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Freight rates and productivity gains in British tramp shipping 1869–1950☆

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Abstract

The standard source for pre-WWII global freight rate trends is the Isserliss index. We think it is time for a new look at his British tramp shipping index, especially given his sources offer vastly more information than Isserliss used. Our new estimates confirm the precipitous decline in real freight rates before World War I, but we also extend them to 1997, a long period of relative stability. In an effort to identify the contribution of transport revolutions to global commodity price convergence, we create route-specific deflators, rather than relying on the Sauerbeck index. Finally, using the price-dual and new factor price indices, we calculate total factor productivity growth for five global routes, and then identify the sources of productivity growth along them.

1. Introduction

The period between 1850 and the First World War saw increasingly integrated global commodity markets manifested by the narrowing of price differentials between trading partners. That pre-war agricultural and non-agricultural prices did converge within Atlantic markets, within non-Atlantic markets, and between them

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has been shown in a number of recent works (Findlay and O'Rourke, 2003; Harley, 1980; O'Rourke and Williamson, 1999; Williamson, 2002).

Economists have mistakenly concentrated on trade policy to explain this globalization trend prior to the First World War. Imlah (1958), for example, started his account of *Pax Britannica* by attributing the world trade boom to British leadership in adopting a liberal trade policy, and historical accounts have always laid great emphasis on the repeal of the Corn Laws in 1846. Indeed, that date has often been designated as a marker for the beginning of a free trade movement as liberal trade policies spread across Europe. However, the movement met resistance after the 1870s as countries on the Continent retreated from openness, and tariffs were raised to far higher levels in the European periphery, Latin America and the rich English-speaking offshoots. Bairoch (1989, pp. 55–8) and others have shown that the rise in European tariffs was a defensive response to competition in local markets increasingly integrated into world markets by a fall in transport costs on land due to railroads and on sea due to shipping. One of the present authors has shown with collaborators that the same was true of the periphery (Coatsworth and Williamson, 2002; Williamson, 2003). If global commodity markets were far better integrated just before the First World War than ever before, and if that happened in the face of rising tariff barriers, then that integration must be attributed to the fall in transport costs on land and sea. Thus, this paper explores British tramp shipping up to 1950, an industry that carried then much of the world's ocean trade in low-value bulk commodities.

There is already much published material showing that freight rates declined precipitously before the First World War (Fischer and Nordvik, 1986; Harley, 1980, 1988, 1989; Isserliss, 1938; North, 1958, 1965, 1968; Stemmer, 1989; Yasuba, 1978). This paper uses a well-known, but incompletely mined, source (Angier) to offer a new global tramp shipping index. Apart from offering a replacement for Isserliss, the paper also fills a gap in the interwar shipping literature, decades that saw policy-induced de-globalization. Since it was published in 1938, the Isserli index ended in 1936. Thus, it did not allow comparisons between trends in tramp shipping before and after the Second World War. Our Global Index is linked to that of Hummels (1999) on shipping freights in the post-World War II era, so that we can say something about the very long run.

We also create route-specific deflators by using the prices of commodities transported on the route. Previous scholars have deflated their nominal freight rate indices by the Sauerbeck-Statist British price index, an index that includes tradables not carried on all routes and non-tradables not carried on any route. Our deflated indices offer a more effective measure of the contribution of declining freight rates to commodity-price convergence across trading regions.

The first half of this paper documents our new freight rate indices for the period between 1869 and 1950. The second half explores the sources of that decline. This is a debate with an impressive pedigree. North's (1958, 1968) productivity gains calculations in shipping surprisingly revealed that larger productivity gains took place before the introduction of the major shipping innovations of the 19th century. North thus concluded that improvements in management and industrial organization drove the fall in freight rates, and that technological change was only secondary. Harley (1988) challenged this long-accepted view by showing that there were significant problems with the North freight rate index. Basically, the early part of the 19th century saw a sharp decline in the stowage factor (i.e., space occupied per ton) of cotton. The packing of cotton bales improved considerably with the introduction of the screw press followed by the steam press, both allowing more cotton to be crammed into holds (Harley, 1988, pp. 856–9). This led to a steep fall in cotton freight rates in the first half of the 19th century. Since North's freight rate index was heavily weighted by cotton, it did not represent general shipping trends. Conducting a productivity gains calculation on a revised index, Harley concluded that the more significant productivity gains took place after 1869, and were attributable to the introduction of the steam engine and improvements in hull technology. The conventional history was reclaimed.

While Harley appeared to have settled one debate,[1] he created another by noting that the shipping industry was marked by joint-production on different legs of journeys (Harley, 1985, 1988, 1989, 1990). Calculating TFP gains without taking into account joint-production could lead to a significant measurement bias the size and direction of which would depend on the shipping route. After analyzing the joint-production issue, we revisit Harley's measurement of TFP gains between 1870 and 1896. Using the price-dual method and new indices for factor prices, we calculate productivity gains for this period anew, not only for the Bombay–UK route examined by Harley but also for four other routes. We then move on to calculate TFP growth for the period between the early 1890s and the First World War, as well as that between the two World Wars, the latter having received relatively little attention in the shipping literature.[2]

Finally, we explore the sources of that productivity experience. Harley (1971, 1972, 1973) has already dealt with the diffusion of steam and metallurgical development in shipping in the late 19th century, but little work has been done comparing the application of such technology across routes. We address the trade-offs between ship size, speed, and cost. In explaining the sources of productivity growth in the late 19th century, we also identify what these trade-offs meant for tramp shipping on individual routes. We then turn to the technological slowdown after 1918.

[1] Harley was not alone. Yasuba (1978) calculated productivity gains in Japanese pre-WWII tramp and liner shipping using quantities of outputs and inputs, and Walter Knauerhause (1968) did the same for labor productivity on German liners in the 1870s and 1880s.

[2] Data limitations force us to restrict our calculations to the British tramp shipping industry, almost entirely ignoring the liner shipping industry. Liners, unlike tramps, operate on fixed time schedules on fixed routes. Tramps are hired to carry either restricted (i.e., specified in the contract) or unrestricted cargoes between negotiated ports, and unless a fixed time charter is negotiated, no time schedule or route is fixed. Tramp shipping dominated trade in commodities. In 1909, a Royal commission found that tramps made up 70–80% of total tonnage, so that liners could not have been more than one-third of the total (Pollard and Robertson, 1979, p. 20). Liners did not operate on full capacity, and carried high value articles that were less bulky. Tramps carried the high bulk, low value staples.

2. Freight rate indices

2.1. The need for new indices

The Isserliss freight rate index has remained the standard source on global freight rates for 1869–1936 even though its construction is flawed. The flaws are more than those pointed out by Yasukichi Yasuba who argued that there is an upward bias in the Isserliss index since "declining rates were quoted only after the number of contracts reaches a certain level, and rising rates for the old established routes tend to remain in the list longer than they deserve" (Yasuba, 1978, p. 13). Isserliss took his data from Angier's annual reports on British shipping, and it is true that Angier's choice of which freight rates to report was somewhat ad hoc. The more troubling problem with the Isserliss index, however, lies with the way the data were aggregated.

Isserliss used Angier's data to form the ratio of the freight rate on each commodity-route to the freight rate on that commodity-route in the immediately previous year. He then took the arithmetic average of all available freight rate ratios for each pair of years, using them to form his global freight chain index. He rebased this chain index in a single year, 1869, using the cumulative product of index values from the global freight chain index. This method of construction invokes large sample properties for relatively small samples and assumes that the sample is representative of global shipping. Basing the index on a single year after having aggregated the ratios in this way requires the implausible assumption that freight rates across regions moved in lock-step with each other.

