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THE QUIET TRANSPORT REVOLUTION: RETURNS TO SCALE, SCOPE AND NETWORK DENSITY IN NORWAY'S NINETEENTH-CENTURY SAILING FLEET

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THE QUIET TRANSPORT REVOLUTION: RETURNS TO SCALE, SCOPE AND NETWORK DENSITY IN NORWAY'S NINETEENTH-CENTURY SAILING FLEET

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Abstract

Interpreting the role of expanding transport in overall production growth in the nineteenth century is still hampered by our lack of understanding of how much and when ocean shipping costs began to fall. This paper exploits new output and freight rate data for one of the world's largest merchant fleets, the Norwegian, 1830–66. We argue that the price of an average shipped ton-mile was subject to three sources of returns to scale. We test for the impact of a changing composition of produced output (the 'composition effect') to account for economies of scope and offer an alternative index for the price of the average ton-mile that shows a strongly falling trend for the entire period. We then turn to the effect that increasing maturity of new routes had on prices, thus analysing returns to an increased network density finding strong evidence for their existence. Finally, we investigate the importance of internal scale economies in firm and ship size based on a cost survey conducted in 1867–70.

JEL classification: N70, F02, R40

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I

Long-distance transport has always played a prominent role within interpretations of nineteenth-century international economic history. The reason for this is obvious: at the heart of the transition of a limited number of successful countries to modern growth was their integration amongst themselves and with a much wider group of regions across the globe. The nineteenth century saw fast growth rates in aggregate output, but rates of growth in trade outpaced those by far, leading Kuznets to argue that the rate of exports and imports to total output might have risen from about 3 percent to 33 percent in the century preceding World War I.[1] Thus, the relevance of long-distance transport in the nineteenth century – including that of shipping – is beyond any doubt.

Nevertheless, our understanding of the costs of production in nineteenth-century shipping is at best rudimentary.[2] Undoubtedly ocean shipping costs fell at some point in the nineteenth century. But there is no consensus as to when, how fast and why they decreased. This is largely because freight rates have proved elusive and because the links between output and costs have been ignored. The scarcity of ex-post observed freight rates has led economic historians to adopt one of two strategies. They have either used a small number of routes for which published freight rates were available and then tried to construct a representative index on that basis, or they have used commodity price differentials between regions to estimate the price wedge between geographically distant markets and interpreted that price wedge more broadly as transaction costs or more narrowly as transport costs.

Most papers that have used published freight rates are based on the famous Isserlis index for British freight rates, which in turn had been extracted from data published in Lloyd's Fairplay lists compiled by the Angiers.[3] These data have been subject to a number of criticisms, some more important than others.[4] We would like to stress here the three that seem most fundamental to us. Firstly,

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[1] Kuznets, 'Quantitative aspects', 70–71.

[2] A large scale utilisation of the unique statistical heritage of maritime history came with the involvement of demographers and economic historians in the field. North's 1958 article on freight rates was paradigmatic in this development. For overview articles on the recent evolution of maritime history, see for instance Williams, 'Progress' and Broeze, 'At Sea and Ashore'.

[3] Angier, *Fifty Years Freights, 1869–1919*, Angier, 'Angier's Steam Shipping Report', Isserlis, 'Tramp Shipping Cargoes and Freights'.

[4] Armstrong, 'Freight Rates Revisited', Fischer, Sahay, and Végh, 'Modern Hyper- and High Inflations', Kaukiainen, 'Gross Freight and Profitability', Klovland, 'Business Cycles', Yasuba, 'Freight Rates'.

the Angier/Isserlis data do not reflect ex-post paid freight rates (i.e. the price actually paid for the service) but ex-ante published rates and we can only assume that ship owners and those wishing to dispatch goods used them as guide prices. Secondly, they reflect freight rates for two very different production technologies, steam and sail. The data do not distinguish the two and thus pose important problems when interpreting the cost structure in shipping and the reasons for trends in freight rates. Thirdly, in order to compile an index based on these rates (or similar other data) the researcher has to choose a number of routes and make sweeping assumptions about what constitutes a representative composition of the output of shipping over the nineteenth century.

The outcome of this last issue, the composition problem, is easily illustrated when comparing the two best known indices of nineteenth-century shipping costs, namely those presented by North and Harley. Harley showed convincingly that North's index was driven by its composition, which gave a lot of weight to North American cotton routes. The unusual economies that were realised by introducing a new packaging technology in cotton meant that North's index reflected advances in packaging technology rather than falling costs in shipping itself. Yet, as we will show below, Harley's index, probably the most widely accepted one at present, is subject to similar limitations and the same is true for that provided Shah Mohammed/Williamson.[5] Both represent notable improvements on the original Isserlis index. But neither can remedy the 'composition problem' because of a serious shortage in the British sources. The absence of data related to the actual output of shipping, i.e. the tonnage transported over time on different routes, means that (*a*) researchers have to make an informed guess which routes are representative in order to avoid extreme selection bias with regard to the weights attached to routes and (*b*) changes to the portfolio of routes over time cannot be taken into account when average shipping costs are estimated.

Dissatisfaction with the use the ex-post published freight rates and problematic weighting, the composition problem, have led Persson and Jacks to approach the problem via commodity price differentials rather than direct measurement of freight rates.[6] This produces some interesting results regarding the potential for market integration since it reflects the total amount of transaction costs more directly. However, without knowledge about freight rates, arguably the largest share of those transaction costs, it is very difficult to understand what drove trends in the price wedge between geographically distant regions. In addi-

[5] North, 'Ocean Freight Rates', Harley, 'Ocean Freight Rates' and Shah Mohammed and Williamson, 'Freight Rates'.

[6] Persson, 'Mind the Gap' and Jacks, 'Intra- and international commodity market integration'.

tion, in most cases the quality of commodity price data means that a price series for pairs of data has to be estimated increasing the likelihood of spurious results.

As a consequence we have at present a host of possible interpretations of how the cost of ocean shipping developed in the nineteenth century. North argued the cost of shipping fell over the entire period 1740 to World War I, but particularly strongly 1815–51 and 1870–73. Harley and Klovland argue that freights fell slowly before the 1860s and only after that date rates began to fall strongly. Shah/Williamson confirm a sharp fall for 1869 to 1913. Persson argued that prices only fell after 1875 and his index decreases much more slowly than some of the others. Finally, Jacks suggests that shipping costs fell throughout the nineteenth century.[7] A similarly diverse picture emerges when looking at the driving forces of the fall. North suggested that institutional improvements and especially safety of shipping explained the fall; Harley and Shah/Williamson saw the technological shift to steam engines and metal hulls as the main source. Jacks has recently taken up the institutional explanation again and complemented it by a number of geographical factors. Persson thought that information transfer technology, the telegraph, rather than shipping improvements, brought down transactions costs, but recently Kaukiainen has shown that information flow improvements preceded the use of the telegraph.[8]

The limited information available on both the timing for and the reasons behind the nineteenth-century fall in transport costs has also made it very hard to understand the larger question of how such a fall was related to the growth of the wider economy. In particular, it seems difficult to answer the question if the process was driven by supply or demand factors. Those authors who favour technology-driven stories naturally seem to imply that a supply 'shock' following the introduction of metal hulls, steam engines and/or the telegraph in turn caused a substantial upturn in world trade.[9] Causality is thus largely derived from the timing of the fall in prices. This is broadly the view adopted by O'Rourke and Williamson (1999) who rely strongly on, and some would argue even overstretch, Harley's index.[10] Since data on the overall volume of produced shipping are scarce it is argued that the volume of trade took off *after* transport costs fell. Those authors who see a more continuous process of expansion of transport volume throughout the nineteenth century tend to argue that

[7] Jacks, 'Intra- and international commodity market integration', p. 399.

[8] Kaukiainen, 'Shrinking the world'.

[9] This view is also supported by some maritime historians. Marriner and Davies argue that technological change furthered productivity gains, which again drove freight rates down. Marriner, 'Recent publications', p. 94.

[10] This point is made by Persson, 'Mind the Gap'.

demand for transport services was a crucial factor in driving down prices. This is argued by Jacks for long distance transaction costs in general and more specifically by Kaukiainen for information costs.[11]

In this paper, we choose a new path to the question of the dynamics of nineteenth-century long-distance transport. We use a database on Norwegian freight rates and produced volumes, which include a full set of annual output data for 1830–65 and freight rates for 1864–66.[12] The observed output expansion, we argue, makes the hypothesis of stable prices until the 1860s very questionable. A proper assessment of the composition problem, i.e. the changing portfolio of routes within total shipping output, illustrates the limitations of the existing partial indices further. We show that a ton-mile of shipping output on different routes was not a perfectly homogeneous good because of the presence of scale economies in shipping. The price of a ton-mile on various routes was therefore different as well. Using 1864/65 freight rates for relative prices we construct an index of the price of shipping output weighted by the ex-post observed output on different routes between 1830 and 1865, which shows that if the composition problem is accounted for, then a substantial fall in the price of the average produced ton-mile can be noted. We then use a cross-section analysis of the complete set of freight rates for all Norwegian routes in 1864–66 to investigate possible sources of changing transport costs. As it turns out the cross-section analysis offers important insights into the time-series behaviour of freights. Our arguments are underpinned further by a contemporary survey of 234 Norwegian *rederier*, shipping companies, in 1867–70.[13] Finally, the conclusions examine some of the implications of our findings and outline areas for future research.

[11] Kaukiainen, 'Shrinking the World'.

[12] For a discussion of the source and methodology see Brautaset and Grafe, 'A long distance affair' and Appendix 1 for a description of these data.

[13] Kiær, *Statistiske Oplysninger*.

II

Our point of departure in this paper is a very extensive data-set on Norwegian shipping in the nineteenth century from the Norwegian *Norges Handel/ Statistiske Tabeller* that allows us to assess the produced volume of shipping from 1830 to 1865. To the best of our knowledge the Netherlands is the only other case where similar calculations have been tried.[14] They enable us to adopt the standard measure of transport economics, namely tonnage transported per distance, or *ton-mile.*[15] The data reflect all Norwegian ships operating in international trade 1830–65 grouped into categories depending on the type of journey, i.e. whether they travelled from/to Norwegian ports (domestic outbound/ domestic inbound) or simply between ports of third countries (third country outbound/third country inbound). Overall our output data represent around 600,000 journeys of Norwegian vessels between 1830 and 1865. All of these were undertaken by sailing vessels with wooden bottoms, i.e. they only represent one technology.[16] Appendix 1 discusses some of the more detailed issues of the output calculations.

