Roots of Growth and Productivity Change in Dutch Shipping Industry, 1500-1800

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Abstract

Shipping was one of the most dynamic industries of the pre industrial period. The paper presents detailed estimates of the growth of output and inputs of the shipping industry in the Netherlands between 1500 and 1800. These are used to study the development of productivity in two ways: by comparing output with inputs (labour and capital), and by analyzing the relationship between output prices and input prices. Both methods lead to different results, which we try to explain. It appears that productivity in this sector increase strongly between ca 1550 and 1620 as a result of technological and institutional changes, such as the increased efficiency of the network. After 1620 labour productivity continued to increase because of factor substitution as wages increased much more than capital costs. The competitiveness of the Dutch shipping sector did not improve anymore after ca 1650, however, which helps to explain why its rapid growth came to an end in the second half of the 17th century.

Introduction

Shipping is generally considered to be one of the most dynamic sectors of the early modern economy, and so was of fundamental importance to the economic development of Western Europe. There is a strong historical tradition that emphasizes organizational and technical progress made in the building and operation of ships during the late middle ages and the early modern period as the main cause behind the dynamism of this sector. Progress may have been slow and by small steps only, but in the long run important improvements were made, thanks to the availability of better ships, improved port facilities, and the integration of shipping networks leading to a more efficient use of these capital goods. This optimistic view seems to be confirmed by recent research by Lucassen and Unger (2000) on the labour productivity of the shipping industry as measured by the ratio between the tonnage of the ships and their crew, a ratio which shows a substantial increase during the early modern period. By contrast, there are also studies underlining the dependency of shipping efficiency on external factors to such a high degree that having better ships was only of minor relevance. In this view, commercial developments enabling economies of scale and political circumstances facilitating or hindering undisturbed sailing were of more importance. Menard (1991) has been the strongest advocate of this point of view. In an important article he argued that sea transport realised only very modest productivity growth in the 400 years between the 14th and the 18th centuries and that the most important explanations for this growth were to be found in the political and commercial developments fostering the safe shipment of large quantities over great distances and not in technical improvements. In a similar debate on the development of trans-Atlantic freight rates in the 18th and 19th centuries the causes of productivity growth in this period are also contested. Douglass North (1958) in a seminal paper – which put him on the road to assessing the importance of institutions for economic development – argued that the decline of 18th century trans-Atlantic freight rates was mainly caused by organizational changes. Knick Harley (1988) has criticized this thesis, pointing out that the decline was very slow in the period before the introduction of steam. In his view it was this 'new industrial technology', i.e. iron ships driven by steam, which 'caused a revolutionary decline in 19th century freight rates' (Knick Harley 1988: 851). Given these conflicting opinions on the extent of and the causes of the growth of productivity in the early modern shipping industry, the question may be raised what caused its long-term expansion: was it mainly caused by increased demand for shipping services, the results of processes of regional and international specialization, or did the growth of productivity – resulting in a decline of real freight rates – also play a significant role?

This paper sets out to contribute to this debate about the extent of and the causes of productivity growth in the early modern shipping industry by studying the performance of Dutch shipping between 1500 and 1800. The Netherlands provides an excellent case study, as it possessed one of the most dynamic shipping industries in this period. Its share in the European fleet increased from about 16% in 1500 to perhaps as much as 40% in 1670, after which it was gradually overtaken by the British (Van Zanden 2001: 82). Moreover, the Dutch shipping industry has been studied quite intensively, and a lot is known about its economic and technological development. Large datasets on the development of shipping on the Baltic, Russia, Asia (monopolized by the East India Company) and the Americas are available, which can form the building blocks for a reconstruction of its growth and development. Via putting together these datasets, it is possible to create a consistent dataset for measuring the development of output and inputs between 1500 and 1800. As part of a project aimed at reconstructing the national accounts of Holland in this period, we estimated the annual output and value added of, and inputs used in, the shipping sector of the Netherlands in this period. On the basis of this research it is possible to measure productivity changes in different ways, and to answer the question how much productivity change occurred in this period. This makes it possible to address the debate mentioned in the introduction.

The debate on productivity growth in Dutch shipping

The dominant interpretation of the success of the Dutch shipping industry in the 16th and 17th centuries stresses the role played by technical progress in shipbuilding. From the end of the 15th century onwards shipbuilders in Holland continuously improved the design of ships, making each generation of vessels more efficient. This culminated at the end of the sixteenth century in the creation of the fluyt or flute (*fluit* in Dutch), the most famous among the different types of cargo carriers the Dutch mercantile fleet was composed of in the 17th century. These fluyts were cheap to build and to exploit. They were built as specialised cargo carriers, which did not need to defend themselves and therefore carried no or only a limited number of guns. Due to the absence of armaments and to simple rigging a relatively small crew was needed to sail the ships, and labour productivity was relatively high. The ships could also be loaded more efficiently, which was in part due to the fact that specialised ships were designed for different routes (De Vries and Van der Woude 1997: 357; Bruijn 1990: 177; Wegener Sleeswyk 2003: 78-85). Variants of the fluyts used in the Mediterranean, for example, were much more heavily built than those used in the rest of Europe as they faced greater dangers from pirates. Fluyts used in the Norway timber trade in their turn had special openings at the bow to be able to load very tall pine trees (Unger 2000: 126). In general, the most efficient fluyt ships were in use during the Twelve Years' Truce, when no armament at all was required. These were extraordinarily long fluyts (Wegener Sleeswyk 2003: 36-37, 73; Unger 2000: 121).

The example of the invention of the fluyt already shows how difficult it is to separate technological change from institutional developments. The new technology was made possible by the pacification of the routes to the Baltic and related routes, to northern Germany and Norway. The Pax Hollandica made it possible to reduce the cannon and other weaponry on the ships, and therefore not only cut capital costs but also labour costs, and increased the space that could be used for transporting goods. In its turn, the Pax Hollandica was the result of the fact that the cities of Holland dominated the political economy of the province, and could therefore use its powers to further their interests. The trade with the Baltic was considered so vital to the interests of the province, that the state tried to impose peace there via peaceful means (diplomacy for example) and via war and preparation for war – it intervened in all major conflicts in the region when its interests were at stake, and used its navy to impose the Pax Neerlandica (Tracy 1990). This had important consequences for the competitiveness of Dutch ships. The protection costs that had in the past been paid for by individual merchants, who paid for the weaponry and the soldiers to protect their ships, were now 'internalized' by the state, and became funded via taxation and the public debt. This 'transfer' of protection costs from private enterprise to the state, made possible the development of ships such as the fluyt, which were much more competitive than previous carriers, and made possible a large reduction of freight rates. Institutional change and technological progress were clearly intertwined, and part of the decline in freight rates that can be observed, is explained by this change in the way in which protection costs were being financed.

Quantitative evidence about the success of the fluyt is mainly based on data related to the size of the crew of Dutch cargo ships. The ton-to-man ratio on board ships has been used as proxy for labour productivity in the shipping sector. This kind of research was originally inspired by contemporary sources, like remarks by the Danish envoy in the Netherlands in 1645, that it was believed that whereas a ship of the Baltic cities would need more than ten men, a Dutch ship of the same size could be worked with six (Boxer 1964: 151). In 2000 Lucassen and Unger published an article summarising and analysing systematic data on labour productivity in shipping in different European countries for the 15th through the 19th centuries. They found dramatic increases in the ton-to-man ratio in Dutch shipping in the 17th century and in English shipping in the second half of the 18th century, while the figures also suggested a decline of this ratio in Dutch shipping in the 18th century (Lucassen and Unger 2000: 130-131). New evidence collected by Van Lottum and Lucassen (2007) questions the decline of labour productivity on Dutch ships in the 18th century, and also suggests that from the 16th to the 19th century developments seems to have been more gradual than was originally thought (Van Lottum and Lucassen 2007). Undisputed are the differences in the ton-to-man ratio according to trade routes. Shipping to the Baltic and Norway for instance required relatively few men while ships going to the Mediterranean or Asia were heavily manned, because the Pax Hollandica did not extend to those routes. The mix of trades in which ships were involved strongly influenced the manning ratios for the fleet as a whole, and the expansion of extra-European shipping in the 18th century had a downward effect on general labour productivity on the Dutch fleet (Lucassen and Unger 2000: 136-137).

Apart from technological progress in shipbuilding a whole range of other factors have been identified as potential determinants of productivity change, including commercial, organizational and political factors. The first we like to mention here are economies of scale resulting from bigger ships. In general, positive effects on labour and capital productivity can be expected from an increase in the average size of ships (Lucassen and Unger 2000: 135). But again the story is slightly more complex. Pierre Jeannin already suggested some 50 years ago that one of the causes of the superiority of Dutch shipping was the use of standardised vessels with sizes confined to a limited range of tonnages. Although Dutch shipbuilders were technically capable of building ships of 400 last (or 800 tons),[1] or more, the Dutch deliberately used much smaller ships in their Baltic ventures after they had found out the optimal size for this trade route. Between 1560 and 1640 they had been experimenting with different types and sizes of ships, and somewhere in the second quarter of the 17th century they had established the optimal vessel size. The average cargo capacity of the ships not only increased but also the range of tonnages became smaller. In the 1630s tonnages mostly varied between 100 and 120 last; the role of much smaller ships became insignificant and ships measuring 140 last or more were registered only infrequently. The resulting homogeneous composition of the fleet reflected the success of the Dutch in developing fluyts of an optimal size (Jeannin 1960: 58, 61, 63).[2] What this analysis points out is that there was an optimal size of ships, beyond which economies of scale were counterbalanced by other effects such as longer waiting periods before a full cargo could be acquired.

Besides the economies of scale resulting from increased ship's capacity, the importance of other economies of scale have been emphasized: those resulting from an increase in the volume of trade. The advantages connected to shipping on a massive scale have been well documented in the case of Dutch shipping to the Baltic in the 16th and 17th centuries. Prices for transport services dropped dramatically, especially during the second and third quarter of the 16th century. The very strong expansion of the volume of shipping to the Baltic (the number of voyages and the size of the commodities transported) is considered to be the main reason behind this (Van Tielhof 2002: 198-199, 327-328). The close interaction of commercial expansion and technological advances has regularly been underlined. The expansion of Dutch trade in the 16th and 17th centuries generated a steadily growing demand for large bulk carriers, making it worthwhile for shipbuilders to experiment with new designs (De Vries and Van der Woude 1997: 355-357, 673; Ormrod 2003: 274).

A third factor besides technological progress discussed in the literature is the efficiency of the network of trading routes**.** The Netherlands were located half way between regions that experienced a long term increase in their bulk exports and/or their need for bulk imports: the Baltic countries (as the main exporters of grains) and southern and western Europe (the main importers).

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[1] In the Baltic and the North Seas the carrying capacity of ships was measured in last, in most other areas in tons. One last is converted into two tons (see Unger 1992: 250 Footnote 9).
[2] Compare the still very wide range of the capacities of Dutch ships visiting Reval in the 1530s: from 20 to 150 last (Mickwitz 1938: 153-154).