2.2. The Angier data

Isserliss reports in an appendix the ratio of the simple average of the highest and lowest freight rates for a commodity-route in that year to the same average for that commodity-route in the immediately previous year. This ratio is not available for all routes and for all years, and the number of gaps in the Isserliss data far outnumber the number of observations. In fact, for almost every commodity-route, it is impossible to judge the level of freight rates relative to 1869. To do so, we would need the nominal freight rates themselves, and while they are not in Isserliss, they can be found in Isserliss' sources. The Angier annual reports included tables of highest and lowest British tramp shipping freight rates for various commodity-routes, and these were compiled in *Fifty Year Freights* (Angier, 1920). From the 1880s onwards, they were published annually in a January edition of *Fairplay* magazine, a leading British shipping journal. While Isserliss stops with 1936, the Angier-based freight index can be extended to 1950, which we do in this paper. Furthermore, while the Angier reports end there, *Fairplay* continued to include its own reports on tramp shipping, at least until 1962. These data make it possible to link our index to the modern era (Hummels, 1999).

Mining these sources, we were able to find freight rates for over 500 commodity-routes from all over the world, but mostly for trade between Europe and the rest of the world, on both homeward and outbound routes. True to the nature of tramp shipping, the freight rates reported are for low-value bulk commodities. Most of the rates were reported in shillings/pence per ton.[3]

Nowhere does Angier make clear why he decided to report certain commodity-routes, though in some cases he does mention that not enough charter parties were reported to him to be able to note the highest and lowest freight rates for the year. We are left to guess that Angier reported only the commodity-routes he thought were important to British tramp shipping.

Finally, we note what Angier almost entirely left out: the short range trade between Britain and continental Europe, and shipping between non-European ports. Thus, we cannot be certain that any index based upon this database is representative of global shipping. At best, the index documents trends in freight rates on bulk commodities between the European center and the periphery.

2.3. Construction of the new indices

Given that the commodity-routes included in Angier keep changing, and that the series have intermittent gaps, it is impossible to aggregate these data directly to form an index of long distance tramp shipping freight rates, but an indirect strategy seems to work: construct indices for outbound and homeward trade between Europe and individual regions,[4] and then aggregate these indices into a final "global" index. These route indices are, of course, themselves useful for analyzing the development of trade between various parts of the periphery and Europe.

Before describing the construction of these route indices, we need to say a word about a technological constraint that must be taken into account in the construction of our freight indices. Harley (1990, pp. 157–8) describes this best:

> Ships float by displacing water. Seawater weighs 64 pounds per cubic foot or displaces 35 cubic feet per ton. Since the ship itself has some weight, cargoes such as coal and heavy grain (wheat, rye, and corn), which occupy forty cubic feet per ton, simultaneously fill up a ship and exhaust its buoyancy. Light cargoes, such as cotton, tend to leave a ship with excess buoyancy for optimal navigation. Consequently, a ship carrying primarily cotton will be willing to take heavy cargoes at low rates. Alternatively, a heavy cargo such as iron or ore will exhaust a ship's buoyancy while it still has empty space. If this is the primary cargo, then light cargo will be sought to fill available space, and low rates will be offered.

[3] There are over 8000 observations. For some commodities, freight rates were reported per 40 cubic feet, though in early years, their freight rates were reported per ton. Where freight rates were not reported per ton, we were able to turn to sources on stowage factors (i.e., the space occupied per ton) from the period to standardize these freight rates. For some commodity-routes (particularly Black Sea grain routes, Newcastle coal routes in the early years, or the timber routes), freight rates were reported in region-specific or trade-specific units. These too were standardized by combing through Angier's reports, the contemporary shipping literature, and the *Oxford* dictionary.

[4] For the sake of consistency and comparability across years and routes, we try to stick to the Angier data as much as possible. Where there are gaps in his data, we turn to previously published indices such as those in Harley (1980, 1985, 1988, 1989, 1990) and Stemmer (1989). It is possible to delve into the shipping press of the period to fill more gaps, but quotes in the shipping journals are difficult to standardize. The text portions of Angier's reports, for example, contain more freight rate quotes than those provided in his tables, but it is difficult to reconcile these with the data in his tables.

Thus, freight rates for commodities with different stowage factors behaved very differently, and they responded very differently to changes in shipping technology. Yet, freight rates for commodities with similar stowage factors behaved similarly.[5] This was so because the tramp shipping industry was competitive[6] and because shippers faced no restriction on the commodities the vessel could carry. Thus, we construct our individual regional indices only from commodities with similar stowage factors.

Our Global Index of long distance tramp freight rates between Europe and the rest of the world is constructed weighting the different regional indices according to the importance of trade to and from that region. We use the *Board of Trade* data (taken from Mitchell, 1992)[7] to compute the ratio of trade to Britain being carried to the individual regions to the total trade carried to all the regions in the database. These ratios formed the weights for the homeward routes. Outbound coal freight indices for the various routes were weighted by the ratio of coal carried to these regions to the total for all the regions in the database (taken from Palmer, 1979). The results are plotted in Figs. 1A and B.[8]

2.4. Nominal freight rate indices

The new freight rate indices confirm what has long been known about pre-First World War shipping costs: nominal freight rates declined along all routes. In the interwar period, however, freight rates recovered their low pre-war levels only in the mid-1930s, for reasons that will be explored in the next section. Replacing the Isserliss index with our new Global Index makes a difference. The new index (Figs. 1A and B) falls faster than the Isserliss index before and after 1884, suggesting that Isserliss understated the fall in freight rates. After the War, Isserliss again understates the fall in global tramp freights. However, in general our new Global Index confirms what was already known about tramp shipping in this period.

Important differences in the behavior of tramp freights emerge when the freight rate indices are examined by region (Tables 1 and 2). The Atlantic routes exhibit a wide variety across different regions and commodities. Timber freights on the eastern North America and Baltic routes fell much more slowly than did grain freights on the same routes before the First World War. This is to be expected because of

[5] To be sure, the range of freight rates was fairly large for most commodity-routes. No doubt individual ships or shippers received lower-than-competitive rates based on fortunate circumstances. Angier reports the highest and lowest rates for each commodity-route. It is impossible to infer the full distribution of freight rates for any commodity-route, but we hope that by using the average of the reported rates, any bias in the indices caused by the use of "atypical" freight rates due to special deals for either ships or shippers is attenuated.

[6] The claim that the tramp shipping industry was competitive is not new. For example, both North and Harley assume as much. A well developed market for shipping contracts already existed in this period, centered around the famous Baltic Exchange in London.

[7] The unweighted average of outbound freight indices was used after 1913 because of lack of data.

[8] Details on the construction of the route and "global" indices are supplied in Appendix 1 to this paper available at Williamson's web site http://www.economics.harvard.edu/~jwilliam/ and on Science Direct.