By the 1870s, after several decades of strong growth both in absolute terms and relative to other nations' merchant fleets, Norway had the third largest shipping fleet in the world.[17] In addition, most authors agree that shipping was

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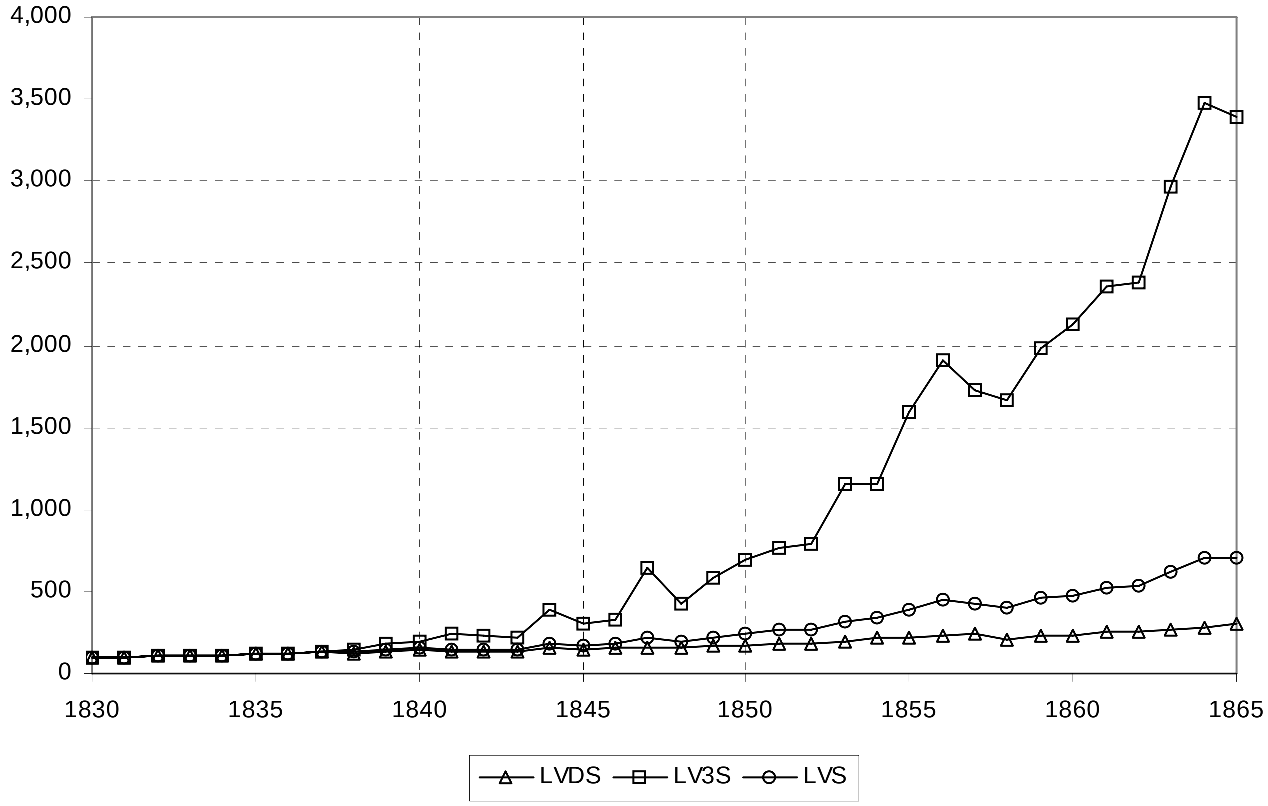
[14] The Dutch series are part of the Reconstruction National Accounts of the Netherlands project. Maritime shipping made up 3.3 percent of Dutch GNP in 1850 and 1.9 percent in 1913. Jan-Pieter Smits, *Dutch GNP and its components, 1800–1913*, table 4.5, p. 50. Most of the data for international shipping services draws upon earlier work by Horlings, for further details see Horlings, *The economic development*, pp. 382–405. The statistics offer new and vital insight into Dutch shipping. However, some of the series are results of bold assumptions. For instance, when estimating distance figures in order to find the output of shipping services, third-country shipping is first assumed to have developed symmetrically to domestically based shipping before the output series are 'smoothened' through applying moving 3-years averages.

[15] Ton and miles refer to net register ton (NRT) and nautical miles respectively. A net register ton equals gross register ton excluding the volume of non-cargo spaces.

[16] Norway's relatively late transition from sail to steam is well documented. Nevertheless, the fleet was technologically representative for the international freight market from 1830 to the late 1860s. Sail edged out steam in all major maritime nations prior to the opening of the Suez Canal in 1869 and the technological transformation by the triple expansion motor in the 1880s. For instance, the fleet of the world's cardinal at sea, the UK, consisted of only 9.7 per cent steam tonnage in 1860 while the corresponding figure was 16.6 percent in 1869. Ville, *Transport*, pp. 47ff.

[17] In 1840 Norway's fleet was already one of Europe's largest but in terms of registered tonnage it was still behind the French and the combined German merchant fleets, and only about 7.5 percent of the size of the British fleet. By 1880 it was the second largest fleet in Europe and almost one quarter the size of the British merchant fleet. See Ibid., pp. 68–71.

Figure 1 Output of shipping, ton-miles 1830–1865 (1830 = 100)



Note: LVDS: Laspeyre's volume index domestic based shipping
LV3S: Laspeyre's volume index 3rd country shipping
LVS: Laspeyre's volume index shipping, overall

a very competitive industry; so we think our results can tell us something about the trends in shipping in the nineteenth century in general.[18] The size of the Norwegian fleet both in terms of number of ships and tonnage increased rapidly at about 5 percent per annum in this period.[19] The expansion in transport output

[18] Norwegian ships were especially concentrated on the tramp shipping of bulk goods. For an in-depth, though national-romantic view on Norwegian shipping see the six volumes commissioned and produced between 1923 and 1951; Worm-Müller, *Norske sjøfarts*. A number of more contemporary studies are available. For the earlier part of the century, see in particular Kristiansen, *Penge og Kapital Næringsveie*, pp. 258–321 as well as Schweigaard, *Norges Statistik*, Tvethe, *Norges Statistik*. For the period after 1850, see; Kiær, *Bidrag*, Kiær, 'Historical Sketch', Kiær, *International skibsfartssstatistik*, Kiær, ed., *Statistique internationale*. Publications by Fischer and Nordvik in the late 1980s and early 1990s are regarded as the standard works on Norwegian shipping 1850–1914, and have gained wide international recognition. See Fischer, Sahay, and Végh, Nordvik, 'Shipping Industries'. Especially two PhD theses deserve mentioning**:** Gjølberg, 'Økonomi, teknologi og historie' and Johnsen, *Rederisstrategi i endringstid*. Moreover, Jan Tore Klovland has recently published a paper offering new estimates and new findings by linking primary cycles and the development in freight rates and commodity prices, Klovland, Business Cycles'.

[19] Brautaset and Grafe, 'A long distance affair'.

produced was similarly astonishing. Figure 1 opposite shows a volume index for domestic and third country shipping. Both expanded strongly but clearly the largest increase was driven by Norwegians selling shipping services abroad. This reinforces our view that Norwegian data are representative for the international shipping market in general.

The process of expansion of transport volume as measured in ton-miles produced by sailing ships seems to have proceeded exponentially at a fairly constant rate after an initial take off at some point in the late 1830s, i.e. once Norway had got through a re-adjustment crisis provoked by the violent changes in demand during and after the Napoleonic Wars. This remarkable expansion was achieved by a fleet of wooden bottom sailing vessels that experienced no major technological metamorphosis, but only very incremental technological progress.[20] This is underlined by the fact that the expansion of the fleet derived from two sources; new-built and second hand vessels. Though there were traditionally strong links between the shipbuilding industry and the shipping industry, by the mid-nineteenth century new-built ships could no longer meet the demand for tonnage – and 1861 was the first year in which second-hand tonnage purchased from abroad outpaced new built vessels. This was a development supported by governmental policies as the Parliament in 1857 had decided to abolish the 20 percent import duty on vessels bought from abroad.[21]

The expansion of output poses an important question regarding the current standard accounts of the price of shipping in the nineteenth century. Is it plausible to assume that freight rates changed little until the 1860s or thereabouts, as Harley had argued, if the volume multiplication was a continuous process throughout the late 1830s to mid-1860s? It seems counterintuitive that an increase in produced volume by a factor of seven or eight within 35 years would not have affected prices per ton-mile in a more substantial way or, in other words, that prices were so inelastic with regard to volumes. The building of sailing vessels (the only technology represented in these data) was a mature tech-

[20] Estimating the productivity increases in sail shipping has been practically impossible. Clearly, improved port facilities, steam tugs introduced in the 1840s in the most advanced river ports and more year round shipping had improved productivity by the mid-nineteenth century compared to the early eighteenth century. Port technology contributed probably more than shipping itself. But neither the timing of those increases nor their size is clear. Ville estimates productivity increases in English coal shipping, probably the most competitive in the world, as between 0.11 and 0.44 percent per annum between 1700 and 1850. Harley argued that TFP in sail shipping increased for the first half of the nineteenth century at 0.63 percent per annum but his calculations assume very high capital costs, which we consider doubtful when compared to contemporary information reported in our table 4 below. Ville, 'Total Factor Productivity', Harley, 'Ocean Freight Rates'.