In his study on Dutch Baltic trade around 1600 Christensen emphasized that the location of the Netherlands, more specifically Amsterdam, gave the Dutch shipmasters the lead over their competitors based in less centrally placed ports. When Dutch ships left the Baltic in autumn, they could spend the winter months sailing to the south to bring grain and load salt or wine for the Netherlands or for the Baltic. The cold season was used for shipping in ice-free regions. Such three-cornered or even four-cornered voyages were easily organised from the centre of the trading network but not from one of its ends (Christensen 1941: 403-404). The competitive advantage for Dutch merchants and ship-owners in organising multiple voyages on the routes where trade vigorously expanded is one of the standard ingredients in the success story of Dutch shipping in the 16th and 17th century (De Vries and Van der Woude 1997: 356). An index of the efficiency of the system is probably the degree to which shipping routes developed which bypassed Amsterdam and other Dutch ports. The contemporary term for passing the Dutch coasts by without calling at a port was *voorbijlandvaert*, a term often used in modern historiography as well. It is a variant of third country shipping. The earliest history of the *voorbijlandvaert* is not entirely clear, but Dutch salt ships were sailing directly from France to the Baltic already in the 15th century. Grain ships were sailing from the Baltic to Spain and Portugal at least since the 1530s when merchants claimed that this was a new phenomenon (Van Tielhof 1995: 153). The importance of the *voorbijlandvaert* has been emphasized again by Lesger who demonstrated that Amsterdam was not in the first place a concrete market where commodities were gathered and distributed, but a centre of information from which trade and shipping was organised, often abroad (Lesger 2001: 197).

The *voorbijlandvaert* contributed to shipping productivity by reducing the need to sail without cargo: in ballast. In the early modern period overseas trade was notoriously unbalanced, as the countries exporting large quantities of voluminous goods usually did not need equally sizeable imports. Shipping capacity was dictated by the volume of the goods traded on one leg of the voyage and ships then had to make the other half of the voyage with an empty hold or only partially laden. The regular appearance of ballasted ships is best known for the Baltic route but in Norway the timber exporting ports faced the same problem, and in northern England the coal exporting ports were also very familiar with it. Obviously, sailing in ballast was inefficient, as the costs for the whole return voyage had to be covered by the goods transported in one direction. Finding additional cargo meant a potential reduction of freight costs with one half. Along with the expansion of the Baltic trade in grain, timber and other bulky commodities after 1500, the Dutch were permanently looking for commodities to take with them eastwards. The success of Dutch shipping depended on this (Unger 1997: VIII, 7). The match between the Baltic and the west and south of Europe was a brilliant one. Creating an integrated, multilateral trading network was the most important way to fight ballast shipping. On the other hand we have to consider the possibility that extensive ballast shipping meant sharpened competition among ship owners, resulting in lower freight rates, at least in the short term. The extent to which ships had to sail ballasted is therefore a fourth factor probably influencing shipping productivity, albeit in a negative or in a positive way.

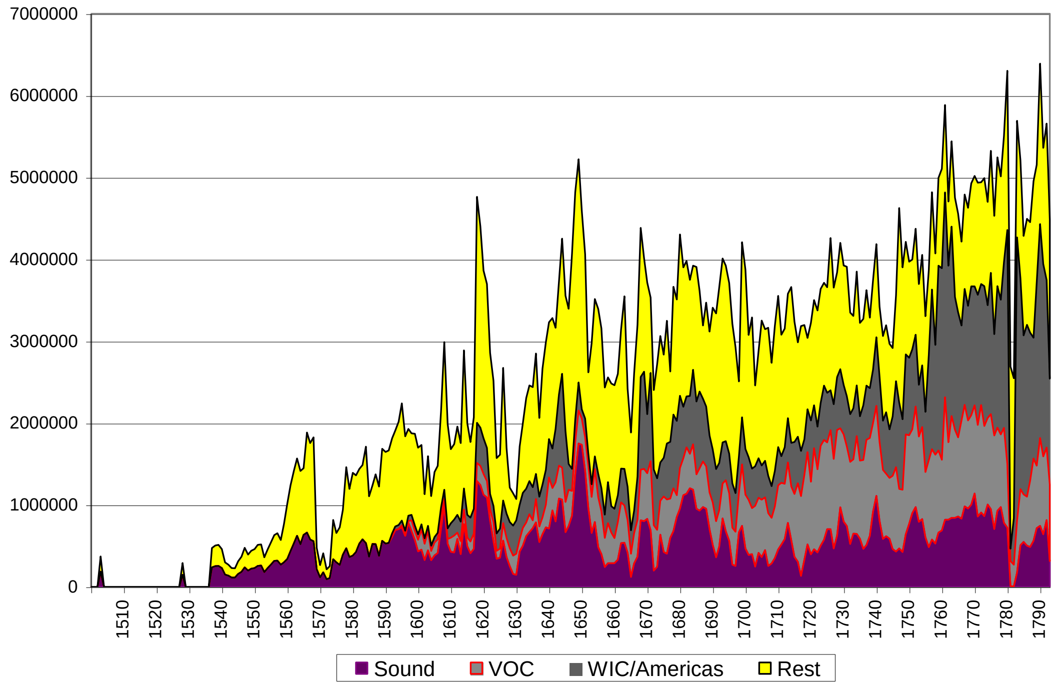
A fifth non-technological factor that seriously hampered the development of the shipping industry was the almost continuous incidence of war and piracy on the high seas, at least beyond the Baltic and the North Sea. Safe seas were the best guarantee for cheap transport. Menard argued that the general political crisis that marked the shift from the Middle Ages to the early modern eras prevented ship-owners to ship wine from Bordeaux to London at the same low rates as in the half century before the Hundred Years' War (Menard 1991:143-145). He showed the same pervasive influence of political circumstances on shipping efficiency for other periods and other regions. The relevance of risks at sea for Dutch freight rates has often been demonstrated (e.g. Van Royen 1996). The effects of war and peace on Dutch shipping were also strongly emphasized by Israel. By analysing the development of freight rates on Dutch ships before, during and after the Twelve Years' Truce with Spain, he showed that those rates were uniquely low in the years the ships could sail unhindered everywhere. According to Israel, it was precisely in this period that the Dutch fleet enormously strengthened its competitive position vis-à-vis its rivals the English, the Danish and Hansa fleets. In this sense, his study of freight rates confirmed qualitative evidence known and cited since long. Transport costs on the other hand shot up very rapidly as soon as enemy ships or pirates were at sea, which happened not long after the truce had ended. This was one of the setbacks Dutch merchants had to cope with during the Thirty Years' War (Israel 1989: 124; Israel 1996: 83). Nevertheless, the role of war is far from clear. When Dutch shipping experienced its Golden Age the Dutch Republic was at war almost permanently. That situation apparently did not prevent long term gains in shipping productivity.

The literature discussed presents us with a long list of factors that may have contributed to productivity growth in the shipping industry, such as technological change in shipbuilding, the increased size of ships, the growth of trade on certain routes, the interconnectiveness of the network of trading routes, the extent to which trade was balanced and the safety of the seas. We will now try to find out how much productivity growth occurred and which factors can be identified as contributing to this increase.

The growth of the Dutch shipping industry

In Appendix I we have presented estimates of the output, value added and inputs of the shipping industry in the Netherlands between 1500 and 1800. The methodology used to reconstruct the development of the shipping industry is the standard system of national accounts (SNA), as for example applied to the past in a number of studies related to the Netherlands in the 19th century (Horlings 1995; Smits 1995; see also Smits, Horlings and Van Zanden 2000). The reconstruction was largely based on three kinds of sources. Firstly, there exist a number of benchmark estimates (by contemporary witnesses) of the size and composition of the merchant fleet and the routes on which they were active, which can be used to anchor all estimates; in particular the estimates for 1636 and 1780 are extremely valuable, but additional benchmarks are available for about 1500, 1532, 1567, 1607 and 1695 (a recent overview of these estimates in Van Lottum 2007 and in Van Lottum and Lucassen 2007). In addition, for a number of routes (to the Baltic, Asia, the Americas) detailed annual estimates are available of the number of ships active on these routes, and their activities (the goods they transported for example). Finally, there is information on the total number of ships entering Dutch ports (from 1642 onwards) and on taxes levied on incoming and outgoing ships (*convooien en licenten*, *paalgeld*, *lastgeld*).

Figure 1 Volume of shipping 1500-1793 (in 1000 tonkm)



NB for the period before 1537 only two point estimates are available (1503 and 1528)

Figure 1 presents an important result of the reconstruction: the development of the volume of shipping (in 1000 tonkm) between 1503 and 1793. It demonstrates the enormous growth of the shipping industry in the Netherlands; total volume increased by a factor of 17 between the first estimate of 1503 and the absolute peak in 1790. The average annual growth rate between those dates was slightly less than 1% (0,9958%), which is quite high for such a long period. Growth was initially rather slow (less than 0.5% per annum between 1503 and 1550) – only during the 1550s and 1560s did a phase of rapid expansion begin, which is consistent with other data (De Vries and Van der Woude 1997: 373). The conflicts of the late 1560s and early 1570s were disastrous for shipping, but after 1576 rapid recovery followed. From the 1590s onwards long distance shipping began to contribute to growth, and a period of extreme fluctuations of shipping ensued, with a remarkable boom during the period of the Truce with Spain (1609-1621), during which the volume more than doubled. This was followed by a very serious downturn in the late 1620s. In the early 1630s another boom began, peaking in the years before and directly after the Peace of Westphalia (the highest level is reached in 1649). In the next hundred years wars still had a strong impact on the industry; the three Anglo-Dutch wars, for example, led to serious declines in activity. In the long term the level remained more or less stagnant at 3 to 4 billion tonkm, however. Whereas during the previous century growth rates of total output had been 2.6% (1550-1600) and 2% (1600-1650), between 1650 and 1750 they were on balance barely positive. Shipping through the Sound declined in these years, as did the trade with the Mediterranean, but this decline was to some extent compensated by the ongoing growth of shipping on long-distance routes – to Asia and the Americas. In the second half of the 18th century growth resumed, to a rate of 1.2% per annum between 1750 and 1790, although it was much less spectacular than during the 1550-1650 period. The Atlantic economy became the most important source of renewed growth. This phase of growth after 1750 is perhaps the most surprising result of these estimates, as the 18th century – and in particular its second half – is usually seen as a period of decline (De Vries and Van der Woude 1997: 674-683). Again the impact of the Fourth Anglo-Dutch war is quite clear from the estimates (shipping in 1781 and 1782 is less than half the level before the War), but the recovery after 1783 is surprisingly strong. The series of the estimated value added of the shipping industry show that, in current prices, total value added increased from 380.000 guilders in 1503 to 19,5 million guilders in 1790. These estimates are consistent with earlier work, by Horlings (1995) for the 19th century and by Van Zanden (2002) for the early 16th century.[3] The series for real value added (deflated with the average freight rate per tonkm) is very similar to Figure 1, and will therefore not be discussed here separately.

Output and inputs compared

There are a number of ways to approach long term productivity growth in the shipping sector. Firstly, we look at the usual measures, and compare output with capital and labour input. Labour productivity can be measured as the ratio between output and the number of sailors involved. Similarly, we can estimate capital productivity by dividing output by the various estimates of the size of the fleet. These direct estimates of capital and labour productivity are presented in Table 1.

