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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 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 very high, much higher than the average for the countries from which the crew was recruited, and secondly that there were close 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.

Keywords: Human Capital, Shipping, Early Modern Period

JEL Codes: J24, N34, N74

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I Introduction

Shipping was a key sector of the pre 1800 economy. Pre-modern growth was to a large extent dependent on processes of commercialization and specialization, based on cheap (inter)national 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 (Acemoglu et.al. 2005; Allen, 2009; Wrigley, 1985), but have not really explained why Europeans were so efficient in organizing large international networks of shipping and trade. Concerning shipping, there is a more qualitative story about the development of ship design, starting with major innovations in the High Middle Ages (as a result of the merging of Mediterranean and Northern traditions of ship design), via the development of the *fluyt* in the 16th century to the major innovations in ship construction in 18th century England (Unger 1978; Lucassen and Unger, 2011). We argue in this paper that this is only part of the explanation of the long-term performance of European shipping in the pre-1800 period. Human capital – the quality of the labour force employed on ships – mattered as well.

In the present study we will demonstrate that (1) levels of human capital on board European ships were very high, much higher than the average for the countries from which the crew was recruited, and (2) that there were strong 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 (Rediker, 1987) not only employing high quality capital goods (increasingly efficient ships), but also, as a complementary input, high quality labour, which was required to operate the increasingly complex ships and their equipment (Lucassen and Unger, 2011: 28-29). In other words, the technological trajectory of European shipping was not simply one of a shifting ratio between capital and labour, but 'raw labour' was replaced by both capital goods and *complementary* human capital. This result is also important for the ongoing discussion about the role of human capital in the pre-1800 economy. Some scholars have argued that skills of 'common workers' were not an important ingredient of pre 1800 economic growth (Allen, 2009; Mokyr, 2002, 2009), our results show the opposite.

The added value of this paper is in the presentation and analysis of a source that has not been used for this purpose – the Prize papers.[1] This source allows us to measure human

[1] National Archives (TNA), High Court of Admiralty (HCA), 32.

capital and labour productivity in international shipping in the late 17th and 18th centuries for a large set of ships from a broad range of countries. These indicators are all derived from the same source, something that was not possible in earlier studies dealing with the issue of labour productivity in the maritime sector, thereby significantly enhancing its robustness (Lucassen and Unger, 2011: 8-9). A recent study using the Prize Papers has shown that overall, human capital levels in the maritime sector were relatively high compared to other sectors of the economy (Van Lottum and Poulsen, 2011). The latter study has, however, not investigated the potential link between skill levels of maritime workers and economic performance nor has it explored the possible effect of other variables that can be derived from this unique source. For example, the Prize Papers make it possible to explore if the hiring policies of masters who were co-owners of a ship were different from other masters, who were simply the hired agents of the owners. We will demonstrate that this mattered: all things being equal, masters who were also co-owners tended to have fewer sailors on board, and therefore realized a higher level of labour productivity. The data also allows us to measure the human capital of the crew (and the master) in two different ways: their level of literacy – measured as their ability to sign a document – and their numeracy – measured as their ability to report exact ages (instead of age heaping). This two-dimensional way of approaching human capital makes it possible to find out what mattered as a determinant of labour productivity: literacy or numeracy. We show that age heaping of the crew was strongly linked to productivity, whereas literacy was unrelated to it, but literacy of the master did matter for productivity.

II Sources and database

Varying from thousands of private letters, to merchant's contracts, muster roles, and logbooks, very few sources encompass such a wide array of historical information about the early modern maritime sector as the Prize Papers archive. The archive consists of all documents relating to the privateering activities of the Royal Navy and its subsidiaries, and is part of the extensive archive of the High Court of Admiralty. The section of the collection we used for our analysis is the court's interrogations of crewmembers of captured ships. When a Royal Navy vessel or a private man-of-war captured what they thought was an enemy ship, the Court needed to establish whether the vessel was in fact a lawful prize – in other words did the ship, crew or cargo belong to an enemy state? To determine this,

crewmembers were cross-examined (if necessary with the help of a sworn-in interpreter) 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 interrogated, commonly it involved only three crewmembers. This was usually a cross section of the ranks aboard; generally the master was interrogated, as well as one or two ordinary sailors, and sometimes also a mate or an officer – a steersman or boatswain for instance.

The interrogations exist for the end of the seventeenth and for different periods of the eighteenth century and the beginning of the nineteenth century. In this paper we will focus on two periods, one at the turn of the seventeenth century (1672-1720), and one a century later (1770-1813).[2] Based on the interrogations, we constructed a (relational) database consisting of all relevant variables of the merchant ships and its crews, such as the country of origin of the ship and its crewmembers, the ship's destination and information relating to the ownership of the vessel. As we were interested in the effect of human capital formation on labour productivity in *commercial* shipping we have deliberately only taken into account captured merchant vessels, meaning that we excluded all fishing vessels and men-of-war or privateers.

We will approximate labour productivity by calculating the number of tons per men, using information derived from the interrogation relating to with the ship's size and the number of men aboard. Because every interrogated crewmember was requested to give his age and needed to sign the document, we were able to measure levels of numeracy (by calculating the level of age heaping) and literacy (through signed literacy). In the latter case, following the extensive literature on this subject, we regarded an individual who signed the document with a signature as literate and with a cross as illiterate; given the method of age heaping (which will be discussed in Section IV) numeracy could only be calculated within a larger population. In one case, however, that of Portuguese sailor Louis de Souza, we did get an insight in the ability (or better the lack thereof) to report exact numbers on an individual level. During the interrogations he replied to the question about his age by stating that he was "between 50 and 60 years old".[3]

A crucial question is to what extent the information given during the interrogations is representative. We believe that the interrogations provide in fact relatively accurate information about the ships that were taken, as well as about the crewmembers themselves.