[21] Brautaset, 'Norsk Eksport', p. 127.

nology and it is hard to imagine bottlenecks in the provision of ships that would have been large enough so that mass production of transport on this scale would not have driven down unit costs per produced ton-mile. Yet, for the period 1830–65 Harley's simple index consisting of Newcastle coal, British North American timber and Baltic shipping would imply an average annual decrease of barely 0.44 percent in freights.[22]

One way of approaching this apparent contradiction is to think about how 'mass production' of transport could have affected freight rates. There are three main reasons why one could expect a change in the average price of a produced ton-mile of shipping as the total output increased strongly. The first one is the 'composition effect' that was already mentioned above. The cost of a produced ton-mile of shipping is not homogeneous across all routes. This is the reason why every given index based on a particular 'representative' set of British freight rates has produced different results. Harley (1988) shows no trend in British freight to the Baltic 1820–1860 but a mildly falling trend for shipping to North America and the Tyne. Thus weighting the index makes all the difference. Since a large expansion in output most likely produces shifts in composition this would have an impact on the overall trend of the price of the average produced ton-mile. The second effect is what could be called the 'maturity effect'. During the nineteenth century Norwegian ship owners decided to boldly go where none of them had gone before. As these new routes became more established we would expect the price per produced unit to fall. The third reason is simple internal scale economies. Expanding volumes could have led to increased size of the shipping companies (*rederier*) probably allowing them cheaper access to capital and other scale benefits. Increased transport output could also have encouraged ship owners to invest in larger vessels with lower manning ratios thus reducing the variable costs.

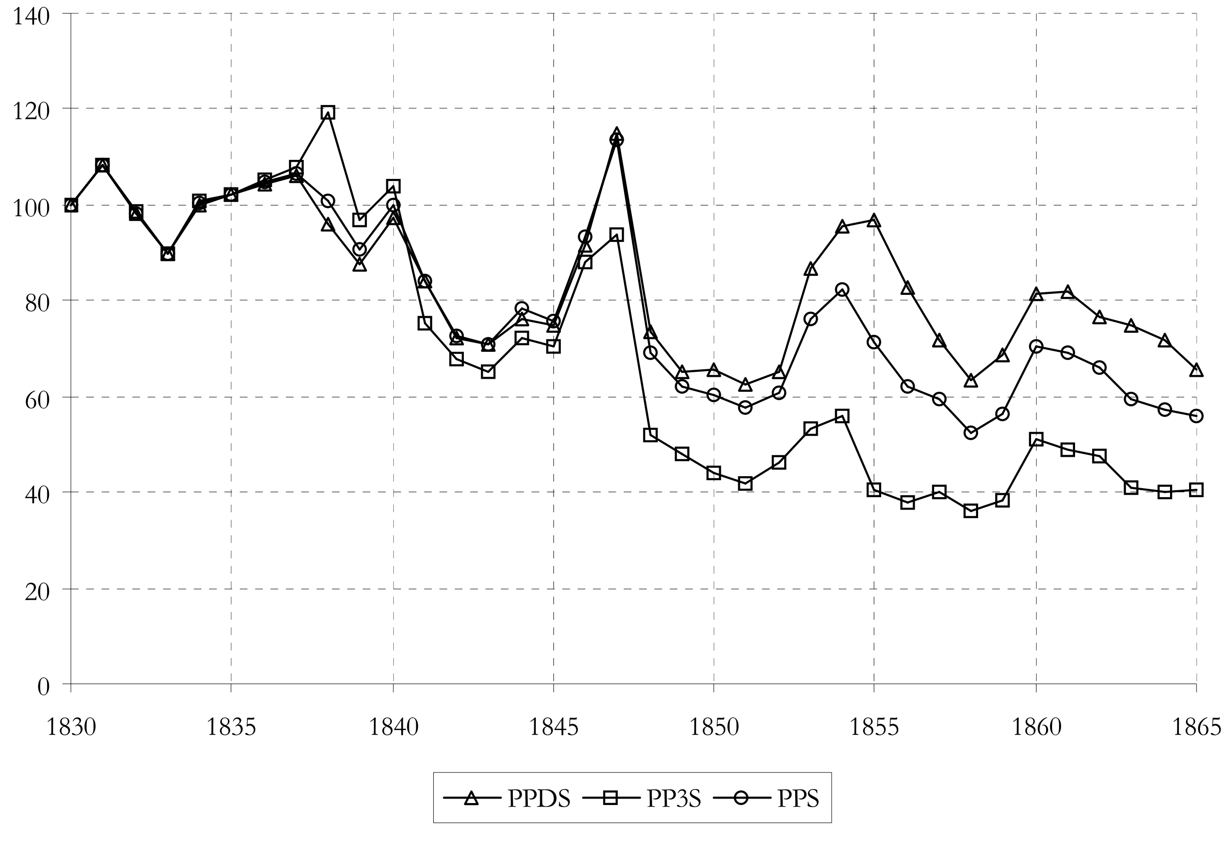
The composition effect

Thanks to the availability of complete data on produced volumes we can avoid the selection bias contained in previous freight rate indices altogether and illustrate the magnitude of the composition effect clearly using the cross-section data for freight rates in 1864/65. It should be noted that these data reflect real ex-post rates collected from Norwegian correspondents around the world and are there-

[22] This calculation is based, like Harley's, on an equally weighted index of the three routes using data from his Appendix, see Harley, 'Ocean Freight Rates'.

fore more accurate than the ex-ante rates used elsewhere.[23] We then back extrapolate the freight rates using Harley's index for Baltic grain, which was based on sailing vessels as well. We agree with most authors that this is the best available partial index. The Baltic grain trade was probably the single most established trade long before the nineteenth century. Therefore it is reasonable to assume that it was not subject to any economies derived from what we call the maturity effect. Also it is unlikely that ship sizes or the size of companies in this trade varied greatly in the mid-nineteenth century. Not surprisingly Harley's partial index for this route shows no trend at all for the period 1830–65. By holding the relative freight rates for each route at 1864/65 constant and back extrapolating them with an index that has no trend this experiment allows us to see what impact changes in composition would have had on the average price of a produced ton-mile of shipping.

Figure 2 Average price of produced ton-miles of shipping 1830–1865 (1830 = 100)



Note: PPDS: Paasche price index domestic-based shipping
PP3S: Paasche price index 3rd country shipping
PPS: Paasche price index shipping, overall

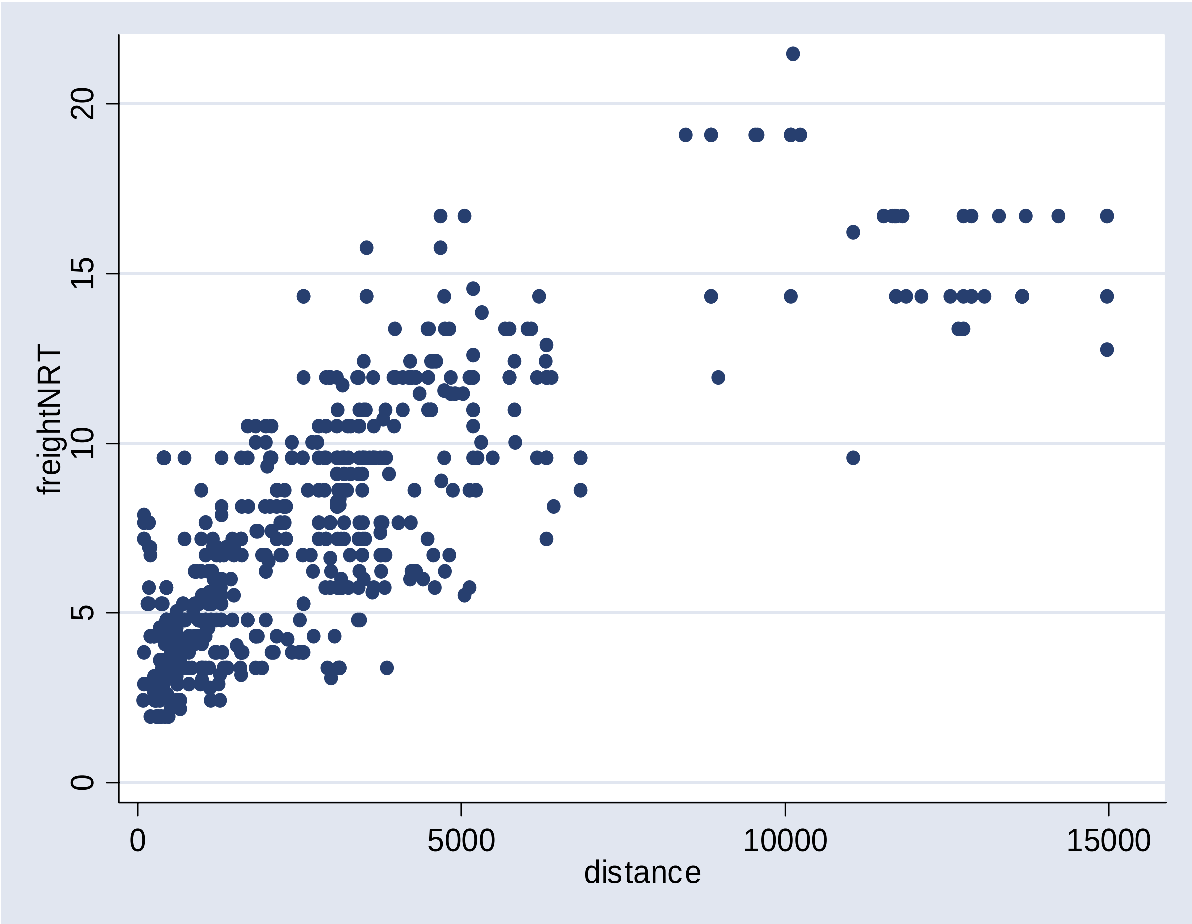
[23] The authors discovered these rates which Anders Kiær, the first director of Statistics Norway, had annotated by hand in his copy of the annual shipping statistics.

The overriding trend is clear beyond any doubt: the price of the average ton-mile of produced output would have been falling by more than 40 percent simply as a consequence of changing composition of output. The composition effect was big and it was bigger in third country shipping (which expanded faster) than in domestically based shipping. This result illustrates powerfully why we think partial indices based on 'representative routes' are likely to be misleading. Our overall index of the price of an average ton-mile falls by about 1.5 percent per annum, that for third country shipping by about 2.5 percent. This implies rates of decrease that are three to five times larger than those suggested by Harley's composite index of Baltic, Tyne and North American timber. Again it needs to be stressed that this exercise does not include price falls caused by rates of specific routes decreasing but only the impact of changing composition on average prices. In other words, the output mix changed over time and with it the average price of a unit of output. Our index thus primarily measures the increase in competitive pressure in world trade. Increasing volumes were indeed impacting on average prices through changed composition. Prices were driven down in a steady process over these decades, which we argued was a more plausible assumption.