The estimates of the size of the labour force and of the merchants fleet are all based on rough estimates made by contemporaries – the most famous one was probably Guicciardini's estimate of the size of the merchant fleet of Holland at about 1565. Other, more detailed estimates, often specified per shipping route, and sometimes combined with estimates of the value of the goods transported, are available for various years. The first (ca. 1500) estimates are based on a very detailed source, the Enqueste of 1494, which specifies for the cities in Holland the number of ships owned. A number of studies – going back to work by Vogel dating from 1915 - have reviewed all of these estimates and made them comparable over time (most recently, Van Zanden 1987, Van Tielhof 1995: 106-108; Unger 1992; Van Lottum 2007, and Van Lottum and Lucassen 2007).[4] All estimates were made consistent over time, for example by substracting the fishing fleet and related employment.

[3] Van Zanden (2002) estimated value added of the shipping sector in Holland in 1510/14 at 305.000 guilders; the difference is due to the activities of the fleet of other provinces, in particular Zeeland.

[4] We made a number of small changes: the 1750 estimate originally did not include the VOC ships, therefore we increased it from 365.000 tonnes to 395.000 tonnes, the estimated size of that fleet in this year; Van Lottum (2007) overestimated in our view the size of the fleet and that of the crew in 1607, which we corrected downward on the basis of our more detailed evidence on shipping via the Sound (his 1607 estimate suggests that both the size of the fleet and of the crew would have been larger than in 1636, which is highly unlikely; the mistake is related to an overestimation of the traffic via the Sound).

Table 1 Output and inputs of the shipping industry, 1503-1780

	Tonnage of the fleet	Labour Force	Output (1000 tonkm)*	Capital productivity	Labour productivity	Capital/Labour ratio
1503	38000	-	372	9,80	-	-
1532	60000	8000	373	6,20	46,60	7,50
1565	160000	-	1615	10,10	-	-
1607	300000	31000	2002	6,67	64,60	9,68
1636	310000	39000	2495	8,00	64,00	7,90
1670	400000	-	3611	9,00	-	-
1694	-	33000	3704		112,20	-
1750	395000	-	4092	10,40	-	-
1780	400000	41000	4413	11,00	107,60	9,80

* five year moving averages (except 1503 and 1532)

Sources: output: see Appendix I; labour force and size of fleet: Van Lottum (2007) and Van Lottum and Lucassen (2007); 16th century: Jansen 1976: 272.

The estimates of Table 1 suggest that capital productivity increased barely in the three centuries between 1500 and 1800. Only the 1565 estimate is a bit of an outlier (perhaps we overestimated growth before 1565), but apart from that, the ratio changes little. This is confirmed by other evidence related to the Baltic trade: the number of trips ships on average made to the Baltic did not increase in the long run: it was about 3 in the 1560s, increased to about 4 in the best years of this trade, during the 1610s (it was 4.4 in 1615), but began to decline afterwards. It fluctuated around 3 again between 1640 and 1680, and fell to on average about 2.5 in the 18th century (Bang and Korst 1906/1953).

The long term development of labour productivity is different: here we find modest growth during the 16th and early 17th century, followed by an increase of about 75% between the point estimates of 1636 and 1694, and stability during the next century. The increase during the 17th century is consistent with the estimates by Unger and Lucassen (2000) about the tonnage per man on the Dutch fleet during the same period. As mentioned already, they also find a strong increase during the second half of the 17th century followed by decline. When we look at their measure of productivity, the tonnage per sailor, which is actually a measure of the capital/labour ratio, we find a modest increase of about 30% during the early modern period, however. Overall, productivity growth was rather small. When we assume that labour and capital both have a share of 50% in value added, total factor productivity increased by about 50%. This is not very much for a three hundred year period, but it is in accordance with Menards view that overseas shipping did not realise important productivity growth during the early modern period. This conclusion is, as usual, as good as the estimates on which it is based – and all sets of estimates, of the output of the shipping industry, and of its inputs, are clearly subject to large margins of error. In view of the fact that these results are very sensitive for the accuracy of contemporary estimates, we will also look at another way to approach productivity change, via the study of relative prices.

An alternative approach based on relative prices

Another approach to estimating the development of total factor productivity growth is to deflate the output prices with the weighted input prices. Shepherd and Walton (1972) and recently Hoffman (2000) and Antras and Voth (2003) have applied this method to the early modern period, showing that total factor productivity growth can be derived from the analysis of changes in prices and factor costs. The key idea is that the price of a certain product is by definition the sum of the weighted remunerations of its factor inputs (the details of this are given by Antras and Voth (2003)). When the price of the output declines compared to the weighted prices of factor inputs, productivity must have increased. The underlying assumption is that markets are not distorted by market power and that prices therefore reflect the costs of producing the output (although Antras and Voth (2003) correctly make the point that excess-profits would also affect other ways of measuring changes in total factor productivity). This assumption is however quite valid for the Dutch shipping industry, where on each route – and in particular on the routes that we study here – many dozens if not hundreds of ships and skippers operated, who were competing intensely for cargo. In general, the market for shipping services was therefore very competitive. However, this does not imply that all contracts that we use were the result of perfect competition. There were strong seasonal fluctuations in the supply and demand for shipping capacity, which may have implied that certain contracts were the result of a sellers' or of a buyers' market. Skippers may have sought extra cargo at low prices because the alternative was to sail out partially in ballast, or alternatively, merchants may have been pressed to ship their goods because the sailing season was coming to an end. Freight rates may therefore fluctuate quite a lot during the year, and between years, and an analysis of changes in productivity of shipping can therefore only be based on a large dataset of freight rates during long periods of time.

In order to establish the price of transport we heavily relied on one kind of source which is found in massive numbers in the Amsterdam notarial archives: chartering contracts. A chartering contract is an agreement between a shipping company and one or more freighters or charterers who charter the ship for a particular voyage or, less often, for a specified period like a month. The freighter chartered the whole or part of the ship to carry a cargo from port A to port B at a certain price. In Amsterdam lots of chartering contracts were notarized, which means that a signed copy was entered in notarial registers (Van Tielhof, 2002: 199, Knoppers, 1976: 17-18, Van Royen, 1996: 108). It is important to stress that these prices were the prices actually agreed upon for a specified transport service.

A number of studies has published freight rates according to these charter contracts for certain routes and/or time periods.[5] We have put together a dataset of 2800 freight rates covering the most important European routes, such as the Baltic, northern Russia, south-western France and Italy. In Appendix II the relevant sources and their problems are dealt with in detail. The main limitations are that 1/ almost all freight rates relate to the period after 1590, and only a few prices for the period before 1590 are available (and for the Baltic trade only); 2/ non-European destinations are not

[5] The freight rates for shipping from France to the Republic were generated in PhD research by Anne Wegener Sleeswijk (PhD Amsterdam 2006). We kindly thank her for placing this series at our disposal.

included here, as the trade on them was (often) monopolized by large trading companies (for the trade on Asia by the VOC).

The alternative approach requires that the output-price series (in this case: the freight rates) is compared with an index of total factor costs. Prizing the labour input is not a problem. Data on wages and on the cost of foodstuffs consumed on board (which should be included in the remuneration of labour) are available (wages of unskilled labourers from De Vries and Van der Woude (1997), and the costs of consumables from Van Zanden (2005)). Capital costs are more problematic. Ideally, one would have prices of ships, but these are not available. We therefore had to simulate the development of the price of ships via the construction of a weighted index of the inputs into shipbuilding (based on the wages of skilled labourers (De Vries and Van der Woude 1997), prices of copper and iron[6], and of timber[7]). Finally, we used a series of interest rates to capitalize the costs of the ships, which was derived from the work by Zuijderduijn (2007) (period 1450-1560) en from the development of interest rates on public debt by Fritschy (2004).[8]

Figure 2 shows the series of the most important input prices. In the long run, the price of iron increased least, and timber prices, which were relatively low during the first decades of the 17th century, and the average prices of victuals, went up most strongly. Copper prices increased more or less at the same pace as the general price level, except for the first decades of the 17th century, which was a period of copper scarcity (Klein 1965: 331). Overall, the curves are dominated by two periods of rapid inflation, between 1550 and 1650, and again after 1750; in view of the strong increase in price levels, the differences between the individual series are rather small.

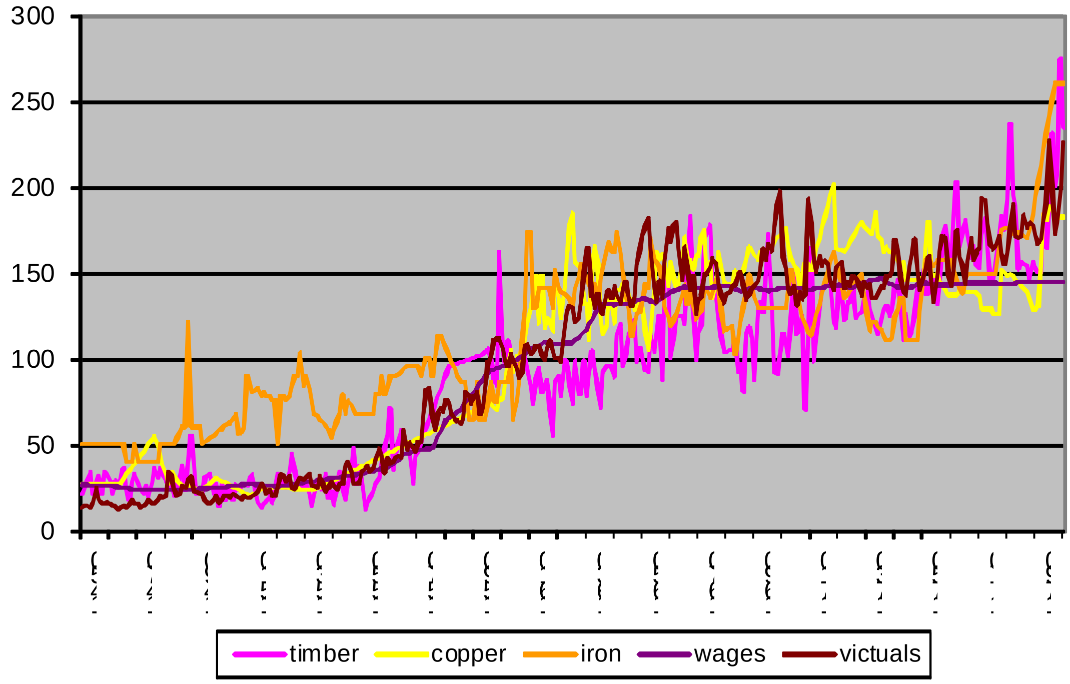
Figure 2.

[6] Prices of copper and iron are derived from Posthumus (1943/64) (17th and 18th century: Amsterdam exchange; 15th and 16th century: Utrecht and Leiden institutions), De Moor (2000), and for the period 1585-1620 De Jong (2005); a few gaps remained, which were filled by simple intrapolation. We are indebted to Michiel de Jong for placing precise price data not published in his book at our disposal.

[7] Timber prices were derived from ongoing research by Christiaan van Bochove into the timber market in the 17th and 18th century, whose data were linked to similar data from the abbey of Leeuwenhorst published by De Moor (2000).