[2] Period 1 deals with ships take the Third Anglo-Dutch Wars (1664-67, 1672-74) and the War of the Spanish Succession (1701-1714); the second period War of the American Revolution (1776-83), the Fourth Anglo-Dutch War (1780-84) and the French Revolutionary and Napoleonic Wars (1793-1815).
[3] TNA, HCA 32/269.

The main reason for this is that the answers to the questions raised in the interrogations could be verified with relative ease by the court, and the crewmembers must have been aware of this. Because all the ship's papers were confiscated, the High Court of Admiralty was able to check whether the provided information was correct or not, and the fact that they kept the documents (they are often still in the archive) makes it all the more likely that they will have used it in court as evidence if necessary. Furthermore, a comparison between answers given in the interrogations and corresponding ships' documents tells us that the answers match very well with the evidence in the documents – although minor differences between the answers and official documents illustrate that it were still personal answers and the answers were not "dictated" by the court.

A second issue is whether or not the captured ships constitute a representative cross-section of the maritime sector. Again, we think there is no evidence to suggest the contrary. First of all, as we will see in the next section, our labour productivity figures fit in quite well with earlier estimates made by Lucassen and Unger (2000; 2011), who based their analysis on different data sources. In other words, the aggregate national or supra-national regional figures of labour productivity we have produced using the Prize Papers yields similar results as those based on a variety of other national sources, indeed they used different sources to determine the size of the ships and the number of men onboard – the crucial ingredients for measuring labour productivity. Of course, it could be argued that because of the privateering practise certain types of ships will have been caught more easily than others. Still, however, it is important to realise that this could vary hugely, depending on not only the size and strength of the privateer or navy vessel, but also that of the merchant vessel. But again, comparisons with in particular Lucassen and Unger's work, shows that our data produces labour productivity figures in line with existing ones, suggesting no abnormalities in both the size of the ship and the number of crews in our dataset. Indeed, our data shows that as the navy, as well as the private men-of-war took ships all around the Atlantic, they captured quite a wide variety of vessels sailing from and to different destination, covering all major trading routes.

Finally, a short note on the sample size of our dataset; we have collected data for 503 ships and 1,384 individual crewmembers.[4] As Table 1 below shows, the sample size for both

[4] To construct our dataset we have used the following archives: TNA, HCA 32/1063, 32/1064, 32/1068, 32/261, 32/266, 32/268, 32/269, 32/271, 32/273, 32/274, 32/275, 32/276, 32/277, 32/278, 32/279, 32/280, 32/282, 32/288, 32/289, 32/293, 32/299, 32/302, 32/316, 32/332, 32/333, 32/335, 32/338, 32/342, 32/343, 32/346, 32/356, 32/359, 32/366, 32/369, 32/371, 32/372, 32/372, 32/395, 32/395, 32/396, 32/401, 32/409, 32/433,

periods is relatively balanced (732 seamen vs. 652). However, the table illustrates that not all nations are represented equally in the dataset. Depending on the war during which the privateering activities took place, the number of ships for each country could vary strongly, and because of England's close proximity to the Netherlands and France (and because of the size of their fleet), these two countries are over-represented in our dataset.

Table 1: Sample size of the Prize Paper dataset

	Period 1		Period 2	
	n ships	n crews	n ships	n crews
Belgium	9	19	6	9
Denmark	24	93	5	15
England	10	20	4	9
France	69	112	64	161
Germany	3	14	16	42
Ireland	9	22	-	-
Italy	1	2	1	3
Malta	1	1	-	-
Netherlands	34	120	88	234
Norway	22	92	1	3
Portugal	3	8	1	4
Scotland	5	18	-	-
Spain	12	31	5	8
Sweden	44	176	27	80
United States	2	4	37	84
Total	*248*	*732*	*255*	*652*

Source: Prize Papers Dataset.

Moreover, inevitably there are very few English ships in the database; they were after all the privateers themselves. The fact that the dataset contains English ships at all is the result of the common practise that when English ships were taken by foreign privateers, but shortly after they were retaken by the navy, the original English crew were interrogated as if they were a foreign crew. Finally, because the sample size of the various national fleets (and hence their crews) differed substantially, in the paper we will cluster them in country groups as to make a more geographically balanced comparison possible and to increase the robustness of the data analysis.

32/441, 32/453, 32/48, 32/488, 32/49, 32/5, 32/51, 32/52, 32/53, 32/54, 32/55, 32/64, 32/65, 32/66, 32/67, 32/76, 32/77, 32/79, 32/8, 32/80, 32/85, 32/92, 32/95, 32/96, 32/97, 49/100.

III Labour productivity

A number of studies have documented the productivity growth in European shipping in the Early Modern period. Some studies 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 on the tonnage per man ratio (Lucassen and Unger, 2000; 2011).[5] The latter approach is one we will also adopt in this paper. As pointed out by Lucassen and Unger (2011), this method has its drawbacks; it for instance lumps in regional variation within national markets, takes into account the burden of the ship instead of the cargo shipped, and fails to capture more general gains in productivity such as increases in average speed. Moreover, it is a partial index of productivity, only relating to labour productivity, and it may therefore show different patterns of change compared to (for example) deflated fright rates, which is a more comprehensive measure of total factor productivity (Van Zanden and Van Tielhof, 2009). Nevertheless, it is commonly accepted to be a good proxy for long term changes in labour productivity on an aggregate level (Lucassen and Unger, 2011).

