2. Origins of ships in the dataset.

a relatively small sample size, the latter three countries are not part of any of the country groups.

3. Representativeness of the data

We believe that the interrogations provide relatively accurate information about the ships. First, as those questioned were likely aware, answers given in the interrogations could be verified with relative ease by the court. Because all the ship's papers had been confiscated (if not thrown overboard before or during the capture), the High Court of Admiralty (or the local Vice Admiralty Court) could corroborate what was said in the interrogations; that they kept the documents makes their frequent use in court all the more likely. The answers given by those questioned, in fact, usually corresponds with the information in the documents – but with enough minor differences to suggest that there was still some room for personal interpretation. The answers were not dictated by the court: they frequently varied among those on board a

Table 2
Total number of crews (including officers) and ships in Period 1 (1702–1712) and Period 2 (1777–1801).

	Period 1		Period 2		Total database	
	N ships	N Crews	N ships	N Crews	N ships	N Crews
British Isles	24	47	231	370	*255*	*417*
France	160	347	233	538	*393*	*885*
Germany	32	122	761	2,180	*793*	*2,302*
The Netherlands	75	250	284	813	*359*	*1,063*
Scandinavia	144	560	503	1,447	*647*	*2,007*
Northern Europe	*275*	*979*	*1,779*	*4,810*	*2,054*	*5,789*
Southern Europe	*184*	*415*	*339*	*764*	*523*	*1,179*
Total	*459*	*1,394*	*2,118*	*5,574*	*2,577*	*6,968*

given ship. The ship's burden, say, would often be slightly different, depending on whether it was cited by the master or by the crew; a sailor accounting for the ship's origin or destination tended to be less precise than a mate when asked the same question. Variations in responses are also likely to have resulted from measures taken to discourage 'cooked-up' answers. As stated outright in the preambles of some of the interrogations, mariners were questioned one at a time and were kept apart from each other before they appeared in front of the court.

A second, related issue is whether the captured ships constitute a representative cross-section of the maritime sector. Again, we think there is no evidence to suggest the contrary. First, our labour productivity figures fit in quite well with earlier estimates made by Lucassen and Unger, who used different sources (2000, 2011). Nevertheless, it is still possible that a section of the ships in our dataset may not be completely representative of the sector at large. For instance, over the course of a war the characteristics of the ships and the number of men aboard may have changed, resulting from (among other reasons) ship owners reacting to the increased threat of privateering. Owners could increase the number of guns on board, or introduce or expand the practise of convoying; such measures could affect productivity and make ships caught sometime after a war's beginning potentially less representative of the sector in peacetime. To establish whether such bias existed in the sample, we have compared labour productivity levels (measured here as tons per man) of all the ships that were taken during the *first* and the *last* year of the French Revolutionary Wars (1792–1802). The latter period is the only span of time large enough to fruitfully compare two individual years. This exercise showed hardly any difference in labour productivity levels between ships captured at the war's beginning war and those taken near its end. In both years labour productivity remained fairly stable and did not differ very much from the overall average. In northern Europe the average labour productivity during this war was 16.8 tons per man; during the first year the average labour productivity was 18.5 (based on a total of 55 ships), in the last year the ratio was 18.0 (179 ships). In the south the differences are also marginal. In the first year of the French Revolutionary Wars labour productivity was 13.4 tons per man (based on 21 ships), in the last year 14.3 (36 ships); the average labour productivity for the ships from southern Europe during the entire war was 13.7.

Finally, it is also important to discuss the representativeness of the *crews*' characteristics. If in particular the more skilled sailors were interrogated, our dataset would show an upward bias with regard to skill. Here, though, one could argue that there may have been incentives for the court and captain to put forth the most highly skilled workers for questioning. After all, they were 'sworn and examined upon such interrogations as shall lead to the discovery of the truth concerning the interest or property' (Starkey, 1990: 25). But the question remains whether court and captain actually reasoned or acted this way. The truth is that we simply do not know the precise particulars of the nomination procedure. There is, however, an indirect way of testing whether such a 'preferential interrogation' of sailors existed. We have compared the characteristics of common sailors of two groups. The first group comprises sailors interrogated in cases when only one interrogation took place; the second encompasses those involved in multiple-interrogation inquiries, i.e., those cases where two or more sailors were questioned. If a selection was being made on the basis of 'skills', the court or the master would have picked the most skilled or experienced sailor aboard in cases where only one common seaman was interrogated. The skill level of the group of singles would likely be higher than that of the men involved in multiple interrogations. We adopted two measures to approximate the *perceived* skill levels of the sailor in the eyes of the master *and* the court: average literacy levels and age. Literacy levels are perhaps one of the most 'recognizable'

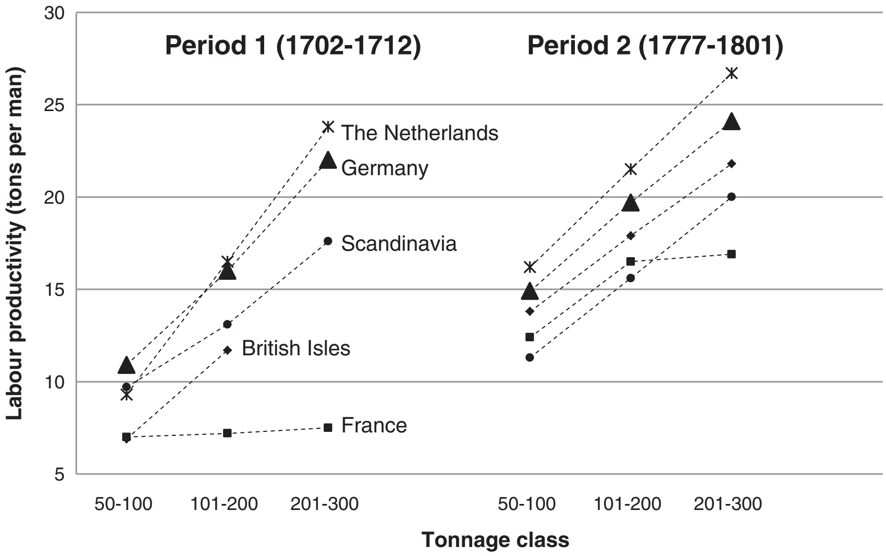


Fig. 3. Labour productivity (tons per man) in European shipping in Period 1 (1702–1712) and Period 2 (1777–1801).

personal skills, in particular for the court, and of course it is a skill that can be analysed using our dataset. The average age of a group is another useful indicator. Although the master of the ship may not directly equate skill with age (as he will have known the men aboard relatively well), it is likely that the court, if they indeed made the selection and wanted to interrogate the more skilled workers, would show a preference for interrogating older (i.e., experienced) seamen. If there was a deliberate selection of men to be questioned, the group of single interrogates is likely to have a higher average age.