But what were the driving forces behind this composition effect, what explains the fact that shipping as measured in ton-miles was not a perfectly homogenous good? The analysis of the extended set of cross section freight rates for 1864–66 offers some further answers to the question of how increased distance helped driving freight rates down.[24] A ton-mile shipped on one route could be different from a ton-mile on another largely because shipping (like most transport systems) is subject to external scale economies in the form of *economies of scope of the network.* The average price of production of a ton-mile of shipping fell with increasing distances because longer trips meant lower ratios of port times to sail times. Capital assets (i.e. the ships) were thus more effectively utilised driving down the fixed costs per ton-mile. This effect becomes obvious when looking at freight rates per distance plotted below in Figure 3, which illustrates the cheaper rates per ton-mile as journeys get longer.

[24] See Appendix 1 for the construction of the series.

Figure 3 Freight rates 1864–66 for routes of different distances (Speciedollar/NRT and nautical mile)



Regression 1 below illustrates this result further. Since the relationship between freight rates and distance is clearly non-linear we use a log-log form to investigate the strength of the relationship.[25]

(1) $\ln Freight = \alpha + \beta_1 * \ln Distance + \beta_2 * year64D + \beta_3 * year66D + \beta_4 * DomIn + \beta_5 * DomOut + \varepsilon$

Freight is the dependent variable; distance and a set of dummies are the independent ones. We use dummies (year64D and year66D with 1865 as reference) to control for the fact that three years of data are included in the estimation. Furthermore, we control for differences that might derive from the fact that there are freight rates for three different 'types' of journeys in our sample,

[25] Interestingly Limao and Venables found a linear relationship between transport costs and distance in a set of shipping data from the late twentieth century. This suggests that either the importance of fixed costs to variable costs has changed systematically or, more likely, that the authors had simply too few cases of shorter routes to detect the non-linear shape of the freight schedule. Limao and Venables, 'Infrastructure'.

namely domestic inbound (DomIn) and outbound journeys (DomOut) and third country journeys. Here third country journeys are the reference category.

The elasticity of freights with regard to distance is about 0.38 and highly significant confirming the fact that increasing distance lowers the cost of the average ton-mile produced. The R^2 is remarkably high at 0.60. The control dummy for 1864 is insignificant, but that for 1866 is highly significant. The coefficient suggests that rates were about 19 percent lower in 1866 compared to 1865 (and 1864) reflecting probably a combination of a real fall in freights and the slightly different structure of the 1866 sample mentioned above.[26] Of the dummies denoting the type of journey, only the one for domestic inbound journeys (DomIn) is significantly different from third country shipping, that for domestic outbound is statistically insignificant. This seems to indicate a systematic difference of domestic inbound freights from the reference category third country shipping.[27]

The negative coefficient for inbound freights sheds some interesting light on Norwegian shipping in this period. As shown above third country shipping expanded much faster than domestically based shipping. Norway's fleet was probably the first that systematically used the advantages of shifting from bilateral to multilateral shipping.[28] As Norwegian vessels benefited from increasing economies of scope, they also became less dependent on domestic exports. At the same time, even Norwegian ships returned to their home ports at times for some of the maintenance. However, as they earned their money in third country journeys ship-owners had to accept discounts in order to find homeward cargoes. The negative sign on the parameter for journeys from abroad to return to Norway would suggest that they cross-subsidised home journeys. This means that the composition effect illustrated here was even larger, given that (relatively cheaper) domestic inbound journeys increased at a slower rate than (relatively more expensive) third country journeys.

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[26] Unfortunately we currently know too little about business cycles in the period, therefore we cannot say if this was a downturn specific to shipping or a symptom of general economic conditions.

[27] The fact that we do not observe any systematic difference between domestic outbound and third country trade also suggests that our choice of British ports as hub for third country shipping in 1864/65 has not biased the results in any serious way.

[28] Norwegian vessels stepped up their involvement in trade in the Baltic as well as transport of Swedish timber in the early 1830s. After Norway entered into a personal union with Sweden in 1814, Sweden-Norway was regarded as one country by important trading partners from the 1820s onwards. Thus, Norwegian vessels were free to transport Swedish goods without being restricted by protectionist measures such as the Navigation Act.

Table 1. Price of shipping a NRT on different routes 1864–66 (dependent variable: ln freight)

Variable	***1***	***2***	***3***	***4***	***5***	***6***
lndistance	0.3830***	0.3747***	0.3309***	0.3184***	0.4585***	0.2997***
	(21.71)	(20.84)	(15.56)	(9.12)	(10.76)	(10.91)
Year64D	0.0353	0.0325	0.0379	0.0423		0.0441
	(0.89)	(0.83)	(0.91)	(1.15)		(1.19)
Year66D	–0.1880***	–0.1910***	–0.1911***	–0.1742***		–0.1807***
	(–5.51)	(–5.47)	(–5.18)	(–5.38)		(–5.21)
DomIn	–0.1008*	–0.1196**	–0.1030**	–0.1161**		–0.1037**
	(–1.91)	(–2.21)	(–2.21)	(–2.04)		(–2.15)
DomOut	0.0381	–0.0198	0.0422	0.0367		0.0433
	(1.00)	(–0.50)	(0.97)	(1.05)		(0.95)
LnRouteVol		0.0069				
		(0.86)				
LnVolume38			–0.0362***			
			(–2.64)			
European				0.1788***		0.1315***
Atlantic				(3.96)		(2.83)
America North				0.1120		0.1058*
Atlantic				(1.59)		(1.71)
Mediterranean				0.2158***		0.1748***
				(3.92)		(3.41)
South Atlantic				0.2973***		0.2930***
				(4.03)		(4.10)
Pacific/Indian				0.3720***		0.3473***
Ocean				(3.86)		(3.79)
LnShipSize						0.0309
						(1.22)
Coal					–0.3332***	
					(–4.05)	
Grain					0.0844	
					(1.61)	
Piece goods					–0.2179***	
					(–2.38)	
Constant	–0.8918***	–0.8749***	–0.1562	–0.5700***	–1.5049***	–0.5522***
	(–5.93)	(–5.47)	(–0.58)	(–2.36)	(–4.74)	(–2.92)
Sample size	578	537	533	578	112	534
R2	0.61	0.60	0.53	0.64	0.77	0.62

* significant at 10 percent level ** significant at 5 percent level, *** significant at 1 percent level

Note: in specification 1,2,4,5 robust standard errors were used to adjust for heteroscedasticity. Specification 4 contains only 1866 values. Dummies are 1 = affirmative, 0 = not affirmative; reference category for coal, grain and piece goods is timber; reference category for year 64 and 66 is 1865; reference category for macro regions is Baltic.

The cross-section analysis shows strong evidence for the presence of economies of scope of the network in Norwegian shipping in the nineteenth century. We also found a notable composition effect when weighting 1864/65 freight rates with the actual produced volumes in 1830–65. The cost of an average ton-mile of shipping would have fallen by as much as 40 percent simply because the composition in the produced output changed in terms of the contribution of different routes. A trend towards an increasing average length of trip from about 1,000 nautical miles to 1,300 nautical miles over-compensated by far one that saw the share of total output constituted by relatively cheaper domestic inbound journeys fall.[29] Our experiment in Figure 2 deliberately excluded the possibilities of other potential sources of changing average costs such as the maturity effect or internal scale economies in shipping production. It represents the lower bound estimate of a change in the cost of the average ton-mile of shipping produced by the Norwegian fleet clearly contradicting those partial indices that suggest no fall in costs occurred before the introduction of new technology in shipping.

The maturity effect

The second reason why changes to average costs in shipping could have occurred is related to possible (external) scale *economies originating from the density of network use*. The intuition of this effect is a simple one. As a new shipping route becomes more established and more ships per year frequent these ports, ship owners will find it easier to get return or onward cargoes (*a*) because increased trade density means a higher likelihood of finding a suitable cargo and (*b*) because more shipping on the route improves the flow of information between ships and ship-owners allowing the latter to line up follow-up business in advance of a ships arrival at port. In addition, it is likely that more trade at the newly integrated ports resulted in a fall of average port charges and improved services such as lading times etc.

Descriptive data on port charges from a contemporary survey of 232 detailed accounts for the years 1867 to 1870 supplied by the ship-owners to the then head of Statistics Norway, Anders Kiær, support this hypothesis.[30] First, tradi-

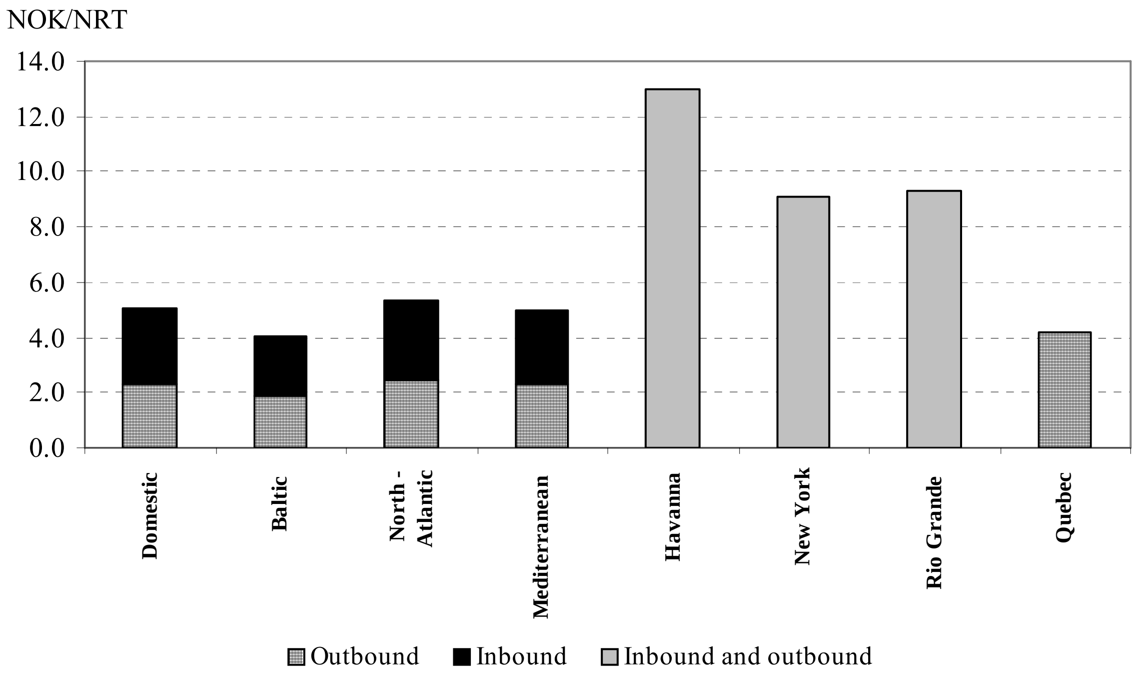
[29] For the average length of trip in this period see Brautaset and Grafe, 'A long distance affair' .