Based on the Prize papers, our results add substantially to the picture of long-term growth of labour productivity in shipping. They make it possible to compare labour productivity between all the seafaring countries of northern and southern Europe, something Lucassen and Unger were not able to do, thereby broadening the geographic scope considerably. In addition, as pointed out in the previous section, our estimates also have the advantage that they are based on one single source whereas Lucassen and Unger had to rely on different sources for estimating the overall tonnage of national crews and the size of total seafaring crews.[6]

By comparing a wide array of sources for a number of countries in North-western Europe Lucassen and Unger (2000) distinguished four phases in labour productivity between 1425 and 1875. The first phase was characterized by an average ratio of 5 tons per man, a productivity level shared by most countries until the end of the sixteenth century. During the second phase labour productivity doubled to 10 tons per man. This phase was first reached by Germany and the Netherlands at the end of the sixteenth century, and lasted until the late eighteenth century. The third phase occurred at the end of the eighteenth

[5] For various approaches see the contributions in the edited volume by Lucassen and Unger (2011).
[6] A similar problem arose in the most recent estimate of the Dutch maritime sector before 1850, see Van Lottum and Lucassen (2007).

century, between circa 1780 and 1850, when rates rose to 17 tons per man. The final phase took place between 1850 and 1875; during this interval the ratio grew to more than 30 tons for every man onboard. Interestingly, the aforementioned two authors found that the Netherlands had an exceptionally high ratio of 20 tons per man at the end of the seventeenth century, not fitting any of the early modern phases, and a subsequent decline of labour productivity during the eighteenth century to half that level a hundred year later. As we will see below, our results match the overall trend Lucassen and Unger found, with the exception of the exceptional development of labour productivity in the Dutch merchant fleet.

Based on the interrogations for period 1 (1672-1720) and period 2 (1770-1813), we calculated ton per man ratios for 15 countries in period 1 and for 12 countries in period 2 (Table 2). As the table indicates, for some countries the sample is quite small, this is why we have grouped the different countries in the remainder of the paper; nevertheless it is instructive to compare the productivity levels on a country level first.

Table 2: Labour productivity levels and growth rates in European fleets

	1672-1720			1770-1813				
Fleet's country of origin	*N*	*Avg Size*	*LP*	*n*	*Avg Size*	*LP*	*Growth rate LP*	*Growth rate size*
Germany	3	130	16	16	180	26	69%	38%
Sweden	37	130	13	27	158	16	19%	22%
Norway	18	115	12	1	330	21	68%	187%
England	5	96	12	3	213	13	6%	122%
Netherlands	28	88	12	84	184	21	72%	110%
Denmark	23	122	12	4	113	14	22%	-8%
Italy	1	98	10	1	120	5	-44%	22%
United States	1	300	9	37	120	10	7%	-60%
Ireland	5	52	7	-	-	-	-	-
France	58	67	6	63	204	10	55%	207%
Belgium	4	85	6	6	89	12	102%	5%
Portugal	1	65	5	1	130	10	85%	100%
Spain	10	72	5	5	166	13	155%	131%
Scotland	5	43	5	-	-	-	-	-
Malta	1	48	3	-	-	-	-	-
Total	*200*	*95*	*10*	*248*	*172*	*16*	*58%*	82%

Source: Prize Papers Dataset.
Notes: LP: Productivity, measured in tons per men.

Table 2 shows, first of all, that if one uses the ton per man ratio as an indicator of labour productivity the sector witnessed a strong increase in the eighteenth century. For the total

sample, ton per man increased by 58%, or almost 0,5% per year – much higher than productivity growth in agriculture or the rest of the economy (which was in the order of 0.1% per year at the most (Allen 2000; Lucassen and Unger, 2011: 19, Table 1-2)). The average size of vessels increased even more (by 82%), which may have been one factor behind the increase in labour productivity (as we will see below). Moreover, there are strong regional differences in the ton per man ratio. Although its sample size is clearly quite small, the German merchant fleet has the highest labour productivity levels in period 1 with 16 tons per man. It is followed by a large group of north-western European fleets, led by Sweden and followed by Norway, England, the Netherlands and Denmark. The labour productivity gap between the ships of the leading (mainly northern European) countries and the rest is quite substantial. The French merchant fleet in the dataset only achieved an average productivity level of 6 ton per man, while Spain – another country for which we have a relatively large sample – only reaches a level of 5 ton for each seaman. As was mentioned above, our results fit in quite well with Lucassen and Unger's overall estimates. Chronologically our period 1 overlaps with their Phase 2, and our averages are marginally higher than their average ratio for this period: 10 tons per man. However, we do not find any evidence for the extremely high performance in the Dutch maritime sector in this period.

When we shift to Period 2, our estimates show that at the end of the 18th century Germany remains to have the most productive fleet by a relatively large margin with 26 tons per man, but behind it the differences have become a bit more pronounced. Compared to its north-western European rivals, which all witness labour productivity growth, the Netherlands fleet makes the largest improvement in productivity levels with an increase of no less than 72%, making it the second most productive fleet in period 2. The Danish and Norwegian sample is too small to really draw any major conclusions on, but the data for Sweden, for which we have a larger sample, shows a modest productivity increase compared to the Dutch fleet. At the bottom half of the table interesting shifts take place as well. Spain and the Habsburg Netherlands show an above average growth in productivity levels, while the French fleet increases from 6 to 10 tons per man or a growth rate of 55%: about the average growth rate in the North Atlantic. Again, our estimates fit in well with Lucassen and Unger's estimates: our Period 2 overlaps with their Phase 3, for which they estimated an average ratio of 17, while our results show a ratio of around 16. The largest difference between the two estimates can again be found in the development of the Dutch maritime sector; Lucassen and Unger's estimates pointed in the direction of a strong fall in labour productivity in the Dutch maritime sector (which they explain by effects of the Napoleonic

Wars) while our results show an increase in the ratio, mirroring the development of other fleets in the same period.