[8] According to these sources, interest rates are stable at 6,25 % before 1576; increase to 8,3 % in that year, declines to 7,1% in 1607 and 6,25% in 1611, to 5% in 1640, to 4% in 1655 and 3,5% in 1747.

Factor costs of shipping industry1450-1800 (1600/1609=100)



On the basis of data from 19th century shipbuilding we tentatively estimated the cost structure of that industry (timber 40%, wages 30%, iron 15% and copper also 15%) (Jansen 1999: 282, 292-3).[9] More information is available on the structure of the costs of shipping. For the period 1589-1598 the account books of a Delft merchant, Claes van Adrichem, break down the costs of ten voyages to the Baltic (with occassional trips to Portugal and France). One third of costs consisted of wages, another third of consumables (also part of the costs of labour), 29% of materials (sails, ropes, timber etc.) and only 4% of war materials (canons, gunpowder) – on most trips to the Baltic the share of the latter was even zero (Winkelman 1981: 534-535). Missing from these costs calculations are capital costs, which Van Adrichem did not book. A tentative estimate of these costs, based on what is known about the price of ships in these years is that the average rate of depreciation was 10%, and that total capital costs may have been as high as wages and consumables together.[10] Similar data are available for voyages to Portugal, Italy and West-Africa from the period 1592-1603, but they also

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[9] Van Bruggen mentions a slightly different distribution for the construction costs of cargo ships around 1677 (timber 50%, wages 22%, iron 8%, hemp 14%, rest 6%). He does not mention his source (Van Bruggen 1977: 58).

[10] In 1677 the VOC paid for a month ship's hire 2400 guilders, of which about half was spent on wages and victuals for the crew (Ketting 2006: 48); Brulez thinks that the often assumed rate of depreciation of 10 % is too high (Brulez 1979: 3, 5); nevertheless, indications of the average life expectancy of Dutch cargo ships range from 7 years to 10-12 years in the 17th century and 15 years in the 18th century (Hart 1977: 108; Unger 1977: 44; Van Kampen 1953:104).

neglect depreciation of ships and interest (De Jong 2005: 106-7). Considering all these sources of information we have assumed the following shares in the cost structure of shipping for the base period 1600/1609: capital costs (interest on and depreciation of the ships): 40%; wages (of unskilled labourers) 30%, consumables (following the consumer price index) 15%, timber 9%, copper and iron 4,5% each (De Jong 2005: 106-107). Because consumables are part of labour costs, this brings the share of labour in value added at about the same level as the share of capital. These are very tentative estimates, but, because all series show a similar development (with the exception of the interest rate), the effect of various assumptions concerning the shares of different factor costs is limited.[11]

[11] We also estimated two alternative series of weighted factor costs, one consisting of 50% wages and 50% capital costs (and no prices of copper and iron), the other one consisting of 70% wages and 30% capital costs; the differences between the three deflators are very small, in particular in the period before 1630; during the whole period 1500/09-1780/89 the series used here increases by 410%, the second series by 381% and the third series by 406%; the choice of the weighting scheme therefore has only a very limited impact on the results of this measure of productivity.

Figure 3

Real Freight rates on the routes to the Baltic and to Livorno (1600/1609=100)

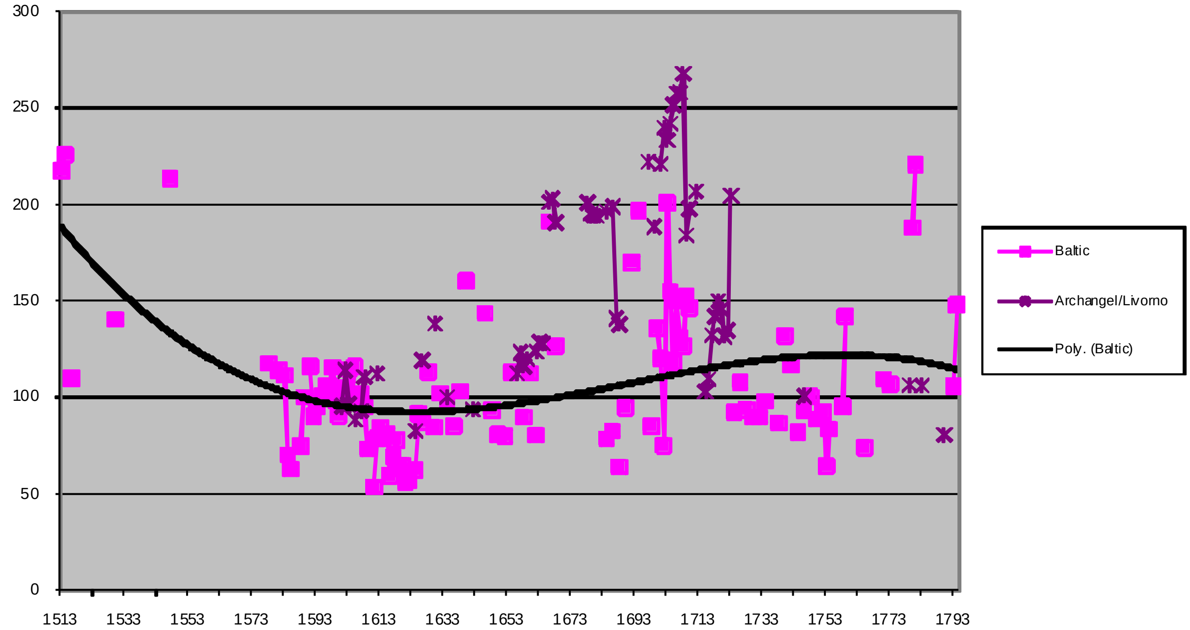
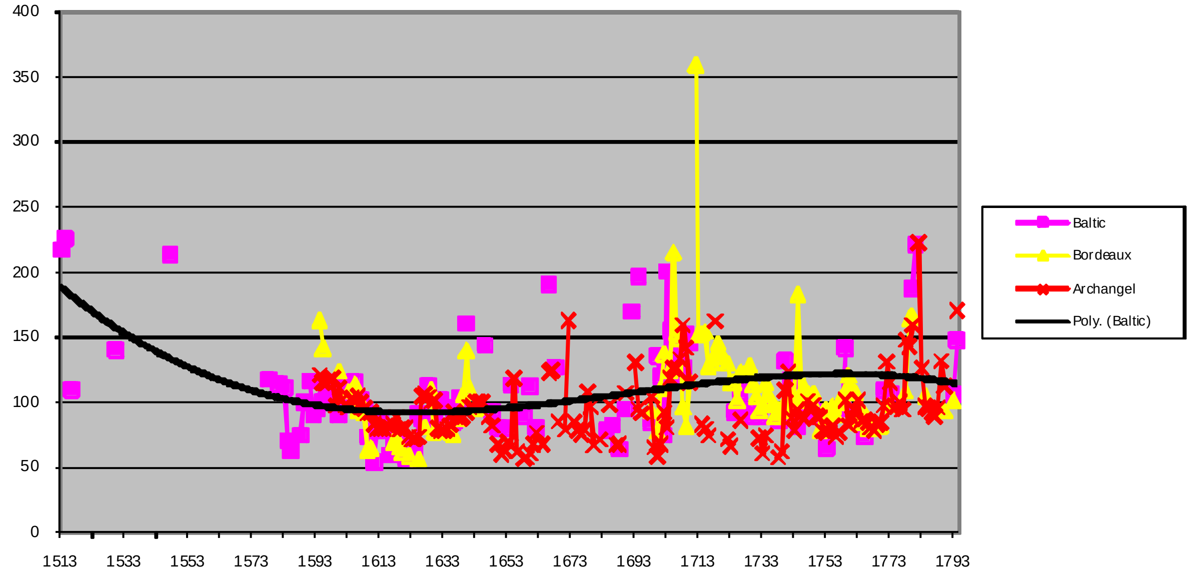


Figure 4

Real Freight rates on Baltic, Bordeaux and Archangel (1600/1609=100)



Finally, we deflated the nominal series of freight rates with the weighted factor costs of the shipping industry, to get estimates of the 'real' freight rates, which we use as our estimate of the development of total factor productivity. We realise of course that the freight rates thus deflated do not really measure total factor productivity growth, but they do give us a useful proxy. Graphs 3 and 4 presents four series, related to the trade with the Baltic (mainly Gdansk), Bordeaux, Archangel and Livorno (the latter ships first went to Archangel to collect merchandise, mainly grains, and then went to Livorno). Only the Gdansk series goes back to the first half of the 16th century. It shows a strong decline during that century; the lowest level was attained in the 1610s, after which real freight rates on this route increased during the second half of the 17th century. A modest decline in the 18th century was not enough to revert to the low values which had characterised the Truce with Spain (1609-1621). The development of freight rates on the other trade routes was not much different, except that in shipping to Archangel the lowest real freight rates were realised a few decades later than on the Baltic route, around the middle of the 17th century. On all routes – and most strongly on the trade to Livorno – real freight rates increased quite a lot during the second half of the 17th century, when the Netherlands was fighting a number of wars with (amongst others) Great Britain. In the 18th century freight rates returned to a lower level, but they remained in general much higher than they had been in the first half of the 17th century. The conclusion must be that Dutch shipping, at least shipping within Europe, was most efficient in the first half of the 17th century and never realised the same high level of productivity in the rest of the early modern period.

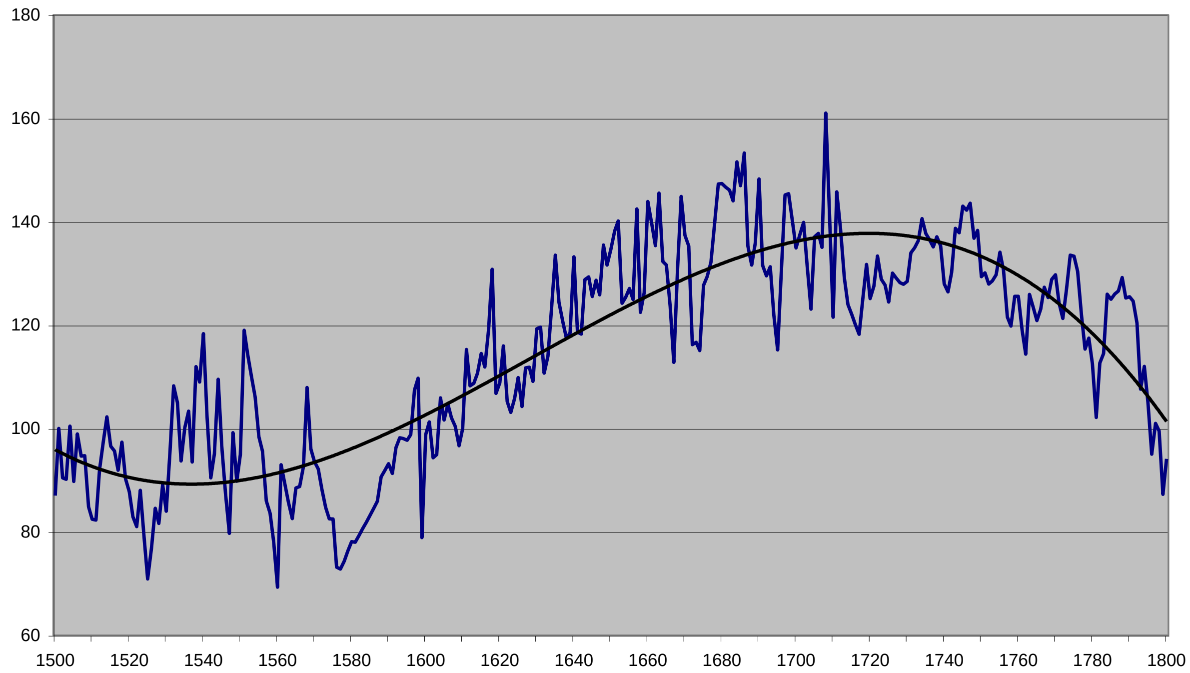
The problem with the data on freight rates is the very limited number of observations for the period before 1590. Fortunately, data on grain prices in the North Sea area and the Baltic can confirm this picture of rapid productivity growth until the 1620s, followed by stagnation afterwards. David Jacks (2004) in his reconstruction of the process of market integration in this region, arrives at identical results. The price gap between the two regions fell strongly between the early 16th century and the 1620s, pointing at increased integration of markets and declining transport costs. He also finds stagnation from the 1620s onwards; perhaps the price gap even increased a bit during the second half of the 17th century. His analysis of market integration is therefore very similar to our results in terms of real freight rates.