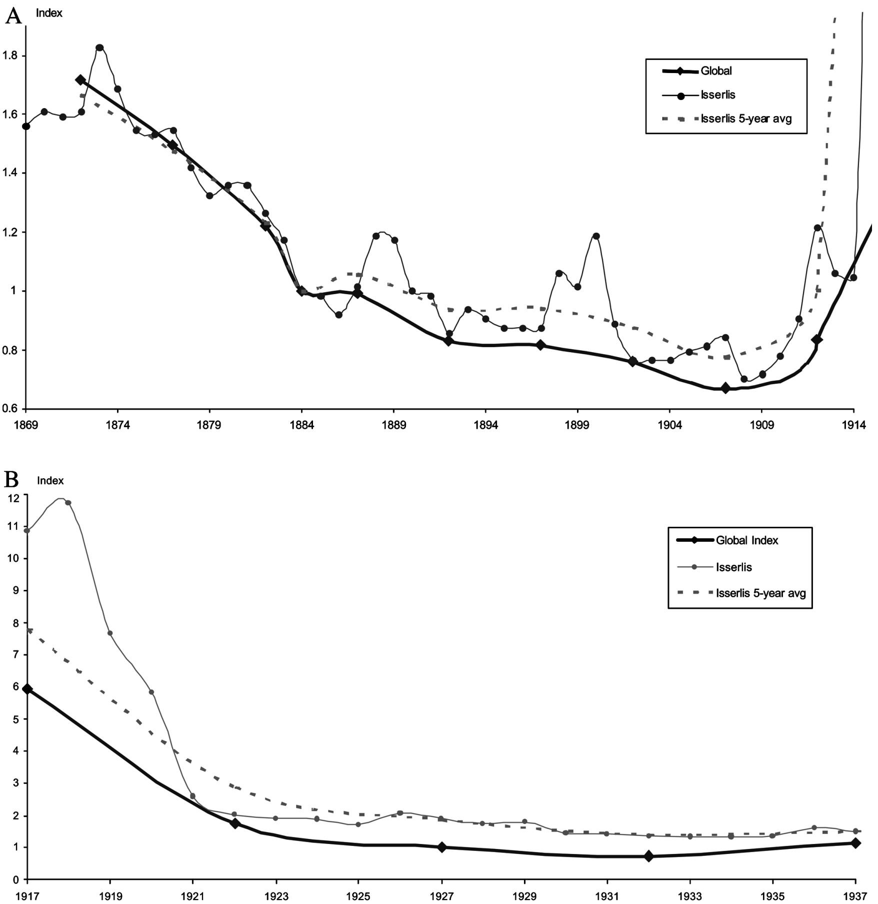

Fig. 1. (A) Nominal freight rate indices 1869–1913 (1884 = 1.00). (B) Nominal freight rate indices 1920–1937 (1884 = 1.00).

joint-production. Timber did not exhaust both buoyancy and space, and thus could not take advantage of the increases in ship sizes that were to drive productivity gains before the War. On the other hand, freight rates on ore carried from the Western Mediterranean, heavier than grain, fell as fast as rates for transatlantic grain cargoes. Freight rates on grain from the Gulf Coast of North America (GNA) and the East Coast of North America (ENA) seem to have followed each other closely, at least between 1884 and 1913, falling by about 25–40%. The fall in grain freights from ENA was slightly sharper than that for GNA in this period. Baltic and ENA rates both fell by about 40% between 1874 and 1884, though the former fell more slowly thereafter. Freight rates for grain from East Coast of Latin America (ELA) fell much slower than for either of these regions between 1869 and 1884, barely dropping by 10% in this period. Between 1884 and 1913, however, the ELA grain index matches

Table 1
Nominal freight rate indices—Baltic and Non-Atlantic routes (1884 = 1.00)

Year	Baltic—Grain	Baltic—Deals	Coal to Baltic	Coal to Genoa	Black Sea—Grain	Coal to Turkey	Egypt—Cotton-seeds	Coal to Egypt	W. India—Grain & General	Bengal—Grain & Similar	Bengal—Lighter Goods	Coal to Colombo	SE Asia—Grain, Sugar
1869	1.822	1.681	1.353	1.595	2.602	1.662	1.783	1.969	2.025	1.827		1.497	1.539
1870	2.205	1.944	1.397	1.685	2.718	1.718	2.065	1.969	2.792	1.655		1.389	1.408
1871	1.922	1.794	1.147	1.378	2.726	1.639	2.130		2.369	2.207	2.714	1.335	1.829
1872	1.935	1.898	1.662	1.486	2.406	1.809	2.054	1.873	2.214	2.310	2.179	1.373	1.902
1873	2.182	2.111	1.279	1.604	2.341	1.854	2.348	1.897	2.436	2.345	2.500	1.297	2.206
1874	1.911	1.912	1.265	1.595	2.146	1.865	2.022	1.825	2.436	2.517		1.438	2.369
1875	1.749	1.710	1.147	1.261	1.962		1.957		2.436	2.206		1.200	2.076
1876	1.943	1.937	1.618	1.270	2.378		2.435	1.224	2.099	1.965		1.135	1.849
1877	1.868	1.751	1.441	1.261	2.550	1.899	1.783	1.515	2.047	1.830		1.151	1.881
1878	1.637	1.598	1.250	1.243	2.112	1.594	1.565	1.489	1.293	1.272		1.259	1.379
1879	1.436	1.516	1.221	1.243	1.517	1.402	1.728	1.296	1.419	1.378	1.714	1.270	1.489
1880	1.366	1.312	1.294	1.315	1.355	1.735	1.370	1.488	1.770	1.613	2.071	1.151	1.688
1881	1.488	1.312	1.471	1.225	1.716		1.913	1.321	1.839	1.689	1.929	0.968	1.742
1882	1.446	1.254	1.176	1.144	1.445	1.187	3.207	1.190	1.409	1.529	1.500	0.957	1.500
1883	1.476	1.430	1.103	1.054	1.272		1.065	1.286	1.292	1.370	1.500	1.038	1.336
1884	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1885	1.242	1.154	0.956	0.919	1.079	0.902	0.913	0.926	0.984	1.047	1.049	0.908	1.016
1886	1.027	1.126	0.882	0.901	0.874	0.952	0.652	0.932	0.866	0.914	0.810	0.843	0.930
1887	1.066	1.179	0.809	0.937	1.163	0.950	0.935	0.905	0.847	0.944	0.864	0.924	0.914
1888	1.344	1.519	0.868	0.892	1.475	0.914	1.283	0.917	0.959	1.139	1.098	1.189	0.914
1889	1.124	1.362	0.838	1.000	1.221	1.073	1.087	1.083	1.004	1.102	1.022	1.005	0.914
1890	0.862	1.098	0.750	0.793	1.055	0.810	1.065	0.881	0.917	0.923	0.842	0.800	0.915
1891	1.148	1.236	0.662	0.703	1.371	0.833	0.978	0.750	0.981	1.061	1.022	0.449	0.977
1892	0.837	0.880	0.706	0.721	0.858	0.850	0.913	0.818	0.795	0.760	0.761	0.097	0.815
1893	0.899	1.006	0.706	0.631	0.919	0.692	0.870	0.652	0.603	0.684	0.730	0.703	0.736
1894	0.760	0.927	0.676	0.523	0.909	0.564	0.935	0.527	0.839	0.790	0.822	0.503	0.792
1895	0.992	1.090	0.588	0.514	0.830	0.616	0.902	0.557	0.747	0.657	0.830	0.524	0.675
1896	0.994	1.027	0.500	0.604	1.062	0.696	1.054	0.702	0.524	0.466	0.558	0.832	0.543
1897	0.917	0.976	0.632	0.883	0.789	0.900	0.870	0.786	0.660	0.548	0.567	0.784	0.572

Table 1 (*continued*)