[30] Kiær, *Statistiske Oplysninger*. The survey of the cost structure of Norwegian shipping companies covers different routes and various cargoes. The annual distribution of accounts is 1867: 57, 1868: 48, 1869: 72, 1870: 55. The figures refer only to Norwegian sailing vessels, and are returns to detailed questionnaires Kiær sent to the shipping companies.

tional staple goods were cheaper than 'new' commodities, such as coffee, in terms of tariffs and loading charges.[31] Secondly, as new trading routes were established and the trade on traditional routes expanded, investment in port facilities resulted in a stepwise cost function, which was likely to be reflected in changing port charges over time.[32] Thirdly, traditional trading routes such as the Baltic had the lowest port charges. Looking at the new trading routes, in particular the trade going on in North and South America and the West Indies, the high port charges exemplify, literally, the high costs of moving from familiar routes with known cargoes in Europe to that of more exotic goods in foreign waters. The chart below shows port charges for bulk goods on European routes, compared to costs of travelling to some of the key American ports.[33]

Figure 4 Port charges by routes and regions (Norwegian Kroner per NRT)

Source: Kiær, Statistiske Oplysninger., pp. 1–6.



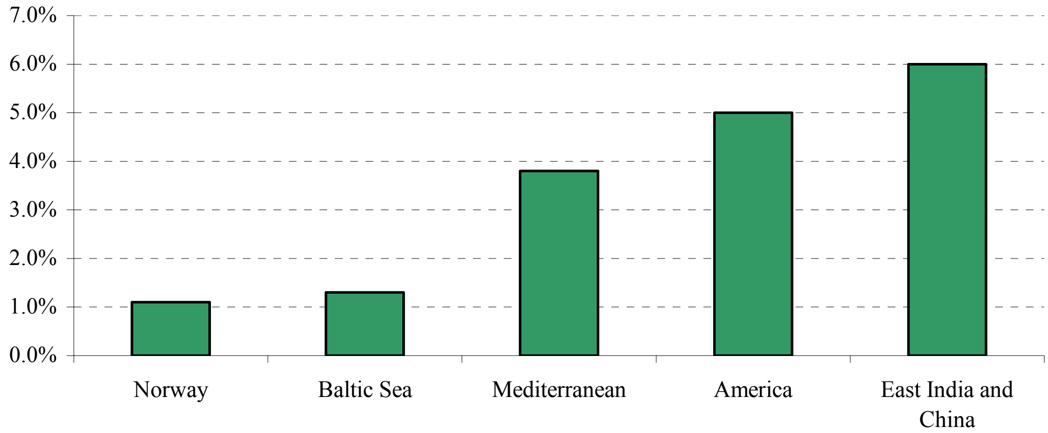
[31] For instance, while the national average for inbound vessels carrying timber to French ports was 2.17 NOK per NRT, inbound vessels carrying coffee to Marseille paid charges of 6 NOK per NRT according to figure offered by Kiær.

[32] Increased demand would lead to logistics getting worse, congestion and an increase in turnaround time, inducing port authorities to develop the facilities in order to gain increased capacity. In time, increased traffic at the port would lead to the reoccurrence of the congestion problem, prompting port authorities to increase the capacity further.

[33] For Rio Grande, the charges are based on salt (in), piece goods (out), for Havana fish (in), sugar (out), for New York sugar (in), wheat (out) and timber outbound from Quebec.

Data on brokerage and consignment commission further strengthens the hypothesis of a maturity effect and economies of density of network use. In the case of domestic outbound shipping, it was quite common to exert a dual role as both consigner and ship owner – particularly in the tonnage demanding timber trade. The combination of being both merchant and ship owner implied a cost advantage compared to foreign competitors, as one did not have to pay brokerage commission. This is the main reason why the brokerage and consignment commissions for domestic-based shipping were so low (see charges compared to other trades in the chart below).[34]

Figure 5 Brokerage and consignment commission as % of freight charges



Source: Kiær, Statistiske Oplysninger, p. 19f.

In principle we would expect the economies of scale originating from the density of network use to be observable in a simple relationship between the total volume of shipping on specific routes and freight rates. Specification 2 in table 1 above estimates a regression of freight rates as a function of volume controlling for distances and the year and type dummies we found to be significant in regression 1. It thus is identical to equation 1 above but adds the logarithm of the volume of trade on each route (lnRouteVol) as an independent variable. As can be seen, volume of shipping on these routes is not significant at the 5 or 10 percent level.

Does this suggest that there were no network density economies in nineteenth-century shipping? We believe not and the descriptive data presented above support this. Transport volume on individual routes might simply be a

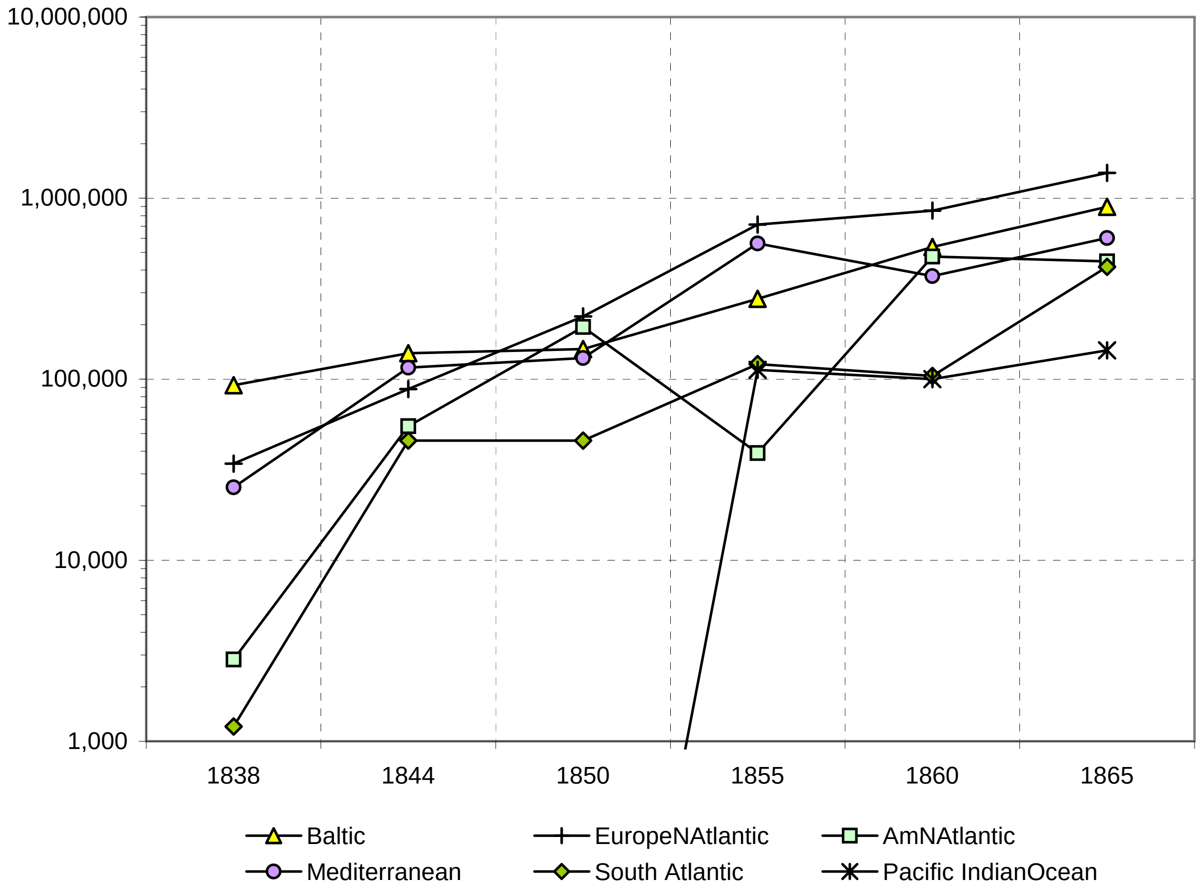
[34] In total, 80 percent of these expenses were paid abroad, and nearly all went to the shipbrokers as consignment commissions, i.e. share of the freight rates that fell to either the consignee or the consigner, were not common, except from in French and Russian ports.

poor indicator given the huge scale effects resulting from the overriding dominance of a few short distance routes. Thus it seems necessary to aggregate the data across more useful categories. The raw data show quite clearly how the process of geographic expansion of Norwegian transport happened. Figure 3 below plots the level changes of produced shipping by six macro-regions on a logarithmic scale. The level differences at the start of this period 1838 were extremely wide. The Baltic accounted for 60 percent of third country shipping, the European Atlantic for 22 percent and the Mediterranean for about 16. Shipping to the Americas was negligible. Norwegian ships had not yet discovered the Pacific and Indian Oceans.

Larger initial levels were generally associated with slower rates of expansion. Shipping into the Baltic was the traditional mainstay of Norwegian transport interests and in turn it experienced the smallest overall expansion over these 35 years, though at a still healthy rate of 8.5 percent per annum. The English Channel routes and other European Atlantic routes were important early on as well but still growing faster than the old Baltic Routes at 14 percent pa. They were followed closely by North Atlantic Routes, which grew strongly until the 1850s. Their expansion afterwards, however, was volatile and tailed off around 1860. In the last period under consideration the annual growth rate was practically zero. Mediterranean routes were long established and experienced the second smallest volume expansion in the nineteenth century (12 percent pa), though they benefited from a mini-boom at the expense of North American Routes during the 1850s as a consequence of the Crimean War. South Atlantic routes expanded fast after the 1850s resulting in a rate of 23 percent pa for the entire period. Finally, journeys into the Pacific and Indian Ocean were still a rarity even at the end of the period under consideration. The first ones were recorded between 1850 and 55 with correspondingly high growth rates thereafter (120 percent for 1850–1865).