To increase the sample size and to make the comparison over time and space more straightforward, in Table 3 below we have clustered the 15 countries of Table 2 into 5 country groups (we will use this categorization throughout this paper). We have combined the Northern European fleets of Scandinavia and Germany, those of France and the Southern Netherlands, the Mediterranean countries, and made a separate group consisting of the United Kingdom and North America; we kept the Netherlands as a separate category.

Table 3: Clustered labour productivity levels (LP) and growth rates in European fleets

	1672-1720			1770-1813			
Fleet's country of origin	*n*	*Avg Size*	*LP*	*n*	*Avg Size*	*LP*	*Growth rate LP*
Scandinavia and Germany	81	125	13	48	165	19	52%
Netherlands	28	88	12	84	184	21	72%
France and Belgium	62	68	6	69	194	10	59%
Mediterranean	13	71	5	7	154	12	116%
England and North America	16	78	8	40	127	10	28%
Total	*200*	*95*	*10*	*248*	*172*	*16*	*58%*

Source: Prize Papers Dataset.
Notes: LP: Productivity, measured in tons per men.

The table demonstrates (unsurprisingly) that the cluster of Scandinavian countries and Germany as well as the Dutch merchant fleet has relatively high labour productivity levels in both periods: about twice as large as the remainder of the North Atlantic merchant fleet in both periods. As a result of the large improvement in labour productivity of the Dutch ships during the eighteenth century, in period 2 the Dutch fleet becomes the fleet with the highest labour productivity; in period 1 the cluster of Northern European countries topped the list. Although during the 18th century labour productivity increases in the Southern European fleet were quite significant (the Mediterranean fleet shows a productivity growth of more than 100%) the difference with leading two clusters remains large. Perhaps somewhat surprisingly this is also the case when we look at the group of English speaking countries. In Lucassen and Unger's estimates the English merchant marine (they did not have estimates for North America) was one of the best performing fleets in the North Atlantic. Although the Anglo-American cluster performed relatively well in period 1, the lack of improvement during the eighteenth century (they achieved less than half the average growth rate) meant that in terms of productivity levels they were on par with the southern European countries

by the end of the eighteenth century. A possible explanation could be that the sample of English ships is relatively small (too small to really draw any conclusions on), and the labour productivity on board of American vessels (this sample is much larger) was in fact relatively low.

Summing up, despite the differences between the various fleets, our data demonstrate that the shipping sector was a very dynamic part of the European economy during the 17th and 18th century, with a – by the standards of the period – rapid overall growth of labour productivity. The next question is how to explain the strong performance of this sector.

IV Human capital levels

Sailors have an 'image problem'. We tend to think of sailors as unskilled and perhaps also undisciplined labourers, drawn from the lowest classes of society, famous for their drinking and other social activities, perhaps not literally the 'scum of the earth', but the image of 'Jack Tar' has never been a very positive one. Although this negative picture has been nuanced considerably in recent years (Van den Heuvel and Van der Heijden, 2007; De Wit, 2009), in the literature they are certainly not considered to be particularly well-trained or highly qualified compared to other professional groups. Our data, confirming a recent study dealing with this subject (Van Lottum and Poulsen, 2011) tells quite a different story.[7] As we explained earlier, we have approached the human capital of the sailors in two ways: via their literacy, and via their 'numeracy', or rather the absence of age heaping through their recorded age.

Let us start literacy levels, presented in Table 4 below. We applied the same categorization in terms of country groups as those in Table 3. Table 3 shows that in Period 1 literacy levels of seamen throughout the North Atlantic were fairly equal at around 70%. The Scandinavian countries somewhat stand out, having the highest level of 76%. During the interval, overall levels increase to around 80%; Scandinavian seamen then no longer have the highest literacy rate, their position is taken over by crews by the Mediterranean countries. The notable exception to the overall increase of literacy levels is the cluster of France and Belgium, which only increases with 1% from 63 to 64% and as a result lags behind in period 2.

[7] The study by Van Lottum and Poulsen, however, took the origin of the sailors as the starting points, not the origin or 'nationality' of the fleet, as we do in the present study.

Table 4: Average literacy levels of crews (excluding masters and officers) in the North Atlantic merchant fleet (literacy rate)

	1672-1720	1770-1813
Fleet's country or region of origin	*Literacy*	*Literacy*
Netherlands	68%	79%
Scandinavia and Germany	76%	87%
France and Belgium	68%	73%
England and North America	63%	84%
Mediterranean	74%	88%
Total	*72%*	*80%*

Source: Prize Papers Dataset.

The numeracy skills of crewmembers can be approximated by the method of age-heaping, a method that has become increasingly popular in the last decade (A'Hearn et.al. 2009). Age heaping is defined as the effect of misreporting of age when a given group of people is asked for their age. When a tendency to give out ages divisible with 5 and 10 occurs, it is a sign that not everyone in the group knows how old they are, which is regarded as a sign of poor numeracy. The Prize Paper source provides the age of nearly every recorded individual, and thus allows calculation of numeracy levels using the age heaping method. We have used the so-called alternative Whipple Index (or $\hat{W}$), developed by A'Hearn et.al. (2009), which gives the share of individuals within a group that correctly reports their age.

Table 5: Numeracy levels of crews (excluding masters and officers) in the North Atlantic merchant fleet (alternative Whipple Index).