Our comparison of the two groups based on both literacy and age provides no evidence that our data contains a bias towards skilled workers; indeed, there is no indication that only 'elite' crewmembers were selected or nominated for questioning. The group of single-sailor interrogations (which was relatively small, N: 57) had an average literacy rate of 51%, whereas the group of multiple-sailor interrogations was even higher: 63% (N: 653). If the court or ship's master had in fact made a deliberate selection, the former would likely have been substantially higher. The differences in average age levels between the 'singles' and 'multiples' group also contradict a selection bias in the sailors' interrogations. The small group of 'singles' had an average age of 26.2, but the other group even averages slightly higher at 29.0. Again, the former group would likely have had a (significantly) higher age than the latter if the court had picked the more experienced, older common sailors.

4. Labour productivity

A number of studies have documented the productivity growth in European shipping in the early modern period. Some have focused on the changes in freight rates as an index of productivity change (North, 1958; Harley, 1988; Van Zanden and Van Tielhof, 2009), whereas others have concentrated, as we have, on the tonnage-per-man ratio (Davis, 1972; Van Lottum and Lucassen, 2007; Lucassen and Unger, 2000, 2011).[3] As pointed out by Lucassen and Unger (2011), this method has its drawbacks. For instance, it obscures regional variation within national markets, accounts for the burden of the ship rather than the cargo transported, and fails to capture more general gains in productivity such as increases in average speed. Moreover, it is a partial index of productivity, relating only to labour productivity, and it may therefore show different patterns of change compared to (for example) deflated freight rates, which is a more comprehensive measure of total factor productivity (Van Zanden and Van Tielhof, 2009). Nevertheless, it is commonly accepted to be an acceptable proxy for long-term changes in labour productivity in aggregate (Lucassen and Unger, 2011).

In their analysis of labour productivity, Lucassen and Unger (2011) demonstrated that during the early modern period ocean shipping underwent a profound

[3] For various approaches to measuring productivity in shipping, see the contributions in the edited volume by Unger (2011).

increase in labour productivity. Our data for the two periods, shown in Fig. 3, shows a similar development. In Fig. 3, labour productivity is shown for three tonnage classes. The division in tonnage is important because we use *average* labour productivity levels in our regression analysis in Section 7. Therefore it is essential to establish whether labour productivity increased across all ship sizes. As the mix of larger and smaller ships differed between countries, growth in *average* labour productivity in a national fleet or within a country group could theoretically result from crews on particular ships (larger ones, for instance) becoming more efficient, while productivity on other ships fell.

First of all, Fig. 3 makes clear that there are apparent economies of scale regarding the ships of nearly all countries. Productivity increases quite consistently with ship size, in particular during the later period. The efficiency increase is shown to be linear in almost all countries, with an increase in the ratio of about 5 between the different tonnage classes. Moreover, the graph demonstrates that labour productivity did in fact undergo sizeable increases across *all* tonnage classes. Finally, the graph emphasises that there were consistent differences in productivity levels between the different country groups. In both periods, ships from the Netherlands have the highest labour productivity in all tonnage classes (except one), and also have the highest average labour productivity in Period 1 (a ratio of 17) and Period 2 (21 ton per man). They are, however, followed relatively closely by the German vessels (Period 1: an average ratio of 16; period 2: 20). Scandinavian ships (on average 13 tons per man in Period 1; 16 in Period 2) and the ships from British Isles follow at some distance in Period 1, but the latter catch up strongly in the intermediate period (the average ratio grows from 9 to 18). Finally, the vessels from France, the only southern European country in the graph, lag behind the others, both at the beginning and the end of the century (in Period 1, an average ratio of 7; in Period 2, 15 tons per man).[4]

In sum, Fig. 3 reveals that throughout the eighteenth century productivity increased in all size classes. What caused these efficiency gains? Lucassen and Unger (2011) mention three broad categories to account for such productivity growth: institutional change on land and at sea; economies of scale; and technological improvements in the design and construction (including the way that ships were handled). They acknowledge, too, the potential importance of the knowledge and skills of crews, particularly in relation to advances in technology and scale, but they emphasise the difficulty of assessing improvements in human capital and its link to productivity gains. Elucidating the latter – i.e., measuring the improvement in the human capital of crews, as well as developing a further understanding of the link between skill and productivity – is what we will focus on in the remainder of this essay.

5. Human capital levels

Most eighteenth-century descriptions of sailors and their colleagues on board deep-sea vessels were far from flattering, although the status or perception of seamen could differ for the various branches of maritime employment. For instance, sailors serving on men-of-war, large East India vessels, and whalers had much worse reputations than that of sailors on board merchant marine vessels (Bruijn and Lucassen, 1980; Dana, 1946). But without a doubt seamen in general had an ‘image problem’. Take this anonymous barb from the *Connoisseur* in 1755: ‘That our ordinary seamen, who are, many of them draughted from the very lowest of the populace, should be thus uncivilized, is no wonder […] but surely there ought to be as much difference in the behaviour of the commander and his crew, as there is in their situation’ (Connoisseur, 1755, 97).

To some extent this particular image of ‘Jack Tar’ still persists in scholarly and literary works. The seaman in general, and the common sailor in particular, is often described as a man drawn from the lowest classes of society, particularly (in)famous for drinking and other social activities (Davis, 1972). He may not be quite the ‘scum of the earth’ but he is certainly not singled out for his self-discipline or skills. Recent scholars have done much to add nuance to this predominantly negative and one-dimensional image. For instance, Rediker (1989) and, more recently, Van den Heuvel and Van der Heijden (2007), De Wit (2009), and Bruijn (2011) have highlighted the seaman’s role as a collective worker and wage labourer and have emphasised sailors’ central role in their families and communities. Still, in most studies sailors are not considered particularly well trained or skilled compared to workers in other occupations. In this section we will reassess their skill level by an analysis of the numeracy and literacy levels of maritime workers compared to those in other occupational groups and the population at large.

We estimate numeracy levels by calculating levels of age heaping. The latter is defined as the effect of the

[4] The labour productivity figures furthermore show that ‘Anglicus’ seems to be somewhat overstating English performance (although our figure is based on ships from the British Isles; i.e., Scottish and Irish ships are included), but he certainly understated that of the French (though they are indeed the worst performers).

Table 3
Signed literacy levels of non-officers ranks aboard merchant ships sailing on intra-European routes in Period 1 (1702–1716) and Period 2 (1777–1801).

	Period 1 (1702–1716)		Period 2 (1777–1801)	
	Literacy rate	N	Literacy rate	N
British Isles	70%	23	69%	124
France	55%	73	42%	233
Germany	78%	45	71%	668
The Netherlands	59%	114	76%	258
Scandinavia	58%	274	62%	439
Northern Europe	*61%*	*456*	*69%*	*1,489*
Southern Europe	*58%*	*106*	*55%*	*323*

Table 4
ABCC index of numeracy of non-officers ranks aboard merchant ships sailing on intra-European routes in Period 1 (1702–1716) and Period 2 (1777–1801).