In regression specification 3 we introduce a simple test of the hypothesis that freight rates in less established regions tended to be higher by adding the levels of output in each macro-region in 1838 in logarithmic form (LnVolume38), for which data are of slightly better quality than the early 1830s. The results for this coefficient are highly significant and suggest an elasticity of freight with regard to the level of volume per region in 1838 of –0.03; a higher level in production in any one region in 1838 was indeed associated with a lower freight rate to that region in 1866. This confirms the existence of a maturity effect: shipping to more mature regions was cheaper. All other coefficients remain stable.

Figure 6 Output of third country shipping by macro-region 1838–1865 (ton-miles)



We can investigate the maturity effect further by looking explicitly at what happened to individual macro-regions. For this purpose we have created dummies for these macro-regions Baltic, European Atlantic, American North Atlantic, South Atlantic and Pacific/Indian Ocean.[35] Specification 4 in Table 1 reports the results. As before, we control for both, distance and domestic versus third country shipping, and none of these parameters changes significantly. The interesting result here, however, is that our cross-section charts the time series of increasing network density by geographic region rather closely. Using Baltic shipping, the most established one, as a reference category we see that all other regions are subject to higher freight rates. The coefficients for European Atlantic, Mediterranean, South Atlantic and Pacific/Indian Ocean are highly significant and reflect what we know about the increasing scope of Norwegian shipping networks. The elasticity of European Atlantic routes suggests they de-

[35] See Appendix 1 for the classification.

manded a premium of about 19 percent over Baltic routes, while the surcharge for Mediterranean was 24 percent, for South Atlantic 35 percent and for Pacific and Indian Ocean 45 percent.[36] This confirms clearly the importance of the maturity effect in reducing transport costs over time as the geographic scope of the network expanded and new regions were added.

Two results from this regression merit a little more attention. Firstly, the coefficient for American North Atlantic suggests that these routes produced the lowest mark-ups compared to Baltic shipping, 12 percent, but it is not significant at the 10 percent level. Partially, this might be because in the case of much of North American shipping Norwegians were pushing not into new markets but into very well established ones. Thus freight rates on Canadian timber were very low even in the early years after the abolition of Britain's protectionist measures. Other routes remained significantly more expensive. It is also possible that on some of these routes by the 1860s Norwegian sail shipping was outcompeted by steam. In any case, the low freight rates might explain why Norwegian ship owners were very cool about North American markets from mid century onwards and shifted their investment increasingly into other routes. The second notable result is the rather large difference between Baltic and European Atlantic freights. While the expansion into the European Atlantic was largely an early-nineteenth-century phenomenon, it was not an opening of a new frontier in the same way as the South Atlantic, Pacific and Indian Ocean routes. In the European Atlantic the insatiable British demand for freight services was most likely the cause keeping rates up. Norwegian shipping danced to the tune of Britain's growing trade and did nicely out of it.[37]

One possibility why the average price of a produced ton-mile of shipping might have differed between these routes is of course that there were differences in freight rates according to different types of cargo transported. If there was a strong correlation between certain goods and regions, this could drive the dif-

[36] Note that dummy variables enter the equation in dichotomous form, i.e. the derivative of the dependent variable with respect to the dummy does not exist. Therefore, the percentage effect takes the form $100 \times g = 100 \times e^{\left(c-\frac{1}{2}V(c)\right)-1}$, where c is the observed coefficient and V the Variance. See Halvorsen and Palmquist, 'The Interpretation' and Kennedy, 'Estimation'.

[37] This also explains why there is so little action in the Harley index. North American routes had already become cheap before this period, while English freight rates were kept high by extraordinary demand. Add to that the most mature route in the Baltic and the index will be stagnant. But as discussed above it misrepresents what happened in world shipping markets.

ferences between the macro-regions defined above. The timber trade e.g. had been the mainstay of Norwegian transport for a long time and is usually associated with the Baltic trade. Testing for the impact of different goods on freight rates is complicated by the fact that we have only a smaller set of rates for 1866 where we have data on type of cargo transported. Table 2 below shows the basic data set of 112 routes for which we have one identifiable cargo. To return to the example of the timber trade, they suggest that it was still very active in the Baltic but Norwegian ships transported timber on European Atlantic, trans-Atlantic, Mediterranean and even Pacific routes. Grain shipments were more clearly clustered on the Mediterranean, while piece goods figure completely out of proportion as North American trade. Thus the impact that commodity specific differences might have had are not that obvious. In order to test this effect we have created four dummies for coal, grain and piece goods with timber as a reference category controlling again for distances. Results are reported in specification 5 in table 1 above.

Table 2 Composition of the 1866 sample regression specification 5 (no. of ships)

Commodity	timber	coal	grain	piece goods
Baltic	17	3	5	2
European Atlantic	11	4	6	2
American North Atlantic	4	2	0	7
Mediterranean	13	8	13	2
South Atlantic	1	2	0	3
Pacific Indian Ocean	3	2	0	2
Total	49	21	24	18

There are too few observations to check for the impact on each macro-region in the estimation. Coal shipments are, as expected significantly cheaper than timber with a highly significant coefficient. The grain dummy just drops out of the 10 percent significance level and suggests that grain freights were higher than timber freights. This could reflect a genuine 'technological' difference to do with lading and handling grain vis-à-vis timber. It could also reflect the fact that many grain ships in the 1860s frequented the relatively new Odessa/Galatzi routes, thus masking a maturity effect. The negative, highly significant coefficient for piece goods is more puzzling since one would have expected bulk goods to be relatively cheaper than piece goods. Taken at face value it would reinforce the view that the low freight rates in the Baltic were really a function of a higher degree of maturity in these markets rather than a function of the type of cargoes that dominated that trade. Yet, the small sample militates against overstretching this particular argument. The high negative coefficient for piece goods could also be due to selection bias in our reduced sample, i.e. the over representation of piece goods in relatively cheaper North American freight rates. At the same time, piece goods were not a very large part of cargoes at any one time, so that it is more likely that the causality runs from cheap North American freights to piece goods than the other way round.[38] Thus caution is called for, when interpreting the piece good result. Yet, overall this exercise suggests that our results for different regions were not simply driven by a 'missing variable' for type of cargo. The maturity effect measured in specifications 3 and 4 does not look very sensitive to the kind of cargo shipped.

Our cross-section of freights has thus helped us to identify an effect that is quintessentially time dependent. We have argued that maturity, or increasing economies in the density of network use, resulted from a number of effects such as easier access to return cargoes, lower port charges and better information. This last effect can be analysed in more detail. Information flows were an important determinant of freight rates, simply because faster information between ports meant ship owners could line up the next cargo and were always informed where their ships were in the first place. Using the Lloyd's List Kaukiainen studied the speed at which information related to the arrival and departure of ships in ports around the world flowed back to Europe.[39] But as opposed to Persson who argued such an improved information flow only really mattered after the telegraph became widely used in the 1870s, Kaukiainen shows that a much more important increase in 'information speed' occurred since the 1820s.

Not surprisingly this process started in the most mature shipping areas, the Baltic and North Sea Routes, followed by the Mediterranean, Indian Subcontinent and US East Coast Routes. Finally, information speed increased on other Asian Routes only after the 1840s and on South Atlantic Routes only from the 1850s. News began travelling faster on the most mature trading routes largely because overland travel improved, i.e. letters travelled much faster overland

[38] The total number of piece good cargoes is also overstated here since they are more likely to appear as single goods, while other cargoes often appeared jointly with different goods and were thus excluded.

[39] Kaukiainen, 'Shrinking the World', Appendix.

than ships around the European Peninsula. However, over the course of the century steam shipping started making a serious difference providing faster and more reliable postal services. On the newer routes the impact of steam technology was even greater given the enormous variations in travel time sail was subject to.

Table 3 below illustrates this pattern for a number of routes. The columns titled Info speed 1830 and 1860 report Kaukiainen's median values for the speed in days at which information flowed back to London.[40] The column Freight Speed 1866 provides average days for journeys undertaken by Norwegian sailing vessels on the same routes (or similar ones in the case of Buenos Aires-Hamburg and Rio-Antwerp). The last two columns report the ratio of Information Flow to Freight speed. This gives an indication of how well ship owners could manage their fleet at both points in time on different routes. Note that it is assumed that freight travel times were the same in 1830 as in 1866, but since there was no major technological change in sailing over this period this seems acceptable.

The result confirms once more the presence of a 'maturity effect' driven by the density of network use. On the well established routes from Archangel and Gothenburg news travelled in half the time that it took the freight even in 1830. In practice this meant a letter could be sent and answered (almost) before the ship came in. From Alexandria news still travelled 40 percent faster than the actual lading and from Rio and New York 30 percent. But from Buenos Aires and Quebec there was practically no difference between information and freight speed, meaning ship captains were out on their own and owners could just hope return cargo would be found when the ship came in. By 1860 the speed at which information travelled had increased on all routes but arguably on the new routes the improvement was not only bigger but also more important since it allowed owners, agents and captains for the first time to communicate efficiently.

[40] Though the speed of information flows increased, it was not always available to everyone and asymmetric information still had a strong influence on strategy and structure in the shipping sector. See Boyce, '64thers' In other words, agglomeration matters. In a more recent work, Boyce analyses how networks reduce transaction costs by looking at the British maritime networks 1870–1939. Boyce establishes how participants relied upon 'network knowledge' and furthers existing knowledge by exposing how maritime networks existed at several levels. Boyce, 'Network Knowledge'.

Table 3 Speed of travel of information and freights, 1830–1866 (days)

from	to	Info speed 1830	Info speed 1860	Freight speed 1866	Info 1830/ freight 1866	Info 1860/ freight 1866
Archangel	London	27	13	48.6	0.56	0.27
Gothenburg	London	8	5	15.1	0.53	0.33
Alexandria	London	53	10	86.8	0.61	0.12
New York	London	26	13			
New York	Antwerp			38	0.68	0.34
Rio de Janeiro	London	58	28		0.69	0.33
Rio de Janeiro	Hamburg			83.8		
Quebec	London	35	12	38.8	0.90	0.31
Buenos Aires	London	76	41		1.01	0.54
Buenos Aires	Antwerp			75.5		

Source: Kaukiainen (2003) and Statistiske Tabeller

The above evidence suggests the clear presence of economies derived from the density of network use. Increased output of ton-miles of shipping on routes that had relatively recently been developed thus would have reduced the price of the average ton-mile even further. A difference in freight rates between ‘mature’ and ‘new’ routes of up to 45 percent in 1864–66 illustrates the forces at work and the comparison of freight and information flow speeds describes that process in some more detail. As a consequence our index presented in figure 2 is definitely underestimating the real fall because we set the relative freight rate per route constant at 1864–66. We now know that that is incorrect, differentials between old and new routes must have been considerably larger in 1830 and therefore our back-extrapolation underestimates the index for the early part of the period making the decrease even steeper.[41]

[41] As a rough approximation we could argue that if ‘new routes’ accounted for about 10 percent of the volume in 1830 and the maturity effect meant they were 40 percent more expensive our weighted index should have had a starting point that was 4 percent higher than the one we calculated. Since new routes were created all the time there is no easy way to model this effect more precisely.