	1672-1720	1770-1813
Fleet's country or region of origin	*Numeracy*	*Numeracy*
Netherlands	95%	88%
Scandinavia and Germany	89%	100%
France and Belgium	82%	79%
England and North America	82%	96%
Mediterranean	-	-
Total	*89%*	*91%*

Source: Prize Papers Dataset.

Numeracy levels could only be calculated for four clusters (the sample size of the Mediterranean was too small) and show quite different patterns over time (Table 5). Most striking is the development shown in the Dutch maritime sector. In period 1 the crew aboard

Dutch ships had by far the highest numeracy skills, and although their literacy skills grow substantially during the interval, numeracy levels fall to slightly below par. How this can be reconciled with growing levels of labour productivity is something we will return to at the end of this paper, but for now it is sufficient to acknowledge that the Dutch fleet is exceptional in this respect. The crews aboard the French and Southern Netherlands vessels have nearly the same levels of numeracy in both periods – replicating the stagnant literacy levels – the crews aboard Scandinavian ships show a strong increase in numeracy skills of about 11% to become the most numerate amongst the crews in the North Atlantic.

Another observation is that when we compare literacy and numeracy levels in both periods it becomes clear that the ratio between the two is much more skewed in period 1 than in period 2. As such, literacy levels seem to catch up throughout the eighteenth century towards a more balanced ratio between the two indicators. The fact that numeracy does not increase much in the eighteenth century could be an effect of the fact that numeracy levels were already at a relatively high level at the beginning of the eighteenth century. As we will see below, comparisons with different occupational and social groups for the latter part of the eighteenth century show that numeracy levels in the maritime sector were among the highest, and as such had relatively little room to move up; this confirms patterns found in the study by Van Lottum and Poulsen (2011).

In the previous section we saw quite a large difference between Northern and Southern European labour productivity levels. To further explore the differences between North and South in Table 6 below we have compared the Northern European countries and the Southern European countries (including the Southern Netherlands). We then also get a large enough sample to make the same comparison for the two human capital indicators.

Table 6: Numeracy (num) and literacy levels (lit) of crews (excluding masters and officers) in the North Atlantic merchant fleet

	1672-1720		1770-1813		Numeracy	Literacy
Fleet's region of origin	*Num*	*Lit*	*Num*	*Lit*	*growth*	*growth*
Northern Europe*	91%	74%	94%	82%	3%	8%
Southern Europe**	83%	69%	80%	74%	-3%	5%

Source: Prize Papers Dataset.

Notes: LP: Productivity, measured in tons per men. * England not included. ** Includes Mediterranean, France and Belgium. Because we clustered France and Belgium into one group, Belgium in this study ends up being part of Southern Europe; correcting for this – it only concerns a small number of ships per period – does not alter the results.

Table 6 shows that also with regard to human capital levels there are distinct differences between Northern and Southern Europe. In period 1 numeracy levels among crews are on a higher level in the north; the differences between the two regions are somewhat smaller in terms of literacy. When we shift from period 1 to period 2, we find the skill-gap between Northern and Southern Europe to grow over time; growth rates are higher in northern Europe, while the overall numeracy level even falls during the interval.

The literacy data allows for a comparison between the sailors in the dataset and the average populations of the countries involved. If we look at the latter (in Table 7 below) we see that despite the differences in skill levels in the maritime sector of the different countries, overall the seamen were very well skilled compared to the average populations. For the Mediterranean countries the difference is particularly striking: only one out of five of the total population could read and write, whereas Table 5 showed that three quarters to almost 90% of the shipping crew was literate. A similar large skill gap exists in Scandinavia, here the sailors also have much higher literacy levels than the average population.

Table 7: Literacy of national populations in Europe, 1700 and 1800

	Overall literacy 1700	Overall literacy 1800
Netherlands	53%	68%
Scandinavia and Germany	19%	35%
France and Belgium	21-36%	37-49%
England and North America	35%	53%
Mediterranean	18-20%	20-22%
Total	*25%*	*33%*

Source: Allen (2003)

When we compare our numeracy estimates with available studies of other occupational and social groups, we see smaller differences. Gregory Clark (2007) estimated overall numeracy levels in eighteenth century English urban areas around 88% and in rural areas around 70%; our estimates show 91%. Unskilled labourers in Denmark around 1800 had a numeracy rate of 90, while the Danish sailors at that time were at 88% (Van Lottum and Poulsen, 2011). Numeracy estimates for burghers in Amsterdam, who can be considered to be relatively well educated, are around 97%, about the same level as the crews aboard Dutch ships in Period 1. The main exception seems to be the French and Belgian case. Various numeracy estimates show levels around 85% (De Moor and Van Zanden, 2010), while our data shows a level of just below 80%. Comparisons with the numeracy estimates presented by A'Hearn et.al

(2009) gives the same result; in large parts of Western Europe numeracy (measured in this way) had increased to 90-100%, a result we also find among our sailors.

V The use of training

Overall, our data shows that the maritime sector had relatively high levels of human capital. The 64,000 dollar question is therefore why sailors were investing so much in these skills. We believe this is first of all closely related to the level of technology in the sector. As mentioned in the introduction to this paper, deep-sea ships were one of the early modern world's most sophisticated pieces of technology (Rediker, 1987: 163). Therefore, to be successful in this sector a certain skill level was necessary. Secondly, there was an incentive to invest in human capital as a result of the way in which the labour market was structured.