Year	Baltic—Grain	Baltic—Deals	Coal to Baltic	Coal to Genoa	Black Sea—Grain	Coal to Turkey	Egypt—Cotton-seeds	Coal to Egypt	W. India—Grain& General	Bengal—Grain & Similar	Bengal—Lighter Goods	Coal to Colombo	SE Asia—Grain, Sugar
1898	1.053	1.098	0.662	0.784	0.900	1.007	0.935	0.881	1.218	0.837	0.823	0.762	0.780
1899	1.051	1.191	0.853	0.838	0.801	0.996	0.870	1.024	0.853	0.772	0.793	0.757	0.738
1900	1.205	1.514	0.926	0.973	1.051	1.171	0.967	1.137	0.868	0.784	0.797	1.070	0.771
1901	0.833	1.012	0.779	0.658	0.772	1.312	0.761	0.696	0.684	0.627	0.675	0.681	0.596
1902	0.758	0.915	0.632	0.486	0.729	0.610	0.761	0.518	0.619	0.532	0.607	0.595	0.541
1903	0.821	1.016	0.632	0.532	0.710	0.616	0.696	0.560	0.708	0.569	0.588	0.519	0.579
1904	0.890	0.964	0.603	0.505	0.656	0.571	0.685	0.628	0.743	0.647	0.766	0.486	0.622
1905	0.871	1.054	0.603	0.559	0.764	0.712	0.761	0.621	0.673	0.554	0.637	0.503	0.565
1906	0.933	1.120	0.721	0.613	0.717	0.687	0.761	0.598	0.667	0.566	0.664	0.595	0.521
1907	0.936	1.088	0.706	0.622	0.686	0.718	0.663	0.656	0.712	0.599	0.588	0.508	0.629
1908	0.785	0.909	0.588	0.559	0.545	0.678	0.500	0.586	0.468	0.456	0.493	0.557	0.487
1909	0.816	1.000	0.618	0.568	0.578	0.616	0.587	0.583	0.666	0.599	0.679	0.422	0.610
1910	0.878	1.006	0.559	0.568	0.728	0.667	0.739	0.616	0.644	0.626	0.569	0.486	0.574
1911	0.921	1.166	0.662	0.685	0.749	0.904	0.826	0.789	0.768	0.698	0.816	0.589	0.650
1912	0.950	1.524	0.985	1.036	1.259	1.099	1.196	0.994	0.996	0.870	0.968	0.692	0.877
1913	0.888	1.364	0.632	0.892	0.823	1.091	0.750	0.952	0.796	0.768	0.842	0.632	0.737
1914					0.698	0.859	1.130	1.327	0.686	0.637	0.797		0.702
1915		3.375					4.304	4.357	2.950	2.502	2.796		2.047
1916		6.833					10.435	8.202	5.924	5.345	5.274		5.030
1917							9.348	11.429	10.088	11.847	18.441		12.961
1918								19.048			20.642		14.874
1919							6.196	5.935	5.609	4.357	5.388		4.901
1920					3.714	6.444	3.478	4.702	3.376	3.674	3.119		2.826
1921					2.000	2.046	1.239	1.726	1.264	1.196			1.236

1922		0.896	1.730	0.946	1.351	0.938	0.883	0.781
1923	1.535	0.908	1.340	0.957	1.131	1.090	0.877	0.848
1924	1.552	0.846	1.323	1.022	1.119	0.964	0.962	0.873
1925	1.361	0.806	1.255	1.307	0.994	0.923	0.877	0.731
1926	1.519	1.166	1.526	2.585	1.098	0.997	0.962	0.744
1927	1.547	0.812	1.379	1.456	1.131	0.977	0.978	0.804
1928	1.507	0.661	1.266	1.278	1.101	0.900	0.844	0.797
1929	1.687	0.780	1.345	1.426	1.051	0.825	0.709	0.618
1930	1.569	0.666	0.848	1.307	0.708	0.719	0.581	0.526
1931	1.305	0.643	0.808	1.174	0.667	0.764	0.714	0.658
1932	1.125	0.592	0.808	1.233	0.649	0.786	0.756	0.633
1933		0.614		1.196	0.598	0.802	0.770	0.620
1934		0.612		1.255	0.667	0.813	0.797	0.637
1935		0.651		1.040	0.815	0.715	0.744	0.579
1936	1.237	0.785		1.864	0.643	1.149	1.043	0.784
1937	1.707	1.211		2.375	0.994	1.300	1.343	1.101
1938	1.161	0.721		1.564	0.673	0.883	0.983	0.772
1939	1.145	0.936		2.844	1.429		1.759	1.209
1940		2.600		5.550	4.369		2.515	2.949
1941					6.667			
1942					7.619			
1943					8.571			
1944					8.571			
1945					6.381	3.346	3.159	
1946		2.792						
1947				5.259		2.231		
1948				4.567	2.429			
1949		1.831		3.359	2.536			
1950		3.016			3.006			

Sources: Angier in *Fairplay*; Coal to Colombo from Jevons (1969) and Angier. Coal to Turkey (Constantinople) from Palmer (1979) and Angier.

Table 2
Nominal freight rate indices—Atlantic routes (1884 = 1.00)

Year	E. Latin America—Grain	W. Latin America—Nitrate	Coal to E. Latin America	Coal to W. Latin America	E. North America—Timber	E. North America—Grain	W. North America—Grain	N. America Gulf Coast—Cotton	N. America Gulf Coast—Timber	N. America Gulf Coast—Grain	W. Medit.—Ore
1869	1.122	1.016	1.376	2.139	1.447	1.762	1.792		1.250		
1870	0.941	1.184	1.213	1.428	1.421	1.651	1.577		1.217		
1871	1.164	1.421	1.276	1.487	1.474	1.778	1.385		1.225		1.737
1872	1.219	1.474	1.394	1.679	1.553	4.460	2.077		1.317		
1873	1.295	1.605	1.570	1.567	2.026	2.058	2.346		1.725		2.443
1874	1.219	1.647	1.344	1.572	2.053	1.857	2.092		1.625		
1875	1.233	1.395	1.109	0.914		1.952	1.462				
1876	1.144	1.289	1.063	1.032		1.675	1.669				1.805
1877	1.061	1.211	1.032	0.995		1.683	1.192				1.628
1878	0.974	0.947	1.032	0.909		1.683	1.269	1.292			
1879	0.949	1.000	1.063	0.947		1.476	1.462	1.249			1.126
1880	1.077	1.105	1.077	0.979		1.397	1.723	1.142			1.398
1881	1.103	1.237	1.027	0.904		1.127	2.269	1.055			
1882	1.103	1.382	1.086	0.952		1.302	1.615	1.185			1.357
1883	0.974	1.026	1.090	0.984	1.289	1.206	1.192	1.077			1.223
1884	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1885	0.923	0.737	0.873	0.979	0.956	0.921	0.948		1.050	0.981	0.957
1886	0.821	0.689	0.801	0.941	0.873	1.048	0.862	0.872	1.050	0.911	0.937
1887	1.000	0.789	0.873	0.973	0.861	0.857	0.776	0.882	0.850	0.820	1.143
1888	0.981	0.842	1.113	1.471	1.165	1.143	0.862	1.071	1.025	1.058	1.389
1889	1.140	0.921	1.412	1.390	1.316	1.334	0.931	1.108	1.400	1.167	1.270
1890	1.257	0.989	1.050	1.310	0.924	1.162	1.086	0.819	1.163	0.999	1.268
1891	1.523	0.816	0.801	0.588	0.867	1.143	1.034	0.872	1.000	0.938	1.205
1892	1.234	0.395	0.724	0.615	0.886	1.104	0.724	0.729	1.013	0.912	1.004
1893	1.084	0.722	0.692	0.781	0.851	0.877	0.707	0.820	1.025	0.754	1.084
1894	1.140	0.674	0.543	0.615	0.826	0.975	0.734	0.850	1.013	0.833	1.213
1895	0.986	0.571	0.516	0.599	0.838	0.936	0.862	0.729	1.013	0.949	1.128
1896	0.877	0.533	0.647	0.722	0.851	1.131	0.690	0.729	1.013	0.991	1.338
1897	0.819	0.732	0.679	0.722	0.826	1.053	0.821	0.702	0.975	0.953	1.213