We have to underline that these changes in total factor productivity refer to shipping and shipbuilding together, as we have not been able to separate the two activities. It is not impossible that the fall in freight rates in the 16th and 17th century was a result of improvements in shipbuilding. One of the defining elements of fluyts was the fact that they were cheaply built. Sometimes the word fluyt was even used more or less as synonymous with cheap ships (Ketting 2006: 23).

Interpretation: differences between the two approaches

First we will focus on the question how to reconcile these different stories. There is a divergence of the two measures of total factor productivity growth during the 1550-1620 period: the near absence of productivity growth according to the comparison between quantities of output and inputs seems inconsistent with the rapid growth of total factor productivity based on the price and wage data. Perhaps less striking is what happened during the rest of the 17th century: the output/input data suggest growth of labour productivity, whereas the price data show a decline in total factor productivity. To start with the latter problem: what is absent from the analysis of quantities is the effect of relative prices. The increase in labour productivity in the 17th century is probably related to the fact that after 1600 wages went up relative to capital costs (see Figure 5).[12] This increase was not dramatic, only by about 40-50% between 1600 and 1700, after which this ratio stabilized (and even declined somewhat after 1760). The increase in labour productivity occurring during the 17th century that can be read from the quantity data, was linked to this relative increase in wage costs. But the price data suggest that this did not really matter much for total factor productivity, which in fact stagnated after the 1620s, when the increase in labour productivity still had to begin. In other words, the increase in labour productivity from Table 1 and from the estimates by Lucassen and Unger (2000) can be interpreted as a reaction to changing factor costs which induced a change *along* the productivity frontier, but did not lead to a change *of* the productivity frontier (i.e. an increase in total factor productivity). In this way, it is possible to reconcile the results of the two approaches for the post 1620 period.

Figure 5 The ratio between wages and capital costs in Dutch shipping 1500-1800 (1600/09=100)



[12] Capital costs are the costs of operating the ships, based on the estimated price of ships, an unchanging rate of depreciation (10%) and the interest rate (which fell from 6,25% to 3,5%); the declining interest rate is the main explanation of the declining relative capital costs.

Such a reconciliation of the different approaches to productivity growth is more difficult for the period 1550-1620, when the data on freight rates point to a substantial increase in total factor productivity, but capital productivity was stagnant and labour productivity went up by about a third only. As explained, a difference between two approaches is that the dual approach also includes productivity growth in shipbuilding. A possible explanation for the different findings is that the rapid productivity growth during the 1550-1620 period was concentrated in shipbuilding, resulting in the development and spread of the fluyt. This led to (much) more efficient and especially cheaper ships, but that it took a few generations – when wage costs started to increase much more the capital costs – before the full potential of the new design in terms of savings on labour costs could be realized.

Compositional effects may also have played a role. The decline in real freight rates appears in the Baltic trade, where large productivity gains were realized. During the same period the trade on other routes – to Asia, the Americas and the Mediterranean - increased much more rapidly than the 'mother trade' with Gdansk. On those ships, defense was vital, and the ratio of sailors per tonne was much higher than on route via the Sound (Van Lottum and Lucassen 2007, table 1; Van Royen 1987: 179). The productivity gains that occurred in the latter trade were to some extend overshadowed by the higher labour requirements on these other routes. This helps to explain that productivity of the fleet as a whole increased only moderately, whereas large gains in total factor productivity were realized on the trade with the Baltic.

Interpretation: determinants of productivity growth

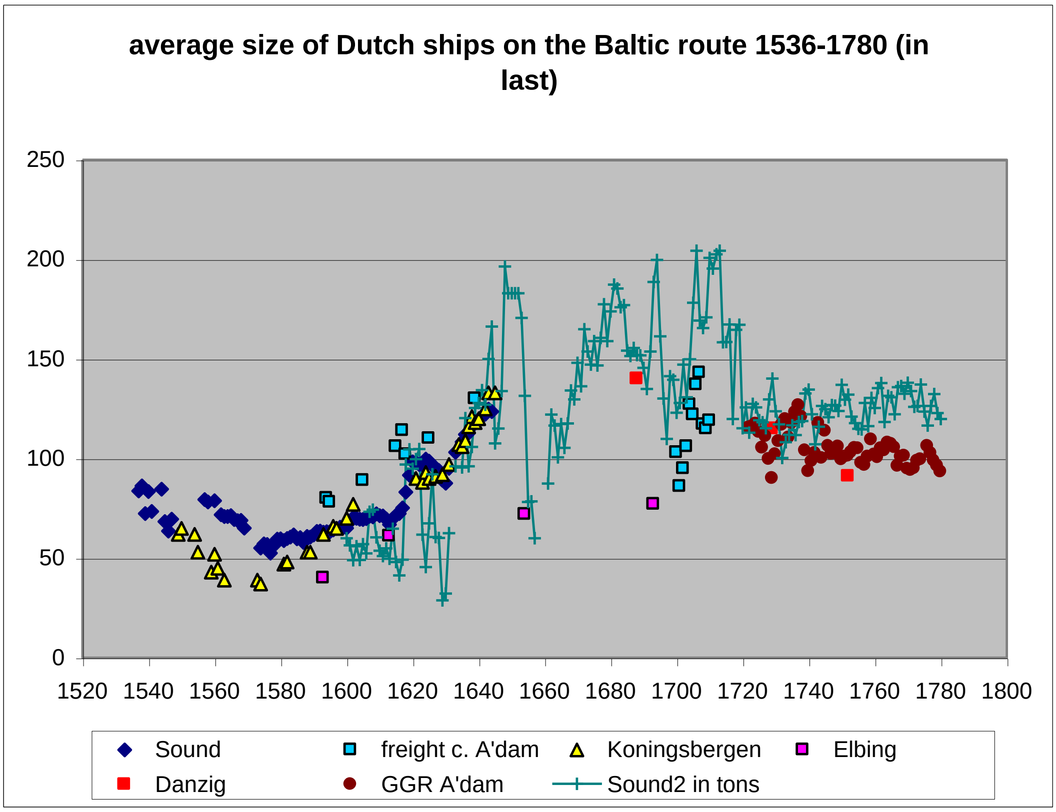
The long term curve of real freight rates – our most important index of productivity growth – appears to confirm the view that technological change occurring in the 16th and early 17th century, a period usually linked to the development of the fluyt, was probably the main force behind the increase of productivity of Dutch shipping. We cannot quantify this source of tfp-growth, however; there are no estimates of the growth of the share of the fluyt in the total fleet, or other indices of technological change that might be used to establish such a link more carefully. The classic story is that the fluyt was developed in the 1590s by a shipwright from the city of Hoorn, and copied gradually by other wharfs and shipowners, and became the dominant ship design during the period of the Truce with Spain (1609-1621), when, as we have seen, freight rates bottomed out. Several historians have, however, said that there was not a single invention, but that the new design was the result of experiments with ship design that began much earlier (Unger 1978: 36), and were related to the new conditions that arose after the Peace of Spiers (1544), after which Holland dominated the trade with the Baltic, and cannon on ships was no longer necessary on this route (Wegener Sleeswyk 2003). The gradual decline of real freight rates between the 1550s and 1620s is therefore consistent with this interpretation of the rise of the newly designed fluyt.

Other factors may also have played a role, of course. As mentioned earlier, the literature suggests a number of other causes of efficiency improvements in the shipping sector as well, which we can now review against the background of what is known about the evolution of freight rates. The first additional factor that might be mentioned is the size of ships – large ships are often thought to be more efficient to build and to operate (per tonne, of course), are better to defend (more sailors and perhaps also more soldiers); on the other hand, it may take more time to load them, and the chances that not sufficient cargo can be found to make a profit increase with size. The balance between the two will obviously depend on the route.

How did the average size of ships change over time? A number of different sources makes it possible to establish this for (different parts of) the Baltic trade (Figure 6). What is striking is that initially the average size of ships tended to decline, most clearly during the middle decades of the 16th century, but, dependent on the sources used, relatively small ships of 50-70 lasts (100-140 tonnes) continued to dominate this route until (again) the 1620s. The breakthrough of the fluyt occurring in this period was therefore not a change in the size of ships, which continued to be rather small.

In the second quarter of the 17th century the size of ships gradually increased, and this rising trend continued into the second half of the century, when average ship size went up to more than 100, perhaps as much as 150 lasts – with occasional peaks of 200 lasts. This happened in a period of strongly increasing freight rates, suggesting that economies of scale were absent, or were cancelled out by other factors, such as renewed threats of war (about which more below). That war and peace may have played a role is also suggested by developments after 1713, when the Dutch more or less withdrew from international power politics, and managed to remain neutral for most of the time. Perhaps as a consequence of this, average ship size declined to a level between 100 and 130 lasts – bigger than the very small ships of the period before 1620, but quite a bit smaller than the large ships which had dominated between 1660 and 1720. Comparing periods of peace in the 17th and the 18th centuries (during the Truce and after 1713) learns that average ship size had risen – perhaps doubled - but as we have seen, there was no accompanying decline in real freight rates. The idea that bigger ships are more efficient is in no way confirmed.