The early modern maritime labour market was a relatively open market, with a high level of horizontal and vertical mobility. Sailors were of course travelling all the time, knew a lot of port cities, and could find out with relative ease where employment possibilities existed. As we will see below, language barriers were also not very important, in fact, sailors from different nations and speaking different languages were very capable of working together on ships. Much of this boils down to the fact that the maritime labour process had a very specific technical vocabulary, which was new to any new sailor, regardless of the place of origin or the language one spoke (Rediker, 1987: 162-163). Having mastered the maritime *lingua franca*, and having 'learned the ropes', the possibilities of horizontal and vertical mobility were ample, not in the least because due to the dangers at sea mortality levels on board were very high. This meant that there was an almost constant need for replacing skilled members of crew, which increased chances for upward mobility (Bruijn, 1997). As within most workplaces, on a ship there were fewer senior positions than ordinary ranks such as that of sailors. A ship of nine men would for instance have one steersman, one mate, a cook, five sailors and a boy. This meant that when a senior position became vacant, there was (potential) room to move up for everyone below. This is illustrated by the case of the Danish steersman Hendrik Splesson. In his interrogation of 1704 he stated that he was the ship's steersman, but that he had taken over the command of the ship when its captain died aboard during their journey from Denmark to Greenland.[8] Many more such cases will have occurred.

[8] TNA, HCA 32/335

There was often plenty of time on ships to acquire new skills and thus to promote ones chances of vertical mobility. Many of the skills could be learned 'on the job', and as such working onboard will in most cases have led to improvements in skills (how much depended on capabilities of course). In any case, it is known that (new) seamen were trained intensively onboard (Rediker, 1987: 162-164). Moreover, although work was indeed intense during relatively short periods of time, they certainly also had leisure time, although this depended on the route. This could also be used to learn, for example to read and write (sailor's probate inventories often show writing materials) or to acquire the (more specific) skills of the ship's carpenter or boatswain. It was of course also in the interest of the master to train his sailors as good as possible, so it is likely that he will have stimulated such activities. In some cases, the practical or vocational training at sea was complemented by the attendance of local schools during the winter, but much will have depended on the region of origin. The latter was mainly a feature of smaller seafaring communities in north-western Europe especially, and will not therefore have been an option for every sailor (Van Royen, 1987; Bruijn, 1997; Van Lottum and Poulsen, 2011; Van Gelder, 1997).

Regardless of whether one acquired new or better skills onboard the ship or during the 'off-season' in schools, there was a clear incentive for investment in skills: wages on board included healthy skill premiums. Table 8 below gives, again based on data derived from the Prize papers, a number of examples of the wage structure of ships from different countries, which indicates that international levels of the skill premium were remarkably similar across time and space. When we set the wage of the steersman (the most skilled and senior officer aboard a ship apart from the master) at a 100%, we can see that a sailor generally earned slightly below half his wage. The wages of mates and carpenters were in between that of sailors and steersmen (around 80% of a steersman wage), while cooks only earned slightly more than an ordinary sailor. Finally, the boy (the lowest rank aboard) commonly received about half the wage of a seaman, or about a quarter of that of a steersman.

Although there could be a wide array of skills for which literacy and numeracy can be an indicator of, there are also quite a few explicit tasks onboard for which these skills might have been useful. For instance, one can assume that it will have been difficult to become a steersman without learning how to read and write: a steersman had to interpret maps, be able to locate the geographic position of the ship, for which 'high tech' instruments (such as the sextant) were developed; the use of them required complex calculations, however. These new technologies became increasingly complex during the 18th

century, when important advances in navigation instruments were made. It also led to the growth of educational facilities. In Holland, for example, in many villages and towns public schoolmasters were also supposed to be able to teach the art of navigation, and in the final quarter of the 18th century specialized vocational schools were set up for the training of young seamen (Davids, 2008: 484-5).

Table 8: Wage differentials aboard European merchant vessels (steersmen: 100%).

Period	Country	Steersman	Mate	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%*

Source: Prize Papers Dataset.

VI Regression results

Our results show that the shipping industry was characterized by high levels of human capital and rapid productivity growth. Can we establish a link between these two features? To test for the effect of skill levels on labour productivity we have tried to explain the variation in the log of the ton per man ratio of the ships in our sample. There are eight independent variables that we could introduce.

The first one is the log of the tonnage of the ship involved (*lnton*); there are reasons to assume that there are economies of scale in shipping: handling a ship requires a certain minimum labour input, but the demand for labour does not increase proportional with size. This variable is, however, also used to calculate the ton/man ratio, and is therefore not really independent of the dependent variable; to deal with this, we have carried out two sets of regressions, one including lnton, another without this variable. To test for productivity growth over time we included *period* as a variable (set at 1 for 1672-1720 and 3 for 1770-1813).

The literacy of the master of the ship (*litmaster*) and the average literacy of the crew (*litcrew*) were also included in the regressions; because of multicollinearity between the two variables, we always included one of them, not both. Numeracy is more difficult to quantify as a variable: as referred to earlier, one needs a large sample of people to get more or less reliable estimates of the degree of age heaping, so it is not possible to get a numeracy index of every single ship. Instead, we used the average numeracy of all ships within the country group the ship belongs to in a certain period, and entered this '*numgroup*' variable in the regressions.[9]

The source also provides information about whether or not the captain was co-owner of the ship, and we expect that this may affect hiring behaviour. By including the *mastowner* dummy, which is set at 1 when the captain does own (part of) the ship, we test for potential agency problems related to the fact that usually the captain decides about how many sailors have to be employed, whereas his income is not directly related to making these costs, as he receives a wage income only. If he is co-owner of the ship, he will have an incentive not to hire too many sailors, because this will affect his income from the ship; finding a positive effect of this variable on labour productivity therefore means that this agency problem did actually exist and had an impact on labour productivity. Table 9 below shows the distribution of this variable over the countries and periods; about one in five ships was co-owns by the master. Although this phenomenon was widely distributed, Table 9 shows that it became particularly important in the Dutch fleet of the late eighteenth century, the share of co-owners nearly doubled in a century's time.