	Period 1 (1702–1716)		Period 2 (1777–1801)	
	ABCC	N	ABCC	N
British Isles	-	-	97%	53
France	82%	58	85%	107
Germany	-	-	97%	549
The Netherlands	90%	89	96%	184
Scandinavia	85%	224	96%	346
Northern Europe	*88%*	*362*	*97%*	*1,132*
Southern Europe	*83%*	*69*	*90%*	*155*

misreporting of the age of cohorts between (and including) 23-year-olds and 72-year-olds (De Moor and Van Zanden, 2010). If within this cohort a more than average tendency exists to report ages divisible with 5 and 10 (i.e., 25-, 30-, 35-year-olds and so on) it is sign that the individuals in the group do not know their exact age, which in turn is a reflection of a low level of numeracy. The level of age heaping is commonly expressed by the so-called Whipple index, which measures the level at which age groups ending on 5 and 0 are overrepresented in a population group.[5] In this study we adopt the alternative Whipple or ABCC Index which reports the *share* of individuals within a group who 'correctly' report their age (A'Hearn et al., 2009).[6] Literacy levels will be estimated by calculating the share of people who were able to sign the interrogation. It is important to stress that these approaches to measuring numeracy and literacy only pick up a minimum investment in both aspects of an individual's (or a group's) human capital. The two proxies make it possible to distinguish the unschooled (or barely schooled) from those that received a form of schooling or training that resulted in basic numeracy and/or literacy skills, but they do not allow us to distinguish the higher echelons of knowledge accumulation. In other words, the method makes it impossible to distinguish between, say, a group of office clerks and one of university professors. Nevertheless, as both measures allow the detection of some degree of schooling and skill level, they are very useful to assess the skill level of common workers.

The literacy levels of common crews derived from our dataset are presented in Table 3. The combined literacy levels for crewmembers in northern and southern Europe very much show a divergent development between north and south. Moreover, the development of literacy in the country groups make clear that on a more disaggregated level, literacy in northern European fleets developed quite differently. In Period 1, the common crews aboard British and German ships have the highest literacy rates of all country groups, with levels of 70% and 78%, respectively; the crews on other fleets had levels below 60%. During the eighteenth century this picture changes substantially. Literacy levels of crewmembers on board British and Scandinavian ships increase slightly. On German and in particular French ships there is a significant drop in literacy levels, the latter of no fewer than 13 percentage points. In fact, only one country group shows a strong increase: the Netherlands. Its growth in the literacy rate of 17 percent points is by far the largest change between periods 1 and 2.

When we turn to the numeracy data in Table 4, we find that numeracy levels of ordinary crewmembers have a much more consistent development over time. Unfortunately, the sample size of the crewmembers aboard the British and German ships is not large enough to allow for the calculation of age heaping levels for Period 1. However, the estimates for the remaining country groups (and the combined groups in the bottom two columns) show that numeracy levels increased across all European fleets. Indeed, common crews in northern Europe all reach a level of about 96–97% in Period 2. Numeracy levels of French crewmembers also increase, though somewhat more moderately, from 82%

[5] The Whipple index gives scores ranging from 0 if the ages ending on 5 and 0 are not represented at all, and up to 500 if all ages mentioned end with 5 or 0. A Whipple index (W) of 100 or lower means that there is no sign of age heaping among these age groups: $W = \frac{\sum(n_{25} + n_{30} + \ldots + n_{65} + n_{70})}{\frac{1}{5}\sum_{i=23}^{72} n_i} \times 100.$

[6] $ABCC = \left\{1 - \frac{(W-100)}{400}\right\} \times 100$ if $W \geq 100$; else $ABCC = 100$.

to 85%. The group of northern and southern European crewmembers show that, as in the case of literacy levels, overall numeracy in northern Europe was higher than in the south.

So how do the levels of literacy and numeracy in the dataset compare to those of the populations of the countries involved? Comparisons between our Period 2 data and literacy rates of average populations in 1800 (based on Allen, 2003: Table 2, 415) show that indeed, seamen had relatively high literacy levels compared to the populations from which they came. The 53% average literacy rate in England in 1800, for instance, is much lower than the 69% literacy rates of common crews aboard ships from the British Isles in Period 2 (see Table 3). And even if the literacy level of French crews in Period 2 was lower than at the beginning of the eighteenth century, the 42% in Period 2 was still higher than the 35% of the average population in 1800. A much larger skill gap existed in Germany: here the sailors had substantially higher literacy levels than the average population: 71% versus 35%. It is likely, however, that part of the difference can be explained by regional variation, for instance between coastal and inland regions. Finally, literacy rates aboard Dutch vessels were also higher than average, though the gap was smaller than in the German countries. In Period 2 common seamen aboard Dutch ships had a literacy rate of 76%, compared to 68% for the overall population in 1800. A similar pattern emerges when we compare our *numeracy* estimates with available studies of other occupational and social groups; we see that the lower-ranked crews aboard the European merchant ships have above-average numeracy levels. Unskilled labourers in Denmark around 1800 show a numeracy rate of 90%, while Danish sailors (which includes men involved in all types of shipping) at that time were at 88% (Van Lottum and Poulsen, 2011). The numeracy levels of sailors aboard the Scandinavian merchant vessels were much higher: 96%. Numeracy estimates for burghers in eighteenth-century Amsterdam, who were relatively well educated (certainly better than the average for the entire population), come in at around 97%, about the same level as the common crewmembers aboard Dutch ships in Period 2 (De Moor and Van Zanden, 2010).

6. Linking human capital and labour productivity

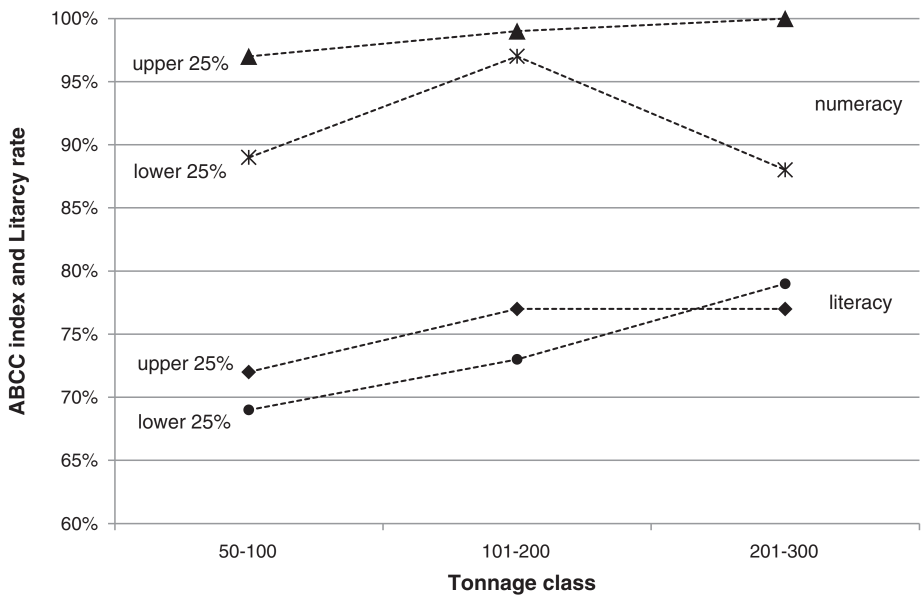
We have seen that the shipping industry was characterized by high levels of human capital and rapid productivity growth. Can we establish a causal relationship between these two features? A relatively straightforward way of finding our whether a relationship between skills and productivity exists is to compare the human capital levels of crewmembers aboard high- and low-performance ships. Such a comparison is given in Table 5, where the human-capital level of common crews (the non-officer ranks) are shown for the upper and lower productivity quartile – i.e., the first and last 25% when ranking ships by labour productivity. Unfortunately, such an analysis is not possible for Period 1: the sample size of separate quartiles is too small to allow for a meaningful analysis.