Figure 6



Sources:

Sound: Calculated average capacity of Dutch ships passing the Sound 1537-1644. (Only) in this period all ships were classified in one of three categories: <30 last, 30-100 last, >100 last. A weighted average is calculated, assuming that ships in the first category averaged 20 last, in the second 65 last and in the third 130 last. Source: Bang and Korst 1906/1953; **Freight contracts Amsterdam:** Average size of ships mentioned in Amsterdam freight contracts for Baltic voyages. As mentioned in the appendix on sources, freight contracts were not made for all voyages. The contracts overestimate average capacity for ships sailing on the Baltic possibly by 10-20 last. Source for 1594-1639: Christensen 1941: 100. Data for 1700-1710 are calculated as weighted averages for three Baltic routes. Source: Van Royen 1996: 119-121 (Baltic (1), (2) and (3)); **KÖnigsberg**: Average capacity of Dutch ships registered in the *Pfundzollregister* in the port of KÖnigsberg. Source: Kempas 1964: 341. The importance of the changes in ships' sizes were discussed by Jeannin, who also published graphs showing these changes but not the original data: Jeannin 1960; **Elbing**: Average lastage of Dutch ships registered in the *Pfundzollregister* in the port of Elbing. Averages are calculated for four periods: 1585-1600, 1601-1625, 1653-1655 and 1685-1700. The averages are located in the graph at 1593, 1613, 1654 and 1693 respectively. Source: Lindblad 1995: 421; **Gdansk**: Average capacity of Dutch ships registered in the port of Gdansk in 1688, 1729 and 1752. Source: Vogel 1932: 129; **GGR**: Average size of ships arriving in Amsterdam from the Baltic, as registered in the *Galjootsgeldregisters*. This concerns the lastage of the ships or SL (scheepslasten) converted in (real) capacity of the ships using the formula developed by De Buck and Lindblad (1,21 SL + 13,7). Sources: De Buck and Lindblad 1983; De Buck and Lindblad 1990: 35; **Sound2**: The average volume of the most important commodities on board ships as registered in the Sound Toll Tables, converted in tons. Source: Bang and Korst 1906/1953.

Another factor relevant to shipping efficiency was economies of scale. During the 1550-1650 period we see a negative relation between freight rates and the volume of trade, in particular in the Baltic trade. The number of ships going through the Sound tended to increase steadily from the beginning of the 16th century until 1608-1618 and showed a subsequent decrease between 1618 and 1665-1672. Theoretically freight costs could have been driven up by the increasing demand for ships before 1620, but apparently this was not the case and shipbuilding kept up with the expansion of trade. The economies of scale probably were realised as follows. The growing density of the use of the shipping routes reduced turn around times by making it easier to find return cargo and intensifying the flow of information. Communication between ports was in this period still heavily dependent on dispatching letters via ships. The inverse relationship between the number of Dutch ships and freight costs was less strong in the period after 1670. The conclusion seems justified that at least the powerful expansion of trade during the 16th and 17th centuries worked to lower freight rates.

The growth of trade also had consequences for the efficiency of the network. Probably the best measure of this is the degree to which *voorbijlandvaert* occurred, when ships from the Baltic bypassed the Netherlands and immediately brought their cargo to (for example) France or Portugal (after 1653 they were not allowed to do this to England, due to Cromwell's Navigation Act); or, alternatively, ships coming from these countries bypassed Amsterdam and sailed for the Baltic directly. From the Soundtoll registers this can be measured, and we can establish the share of ships participating in this *voorbijlandvaert*. Another index of (in)efficiency is the share of ships – according to the same sources – having only ballast on board. Figure 7 shows the long term evolution of both indices of (in)efficiency. There clearly is a negative correlation between these two proxies: between 1550 and 1650 the share of *voorbijlandvaert* goes up strongly, from a few percent to 20-30% of all trade via the Sound, whereas the share in ballast declines from about 40% to 20%. The strong decline in real freight rates that we established during this period, is therefore also linked to major improvements in the network of trade – a factor which may have been of comparable importance as the invention of the fluyt in the same years. The second half of the 17th century witnesses a sharp deterioration of the quality of the network: ballast goes up again, and *voorbijlandvaert* declines sharply, in particular in years of war during the mid 1670s and between 1690 and 1713 (when the Netherlands was almost constantly in war). After 1713 things change again for the better: *voorbijlandvaert* becomes popular again – after 1756 even more popular than it was in the mid 17th century – but the share of ballast, after an initial decline during the 1710s, returns to a relatively high level. Clearly, there is a strong link between the efficiency of the network and the level of real freight rates.

Finally we have to look at the effects of warfare. During large parts of the period, the Netherlands was in a state of war with its neighbours and rivals: with Spain between 1572 and 1648 (with the exception of the truce between 1609 and 1621), with England during four Naval wars (1651-53, 1665-1667, 1672-74 and 1780-84), with France (and almost all its other neighbours) between 1672-1678 and 1700-1713. In the 17th century a large share of the burden of international warfare fell on the Dutch, who also heavily subsidized its allies. After 1713 the Dutch tried to stay neutral, because the state could hardly pay for the enormous expenses of warfare on land and water anymore. The presented series of real freight rates suggest that the impact of war on the level of freight was higher in the post-1648 period – when the Dutch were fighting against the British and the French, both countries with large navies – than before 1648, when the primary enemy was Spain. This may have contributed to the worsening of the performance of the shipping industry in the second half of the 17th century. We can measure the impact war had on freight rates by comparing, per subperiod, the difference in average real freight rate between years with and without war (indices 1600/1609=100). Before 1650 the difference is 35%; on average, freight rates in years of war are 35% higher than in years of peace, which is substantial. After 1650 the difference is only slightly bigger, namely 41%, only marginally larger than what we found for the period before 1650. War can therefore not help to explain the poor performance after 1650.

Figure 7

Voorbijlandvaert and ballast (both as % of total traffic), 1557-1794

Conclusion

The shipping industry was a very dynamic part of the early modern economy of the Netherlands, with a long term growth rate of output and real value added close to 1% per year. The reconstruction of the development of its output also demonstrated that it was a very unstable part of the economy, with huge fluctuations due to wars, trade blockades, and other forms of political intervention, a fact very much stressed by Israel (1989). The secular trends in the world economy are clearly reflected in its growth performance: growth is concentrated in the 1550-1650 period, and reoccurs between 1750 and 1780 or even 1790. Within the 1550-1650 period, growth spurts occurred during Antwerp’s ‘golden age’ in the middle decades of the 16th century, followed, after a sharp contraction of the sector during the late 1560s and early 1570s, by the most significant period of expansion between the late 1570s to the 1620s; a brief period of growth happened in the final decade of the war with Spain (late 1630s and 1640s).

This strong expansion of the shipping sector can only partially be explained as resulting from strong increases in total factor productivity. Looking at the ratios between outputs and inputs shows that capital productivity in the shipping sector itself increased only little if at all, and that labour productivity probably doubled, which contrasts sharply with the fact that total output grew by a factor 17 between 1503 and 1790. This picture changes, however, when the relationship between output prices and input prices is analyzed. This alternative approach to estimate total factor productivity necessarily, as a result of the fact that reliable prices for ships are not available, comprises the integrated shipping sector - both shipping and shipbuilding. When nominal freight rates are deflated by a weighted index of input prices, a strong increase in total factor productivity can be observed in the period between about 1550 and the 1620s (presented here as a large fall in real freight rates). There is however a reversal of this trend after the 1650s; real freight rates went up during the second half of the 17th century, came down again somewhat after 1713, but did not reach to the low levels of the first half of the 17th century anymore during the rest of the 18th century. This chronology differs from that suggested by the development of labour productivity, as manning ratios improved all along the 17th century, but stagnated during the 18th century.

We have attempted to offer an explanation for this discrepancy. The increase in labour productivity during the 17th century found also by Unger and Lucassen (2000) points in our view to a changed ratio between capital and labour input in response to changes in factor prices, i.e. the relatively strong rise of wages in this period versus declining capital costs due to falling interest rates. But this increase in the ton per man ratio during the 17th century does not seem to be related to total factor productivity growth, as measured by the price data; the decline in real freight rates predates the rise in labour productivity, which appears to occur in a period when real freight rates have bottomed out, and start to increase again. The increase in labour productivity seems to point to a movement along the production possibilities curve caused by changes in factor prices, and not of a change of that curve.

Our study makes it possible to tentatively explain the decline of real freight rates between 1550 and 1620. The development of the fluyt was probably the most important explanations of the increase in productivity in these years. Another factor was the increased importance of multilateral routes and the growth of the trading network. The strong growth of the *voorbijlandvaert* between the Baltic and France, Portugal, Spain and Italy after the middle of the 16th century until the 1620s coincided with a secular decline in freight rates, and a sharp reduction in the share of ships in ballast. This all points to sharp increases in the efficiency of the network during these years. From the middle decades of the 17th century the multilateral character of the shipping network was under pressure from growing international competition, in particular from the English (who specifically aimed at this target with the Navigation Acts of the 1650s). The gradual loss of this integrated network during the second half of the 17th century was detrimental to the efficiency of Dutch shipping.

Changes in the average size of ships did not have the expected effects on freight rates. Between 1550 and 1620 the average size of ships (on the Baltic route) declined. The tendency towards larger ships employed during the second half of the 17th century probably reduced the manning ratios and therefore improved labour productivity, but in other respects they were less efficient and seem not to have contributed to a higher total factor productivity. Again, the relationship between total factor productivity and labour productivity is quite complex, and the changes in manning ratios only point to part of the story. Yet, it remains rather puzzling that the strong decline in real freight rates between 1550 and 1620 – pointing to strong increases in total factor productivity – did not have a big impact on labour productivity; we cannot exclude the possibility that measurement errors play a role in this as well.

Finally, the analysis presented here also demonstrates, in our view, that in explaining productivity change it is almost impossible to separate political and commercial from technological factors. The story of the fluyt, a new technology made possible by the imposition of the Pax Hollandica, which was in turn linked to the specific political economy of Holland, illustrates how political and technological factors were intertwined. The fluyt was also the result of the strong expansion of the shipping sector and industry in the 1550-1620 period, making possible increased specialization (different ship designs for different routes). Productivity growth therefore was based on changes in commerce, politics and technology that to a large extent occurred at the same time, and produced a cumulative process of growth lasting from the middle of the 16th century to the 1620s (or perhaps the 1640s and 1650s). From the third quarter of the 17th century onwards – that is, earlier than suggested in recent literature - the tide seems to have turned, and stagnation set in, which resulted in a rise of real freight rates and a worsening of competitiveness. The inability to improve shipping efficiency after the first quarter of the 17th century made the Dutch vulnerable to competition. The stagnation in shipping efficiency from the 1620s onwards not only harmed the competitive position of the Dutch mercantile fleet but probably also the general economic development of the Republic. One of the most strategic sectors turned from being a source of rapid productivity growth to stagnation.

APPENDICES ARE NOT FOR PUBLICATION IN THE JOURNAL; THEY CAN BE PUBLISHED ON OUR WEBSITE

Appendix I: **Estimates of the output, value added and inputs of the shipping industry in Holland 1500-1800**

The methodology applied to the reconstruction of the development of the shipping industry is the standard system of national accounts (SNA), as applied to the past in a number of studies related to the Netherlands in the 19th century. In particular the study by Horlings (1995) on the Dutch services sector in the period 1800-1850 has been used as a model, making it possible to link the estimates from this study to the 19th century estimates. The following estimates have been made:

- The volume of international shipping (in million tonkm) between Dutch ports and other ports
- The load factor (per route and on average): which share of the shipping capacity (on different routes) was actually used to transport goods
- The volume of transported goods (in million tonkm), the product of the two
- The freight rate (per route and on average): how much was being paid for transporting these goods
- The total freight sum, the product of the previous two estimates
- The value added of the shipping industry, the result of subtracting estimates of the value of inputs from the total freight sum
- Finally, to estimate the development of total factor productivity, information on the development of factor costs is also needed.