1898	1.049	0.825	0.724	0.829	0.951	1.150	0.801	0.808	1.225	1.189	1.364
1899	1.333	0.852	0.543	0.829	0.926	0.988	1.002	0.765	1.119	1.086	1.229
1900	1.153	1.007	0.787	0.802	1.176	1.208	1.202	0.870	1.213	1.347	1.543
1901	0.894	0.775	0.575	0.781	0.876	0.760	1.134	0.599	0.975	0.889	1.128
1902	0.811	0.581	0.498	0.481	0.751	0.604	0.809	0.508	0.825	0.789	1.186
1903	0.931	0.442	0.421	0.727	0.813	0.682	0.541	0.536	0.831	0.753	1.141
1904	1.008	0.597	0.376	0.508	0.726	0.760	0.654	0.492	0.838	0.720	1.059
1905	0.787	0.570	0.457	0.508	0.738	0.799	0.714	0.547	0.800	0.792	1.178
1906	0.752	0.542	0.588	0.561	0.701	0.780	0.779	0.547	0.813	0.711	1.193
1907	0.794	0.457	0.579	1.016	0.801	0.689	1.026	0.552	0.819	0.745	1.130
1908	0.711	0.457	0.452	0.775		0.565	0.809	0.481	0.769	0.678	0.981
1909	0.624	0.527	0.462	0.695		0.572	0.807	0.547	0.731	0.612	1.011
1910	0.624	0.554	0.665	0.717		0.543	0.840	0.564	0.769	0.679	1.110
1911	0.674	0.585	0.774	0.952		0.741	0.988		0.800	0.681	1.171
1912	1.241	0.756	0.896	1.134		1.053	1.261		1.194	1.096	1.424
1913	1.053	0.783	0.756	1.150		0.897	1.261		1.006	0.921	1.227
1914	1.309	0.713	0.677			1.442	1.093		0.950	0.856	1.134
1915	3.482	1.875	1.444		2.577	3.859	2.521	2.536	2.250	0.849	3.025
1916	6.222	3.642	2.493		5.904	5.823	4.414		5.050	1.034	4.254
1917	16.285	4.604	5.120			11.110					8.428
1918	11.477	6.379	2.312								6.783
1919	10.314	5.919	1.838		6.054	4.054			3.700	9.266	4.688
1920	5.926	2.486	0.756		4.954	3.470	3.880		2.950	3.099	6.122
1921	1.834	1.480	0.682		2.502	1.054	1.999		1.950	1.549	2.197
1922	1.457	0.898	0.606		1.401	1.053	1.126		1.350	0.913	1.815
1923	1.178	0.881	0.767		1.376	0.930	1.059		1.313	0.811	1.806
1924	1.385	0.743	0.536		1.401	1.037	1.055		1.333	0.887	1.714
1925	1.038	0.684	0.519		1.276	0.846	1.029		1.275	0.763	1.601
1926	1.715	0.697	0.626		1.251	1.504	1.059		1.013	0.796	1.991
1927	1.426	0.845	0.553		1.426	0.852	1.029		1.319	0.787	1.472
1928	1.214	0.691	0.389		1.256	0.987	0.937		1.125	0.708	1.463
1929	1.020	0.671	0.375		1.516	0.758	0.844		1.169	0.656	1.580
1930	0.851	0.605	0.389		1.351	0.536	0.622		1.088	0.476	1.296
1931	0.988	0.618	0.378		1.076	0.545	0.692		0.950	0.475	1.175
1932	0.904	0.602	0.367		1.038	0.580	0.633			0.684	1.182
1933	0.846	0.579	0.395		1.001	0.501	0.585			0.669	1.265

Table 2 (*continued*)

Year	E. Latin America—Grain	W. Latin America—Nitrate	Coal to E. Latin America	Coal to W. Latin America	E. North America—Timber	E. North America—Grain	W. North America—Grain	N. America Gulf Coast—Cotton	N. America Gulf Coast—Timber	N. America Gulf Coast—Grain	W. Medit.—Ore
1934	0.850	0.503	0.474		1.051	0.473	0.581			0.651	1.265
1935	0.865	0.520	0.496		1.051	0.564	0.552			0.672	1.349
1936	1.209	0.487	0.677		1.251	0.655	0.744			0.795	1.910
1937	1.633		1.523		1.826	1.250	1.103			1.081	2.925
1938	1.314		1.714		1.301	0.952	0.792			0.748	2.016
1939	2.001		2.143		2.052	2.453	1.174			1.662	5.497
1940	5.509		2.571		6.004	4.173	2.773			3.922	13.132
1941			2.571								
1942			2.205								
1943											
1944											
1945			1.128			3.782	3.243			3.437	9.773
1946			1.776			3.449	2.840			3.471	9.520
1947		2.641	1.827			3.599	2.898			3.766	8.877
1948		2.325				2.998	2.647			3.310	7.930
1949		2.111				2.816	2.025			4.135	6.937
1950		1.546				3.280	2.812			3.258	7.870

Sources: Angier in *Fairplay*; W. Latin America Nitrate before 1890 from Stemmer (1989); E. Latin America Grain before 1880 from Harley (1989); Coal to Latin America from Jevons (1969) and Angier.

the performance of GNA and ENA grain freight indices in this period. Freight rate series for the west coast of North America (WLA: grain) and Latin America (WLA: nitrates) are also presented in Table 1. These routes were dominated by sailing vessels. Rates fell steeply for the WNA grain route before 1884. For WLA, however, freight rates fall only after 1884.

The behavior of Latin American freights cannot be explained by the diffusion of new shipping technologies or distance. WLA, for example, was closer to Europe than WNA, and yet rates fell faster for the latter route. Harley (1989, p. 327) remarks upon the complexity of the relationship between outbound and inbound freights in Latin America. The next section examines how freight rates on various legs of voyages were not determined independently. Demand for inbound and outbound shipping fluctuated erratically for Latin America. Before 1884, coal freights for the East Coast of Latin America were falling quicker than freights for coal carried to most other regions (Table 1). Coal freights for ELA were certainly falling much faster than outbound grain freights. The explanation for the behavior of Latin American freights likely lies with shipping demand in these regions.

The First World War saw freight rates peak for the Atlantic routes. They fell slowly in the interwar period. It was only around 1933/4 that nominal freight rates reached their pre-war levels, but they rose again with the onset of the Second World War.

Coal freight rates (Table 1) do not seem to have been correlated with distance either. Bombay coal freights, for example, fell much faster than Colombo coal freight rates before 1884, even though Colombo was only slightly farther away from Britain than Bombay. Outbound coal freights from Britain seem to have fallen drastically in the interwar period, unlike homeward freight rates.

Homeward freight rates for non-Atlantic routes (Table 2) fell precipitously between 1869 and 1884. Particularly noteworthy were grain freights from Black Sea ports, that fell by over 60%. Freight rates for western Indian and Bay of Bengal ports fell by over 40% in this period. Unlike timber on the Atlantic routes, freight rates on lighter commodities that did not exhaust both buoyancy and space actually fared better that freight rates for commodities with stowage factors similar to grain. Freight indices for lighter cargoes such as jute transported from the Bay of Bengal fell by over 65%, although it is unclear how much of this fall was actually caused by better packing. For Southeast Asia, where the diffusion of steam technology in shipping was slower because of distance, freight rates fell much more slowly than for India. After 1884, however, the freight indices for these routes mirror each other for similar types of commodities. Freight rates fell by up to 25% before the First World War. As in the Atlantic homeward routes, freight rates fell gradually from their wartime heights in the interwar period.