A seventh variable we included relates to the origin of the crew. We know if the crew of the ship consisted of sailors from various countries, or was homogenous in this respect. We therefore created a *nationmix* dummy, set at 1 when the crew was mixed, and expect that this may have affected labour productivity: perhaps the fact that different languages are used had a negative effect on productivity. Finally, most testimonies contain information about the route of the ship, where it came from and its port of destination. This obviously has consequences for the number of sailors a captain would like to have on board: the longer and the more dangerous the trip, the more sailors were needed. Broadly speaking, two groups can be distinguished: the long trips crossing the ocean (to the Americas, Africa or Asia), and the intra-European trips; we therefore added an *ocean* dummy, which is one in

[9] Distinguishing different sub-groups, such as masters or crew, resulted in numeracy estimates which were very strongly correlated with *numgroup*, and were therefore not used)

the former cases – we expect a much lower tonnage per man ratio for those long trips.[10] The results of the regressions are presented in Table 10.

Table 9: Level of ownership

	Period 1			Period 2		
Country	no. of owners	total no. of ships	share	no. of owners	total no. of ships	share
France	21	69	30%	13	64	20%
Sweden	12	44	27%	6	27	22%
Denmark	6	24	25%	1	5	20%
Norway	5	22	23%	0	1	0%
Netherlands	5	34	15%	25	88	28%
England	1	10	10%	0	4	0%
Spain	1	12	8%	0	5	0%
Germany	0	3	0%	6	16	38%
Portugal	0	3	0%	0	1	0%
United States	-	-	-	3	37	8%
Total	*54*	*221*	*24%*	*56*	*248*	*23%*

Source: Prize Papers Dataset.
Note: only countries that have a sample size of at least three ships in one period are taken into account in this table.

Table 10: Explaining tonnage per man

	(I)	(II)	(III)	(IV)
Lnton	.433***	.485***	--	--
Period	.125***	.127***	.245***	.256***
Litmaster	.060	--	.391**	--
Litcrew	--	-.019	--	.073
Numgroup	1.258***	.624**	1.269**	.977**
Mastowner	.130**	.089**	.082	.013
Nationmix	.122**	.083**	.225***	.230***
Ocean	-.495***	-.581***	-.424***	-.500***
R2	.59	.66	.35	.34
N	332	335	332	335

The results in Table 10 show, as expected, a strong effect of period and of size (*lnton*) on labour productivity. Another consistent result is that numeracy (of the group) has a strong effect on labour productivity, much stronger than the effect we get for the literacy of the

[10] We have also experimented with a dummy for trips from and to the Mediterranean, because from Dutch studies (Van Royen 1987) we know that the ton/man ratio was also relatively low on this route, possible due to the dangers involved (slave raiding from North African ports), but such a dummy did not produce significant result – we therefore have not included it in the regressions presented here.

captain (which is only significant in one specification) and the literacy of the crew (which is not significant at all). The *ocean* dummy gives, also as expected, a strong and systematic negative effect – ships on those long distance routes simply need more sailors. Moreover, labour productivity is also higher when the master of the ship is also a co-owner, pointing to the agency problems we introduced briefly already.

Interestingly, having a mixed crew also seems to result in higher labour productivity. The fact that language did not have a negative effect on labour productivity can probably be explained by the shared maritime lingua franca we referred to in the previous section, but the fact that it had a positive effect is indeed an interesting finding. We think that this might be related to the fact that countries that had access to an international labour market had a significant advantage over those who did not. This can be explained in two ways. The first is related to the concept of labour hoarding, which in turn is related to institutional barriers for hiring foreign seamen. In England the Navigation Acts limited the number of foreigners on board, but also in France it was relatively difficult to hire seamen of foreign origin, because they had to proof they were French residents, usually by showing a French marriage certificate (Le Goff, 1997). Different restrictions applied in Spain, where like in the English case until 1737 a quota on the number of foreign sailors existed. Even when these restrictions were lifted, foreigners had to meet various criteria before being allowed to muster (Rahn-Phillips, 1997). This means that a master of a French or Spanish ships probably had to 'hoard' a few men because there was always the risk not being able to hire in foreign port cities – which could be necessary because of the high mortality on board. A captain who has the possibility to hire regardless of origin obviously does not have the same problem, and can therefore initially employ fewer sailors – thus resultin in a lower ton-man ratio. A second (though related) explanation is that when one has the availability over a larger labour pool it obviously becomes easier to select suitable, qualified workers because one has a large pool to choose from. Indeed most north-western European countries had no institutional barriers against foreigners (Lucassen, 1997; Van Lottum 2007; Van Lottum et.al, 2011), and in particular those countries with relatively high wages, such as the Dutch Republic up until the mid-eighteenth century, were able attract the best workers (Van Lottum and Poulsen, 2011; Van Lottum, 2011). Only when as a result of increased competition wages started to converge they lost much of its attracting power, leading to a shrinking of its hinterland and thus a smaller labour pool.

In sum, the regression results for the overall maritime sector demonstrate the importance of numeracy for labour productivity, but at the same time also show that literacy

seems to be less relevant. This pattern changes, however, when we add country dummies to the regressions. Because the samples of a number of countries are too small to be included, we have grouped (again) countries into three larger regions: the English speaking world (England, Scotland, Ireland, and the US), the German, Dutch and Scandinavian region (speaking Germanic languages), and the Roman countries (Belgium, France, Italy, Spain). As noted already, this corresponded with regional patterns in labour productivity and human capital.