Internal scale economies in shipping

A final reason why we might expect freight rates to change as the produced volume of shipping expands is internal scale economies in both ship size and firm size. Returning to Kiær's analysis of shipping accounts 1867–1870, gross freight earnings are distributed according to fixed and variable costs as well as net profits.

Table 4 Breakdown of freight rates as reported by Norwegian ship-owners 1867–70[42]

Cost elements	
Freight fixture, consignment, commission	3.40%
Port charges and other port related expenses	23.20%
Maintenance etc.	11.60%
Depreciation	4.50%
Insurance of ship and cargo	7.70%
Crews pay and provisions	33.40%
Net profits	16.20%

Source: Kiær, Statistiske Oplysninger, p. 21

As previously mentioned, longer distance stimulated investments in larger vessels. While loading charges and lighthouse charges correlate with the size of the ship, this is not the case with pilotage, anchoring charges, tugboat charges etc. Anders Kiær argued that this was one of the main reasons why the smaller vessels were more expensive to run than the larger ones.[43] Regarding ship size this is a relatively intuitive process. Larger ships have on average lower man-

[42] Two more elements in this cost breakdown should be noted. The author himself felt that maintenance costs seemed quite low. However, again this was probably a reflection of the use of a mature technology localised in an area of Norway that was highly specialised in providing related goods and services. Finally, the net profit rate seems rather impressive. However, the calculation does not include interest rates, at the time nominal rates were around 6 percent in Norway. Even if most Norwegian ships were financed through reinvestments of profits this was the opportunity cost of engaging in trade. Hence the actual profit rate would have been closer to ten percent.

[43] Thus, this implies that these data are less representative for smaller vessels as the large ships in the sample drives down the port charges per unit of tonnage.

ning ratios and therefore economize on wage costs or to put it another way they lower the variable costs per trip. Brautaset and Grafe (2003) showed that average ship size did indeed increase over time and that manning ratios had fallen in 1865 to little over 50 percent of what they had been in 1835.[44] Thus we would expect to find ship size also as an important determinant of freight rates for our 1864–66 freight rate sample. In fact, Harley thought that much of the modest TFP growth in British sail shipping derived from larger ship sizes.[45]

We test this in regression specification 6 in table 1 above based on our preferred specification 4, it now introduces the average ship size on each route (lnshipsize) in log form as an additional variable. As it turns out it is not significant while the other coefficients change only very slightly in size. The only other difference between specifications 4 and 6 is that American North Atlantic comes from just outside the 10 percent significance level to just inside that threshold. The reason for the non-significant ship size variable is most likely that increasing ship size itself was driven by the expansion of longer routes and therefore a consequence of the structural change of production rather than a driving force. There were more incentives for ship-owners to employ larger ships on the longer routes. Ships in the Baltic and North Atlantic route had average sailing times in the late 1860s was around 7.5–8 months per annum. Compared to this, ships on transatlantic routes were sailing 11 months a year, thus improving the capital utilisation.[46]

If there were few economies coming from ship size what about the size of the shipping companies or *rederier*? After all we would expect larger concerns to have better access to capital and benefit from other scale economies. Brautaset and Grafe (2003) argued that the way the sector was organised was probably

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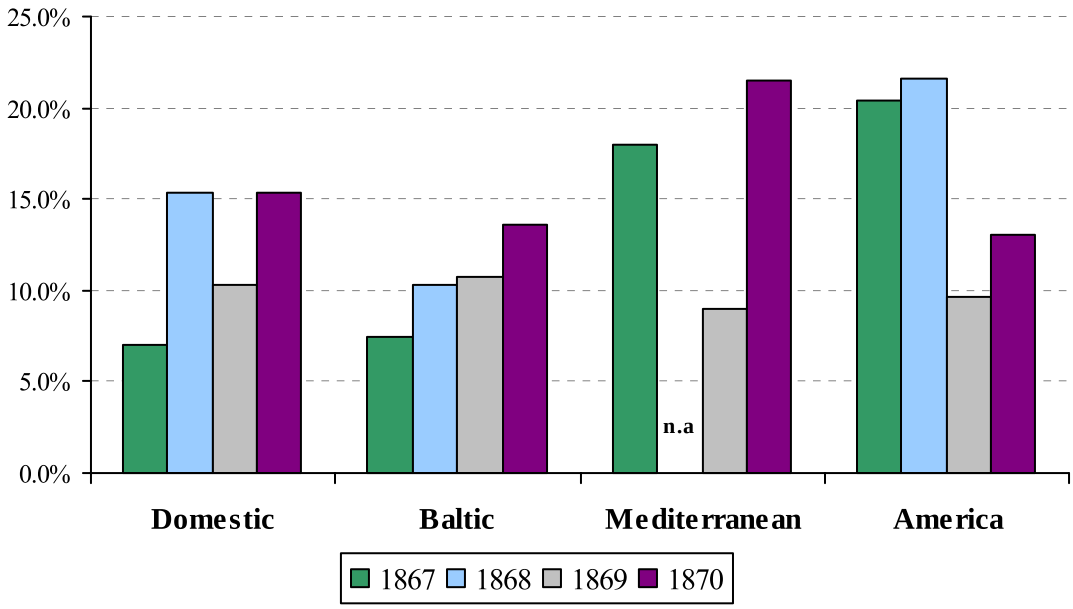
[44] Though there is a lacuna in the literature on the use of child labour onboard vessels, the historian Espen Søbye has given an indication on the scale of child labour in Norwegian shipping during the nineteenth century. See Søbye, 'Tallenes fortellinger', '1894 – annus horribilis: Skipsforlis 1851–1998', p. 123. Based on contemporary statistical surveys on social conditions in Norway, Søbye argues that children between 6 and 13 years were more frequently used as labour on vessels in the first phase of the expansion period from around 1840. Towards the end of the century, the average age of new seamen increased. For seamen starting their work ashore 1885–1894, was 9 percent 14 years, 60 percent 15 years and 17 started at the age of 16. More research has to be done in order to be able to assess how much child labour mattered in terms of cost-structure and to what degree this was a phenomenon specific to the Norwegian expansion.

[45] Harley, 'Ocean Freight Rates'.

[46] Kiær, pp.16–22. For 1867 the average was 9.6 months, for 1868 10.7 months, 1869 the average was 11.6 and for 1870 11.4 months.

the most unusual attribute of Norwegian shipping. During the phase of fastest expansion no large ship-owning interests emerged. Ships were owned locally in traditional *partenrederij*, i.e. in shares held by a number of individuals. At the same time, Norwegian ship-ownership was geographically very concentrated. In the 1870s, the region of Agder had a population of about 150,000. Studies have shown how it managed to control 2% of the world's shipping tonnage.[47] Together with the two other major shipping ports, Drammen and Tønsberg, in nearby counties, Agder in 1866–67 controlled nearly half of the Norwegian merchant fleet.

Figure 7 Net profits as percentage of gross freight earnings



Again the evidence concerning the market structure of shipping in Norway indicates that network density, this time amongst ship-owners, investors, brokers and sailors at home, was more powerful than internal scale economies that could have been provided by a process of vertical integration of firms. Here, presumably the choice of technology made a large difference. It is likely that the relatively small capital outlay for sailing ships made a competitive sector of small shipping firms more efficient than a concentrated one. In principle the notable absence of internal scale economies in firm and ship size compared to the clear presence of economies of scope and network density is not that surprising. Studies of twentieth-century railway networks found similar evidence suggesting that network economies are really far more powerful in the longer run in

[47] Johnsen, *Rederistretegi i endringstid.*

driving down transport production costs than firm size.[48] However, ship owners were not looking at production costs *per se*, they were looking for the excess of the freight rates charged over the costs to be as high as possible. The profit figures found by Kiær show clearly that Norwegians did not continue to invest in sail ships up to the 1890s because they did not have access to capital to invest in metal hulls and steam; they invested because the sector continued to be highly profitable (see table 4 above). Profit rates were notably volatile and substantial. A further breakdown of profits by different trades explains why Norwegian ship-owners expanded with so much enthusiasm into the new routes, even if these, as we have argued above, were subject to much higher port charges, brokerage costs and such like. Figure 7 above shows that net profits in the old established trades were lower than in the newer ones. Thus ship owners got their cut from the higher freight rates that applied in the new trades and happily reinvested in these ventures.

[48] Caves et al., 'Network effects'.

III
Conclusions

In this paper we have shown how the output of the Norwegian shipping sector expanded rapidly in the period 1830 to 1865 offering for the first time complete volume data for one the major shipping industries at the time. We have argued that the sheer volume expansion of shipping make this data difficult to reconcile with those partial freight rate indices, such as Harley's, that suggest that nothing happened to freight rates before the introduction of metal hulls and steam ships, in other words before a major technological shift occurred. We have identified three areas in which a fast expanding transport sector should have realised scale economies, represented by the composition effect, the maturity effect and internal economies of scale. Our experiment of back extrapolation shows that indeed the existing partial indices miss completely the composition effect that drove down the price of the average produced ton-mile of shipping. This was a consequence of increased average journey length or economies of scope. The cross section analysis showed that there is indeed a non-linear relationship between length of journey and freights.

What is the meaning of such a decline in the price of the average price of a ton-mile of shipping? After all the discussion of the composition effect abstracts deliberately from the possible fall in rates on individual routes (covered by the maturity effect). Thus it could be objected that for an individual engaged in shipping goods on a specific route, say London – Kaliningrad (Königsberg) a fall in the price of the average ton-mile on all routes was purely hypothetical as long as the price on the route London – Kaliningrad did not change. Such an objection misses, however, the very character of nineteenth-century 'globalisation'. The increasing scope of world trade and the opening of new regions increased the competitive pressure on the Kaliningrad route. Thus the opening of the Odessa and trans-Atlantic grain routes changed the market environment for everyone engaged in the Baltic grain trade, whether freight rates on Baltic routes changed or not.