2.5. *Real freight rate indices*

In order to deflate these nominal indices, we, like other scholars, turn first to the Sauerbeck index. But the Sauerbeck index is imperfect for the purpose of measuring the contribution of declining freight rates to commodity price convergence between

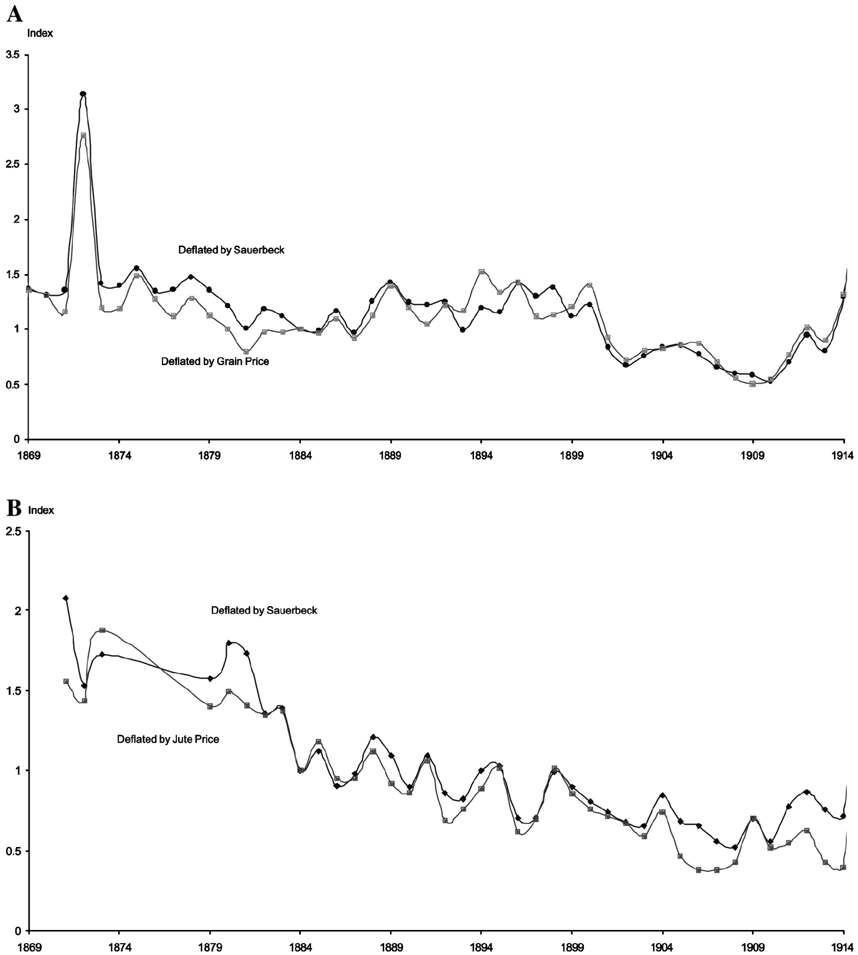

Fig. 2. (A) Real freight rates for wheat from Eastern Coast of North America to UK (1884 = 1.00). (B) Real freight rates for jute from Calcutta to UK (1884 = 1.00).

trading locations since it includes non-tradables and many tradables not carried on all routes. As an alternative, we construct route-specific deflators by taking the unweighted average of the prices of the commodities included in the commodity-routes.[9] The commodity-deflated and the Sauerbeck-deflated real indices are both presented in an Appendix 2 to this paper (see footnote 8).

Figs. 2A and B illustrate the impact of the deflators by plotting both real indices for two cases: the American wheat trade and the Calcutta jute trade. The Calcutta nominal freight rate index deflated by jute prices fell faster after 1873 than the same

[9] Our deflation method is consistent with what has become common in the transport literature on the half century since 1950. See Hummels (1999).

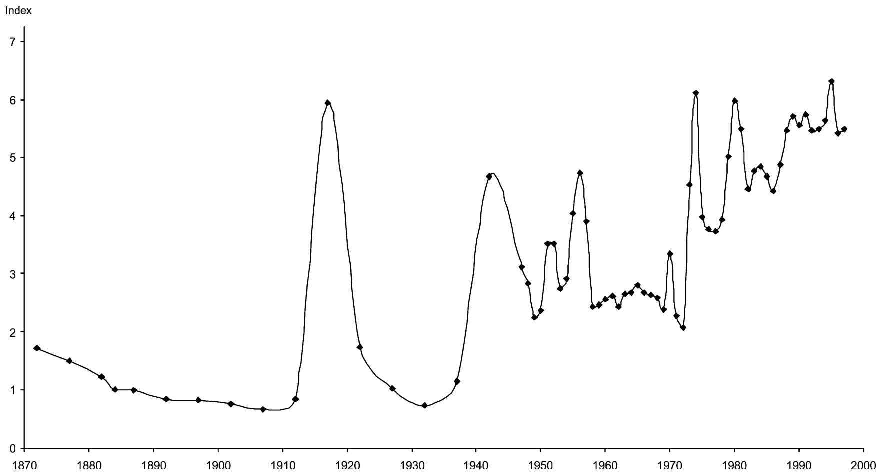

Fig. 3. Global nominal freight rates 1870–1997 (1884 = 1.00).

index deflated by Sauerbeck. The difference between the commodity-deflated and Sauerbeck-deflated indices is less pronounced in the ENA-grain route, perhaps because wheat prices get a large weight in the Sauerbeck index.

2.6. Extending the global index to 1997

Looking at the modern era, David Hummels (1999) reports the Norwegian Shipping News global freight rate index for tramp charters starting in 1947. Fig. 3 and Table 3 use this to link our series with that of Hummels, making it possible to plot global nominal freight rates for the 127-year period between 1870 and 1997.[10] The nominal freight rates seem to trace out a U-shaped pattern. In Fig. 4, the trend in real tramp freight rates is documented for the 127-years. The period between 1870 and 1914 saw an almost uninterrupted fall in shipping costs relative to the prices of the commodities carried along almost all routes; the war and interwar years were ones of great instability and little downward trend; and the half century since were years of stability and no downward trend.

Hummels (1999, p. 12) blames the post-World War II increase in nominal freight rates on the rise in factor prices. The sharp rise in the 1970s (Fig. 3) was, no doubt, related to the dramatic quadrupling in oil prices at that time, but other major inputs also recorded a 10–30% rise. A 1977 UNCTAD report claimed that even port costs were rising due to mushrooming labor costs and other cost pressures (Hummels, 1999, p. 13). Of course, tramp shipping had to deal with rising input costs before 1950 too, and the real indices in Fig. 4 are, after all, deflated by commodity prices. The key, therefore, to long run trends in freight rates was and is total factor produc-

[10] Appendix 1 explains exactly how these indices are linked (see footnote 8).

Table 3
Global nominal and real freight rate indices (1884 = 1.00)

Year	Nominal index	Deflated by Sauerbeck/RPI	Deflated by commodities
1870–1874	1.72	1.27	1.22
1875–1879	1.50	1.26	1.29
1880–1884	1.22	1.12	1.18
1884	1.00	1.00	1.00
1885–1889	0.99	1.09	1.08
1890–1894	0.83	0.93	0.83
1895–1899	0.82	0.99	0.92
1900–1904	0.76	0.83	0.70
1905–1909	0.67	0.68	0.66
1910–1914	0.83	0.77	0.75
1915–1919	5.95	2.79	2.23
1920–1924	1.74	0.83	0.67
1925–1929	1.02	0.63	0.64
1930–1934	0.73	0.66	0.58
1935–1939	1.14	0.95	0.75
1940–1944	4.67	2.43	0.98
1945–1949	2.73	0.94	0.56
1950–1954	3.01	0.62	0.35
1955–1959	3.51	0.65	0.54
1960–1964	2.59	0.36	0.42
1965–1969	2.62	0.33	0.42
1970–1974	3.67	0.18	0.45
1975–1979	4.09	0.16	0.35
1980–1984	5.11	0.11	0.37
1985–1989	5.04	0.09	0.45
1990–1994	5.58	0.08	0.41
1995–1997	5.74	0.07	NA

Sources: Data for 1870–1950 from Angier and other sources (see text). Rates after 1950 from Hummels (1999). For construction of Global Index, see text. Real Indices deflated by Sauerbeck-Statist Index till 1950, by UK RPI thereafter.

tivity growth. Any retardation in the fall in freight rates plotted in Fig. 4 must reflect a slow down in the rate of productivity advance.