Table 5 shows that in both regions performance levels do indeed correlate with human capital levels: numeracy and literacy levels were substantially higher aboard the most productive ships. It also shows that the difference between the upper and lower quartile in northern Europe is substantially smaller than in the South – though, as we have seen above, the northern European human capital levels were already at a much higher level.

As Section 5 showed there were economies of scale in early modern shipping, i.e., smaller ships tended to be less productive than large ones – one must take an additional step to determine whether Table 5 does not simply reflect a correlation between human capital levels and ship size. Therefore, Fig. 4 shows the human capital and labour productivity levels for each of the three tonnage classes introduced in Section 5. As the sample size for southern Europe was too small to be split up into the three tonnage classes, we can only look at northern Europe in Period 2 (the sample size for northern Europe in Period 1 was also too small for such an analysis). In the table we again look at the upper and lower 25% of the ships when ranked by labour productivity.

Table 5
ABCC and literacy rate for non-officers ranks aboard the 25% least and 25% most productive ships, Northern and Southern Europe, Period 2 (1777–1801).

	Northern Europe				Southern Europe			
	Numeracy		Literacy		Numeracy		Literacy	
Labour productivity	ABCC	N	Literacy rate	N	ABCC	N	Literacy rate	N
Lower 25%	94%	269	75%	381	76%	48	45%	98
Upper 25%	99%	302	77%	369	91%	41	56%	70
Difference	*+5%*		*+2%*		*+15%*		*+11%*	



Notes: 50-100 tons: ABCC lower 25%, N: 122; upper 25%, N: 94; Literacy lower 25%, N: 139; upper 25%, N: 133. 101-200 tons: N: 146/137; 175/166). 201-300 tons: N: 47/50; 58/61.

Fig. 4. ABCC and literacy rate for the 25% least and 25% most productive ships by tonnage class, Northern Europe, Period 2 (1777–1801).

Fig. 4 broadly confirms the findings of the previous table: the most productive ships carry the crews with the highest human capital levels. The only exception can be found in the highest tonnage class. Moreover, Fig. 4 also makes clear that there is some evidence (without testing for its significance) to link ship size and human capital levels. Aboard ships in the upper quartile, numeracy levels increase in all instances; literacy levels increase only between the first two tonnage groups. However, the variation in the difference between the three classes shows that ship size does not drive the overall difference aboard the most productive ships as they were shown in Table 5. With regard to numeracy in both the smallest and the largest tonnage classes common crews have a substantially higher level of human capital; in the case of literacy this applies to the first two tonnage classes.

Let us now turn to a more a more rigorous quantitative analysis of the dataset in a regression analysis that aims to explain the variation in the tonnage-per-man ratio. Several possible explanatory independent variables can be introduced, most related to human capital. Nevertheless, the dataset also allows for the effects of other relevant factors to be tested. For instance, the source also gives information about a ship's age, which may provide information regarding the level of technology. The dataset also contains information about a vessel's ownership; more specifically, whether the captain was co-owner of the ship. Fortunately, we have this information available for nearly all ships in the dataset (2,532 of the 2,577 ships). By including in the analysis what we call the *mastowner* dummy, which is set at 1 when the captain owns part or all of the ship, we can test for potential agency problems that might result from the captain's playing a central role in hiring. Crucially, in most cases the master decided how many sailors needed to be employed. If a captain was not an owner, his income was not directly related to setting these costs, as he received only a wage income. However, if the captain was an owner, he would have had an incentive not to hire too many sailors, which might diminish his income from the ship. A positive effect of this variable on labour productivity would mean that there was in fact an agency problem and it exerted an impact on labour productivity. There is also a potential effect of the variable related to the skill levels among the crew. If the master chooses to economise with regard to crew size, the incentive to hire *skilled* workers becomes more important. After all, a captain would not willingly jeopardise the success of an enterprise in which he has a stake, and would therefore be likely to seek out the best men possible. Table 6 shows the distribution of this variable over the country groups and periods; about one in three ships was co-owned by the master.

As our primary goal is to determine whether a link existed between human capital and labour productivity,

Table 6
Master-ownership of merchant ships sailing on intra-European routes in Period 1 (1702–1716) and Period 2 (1777–1801).

	Period 1 (1702–1716)	Period 2 (1777–1801)
British Isles	43%	23%
France	33%	26%
Germany	47%	37%
The Netherlands	9%	30%
Scandinavia	36%	14%
Northern Europe	*31%*	*28%*
Southern Europe	*34%*	*29%*

most of our independent variables relate to the two human capital indicators discussed in Section 6. We can employ the following variables: ship-specific estimates of the literacy of the master of the ship (Litmaster) and of the crew (Litcrewship); the per-country group average literacy of the crew (Litcrew), masters and officers excluded, and of officers and crew (Litall); and the per-country group average numeracy of the crew (Numcrew) and of officers and crew (Numall). Numeracy estimates per ship are not available: because one needs a large sample of people to get more or less reliable estimates of the degree of age heaping, it is impossible to get a numeracy index of every single ship. The variables reflecting human capital range from zero to one; the numeracy variable is, as explained, the ABCC index. Litmaster and Litcrewship are only weakly correlated with the other human capital variables, but the four others (Litall, Litcrew, Numcrew, and Numall) are all strongly correlated (.7 or higher) and therefore enter the regressions separately (see the correlation matrix in the Appendix A). Finally, to further test for productivity growth over time we included a Period dummy, set at 1 for Period 2 (1777–1801).

The distinction between literacy by ship and by country group allows us to test two related hypotheses, one 'hard' and the other 'soft'. The 'hard' hypothesis about the effect of human capital on labour productivity is that the design of the individual ship – and therefore the labour required to manage it – is related to the skill level of the crew and/or the officers. For this to hold, we have to demonstrate a link between labour productivity and skills at the level of the individual ship. The 'weaker' version of the hypothesis maintains that this link exists at the country level: the design of ships in country A is different – making possible a higher level of labour productivity – than the design of ships in country B, because it reflects the higher skill level of the labour force of country A. In this latter hypothesis, we expect a relationship between labour productivity and Litall and Litcrew, but not necessarily with Litcrewship.