The composition effect also matters when considering the larger questions about the relation between transport costs, trade growth and GDP growth. The fall of our index throughout the period 1830–65 invites us to rethink the relation between overall output growth and transport growth. It clearly indicates that there was no one-off macro-technological event such as the introduction of iron hulls and steam engines in shipping that drove down shipping costs as a largely exogenous factor. Rather transport seems to have responded to increased demand for services coming from a growing world economy rather more continuously in the period 1830 to 1865. This in turn would mean that the transport sector should be considered an endogenous factor in accounts of nineteenth- century growth.

Further analysis of the cross section freight rate data has suggested that there were large increasing returns to density in the shipping network as the number and tonnage of ships frequenting each new macro region increased. While freights for different goods were distinct those goods were not as clearly associated with regions as to explain the main result. At the same time we saw that technology might have mattered indirectly for Norwegian shipping since the introduction of steam reinforced an already existing endogenous process of faster information provision which in turn again mirrored the pattern of development from established shipping regions to new ones. Hence we argue that the 'maturity' effect means our conjecture price of transport index in figure 2 still underestimates the fall in prices.

The findings in this paper substantiate that there was economic rationality behind the Norwegian's strategy of continuing to invest in a mature technology as profit rates were attractive. This would suggest that Norway did not continue to invest in sail even when the British fleet was switching to steam because of path dependency and technological lock-ins. As we have shown above, during this period this was a profitable sector.[49] Sailing vessels remained profitable in long-distance trades for decades for several reasons. Firstly, Norway enjoyed a first mover's advantages in third country shipping, which manifested itself in systematic re-investments in tonnage from the 1830s onwards. The country also had absolute advantages through shipping clusters of human capital as well as cheap and abundant inputs. Its comparative advantage derived in part from the lack of alternative domestic investment opportunities but more importantly from the incumbent advantages resulting from the overarching importance of returns to network scope and density. Among these sources of market advantage, it is likely that the cost elements and the incumbent advantages were particularly important. Similarly, new trade routes implied higher costs of production, but per piece charges and higher utilisation rates per annum and trip gave ship-

[49] We have no data to assess, if net profit rates were above or below those of the competitors, e.g. British steam shipping. In such a competitive market they should have tended to converge once the relatively higher risks of sailing were taken into account. However, much of the literature has suggested that a continued investment in sail was a function of lock-ins and ongoing even when the sector was not profitable any longer. This is clearly not true as Norwegian sailing freights were competitive internationally.

owners incentives to further expand into the newer routes and to drive down the average cost of produced ton-mile still further. Moreover, as can be seen in Figure 7 above, the new routes also lured ship-owners by offering the prospects of higher returns than traditional routes.

To date there is little consensus among economic historians about timing, scale and causality of the fall in international freight rates prior to 1914. The economic historian's interest in freight rates is largely motivated by the search for the driving forces in the globalisation process in the nineteenth and early 20th century. In the textbook literature it is commonplace to argue that freight rates fell rapidly after 1870 through productivity gains in response to a technological shock led by innovations in steam technology.[50] Falling transport costs opened up trade in an ever expanding network, trade propelled growth through realisation of the economic potential of differences in factor endowments, which again meant convergence in prices – in itself a definition of globalisation.[51]

As a consequence of this line of logic, if we do not know the full story of falling transport costs – we do not know the full story of globalisation in the nineteenth century either. The dynamics of falling transport costs advanced what Harvey called the 'space-time-compression', that has been so central for global economic and cultural interaction.[52] The findings in this paper, namely that economies of scope and scale drove shipping costs down before the advent of major technological macro inventions, demonstrate that further research is needed in order to advance our knowledge of falling transport costs in the nineteenth century. We believe that the way forward is through systematic micro studies intimately linked to studies of a merchant fleet at macro level. Norwegian sources and the Norwegian merchant fleet offer such an opportunity. Some work has already been done, but its scope remains to be realised in terms of understanding the wider implications for global economic development.

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50 For recent textbook literature on the topic, see for instance Abramovitz, 'Catching Up, Forging Ahead, and Falling Behind', and Thomas, 'The service sector'. Thomas offers estimates of productivity gains in the service sectors on the basis of figures by Feinstein, but he emphasises the crudeness of the results. Thomas p. 129. includes the shipping industry, though the latter are rather crude as they draw heavily upon existing literature and are thin on empirical evidence.

51 See for instance Harley, 'Trade 1870–1939', pp. 165f.

52 Harvey, *The Condition*.

Appendix 1

Output data

The physical measure of the volume of the production of freight services is *ton-mile*, which means the tons of cargo (net register tons [NRT]) multiplied by the distance travelled measured in terms of nautical miles. The single most important source for finding data on Norwegian ships in international trade is *Statistiske Tabeller*, i.e. Statistical Tables. Between 1837 and 1892, the fiscal system was based on indirect taxes.[53] Duties on foreign trade, including the export of freight services, constituted the most important source of income for the public purse explaining the unusual diligence of Norwegian authorities when it came to registering shipping.[54] The tariffs were levied on the basis of volume. Relevant information can be found in a systematic form in the statistical tables published by the Department of the Interior and The Royal Department of Excise and Customs.

The database consists of annual figures for voyages made by Norwegian vessels going in international trade. The original reports state the number of ships, their capacity, and distinguish between ships carrying cargo and ships going in ballast. We also get the geographical composition as the figures are organised around ports/geographical areas of departure and arrival; around 40 ports for domestic based shipping and similarly for third country shipping. In total, our database covers some 600,000 journeys made by Norwegian vessels between 1830–1865. The wealth of information available from this source made some degree of aggregation necessary. Matching all Norwegian ships, 5,000–7,000 vessels a year, to their destinations is not practicable. Instead, eight different routes have been constructed for domestic based shipping and 12 routes for third-country shipping.

Finally, our estimates are built upon the assumption that vessels registered by the customs to be carrying cargo had full capacity utilisation. Contemporary economists and the authors of the various volumes on Norwegian maritime history point out that vessels were declared as fully loaded even if that was not necessarily the case.[55] According to tax regulations full customs was declared when the vessel was carrying more than a quarter of its capacity. Likewise, if

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[53] Brautaset, 'Norwegian Economic Policy'.

[54] Hodne, *Stortingssalen som markedsplass. Statens grunnlagsinvesteringer 1840–1914*.

[55] See among others: Schweigaard, p. 173, Bind 3.1, p. 295.

the vessel was carrying less than a quarter of its capacity, it was declared to go in ballast and thus thereby 'tax-free'. We assume that the arrangements for levying tax and the incentive structure this created makes it a realistic assumption that vessels carrying cargo less than a quarter of their capacity and vessels carrying less than their full capacity even out in the broader picture. Moreover, we assume that there was no deck cargo. Indeed, the phenomenon of deck cargo was in retreat in this period of shipping, and the largest shipping nation, the UK, prohibited deck cargo by law in 1837.[56]

One shortcoming of the data is that for third country shipping up to 1864/65 we have only one end of the journey. However, the data show clearly that British ports entirely dominated in Norwegian third country shipping, so that we used them as a point of reference for the distance calculations. Britain was the centre of gravity around which nineteenth-century world trade evolved. In 1838 it accounted for over 28 percent of Norwegian third country shipping in terms of vessels with cargo arriving in a foreign port from another foreign port, while France accounted for 25 percent. In 1848, Britain's share had increased to 38 percent, France's declined to 9.[57] The main reason behind this British increase and the French decline, was the gradual change of British import duties on timber, which ended decades of a regime giving preference to Canadian timber, from 1842 onwards.[58] In 1858 Britain's share had increased further to 45 percent, a position it held well into the 1860s.[59]

The price series 1864–66

The cross section analysis in regressions 1–6 relies on prices derived from the same sources. Anders Kiær, the first director of statistics Norway, took a special interest in maritime data and began apparently in the early 1860s to correspond with Norwegian and other representatives around the world collecting their observations of real ex-post paid freight rates charged by Norwegian ships. The

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[56] Williams, 'State Regulation of Merchant Shipping 1839–1914: The Bulk Carrying Trades', p. 78.

[57] *Departementet for det indre, Statistiske Tabeller for Kongeriget Norge. Tiende Række, indeholdene Tabeller, vedkommende Norges Handel og Skibsfart i Aaret 1850*, Anhang, table 5, pp. 252f.

[58] Brautaset, 'Norsk Eksport', p. 174f.

[59] *Departementet for det indre, Statistiske Tabeller for Kongeriget Norge. Nittende Række, indeholdene Tabeller, vedkommende Norges Handel og Skibsfart i Aaret 1858*, tables 12 and 13, pp. 130–139.

earliest of these data are contained in Kiær's handwritten notes on his own copies of the volumes statistics for 1864/65. In 1866 these data were included in the published volumes. In order to get as precise data for freights per ton-mile as possible for the regression analysis we matched every single route by its exact distance for the in depth data set 1864–66. This produced a set of 578 routes for which we had prices. For the 1866 data we also have complete information for third country shipping including both port of origin and destination. Distances were calculated using modern sea lines and adjusting for alterations such as the Suez, Panama and Kiel Canals. For the purpose of the calculations we ignored the fact that actual distances travelled might differ on outbound and inbound journeys depending on winds and currents. The basis for the distance calculations is www.MaritimeChain.com and www.world-register.org. The distances thus do not claim to represent neatly the actual time a ship took. They also bias our results for the volume of shipping downwards since we assume direct line sailing.

The macro-regions

For the classification of the macro-regions Baltic, European Atlantic, American North Atlantic, Mediterranean, South Atlantic and Pacific/Indian Ocean we use the 'further out' port as a guide. A trip from Hamburg to New York is thus classified as American North Atlantic. European North Atlantic includes North Sea, Irish Sea and French and Spanish Atlantic ports as well as Archangel. Pacific/Indian Ocean contains Pacific ports in North and South America as well as Asian ports in either ocean, Oceania and a few East African destinations. There was a small but increasing number of journeys into the Black Sea, which were included in the Mediterranean category.

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