3. Total factor productivity growth

3.1. The problem of joint production

The assumption of long run Marshallian competitive equilibrium, whereby the average freight charge is equal to the average cost of the journey, allowed North to write total factor productivity growth as

$$A^* = P_i^* - P_f^* = Q^* - Q_i^*, \tag{3.1}$$

where A is total factor productivity, P_i is an index of factor prices weighted by factor shares, P_f is the freight rate index, Q is the quantity index of outputs (i.e., amount of

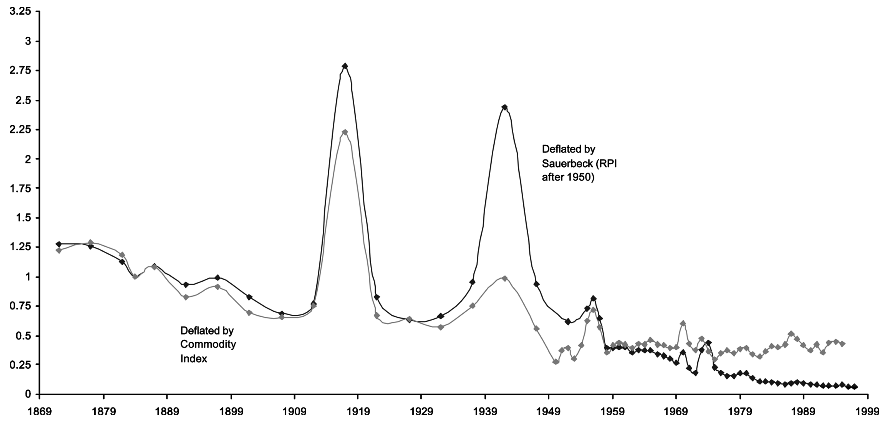

Fig. 4. Real global freight rate index (1869–1997) (1884 = 1.00).

goods carried), and Q_i is an index of the quantities of various inputs weighted by factor input shares, and the * superscript denotes rates of change.

North's assumption is reasonable, given the competitive nature of tramp shipping. The fact that shipping and ship building were relatively small players in the markets for labor, capital, metal and machinery also supports the assumption that factor prices were exogenous to this industry. However, and following Harley's suggestions (1985, 1988, 1989, 1990), we depart from North's additional assumption that joint production along outward and homeward routes did not matter. Since freight rates carried on each leg were often interdependent, average freight rates did not always equal average total costs on individual journey legs. Productivity gains calculated only on a single leg are likely, therefore, to be incorrect.

The existence of shipping capacity in one direction automatically creates shipping capacity in the other since ships return to their homeports for repairs and to return their crews.[11] As long as the demand for ship space and costs associated with running the ship on both legs of the journey were the same, freight rates would also be the same. The assumption of similar costs is, however, unrealistic. In the 19th and early 20th centuries, Britain was the primary supplier of the world's coal used as bunker fuel, and the cost of bunker coal thus increased with distance from Britain. Fuel costs on the voyage back to Britain were higher than on the outbound voyage. Crew costs were also usually different on the two legs. Lewis Fischer (1989) has claimed that the markets for able-bodied seamen in northern European ports were not well integrated, and that seamen earned more if they were hired at major ports, such as Liverpool. There is also ample evidence that Indian seamen on British ships earned less than their European

[11] Emergency repairs were done along the way as needed. Due to docking costs in ports abroad and the prominence of the British shipping industry, most large-scale repairs that could be put off were done at home. It also appears that the vast majority of seamen on British ships were hired in British ports. Roughly 83.5% of the seamen on British ships in the ACPS data base (see below) were hired at home. Of the completed entries in this data base, nearly 91% of the seamen hired in British ports were discharged in Britain.

counterparts. Indian seamen formed a substantial portion of the British shipping labor force, as high as 20%. Potentially, ships could lower marginal costs by hiring in lower-wage ports *en route* or at their destination. Likewise, ships and crewmembers could agree to part company at low-wage ports of call along the journey.

More importantly, if demand for shipping space on one leg of the journey exceeded demand on the other, and if ships engaged on that leg until the rate there fell to equal the cost of production on that leg alone, there would be excess capacity on the return leg. Competition for return cargo among the ships that had carried the outward cargo would result in freight rates that failed to cover the cost of production on the return voyage. Thus, competitive equilibrium saw to it that tramps charged rates based on the voyage as a whole.[12]

In the long run, ship owners would want to use their ships with "optimal" qualities fitting the specification of the trade and the route so that the cost of operation would be minimized. Costs included the interest paid on the price of the ship. Larger, faster and more specialized ships were more expensive to build. The literature suggests that this trade-off often saw tramp ship owners purchasing ships that were not entirely top-of-the-line, but of medium sizes and moderate speeds, with few or no special fittings for particular trades. The ship-building industry, itself an extremely competitive industry, contributed to this trend by churning out medium-sized steamers in anticipation of demand, and these were sold at prices much lower than those of made-to-order vessels (Pollard and Robertson, 1979, p. 20). It was thus possible by the 1930s for the tramp ship owner to describe an "ideal" tramp ship as a medium-sized, moderate speed nondescript jack-of-all trades steamer with no special fittings for any particular type of trade (Sturmey, 1962, p. 35). How the trade-off between speed, size and cost was played out in tramp shipping on various routes is further explored in Section 4.

The analysis of joint production along two legs can, of course, be extended to journeys with more than one leg, as long as the condition holds that the supply of shipping space in one leg implies a supply of shipping space in another leg. Thus, economic profits on a tramp journey from Britain, dropping off coal at Suez, traveling in ballast over the Red Sea and the Arabian Sea to Bombay, and traveling back to Britain with a cargo of general goods would be zero in long run competitive equilibrium, just as they would be zero if the coal were to be carried through Suez and dropped off in Bombay instead. The freight rate on the homeward route from Bombay would have to be the same no matter which route was taken to get there. The freight rate on coal to Suez and the average cost of traveling in ballast from Suez to Bombay would have to equal the freight rate on coal to Bombay.

[12] There is the possibility that demand on the outbound leg might be lower than demand on the homeward leg no matter what the freight rates were. Ships had the option of either taking cargo for free, or taking the outbound leg in ballast. Since there were costs associated with loading and unloading cargo, ships may have preferred to travel in ballast, since loading and unloading ballast was typically less expensive than handling cargo. If some ships decided to take cargo on the outbound route, freight rates for the outbound cargo would equal the average cost of collecting, carrying and unloading them. Freight rates on the homeward cargo would equal the average total cost of the round trip less the marginal cost of carrying outbound cargo. Total costs of the journey would have still equaled total revenue.

There was another kind of joint production relevant in this period (Harley, 1990). Freight rates were determined jointly not only on the different legs of the journey, but also for different commodities carried on any single leg of a voyage. This jointness arose because of the disparity between bulk and weight of different commodities and the limitations of navigational technology in this period that required buoyancy to be filled.

Freight rate, and thus productivity gain, calculations should control for a mixture of commodities as well as for a mixture of legs (Harley, 1990, p. 158). Calculations of productivity gains that do not take into account both types of jointness of production could be misleading. If the index for a particular leg of a voyage were used in calculating productivity gains, and if freight rates on that leg fell faster than freight rates on the journey taken as a whole, productivity gains would be overstated. Similarly, if freight rates on the individual good fell much faster than on other commodities, productivity gains would be overstated.

It is difficult to adjust for the second kind of joint production simply because the interrelationships among different cargoes were so complex. Luckily, on the routes where freight rates for different commodities were interrelated, we are often able to isolate time series of freight rates that were determined independently. In the case of the North Atlantic trade, where joint production of the second kind were particularly important, Angier's data present us with a series of charter party freight rates charged by tramp steamers that carried only grain to Europe. No adjustment is necessary in this case for the second type of joint production. Our productivity gains results for the Baltic, however, require the disclaimer that joint-production of grain freights with timber freights were not taken into account.