Table 11: Explaining tonnage per man - including country/region dummies

	(I)	(II)
Lnton	.393***	
Period	.164***	.282***
Litmaster	-.059	.187
Numgroup	-.637	-.864
Mastowner	.102**	.044
Nationmix	.027	.099
Ocean	-.164***	-.215**
German	.296***	.510***
Roman	-.207**	-.109
N	332	332
R2	.64	.45

Table 11 presents the results with region dummies. The size of ships and the period are still strongly and positively correlated with labour productivity, and the effect of co-ownership of the captain is similar to that found in the first series of regressions (that is: significant when *lnton* in included in the regressions, and not significant when this variable is not included). The effects of numeracy and literacy disappear however in this specification – they are clearly related to regional clustering of variables. Also the positive effect of a mixed crew seems to have disappeared in the regressions with region dummies, but the ocean dummy is again negative and highly significant. The dummies more or less reflect what we know from Table 1 about average labour productivity: Germany, The Netherlands and the Scandinavian countries have on average a much higher labour productivity than the average, whereas in the Roman world it is clearly below average.

How do we interpret the results of the two sets of regression in the previous section? Do they show that regions matter, and not the skills and capabilities of the crew? We think

such a conclusion is unwarranted. The changes which result from excluding or including the regional dummies point to the fact that there existed regional differences in production technologies: in the 'German' speaking world, of which the Netherlands was probably the core country, labour productivity was much higher than in the other two regions, but this higher labour productivity was made possible by the high skill level of the crew and the masters. The increase in labour productivity that occured was, to some extent, a substitution process in which raw labour is replaced by skilled labour and capital goods – in other words, increased labour productivity is only possible when the skill level of the crew and the master is relatively high. The fact that the link between numeracy (and literacy) and labour productivity disappears when regional dummies are added, means that these production technologies are region-specific, that there existed systematic regional differences in factor combinations. This results in a 'crowding out' of the effect of numeracy (and literacy) on labour productivity by the region dummies.

VII Conclusions

International shipping was a very dynamic part of the pre-industrial economy, in which, as the estimates that we presented here demonstrate, labour productivity (measured in tons per man) increased strongly in the eighteenth century. This happened in all parts of Western Europe, but our figures also show that the large gap in labour productivity between the Northern and the Southern of the continent remained unchanged: labour productivity levels were on a much higher in the North-western European fleets than in their southern counterpart, confirming general studies on relative economic performance in early modern Europe. The increase in labour productivity in this sector was also much faster than that in most other sectors of the economy for which we have figures, and in particular much faster than the modest growth of productivity in the agricultural sector.

Overall, human capital levels in the maritime sector were on a relatively high level compared to other sectors of the economy. This was true all around the North Atlantic. However, as with labour productivity there is also a north-south divide in terms of human capital levels. Our study shows that seamen on board of the northwestern European merchant fleet have higher human capital levels than their colleagues in the south, this is particularly the case with numeracy skills, but also literacy levels were higher in the north. In the second period both indicators diverge further in favour of the northern European fleet.

Workers in the maritime sector are likely to have invested in skills for two main reasons. First of all, because of the relatively sophisticated environment a certain skill level was necessary, and skilled workers will therefore have been in larger demand when hired. Secondly, there was an incentive to invest in skills because it was an open market with a high level of vertical and horizontal mobility. The latter combined with sizeable skill premiums meant that there were monetary returns to investments in training.

The regression analysis showed (as the aforementioned analysis of the descriptive statistics already suggested) that human capital levels, in particular numeracy skills had a positive and significant effect on labour productivity. Literacy mattered as well, but only in the case of masters. That institutional barriers also seemed to matter was shown by the fact that labour productivity was higher when crews were of mixed nationality. This is likely to be linked the positive effect of having a large international labour markets at one's disposal. Those fleets that had restrictions on the number of foreigners that could be mustered (like France and Spain) had to 'hoard' men because there was a risk of not being able to muster new men in foreign ports. Fleets without these regulations (such as the German, Dutch and Scandinavia merchant fleet) could therefore sail with fewer men. Moreover, without barriers against employing foreign crews, ship masters had a larger labour pool at their disposal, which made it easier to select workers with the best skills.

(Co-)ownership of the master also proved to have had a positive significant effect on labour productivity. This can be explained by the fact that captains played a pivotal role in the hiring procedures. Hiring more sailors will have affected the master's income, meaning that there was a clear incentive for hiring fewer men. The latter is likely to be part of the explanation of the conundrum we found in the developments of the Dutch fleet. This fleet showed rising labour productivity levels between the two periods in tandem with falling human capital levels of its crews. It was in fact the only country that showed decreasing numeracy levels of its crews, it fell from exceptionally high levels to around par. At the same time numeracy levels fell, the Dutch fleet showed a very strong increase in the number of master-owners (much more so than in other countries). The fact that the number of master-owners doubled between during the eighteenth century therefore seems to have 'compensated' for decreasing skill levels. An additional explanatory factor, forwarded by Jan Lucassen (2011) – and which could not be tested in our regression analysis – is that increased efficiency of dock workers led to overall efficiency of shipping because ships did not have to take as many sailors for loading and offloading. Although more research is

necessary, it is very well possible that this development aided the Dutch fleet in particular, and thus balanced the loss of skills of its crews.

The most important finding of our paper is, however, that human capital really mattered for productivity and performance in the shipping industry. Moreover, the spillover effects of this industry are enormous: without a highly productive shipping sector the rise to dominance on global markets of both the Netherlands and Great Britain would have been unfeasible, nor would they have been able to develop into the 'modern' economies that generated processes of long-term economic growth in this period (De Vries and Van der Woude, 2000).

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