The dataset we use in the regression analysis is the same as has been used in the previous sections. The logarithm of the tonnage-per-man ratio is used in the regressions to ensure that extreme values do not play a disproportionate role. In addition, all independent variables have been standardized to make it easier to interpret the coefficients found. As mentioned above, the age of the ship was used in the regressions as a control variable, but its coefficient was always very close to zero (and insignificant); we therefore do not report these results. The equation including Mastowner, Litmaster, and Period serves as a baseline model, to which we add the human capital variables separately to avoid collinearity issues (see the correlation matrix in the Appendix A). The results of the regressions are presented in Table 7. Equations (I)–(V) report on the outcomes of the 'weaker' hypothesis about the effect of human capital on labour productivity, whereas (VI)–(VII) report on those of the 'hard' hypothesis. We could add country dummies only in regression VII, as they correlated too strongly with the country-specific levels of literacy and numeracy in specifications (II)–(V).

The results in Table 7 show a strong and consistent effect of the various country-specific measures of human capital on labour productivity; as regressions (II) to (V)

Table 7
Explaining the log of tonnage per man of merchant ships sailing on intra-European routes in 1702–1716 and 1777–1801.

	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)
Mastowner	.047	.064	.056	.022	.043	.065	.035
	(1.23)	(1.67)	(1.47)	(0.76)	(1.17)	(3.31)	(1.96)
Litmaster	.134	.099	.081	.092	.085	.142	.098
	(9.14)	(5.19)	(3.84)	(9.75)	(13.09)	(5.85)	(4.43)
Numcrew		.32					
		(7.05)					
Numall			.450				
			(11.67)				
Litcrew				.359			
				(4.10)			
Litall					.343		
					(3.61)		
Litcrewship						.066	.014
						(2.90)	(0.62)
Period	.487	.282	.187	.392	.324	.428	.366
	(3.51)	(1.79)	(1.46)	(2.44)	(1.98)	(15.7)	(14.4)
Country dummies	No	No	No	No	No	No	Yes
R2	.24	.30	.32	.35	.32	.21	.35
N	2048	1956	1982	2048	2048	1899	1899

Notes: T-values in parentheses. The coefficients are standardized (see the descriptive statistics in the Appendix A). In regressions (I)–(V) the standard errors are clustered at the country level to control for serial correlation in the un-observables. In regressions (VI)–(VII) the standard errors are clustered at the ship level. Regression (VII) includes country-specific dummies to allow for country fixed effects.

demonstrate, literacy and numeracy of crew has a strong positive effect on tonnage per sailor. We therefore find strong confirmation of the 'weak' hypothesis. At the level of the individual ship – testing the 'hard' hypothesis – the results are more mixed: the literacy of the master shows a consistent positive coefficient in all regressions (but almost all masters are literate), but if country dummies are included the literacy of the ships' crews no longer affects labour productivity. The regression analysis also shows that it is difficult to disentangle which of the two human capital indicators had the largest effect. Although the development of literacy rates was somewhat more dynamic over time, Table 7 shows that overall literacy and numeracy were almost equally important for labour productivity. This is not surprising given the strong correlation between the two measures. Another consistent result, which is plausible given the descriptive statistics in Section 5, is that there is a significant increase in labour productivity in the second period. Finally, the analysis also shows that the captain's full or partial ownership of the ship was positively related with labour productivity, but only in one case (VI) do we find a significant effect.

7. Explaining the link between human capital and performance

Now we have established that our data shows a link between human capital and labour productivity, how do we explain this connection? We believe that much of this relation is related to the working environment. The fact that ocean- or sea-going ships were relatively sophisticated pieces of technology, and *therefore* required a skilled labour force, is the core issue, though in itself this is not a sufficient explanation. After all, sophisticated machineries do not necessarily require much education or training among common workers; in the industrial era a limited number of engineers combined with a massive unskilled labour force were able to fully utilise relatively complicated technology. It is our contention, however, that the early modern maritime sector did require an all-round skilled crew. To some degree this was already true aboard seventeenth-century merchant vessels, but in the eighteenth century a combination of technological change and – often as a result thereof – a reduction of crew sizes led to 'crews [needing] to learn more and […] work harder' (Rediker, 1989: 121). Indeed, the extra effort and level of seamanship aboard the common merchant vessels applied not only to officers but also to those 'before the mast'. Only with the expansion of officers' schools in the nineteenth century and the introduction of steam engines did the distinction between officers and common workers become more pronounced on board the common merchant vessel (Rediker, 1989: 87–88). On board pre-industrial merchant vessels, however, crucial maritime knowledge was *not* limited to officers.

So what were the tasks on board merchant ships, and what skills were required? Although differences existed between ships of different sizes and routes, on most ships there was a more or less uniform division of labour. On top of the pyramid stood the master or commander: usually appointed by a merchant, he was responsible for all matters relating to cargo and sailors. His key task was navigation, however, which during the course of the eighteenth century involved instruments and mathematical calculations of increasing complexity (Davids, 2008). While on shore the master was also in charge of all business transactions. The second man on board was the mate or chief mate (sometimes, depending on the country, called the steersman or lieutenant), who was in charge of the daily management of the ship, including the managing of the crew. He also had to possess knowledge of navigation and often drafted entries for the logbook. Should the master perish during a voyage, it was customary for the mate to succeed him. The boatswain (or 'bosun') was the senior crewmember (i.e., of the non-officer class) on board, and functioned as a foreman for the crew and craftsmen, and as an intermediary between the officers and the crew. His other tasks involved the maintenance of the ship, in particular the rigging and sails, and the supervision of the stores. Finally, though many of his tasks were repetitive and required brute physical strength, the common sailor was far from unskilled. Sailors, in the common saying, had to 'hand, reef and steer' – and to 'steer' meant they had to understand the functioning of a compass. Common sailors were often divided in two categories: *able bodied* and *ordinary* sailors, the first being more skilled (and/or experienced) than the latter. Able bodied sailors aboard merchant vessels were, for instance, expected to be expert helmsmen.[7]

This short sketch of the most important ranks on board a merchant vessel shows the need for a variety of skills, which can be linked to our measures of literacy and/or numeracy as shown in Section 6. Navigation involved relatively advanced arithmetic; bookkeeping and maintaining the logbook presupposed a degree of numeracy and literacy. But also the tasks of the non-officer ranks (boatswain and below) increasingly required more than just physical strength and involved a deeper knowledge of various aspects of seamanship, including navigation. Although literacy was necessary to study the more mathematical aspects of seamanship (which also explains

[7] The description of ranks is based on Davis, 1972; Rediker, 1989; Falconer, 1784; Dana, 1863; Boulet and Couwenberg, 1857.

the strong correlation of the overall levels of numeracy and literacy) many sailors would have developed relatively good numeracy skills, as is confirmed by the figures presented in Section 6. Indeed, as Rediker (1989: 95) explains, the lower ranks often had a very good understanding of the intricate functioning of a ship, and when the wrong orders were given by the officers, common sailors 'were usually able to counteract such danger through their own knowledge of the labor process'. Centralised knowledge of the ship and its navigation was not yet the sole privilege of the officer class, as it would become in the latter part of the following century.