It is clear that a lot of detailed information is needed. Fortunately, the Dutch shipping industry has been the subject of a lot of in depth research. We are particularly well informed about two large segments: the route to the Baltic via the Sound (thanks to the invaluable registers of the Sound toll and the many studies based on this source), and the trade with Asia, carried out by the Dutch East Indies Company (VOC), of which the accounts have been preserved and have been studied quite intensely. Also the development of shipping with (West)Africa and the Americas could be studied separately, thanks to a number of sources pertaining to these routes. The other routes however – the trade with Russia/Archangel, Norway, England, France, Portugal/Spain and the rest of the Mediterranean (which will be grouped under the heading 'the rest') – could not be studied independently. For the period after 1642 their importance could be derived from the number of ships entering Amsterdam/Holland, which forms the basis for the annual estimates for 'the rest' .

First series of estimates: total volume of shipping (in million tonkm)

Starting point are the two benchmark estimates for 1636 and 1780, which are presented below (tables A.1 and A.2). Next, shipping through the Sound was estimated for 1503, 1528, and 1537-1780, using the information from the Sound toll registers (Bang and Korst 1906/53). Starting point was the number of voyages to the west, and estimates of the average size of the ships acquired from 1/ the data on ships sizes for the period 1537-1644 and 2/ estimates of the quantities of the transported goods divided by the number of ships for the period 1600-1780. The comparison between these estimates shows that the estimated average size of ships in lasts between 1600 and 1644 is almost the same as the estimated quantity of transported goods in tonnes. This suggests a loading factor of about 50%, as one last is two tons. Moreover, it was assumed that ships came from/went to Gdansk, to which the average distance is 1552 km.[13]

Shipping volume by the VOC could easily be estimated on the basis of the data on the number of ships leaving for Asia and coming from Asia, and their tonnage from Dutch Asiatic shipping by Bruijn, Gaastra and SchÖffer (1979/87) and Bruijn (1990); shipping within Asia was not included in the estimates, and it was assumed that all ships went to/came from Batavia (distance from Amsterdam: 21107 km).

Shipping volume of the WIC/to the Americas is estimated in the following way: for 1780 we used the data from Vander Oudermeulen (1801), which gives detailed estimates of shipping volumes on all major trade routes at about 1780; this series was linked to the yield of the *paalgeld* paid explicitly by WIC/American ships from Heeres (1982), a series that goes back to 1712. Between 1636 and 1712 the series was based on an index of the activities of the WIC in these years, derived from Den Heyer (1997), which is the average of trade in slaves and the export of gold from West Africa. For 1636 this could be linked again to the benchmark estimate of total shipping activity by the States of Holland of that year; between 1592 (when this trade began) and 1636 this estimate is based on the development of sugar imports from Brazil from Gelderblom (2004).

The remaining shipping activity is estimated as follows: from a number of sources (a.o. *paalgeld* and *lastgeld*) Welling (1998) has estimated the number of ships entering the port of Amsterdam between 1742 and 1810, a series that can be extended back in time (until 1643) using the same data for 1662-1747 published by Oldewelt (1953), and in addition the yield of the *lastgeld* for the period 1643-1662 from the same source. We estimated the share of other port cities via their share in the *convooien en licenten* of these years to get a series of ship entries into the Netherlands (Amsterdam’s share fluctuated around 75%). From this series of total number of entries into the Netherlands between 1643 and 1810 we substracted the entries from the Baltic, from Asia and from Africa and America estimated previously, to get a series of estimates of entries from ‘the rest’ (meaning all trades except the three estimated already). The average ‘production’ in terms of tonkm of these entries can be estimated from the benchmark estimates for 1636 and 1780, which appears to be almost exactly the same (457.000 tonkm in 1636 and 462.000 tonkm in 1780). We therefore have assumed that this ‘production’ per entry remained constant and was the average production of all ships entering from the rest (from Russia/Archangel, Norway, England, France, Portugal/Spain and the rest of the Mediterranean). For the period before 1643 we have assumed that the growth of the ‘rest’ was related to the expansion of the shipping through the Sound, and to the degree of *voorbijlandvaert* that can be found in the data on that source (Bang and Korst 1906/53). The idea is that the share of *voorbijlandvaert* , which increased from 1-2% of total shipping in 1557/58, when the first data are available, to sometimes as high as 35% of total shipping in the 1620s and 1630s, reflects the multipolarity of the trading system, in particular the growth of other routes besides the classic trade through the Sound. The expansion of the *voorbijlandvaert* from the mid 1550s onwards, for example, is related to the growth of shipping to Spain and Portugal, where the demand for grains

[13] Distances between ports are derived from http://www.portworld.com/map/

from the Sound increases strongly, leading to a rapid expansion of Dutch shipping. The formula for estimating the shipping volume of the 'rest' is chosen in such a way that if *voorbijlandvaert* is zero (as it was in 1557/58), the volume of shipping of 'the rest' is identical to that via the Sound. For 1636 we know from the benchmark estimates mentioned already that the ratio between Sound and 'the rest' is 1.7 (which is also exactly the ratio we get in 1643 when going back in time via the total number of entries, as explained above). Before 1557 it was assumed that the shipping volume of 'the rest' was equal to that via the Sound, which is consistent with the estimates of contemporaries used in Table 1 of this paper.

Towards value added

Three intermediary factors have to be estimated to arrive at estimates of the value added of the shipping industry:

1. The load factor: the share of the shipping capacity used to transport goods; Horlings (1995) estimated these for the 1800-1850 period, and arrived at averages between 30 to 40%, the result of the unbalanced character of most trade, and practical limitations of using the shipping capacity; almost similar shares (50%) could be estimated for the Sound route after 1600, when we have data of the amounts of goods carried westwards and eastwards, and the capacity of the ships; for the VOC trade the load factor could also be estimated, as it is again known that most ships left for Asia almost empty, which was to some extent also true for the trade with Africa and Latin America; for the shipping on the other routes, it was estimated that the share of ballast was half that of the Baltic, as this trade was generally more balanced; overall, our estimates result in a small decline in the overall load factor from 40-45% in the 16th century to 35-40% in the 18th century, which is mainly the result of the growing importance of long-distance trade with a below-average load factor (Horlings 1995: 393 estimates for 1807, a year of crisis, 34%, rising to 45% in 1830);

2. Freight rates: see Appendix II. For the trade with the Americas there were hardly any freight rates available so we used data of actual costs of the ships involved by the Middelburgsche Commercie Compagnie (from Reinders Folmer-van Prooijen 2000: 182-211). For the trade with Asia we used data of actual costs of the ships from the accounts of the VOC (from Bruijn 1990 and De Jong 2005).

3. Finally, the share of value added in total freight sum had to be estimated; we used the estimates of the structure of the shipping costs discussed in this paper to estimate this share at 70% for shipping via the Sound and ' the rest', and 60% for long distance routes (Asia and Africa/Latin America), as the later used more inputs, mainly as a result of the higher capital intensity of shipping on these routes (Horlings (1995) estimated this share at 66%).

Table A.1 Shipping in 1636 according to the Holland Estates

	Number of ships	Number of voyages	Distance in km	Last per ship	Shipping volume in 1000 tonkm
Baltic	400	1200	1552	100	744960
Norway	350	1400	937	150	787174
Northern Germany	150	450	491	20	17668
Dover, London and Newcastle	100	300	500	40	24000
Rest of England and Scotland	50	150	5	30	9000
Calais	10	50	291	20	1163
NWFrance	140	420	509	40	34225
SWFrance	300	750	1428	100	428368
Russia	40	80	3637	120	139673
Mediterranean	50	100	4170	150	250200
VOC		8	21107	300	202627
WIC		37	8328	250	308149
Total	1590	4945			2947208

Source: Municipal Archives Amsterdam, 5025, nr. 16 (18/7/1636)

Table A.2 Shipping at about 1780 according to Van der Oudermeulen (1801)

	Value of Trade (million guilders)	Voyages	Distance in km	Last per ship	Shipping volume in 1000 tonkm
Surinam	8	55	7543	400	663801
Demerary	4,5	27,5	7628	400	335649
Berbice	1	6	7628	400	73233
Slavetrade	1,5	3	7480	400	35905
St.Eustatius & Curacao	9	37,5	7917	400	475038
East Indies	35	20	21107	500	844290
Baltic		970	1552	100	602176
Rest North	55*	780	600	100	187200
UK	43	1300	515	150	401588
France	37	390	1019	150	238352
Portugal	17	66	2063	150	81700
Spain	28	125	2471	150	185293
Mediterranean	12	25	4170	200	83414
Levant	6	15	5906	200	70872
North America	3	67,5	6482	250	437535
	260	3887,5	1213		4716046

*Includes Baltic

Appendix II: **Sources concerning freight rates**

In order to establish the price of transport we heavily relied on one kind of source which is found in massive numbers in the Amsterdam notarial archives: chartering contracts. A chartering contract is an agreement between a shipping company and one or more freighters or charterers who charter the ship for a particular voyage or, less often, for a specified period like a month. The freighter chartered the whole or part of the ship to carry a cargo from port A to port B at a certain price. The contracts contain the name of the shipmaster who was acting in the name of the shipping company, his residence, the name of the charterer (s), the name of the ship, the freight charge and often but not always the tonnage of the ship and the kind of cargo and its quantity or weight. The chartering contracts are also called charter-parties or freight contracts. In Amsterdam lots of chartering contracts were notarized, which means that a signed copy was entered in notarial registers. An unknown number of them were not (Van Tielhof 2002:199; Knoppers 1976: 17-18; Van Royen 1996: 108). It is important to stress that these prices were the prices actually agreed upon for a specified transport service.

The market for freights in Amsterdam must have expanded considerably in the course of the 16th century, along with the expansion of overseas trade and shipping. In the 15th century chartering contracts were probably still concluded on the first of the two big fairs, where foreign merchants appeared to look for possibilities to ship their goods (Posthumus 1953: 130). At the end of the 16th century chartering contracts were signed all year round. Jan Franssen Bruyningh started to work as a notary public in Amsterdam in October 1593, and had a large clientele of merchants and ship-owners from the start. Every year, about hundred freight contracts referring to voyages to the Baltic are documented in his protocols. Bruyningh also witnessed huge numbers of charter parties referring to other trade routes, such as Spain and Portugal for which about 50 contracts remain in his protocols each year.[14] It is highly probable that Bruyningh did not build his practice up from nothing but that he continued the flourishing practice of a predecessor. This can very well have been notary public Frans Anthonisz Bruyningh, who had a big practice in Amsterdam from 1579 to 1591 (IJzerman 1931: 164). This notary's archives unfortunately have been lost, which prevents us from studying the influence of the massive immigration of Antwerp merchants on the Amsterdam freight market after the fall of Antwerp in 1585. The wealth of contracts remaining since October 1593 at least shows that a fully developed market for freights existed by then.

The massive character of the freight market had several consequences. For a start it moderated price fluctuations. Freight charges in Gdansk in the 1580s, mentioned in mercantile correspondence, show intense price volatility unknown in Holland (Van Tielhof 2002: 209-210). Transport was probably also relatively cheap in Holland, thanks to the volume of shipping services. It was about as expensive to charter a ship for a single voyage from Gdansk or from Bordeaux to Holland as to charter a ship for a return voyage to these destinations starting in Holland, although the latter trip would take twice as much time. Lastly, conditions on the freight market in Amsterdam served as a guideline for other port cities. 18th-century mercantile correspondence shows that information about ships chartered in Amsterdam heavily influenced the price formation process of freights in Bordeaux (Wegener Sleeswijk 2006: 361).

Objections have been raised against the charter-parties saying that they are not representative for Dutch trade and shipping in general. Christensen signalled in his fundamental study on Dutch Baltic trade that only for a small part of all voyages a notarial contract had been concluded. To make things worse, this part varied according to the trade route and the ship's carrying capacity. For simple, routine return voyages to the Baltic much less contracts were found than for multilateral trips via western Europe to the Baltic or vice versa. In general, contracts were more likely made for longer trade routes than for shorter ones, and more often for big ships than for small ones.[15] Although shipping between the Dutch Republic and north-western Germany and the British isles was intense, chartering contracts for these routes are very rarely found.[16] Quite different is the situation in regard to the White Sea. Numerous chartering contracts remain for trips to Archangel for the whole of the 17th and 18th centuries. An important explanation for the discrepancy between the number of contracts and total shipping from Amsterdam is the entanglement of trade and shipping in Holland (Lesger 2004). Many shipping companies traded on their own account,

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[14] All freight contracts having the Baltic as destination have been published by Winkelman (1977/83) II-VI; an overview in vol. VI, 831-832. IJzerman published more than 1000 contracts for voyages to Spain and Portugal in the period 1593-1602, or about 100 a year. About half of them are multilateral voyages overlapping with Baltic voyages (IJzerman 1931: 164, 286-287).

[15] Christensen 1941: 102, 284. Christensen estimates that for only 10-30% of all the voyages to the Baltic a notarial contract was made, 281-182.

[16] Van Royen (1996: 114) collected all freight contracts in the period 1700-1710 but found only very few for these routes.

especially on certain trade routes and the timber trade to Norway can serve here as an example. Trade was usually in the hands of the ship-owners and only a relatively small part of the ships was chartered (Boon 1996: 58; Hart 1997: 121; Lesger 2001: 63). On the other hand, at most a third or a quarter of the ships sailing to the White Sea is thought to have been laden with goods owned by the shipping companies while the rest of them, the majority, was chartered (Hart 1973: 105, Footnote 8). The selection of freighters appearing in the contracts needs some qualification too. Foreign charterers appear relatively often as they are less likely to own (parts of) ships they can use. The mass of Dutchmen owning ships or parts of them felt less need to sign a contract and notarize it. Fortunately, all these objections against the chartering contracts are not relevant for our purpose. We are interested in transport prices and we can assume that the price agreed upon accurately reflects market conditions on the moment the contract was concluded.

Another concern in this respect is the presence of (sometimes hugely) varying price differences within one single year. This could be the result of special circumstances, as the beginning or end of a war, which tended to reduce or drive up freight rates. At the end of the shipping season, in autumn, prices tended to go up to account for the bigger risks of having to deal with bad weather. Moreover, it is undisputed that shipmasters enjoying a good reputation were able to negotiate better rates than others (Van Tielhof 2002: 212). As it is our main objective to trace the long term development of the efficiency of Dutch shipping, we would like to have prices reflecting the average price paid in a particular year, and prevent that prices resulting from specific personal, climatic or political circumstances gain too much weight. We therefore choose to concentrate mostly on trade routes for which many contracts are available to reassure that the rule of large numbers applies. The availability of rates, largely thanks to previous work of different scholars, therefore became an important condition for the selection of the routes.

The largest number of freight rates at our disposal apply to shipping from Amsterdam to Archangel. Hart published freight rates based on 631 prices for return voyages in the period 1594-1645, which is an average of more than 12 per year (Hart 1973: 8, 11-12). For the second half of the 17th century he was not able to find as many prices, only 148, which is less than 3 per year. This series could be continued thanks to a publication by Van Royen of Dutch freight rates on all the important trade routes in the period 1700 – 1710 (Van Royen 1996: 124). His yearly averages for shipping to Archangel are based on 395 separate prices, or an impressive 36 per year. For the present article we have collected 618 chartering contracts in the Amsterdam notarial records for return voyages to Archangel in the period 1714-1794, which is almost 8 prices per year. In total, 1792 freight rates.

The Baltic trade is also well documented, as can be expected in view of the importance it always had in the Dutch trading network. Despite the phenomenon of contracts which were not notarized, especially in the 18th century, and the entanglement of shipping and trade reducing the number of ships actually chartered, our series are based on more than 500 separate prices. Van Tielhof published freight rates for single voyages from Reval (Tallinn) to Amsterdam (1513, 1514, 1516, 1530, 1547); 45 prices for single voyages from Gdansk to Holland (1578-1595) and a series for return voyages from the Dutch Republic to Gdansk and nearby ports based on 482 individual prices (1591-1758) (Van Tielhof 2002: 198, 203, 340-345). We collected another 16 prices in the Amsterdam notarial records for the period after 1758, and took freight rates for return voyages to Gdansk or Königsberg in 1753 and 1759 from an article by ’t Hart and Van Royen (1984: 100).

A third trade route which is sufficiently documented is shipping to Bordeaux. Israel published series of freight rates for several trade routes in the first half of the 17th century, among which figure 34 prices for transporting wine from Bordeaux to Amsterdam (1594-1643) (Israel 1989: 90, 135). For the 18th century we were able to make use of the data generously given to us by Anne Wegener Sleeswijk. She collected freight rates for transport from Bordeaux or Libourne - also in Guynenne - to Amsterdam or Rotterdam in 1698-1793, and calculated yearly averages based on 361 individual prices (discussed in Wegener Sleeswijk 2006). Unfortunately a gap is left between the two series, spanning the second half of the 17th century.

In order to include shipping to the Mediterranean in our survey we fell back on the transport prices Hart presented in his study on the Archangel trade, as he also considered shipping from Amsterdam via the White Sea to Italy. There were never many ships involved in this multilateral trade, but it was a constant part of Dutch shipping in the 17th and 18th century. We used his 40 prices for the destination Livorno in the period 1601-1699 (on this route the freight rates usually did not involve the voyage back to Amsterdam) (Hart 1973: 17-18), and collected an additional 19 freight rates in the Amsterdam notarial records for 1712-1790. For the first decade of the 18th century rates were again provided by Van Royen who based his averages on 36 prices. The data on this route are few, but they cover a relatively large part of the trade on this route.

In all, more than 2800 prices, and although this number covers only a small part of all the voyages undertaken by Dutch ships in the period under study, it should be sufficient to overrule all kinds of particularities and give a trustworthy picture of the development of transport prices on Dutch ships.

Practically all of these prices come from chartering contracts in archives of notaries based in Amsterdam. As a consequence our data are scarce before circa 1590, when there is a lack of notarial archives. Another problematic period is the second half of the 18th century. After the middle of the century the number of notarial contracts for voyages to the Baltic and the Atlantic coast of France diminished. As Wegener Sleeswijk has suggested there is reason to think that in this period the need to notarize the contracts was felt less than before. Freight contracts were thus still made, but more often by private contract (Wegener Sleeswijk 2006: appendix VII). To supplement the data from the notarial registers, the Amsterdam price currant is useless because it unfortunately did not mention freight rates. To a limited extent, especially for the 16th century, we were able to collect freight rates from mercantile account books, but it is surprising how few private archives of Dutch merchants have remained. Only a very limited number of the thousands of prices have been taken from mercantile account books.[17]

A final consideration about the freight contracts as a source concerns their homogenous character. Almost all of the prices were expressed in guilders per last.[18] These lasts were often specified as rye lasts, which is explained by the dominance of grain on these trade routes. When no

[17] The prices for the first half of the 16th century are from the account books of a Reval merchant, but refer to the freight for Dutch ships. Prices for 1578-1595 are from the private archives of a Delft merchant.

[18] In the first half of the 18th century the prices for shipping to Livorno via Archangel were expressed in ducats, which have been converted into guilders (1 ducat = 3 guilders).

specification was added, we have interpreted lasts as rye lasts. In some contracts there were only prices for other commodities. We then used the prices for wheat or barley, and if they also lacked, the price for linseed of hemp. These were not much different from the rye last, as is apparent in those cases were the same tariff is explicitly mentioned for all grains, or cases where transport of wheat costs one guilder per last more and barley one guilder less than transport of rye (Hart 1973: 9). Prices per last of tar and timber were always neglected as the tar and timber last differ too much from the rye last. In the 18th century an official ship's last came into use in Holland, specifically meant to indicate the carrying capacity of ships irrespective of the goods loaded. These ship's lasts were considerably bigger than, for example, rye lasts or timber lasts. Probably the ship's lasts were expressed in specific gravity of water (Wegener Sleeswijk 2003: 89). These ship's lasts were used in the collection of certain duties in the port of Amsterdam in the 18th century and in other circumstances, but charterers and shipping companies did not change their habit of expressing transport prices per last of rye. Prices for shipping between Guyenne and the Dutch Republic were always expressed per ton of wine. To facilitate the comparison with other routes, we have converted them to rye last by equalling 1 rye last to 2 tons of wine. Our nominal prices thus all give prices per rye last.

We have neglected the particular conditions and arrangements made in the contracts, such as the maximum of lay-days, the right for the crew to take some goods with them at no charge ('*voering*', '*Kinderführung*') and the hat-money or special reward for the shipmaster personally ('*kaplaken*').[19] Often the value of these extra remunerations was not known or it was impossible to convert them to prices per last. In any case, their relevance to the transport costs in general was limited, and there was no tendency for them to diminish or grow larger in the long run.[20]

Prices used for deflating the freight rates:

Wages: wages on unskilled labourers from De Vries and Van der Woude (1997)

Victuals: index of the cost of living from Van Zanden (2005)

Iron and Copper: Posthumus (1943/64) (17th and 18th century: Amsterdam exchange; 15th and 16th century: Utrecht and Leiden institutions), De Moor (2000), and for the period 1585-1620 De Jong (2005); a few gaps remained, which were filled by simple intrapolation.

Timber: same sources as iron and copper prices: Posthumus (1964): series 216, 268, 316, 317, 318, 328, Middelhoven (1978), and De Moor (2000); we thank Christiaan van Bochove for making these data available to us; we also had to intrapolate gaps in this series.

[19] Only in the case of the freight rates to Bordeaux in the 18th century the hat-money was added to the freight price as far as possible. Wegener Sleeswijk 2006: Appendix VII.

[20] This is the impression conveyed by the contracts for rye shipments from Gdansk to Amsterdam and it was also remarked by Knoppers in relation to the hat-money for voyages to Archangel (Knoppers 1976: 45, Footnote 107).

Zuijderduijn (2007) (period 1450-1560) en from the development of interest rates on public debt by Fritschy (2004).

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