Not having the right skills had serious consequences, and it was considered a deliberate act of deception to pretend to have certain skills, and for instance muster as an able bodied sailor without having the necessary experience. During his stint on board an American merchant vessel in the 1830s, Richard Henry Dana, Jr., observed the effect of a common sailor not having the right skills: "If, for instance, the articles provide for six able seamen, and if one of the six turns out not to be a seaman [this] makes her [i.e., the ship] short-handed for the voyage. […] if the delinquent was not a capable helmsmen, the increased duty at the wheel alone would be, of itself, a serious evil" (1946: 159). In sum, a lack of skilled workers could not only diminish productivity, since often specialised tasks had to be performed by fewer men, it could even lead to danger, particularly when there were fewer men to assign to steering (an around-the-clock task): the shortage inevitably led to longer, or more, turns at the helm for every man. The falling tonnage-to-man ratio on board merchant marine vessels made skill level more important: with the reduction of crew sizes all functions became more specialised, and crews were under greater pressure to perform. The latter observation tallies with the outcome of the regression analysis: master-owners tended to be in charge of the more productive ships, but these men would have been mindful of the risks of taking fewer men on a journey.

A further issue to be addressed is the individual's process of human capital acquisition. The most obvious explanation of the relatively high human capital investments in the sector is that one simply had to have certain skills, and thus training, to function properly in the maritime world. As Falconer's Universal Dictionary of the Marine (1784) explains, a sailor is a 'person *trained* in the exercise of fixing the machinery of a ship, and managing her' (our emphasis). Davis (1972: 117–18) states that it took a ship's boy around two or three years to become an ordinary sailor – it took even longer to become an *able bodied* sailor. Some went even further, and argued that not everyone *could* rise up the ranks. In a parliamentary committee in December 1781, Lord Mulgrave, himself an experienced Navy officer, argued for a focus on quality, and stressed the difficulty of finding qualified sailors: 'Seamen [were] not to be made in one, or two, or three years; nay, many thousands of ordinary seamen could never be made able seamen. […] it required propensity, as well as understanding' (Parliamentary Register, 1782: 101–2).

There were roughly two ways in which a potential seaman could acquire the required skills: through formal education or by vocational training, i.e., by 'learning on the job'. In some countries, like England, the latter often involved a quite rigid (and expensive) apprenticeship of around three to five years. In the Netherlands, for instance, such a formal framework was much less prevalent. Nevertheless, as we have just seen, in all cases there was a significant period of time involved to 'learn the ropes'. In fact, individuals could still be rated as a boy if the right skills were lacking – regardless of age or stature (Dana, 1863: 160). The dataset shows that of the 198 interrogated boys, 30 were 18 years or older. Indeed, training was essential to acquire all the basic aspects of seamanship, such as steering and basic navigation, and to get a wider knowledge of the functioning of the ship's rigging and sails. However, with technological advancements in navigational instruments, some form of formal training on land became necessary for most to really acquire skills in navigation. It required 'a thorough knowledge of those matters which they have every day experimentally proved, as well as theoretically incalculated', as an article in the *British Press* in 1811 put it (Public Journals, 1812: 50). Indeed, although the practical use of instruments was still best learned at sea, and in the eighteenth century there was a marked rise in publications devoted to practical navigation, the mathematics it involved could best be mastered through schooling (Davis, 1972: 124–26). When the boatswain Hans Michelsen Brenk was interrogated in Newcastle in September 1794 he was asked, as was customary, how long he had known the master. He answered that they had known each other since they had been 'school fellows'.[8]

Even if much maritime training happened on board ships at sea, some of the sailors had also received a more formal education. But in the early modern period not many schools provided specifically maritime education. In London a navigation school was founded in 1673 (Davis, 1972: 124), followed by one in Copenhagen two years later, specifically for the merchant marine (Feldbæk, 1997: 189). In England a few more mathematical schools teaching would-be seamen were established at the

[8] TNA HCA 32/689.

beginning of the eighteenth century (Davis, 1972: 124–25). Nevertheless, maritime schools proper were still relatively rare in the eighteenth century, and were mainly a feature of smaller seafaring communities in northwestern Europe (and thus of relatively small scale) (Van Royen, 1987; Bruijn, 1997; Van Lottum and Poulsen, 2011). For most aspiring seamen the best way to acquire advanced mathematical skills was to take lessons from private teachers who were often ex-captains or practical seamen (Davis, 1972: 125).

Acquiring these additional skills was essential to those hoping to reach the higher ranks, which leads us to a second (though related) cause of the relatively high human capital levels in the maritime sector: investment in one's skills paid off. In the northwestern European labour market of the eighteenth century, opportunities abounded for working one's way up the career ladder if one put enough into training. Although it was often a gradual process, it was possible to advance from boy to chief mate on merit (cf. Davis, 1972: 126). Van Royen (1987: 144) demonstrated that in a span of ten years, no less than 61% of the common sailors on board Dutch merchant vessels had been promoted to a higher rank. The ultimate step from mate to captain was a much higher hurdle, and often depended on factors beyond one's control; as the master was appointed by the merchant, having sufficient *social* capital was as essential as the human capital one possessed (Davis, 1972: 126–27).

Indeed, rising through the ranks, from boy to ordinary sailor and so on, was possible and was certainly rewarding: wages on board included substantial skill premiums. Table 8 gives several examples of the wage structure of ships from different countries, which indicates a remarkable similarity among levels for the skill premium over time and for various nationalities. When we set the mate's wage at 100%, we can see that a sailor generally earned slightly below half his wage. The wages of the boatswain and carpenters were in between that of sailors and mates (around 80% of a mate's), while cooks earned just slightly more than an ordinary sailor. Finally, the boy (the lowest rank on board) commonly received about half the wage of a seaman, or about a quarter of that of a mate.

8. Conclusions

Crucial to the pre-industrial economy, international shipping was a highly dynamic sector. Based on a dataset comprising more than 2,500 ships, our estimates show that labour productivity (measured in tons per man) increased sharply during the eighteenth century. These efficiency improvements can be found in all parts of Western Europe, but our figures also show that the large gap in labour productivity between the northern and the southern parts of the continent remained unchanged: labour productivity levels were much higher in the northwestern European fleets than in their southern counterparts, confirming the results of other studies on relative economic performance in early modern Europe.

Our dataset also contains diverse information about the maritime workforce of the eighteenth century, which allowed us to calculate numeracy and literacy levels for nearly 7,000 individuals. We show that overall, human capital levels in the maritime sector occupied a high level compared to other sectors of the economy. That these levels were high indicates that investment in human capital (either as a result of formal education or on-the-job training) was relatively large. This was true all around Europe. However, as with labour productivity, there was also a north–south divide in terms of human capital levels, especially towards the end of the eighteenth century. Seamen on board the ships of the northwestern European merchant fleets had higher human capital levels than their colleagues in the south. This is particularly the case with numeracy skills, but literacy levels followed the same geographical pattern. In the second period both indicators diverge further in favour of the northern European fleet.

The analysis of the basic data as well as the regression analysis showed the significance of human capital for labour productivity. The most productive ships in our

Table 8
Wage differentials aboard European merchant vessels.

Period	Country	Mate	Boatswain	Carpenter	Cook	Seaman	Boy
1	Netherlands	100%	-	-	55%	43%	30%
1	Sweden	100%	61%	89%	61%	40%	20%
2	France	100%	51%	79%	-	46%	23%
2	Netherlands	100%	80%	-	56%	48%	24%
2	Sweden	100%	80%	73%	56%	45%	17%
2	Germany	100%	67%	53%	-	50%	
2	Spain	100%	-	60%	-	46%	-
1 and 2	*All*	*100%*	*68%*	*71%*	*57%*	*45%*	*23%*

dataset sailed with crews that had the highest levels both of numeracy and literacy. Those workers who invested in their own human capital (indicated to us by the literacy and numeracy proxies) were in fact the most skilled workers. The quantitative analysis showed that at the country level the two dimensions of human capital, numeracy and literacy, had a positive and significant effect on labour productivity. In most specifications of the regression, productivity was also higher on ships co-owned by the captain, but this effect was usually not significant. Workers in the maritime sector are likely to have invested in skills for two main reasons. First, the relatively sophisticated technical environment made a certain skill level necessary, and skilled workers would therefore have been in greater demand when hired. Second, there was an incentive to invest in skills because of an open market (in particular in northern Europe) that allowed considerable vertical and horizontal mobility. This latter feature, combined with sizeable skill premiums, meant that there were monetary returns to investments in training.

A question left unanswered here is why there are such substantial differences in human capital levels between the northern and southern fleets. If human capital was so important for productivity in the maritime sector, why then do we see such large geographical differences for both indicators but, above all, no convergence over time? More research is necessary to fully understand the (growing) differences in skill levels between north and south. A comparative analysis of investments in human capital in this sector (i.e., in maritime schooling and training) may shed light on this, in particular when the latter is linked with differences in the adoption of various maritime technologies. There is, however, an alternative institutional explanation which merits attention. A key difference between the northern and southern European fleets was the level of internationalisation; northern European fleets tended to sail with much more international crews than those south of the Habsburg Netherlands (Van Lottum et al., 2011). In France, for instance, it was relatively difficult to hire seamen of foreign origin, because they had to prove they were French residents, usually by showing a French marriage certificate (le Goff 1997). Different restrictions applied in Spain, where, until 1737, there was a quota on foreign sailors. Even when these restrictions were lifted, foreigners had to meet various criteria before being allowed to muster (Rahn Phillips 1997). Fleets without such regulations (such as the German, Dutch, and Scandinavian merchant fleets) could much more easily employ foreign crews, and did so in very large numbers (Van Lottum, 2007). As a consequence, shipmasters from these countries had a larger labour pool at their disposal, which made it easier to select workers with the best skills (although sometimes at a premium). Even if, due to lack of investments in seamen's education, for instance, 'locally sourced' labourers lacked sufficient skill, a skipper could turn to the international labour market and 'import' skilled workers (thus making investing in one's skills all the more important). Moreover, this flexible and in many ways modern international labour market also facilitated (and accelerated) the spread of knowledge and exchange of ideas. After all, much of the maritime training (and therefore knowledge exchange) took place *on board* a ship. Compared to the fairly isolated and more sedentary labour markets of the south, the relatively large number of labour migrants aboard northern European vessels thus ensured a much faster spread of state-of-the-art shipping knowledge, both theoretical *and* practical.

Let us, however, conclude with the most important finding of our paper: human capital really mattered for productivity and performance in the shipping industry. This, we show, is consistent with contemporary writings about the importance of a skilled labour force on board the ships, and with increasing investments by sailing communities into training and education. The spillover effects caused by the evolution of this industry were enormous. A highly productive shipping sector enabled the Netherlands and, later, Great Britain to dominate global markets. Nor would these nations have been able, without such a high-performing shipping industry, to develop into the 'modern' economies that generated processes of long-term economic growth in this period (De Vries and Van der Woude, 1997).

Acknowledgments

The work underlying this article was made possible by a by a grant of the Economic and Social Research Council (ESRC) (RES-062-23-3339): 'Migration, human capital and labour productivity: the international maritime labour market in Europe, c. 1650–1815'), and a British Academy Postdoctoral Fellowship (PI on both projects: Jelle van Lottum). We very much thank Sandra de Pleijt (University of Utrecht) for her advice on the econometric analysis and Aske Brock (University of Kent) and Catherine Sumnall (University of Cambridge) for their help in collecting the data and constructing the database. Aske Brock also provided us with some very good suggestions about maritime careers and life on board. Jim Gibbons we thank for copy editing the paper. Finally, we benefitted greatly from the comments and suggestions received from Hans-Joachim Voth, two anonymous referees and from participants of research seminars at the universities of Utrecht, Osaka and Hitotsubashi and during a session at the World Economic History Conference in Stellenbosch. The usual disclaimer applies.

Appendix A. Further details concerning the variables used in the regression analysis

A.1. Correlation matrix

	Lnprod	T	Mastown	Mastlit	Numcrew	Numall	Litcrew	Litall	Crewlitship
Lnprod	1.000								
T	0.4472	1.000							
Mastown	0.0766	−0.0011	1.000						
Mastlit	0.1690	0.0857	−0.0271	1.000					
Numcrew	0.4742	0.7413	−0.0066	0.1587	1.000				
Numall	0.5208	0.7922	−0.0023	0.1818	0.9417	1.000			
Litcrew	0.4597	0.3567	0.0745	0.1255	0.7805	0.6529	1.000		
Litall	0.4510	0.5515	0.0137	0.1667	0.9370	0.8301	0.8961	1.000	
Crewlitship	0.1543	0.2097	0.0104	0.0745	0.2635	0.2558	0.2240	0.2578	1.000

A.2. Descriptive statistics of variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Lnprod	2471	2.67732	.4436079	.5389965	3.84303
t	2575	.8217476	.3827994	0	1
Mastown	2532	.2819905	.4500576	0	1
Mastlit	2134	.9854733	.1196762	0	1
Numcrew	2389	.9355295	.0527162	.82	.97
Numall	2421	.9377654	.0569508	.76	1
Litcrew	2575	.6414835	.0967493	.42	.78
Litall	2575	.8376621	.0846363	.66	.91
Crewlit_ship	2303	.804183	.3114169	0	1

References

A'Hearn, B., Baten, J., Crayen, D., 2009. Quantifying quantitative literacy: age heaping and the history of human capital. Journal of Economic History 69, 783–808.

Acemoglu, D., Johnson, S., Robinson, J.A., 2005. The rise of Europe: Atlantic trade, institutional change and economic growth. American Economic Review 95, 546–579.

Allen, R.C., 2003. Progress and poverty in early modern Europe. Economic History Review 3, 403–443.

Allen, R.C., 2009. The British industrial revolution in global perspective. Cambridge University Press, Cambridge.

Anglicus, 1791. One Englishman a match for three Frenchmen, proved. The Bee or literacy intelligencer, pp. 176–178 (April).

Anonymous, 1812. French infant marine. James Ridgway, London (October (1811), published in The Spirit of Public Journals for 1811 (London)).

Anonymous, 1755. The connoisseur 84, 95–102.

Boulet, L.A.J., Couwenberg, J.J., 1857. De zeevaart, of De kennis van schip en tuig, der werkzaamheden en verpligtingen aan boord; als ook: over de zamenstelling en het verband der koopvaardijschepen: benevens: een beredeneerd woordenboekje der zeemans kunsttermen. C.F. Stemler, Amsterdam.

Bruijn, J.R., 1997. Career patterns. In: Royen, P.C., Bruijn, J.R., Lucassen, J. (Eds.), Those emblems of hell? European sailors and the maritime labour market, 1570–1870. International Maritime Economic History Association, St. John's, pp. 25–34.

Bruijn, J.R., 2011. Commanders of Dutch East India ships in the eighteenth century. Boydell Press, Woodbridge.

Bruijn, J.R., Lucassen, J. (Eds.), 1980. Op de schepen der Oost-Indische Compagnie. Vijf artikelen van J. de Hullu. Wolters-Noordhoff, Groningen.

Dana Jr., R.H., 1863. The seaman's manual. Edward Moxon & Co., London.

Dana Jr., R.H., 1946. Two years before the mast, a personal narrative of life at sea. The World Publishing Company, Cleveland and New York.

Davids, C.A., 2008. The rise and decline of Dutch technological leadership. Technology, economy and culture in the Netherlands, 1350–1800. Brill, Leiden and Boston.

Davis, R., 1972. Rise of the English Shipping Industry in the 17th and 18th Centuries. David & Charles, Newton Abbot.

De Moor, T., Van Zanden, J.L., 2010. Every woman counts: A gender-analysis of numeracy in the low countries during the early modern period. Journal of Interdisciplinary History 41, 179–208.

De Vries, J., Van der Woude, A., 1997. The first modern economy. Success, failure, and perseverance of the Dutch economy, 1500–1815.

De Wit, A., 2009. Leven, werken en geloven in zeevarende gemeenschappen Schiedam, Maassluis en Ter Heijde in de zeventiende eeuw. Aksant, Amsterdam.

Eyck van Heslinga, E.S., 1982. De vlag dekt de lading. De Nederlandse koopvaardij in de Vierde Engelse oorlog. Tijdschrift voor zeegeschiedenis, 1, pp. 102–113.

Falconer, W., 1784. A universal dictionary of the marine. T. Cadell, London.

Feldbæk, O., 1997. Dansk Søfarts Historie. Vol 3, Storhandlens tid 1720–1814. Aksant, Copenhagen.

Harley, C.K., 1988. Ocean freight rates and productivity, 1740–1913. The primacy of mechanical invention reaffirmed. Journal of Economic History 851–876.

Lucassen, J., Unger, R.W., 2000. Labour productivity in ocean shipping, 1450–1875. International Journal of Maritime History 12, 127–141.

le Goff, T.J.A., 1997. The Labour Market for Sailors in France. In: van Royen, Paul, Bruijn, Jaap R., Lucassen, Jan (Eds.), Those emblems of hell? European Sailors and the Maritime Labour Market 1570-1870. International Maritime Economic History Association, St. John's, pp. 287–327.

Lucassen, J., Unger, R.W., 2011. Shipping, productivity and economic growth. In: Unger, R.W. (Ed.), Shipping and economic growth, 1350–1850. Brill, Leiden and Boston.

Mokyr, J., 2002. The Gifts of Athena. Princeton University Press, Princeton.

Mokyr, J., 2010. The enlightened economy: An economic history of Britain, 1700–1850. Yale University Press, New Haven and London.

North, D., 1958. Ocean freight rates and economic development 1750–1913. Journal of Economic History 18, 537–555.

Rahn, Phillips C., 2010. The Labour Market for Sailors in Spain, 1570-1870. In: van Royen, Paul, Bruijn, Jaap R., Lucassen, Jan (Eds.), Those emblems of hell? European Sailors and the Maritime Labour Market, 1570-1870. International Maritime Economic History Association, St. John's, pp. 329–348.

Rediker, M., 1989. Between the devil and the deep blue sea. Cambridge University Press, Cambridge.

Parliamentary Register, 1782.

Smith, A., 1778. An inquiry into the nature and causes of the wealth of nations. W. Strahan and T. Cadell, London.

Starkey, D.J., 1990. British privateering enterprise in the eighteenth century. University of Exeter Press, Exeter.

Unger, R.W., 1978. Dutch shipbuilding before 1800. Ships and guilds. Van Gorcum, Amsterdam.

Unger, R.W., 2011. Shipping and economic growth, 1350–1850. Brill, Leiden and Boston.

Van den Heuvel, D., Van der Heijden, M., 2007. 'Sailors' families and the urban institutional framework in early modern Holland. The history of the family, 12, pp. 296–309.

Van Lottum, J., 2007. Across the North Sea: The impact of the Dutch Republic on international labour migration, c. 1550–1850. Aksant, Amsterdam.

Van Lottum, J., Lucassen, J., 2007. Six cross-sections of the Dutch maritime labour market: A preliminary reconstruction and its implications (1610–1850). In: Gorski, Richard (Ed.), Maritime labour in the Northern Hemisphere c. 1750–1950. Aksant, Amsterdam, pp. 13–42.

Van Lottum, J., Poulsen, B., 2011. Estimating levels of numeracy and literacy in the maritime sector of the North Atlantic in the late eighteenth century. Scandinavian Economic History Review 59 (1), 65–80.

Van Lottum, J., van Voss, L. Heerma, Lucassen, J., 2011. National and international labour markets. In: Unger, Richard (Ed.), Shipping and economic growth, 1350–1800. Brill, Leiden and Boston, pp. 309–352.

van Rossum, M., van Voss, L. Heerma, Lottum, J. van, Lucassen, J., 2010. Sailors in European, Atlantic and Asian Waters: National and International Labour Markets 600-1850. In: Fusaro, Maria, Polonia, Amelia (Eds.), History as Global History, Research in Maritime History No. 43. International Maritime Economic History Association, Leiden and Boston, pp. 47–72.

Van Royen, P.C., 1987. Zeevarenden op de koopvaardijvloot omstreeks 1700. De Bataafsche Leeuw, Amsterdam.

Van Zanden, J.L., van Tielhof, M., 2009. Roots of growth and productivity change in Dutch shipping industry, 1500–1800. Explorations in Economic History 46, 389–403.

Wrigley, E.A., 1985. Urban growth and agricultural change: England and the Continent in the early modern period. Journal of Interdisciplinary History XV, 683–728.