The first type of joint production between different legs of the journey is easy to accommodate. As long as there is no joint production of the second type, the sum of freight rates per unit weight or space would equal the sum of marginal costs of the different legs of the journey. Thus, even though the individual freight rates on individual legs of the journey do not equal the marginal cost associated with undertaking the voyage on that leg, freight rates on the voyage taken as a whole do equal the average total cost of the voyage. We add outbound coal freights (per ton) to the freight rate (per ton) on the homeward journey on that route for a commodity with stowage factors similar to grain. This sum should equal the average total cost of the journey in long run competitive equilibrium.

3.2. Total factor productivity growth

Harley (1988) calculates productivity gains on the UK–Bombay route for the outbound coal trade and the inbound general goods trade and thus implicitly confronts the joint-production problem raised above.[13] First, we redid Harley's

[13] His TFP growth calculations are taken from his 1972 Ph.D. dissertation (although Harley does not mention joint-production in the thesis).

Table 4
TFP growth before World War I

	ENA (%)	Alexandria (%)	Riga (%)	Bombay (%)
1871/3–1887/9				
Average change in nominal freight rates	−2.23	−2.56	−2.93	−3.03
Contribution of				
Wages	2.16	1.88	1.64	1.59
Ship prices	33.1	28.8	25.1	24.3
Coal prices	30.2	25.4	24.5	20
Average TFP change	0.76	1.12	1.43	1.64
1887/9–1909/11				
Average change in nominal freight rates	−1.92	−1	−1.63	−2.12
Contribution of				
Wages	−3.5	−6.76	−4.2	−3.2
Ship prices	23.1	44.3	27.4	21
Coal prices	−1.4	−20.8	−10.2	9
Average TFP change	1.58	0.84	1.94	1.55

Sources: Appendix 3 (see footnote 8) for factor prices. Factor shares are as follows: Coal 28.6%, Capital costs 57.1%, and Wages 14.3%. Port costs and other factors have not been included for lack of data.

calculations for the period between 1871–1873 and 1887–1889 using much improved factor price data, in particular new wage and coal price data (Appendix 3: see footnote 8). Second, we extended the calculations to 1909–1911. Third, and in order to increase generality, we added TFP growth measurements for three other routes—UK–East Coast of North America, UK–Alexandria, and UK–Riga—again using data for outbound coal freights and inbound bulk commodities with stowage factors similar to that of grain. The pre-war TFP growth results are summarized in Table 4.

Between 1871/3 and 1887/9, 50–65% of the fall in nominal freight rates can be explained by the decline in nominal factor prices. Falling ship prices, driven by the introduction of cheap iron hulls and productivity gains in the shipbuilding industry, resulted in around 25–35% of the fall in freight rates. Productivity gains in the coal industry no doubt contributed to the fall in coal prices, but the decline in shipping costs also meant that Welsh bunker coal picked up at non-British ports was getting cheaper. Productivity gains in the shipping industry account for the rest of the fall in freight rates (35–50%).

These productivity estimates differ from Harley's. Harley estimates annual TFP growth for the Bombay route between 1873/4 and 1890/1 to have been 3.1%, while we estimate a more modest, and perhaps more plausible, 1.6%. Part of the difference can be attributed to the fact that our freight rate index falls less steeply, and this fact can be explained mainly by Harley's inclusion of the unusual years 1874 and 1890 in his calculation. We elected to choose less unusual end point years since 1874 saw freight rates spike upward to a half-decade high, while 1890 saw freight rates collapse to their lowest.[14]

Productivity growth rates on our other three sampled routes were lower than those on the Bombay route. TFP growth along the ENA and Alexandria routes were the lowest of the four presented in Table 4. The probable explanation is that these two routes had already absorbed the new changes in steam technology and thus they are likely to have recorded higher TFP growth rates in the 1860s and early 1870s; after all, steam technology was well established in the transatlantic trade by the early 1870s. Alexandria also had been early in adopting the steamship since the new technology was not susceptible to variable Mediterranean winds. In contrast, the Bombay route introduced the steamship only with the construction of the Suez Canal in 1869. Naturally, the adoption of the new technology saw higher subsequent productivity gains along the route.

The Riga route, though closer to Britain, was slower in adopting the new shipping technology than were either the ENA and Alexandria routes. The route had long been known as a backwater for older and slower vessels, but the gap between the mean age of the British fleet and the age of British ships in the Baltic was narrowing in the 1870s and 1880s, and by the start of the 1880s, the majority of the Baltic timber trade was carried on steamships (Fischer and Nordvik, 1987, pp. 103–5). Thus steam technology came on in a rush during the 1870s and 1880s, and this fact contributed to the rapid TFP gains along the Riga route, much like those along the Bombay route.

Average export prices for British coal were increasing between 1887/9 and 1909/11, and on the shorter routes such as the Baltic and the Mediterranean, coal freight rates did not fall quickly enough to override the rise in "world" coal prices. The cost of bunker fuel at foreign ports along these routes thus increased, retarding the fall in freight rates especially on the Riga and Alexandria routes. For the ENA and Bombay routes, coal freights fell fast enough to overcome the rise in "world" coal prices. Along the Bombay route, the fall in the price of bunker fuel contributed to about 10% of the fall in freight rates. Along the ENA route, the effect of coal prices was negligible.

Declining ship prices induced a similar fall in freight rates in both periods. During this second period, however, there is also a wider variation of TFP growth among routes. Continued high productivity in the Baltic can partially be explained by continued diffusion of steam technology along the route: while other routes had gone over to steam almost entirely by the 1890s, about 20% of Baltic ships trading in timber were still powered by sail even at the turn of the century (Fischer and Nordvik, 1987, p. 105). For other routes, it is more difficult to make the argument that these big productivity gains were a function of the diffusion of steam technology. The old transatlantic route underwent an acceleration in TFP growth between 1871/3–1887/9 and 1887/9–1909/11, achieving TFP

[14] To avoid biasing our results through our choice of end points, we use three-year averages of freight rate indices and factor prices in our calculations.

growth rates similar to those along the Bombay route, where rates had been maintained. These results confirm that the fall in global freight rates between 1869 and 1913, reported in Figs. 3 and 4, can be attributed to high TFP growth rates across all routes.

The availability of outbound coal freight rates for Alexandria and North America make it possible to extend these calculations up to 1932–1934, immediately prior to the introduction of government regulations in 1935 that aimed at limiting competition in tramp shipping (Sturmey, 1962, p. 110). In order to exclude the effect of the First World War, we make two calculations: the first is for the period between 1909/11 and 1932/4, and the second for the period between 1923/5 and 1932/4. The results are summarized in Table 5.

Factor prices jumped during the First World War, and even by 1923/5 wages, ship prices and fuel prices were still about double those in 1909/11. Even though post-war nominal factor prices declined in the 1920s, they never recovered their lower pre-war levels between 1909/11 and 1932/34. It was inflated factor prices that prevented freight rates from falling (Figs. 3 and 4), not slow productivity advance. Indeed, TFP growth rates in this period were at least as high as pre-war: TFP growth rates for ENA actually doubled after 1909/11, those for Alexandria also rose, and only those for Bombay fell.

However, TFP growth rates between 1923/5 and 1932/4 were much smaller for all three routes than they were between 1909/11 and 1932/4, implying that the First

Table 5
TFP growth in the interwar period

	ENA	Alexandria	Bombay
Distance from UK (Naut. Miles)	3000	3000	6200
1909/11–1932/4			
Average change in nominal freight rates	−1.39%	1%	1.35%
Contribution of			
Wages	−100.84%	54.55%	42.07%
Ship prices	−268.9%	145%	112%
Coal prices	−53.4%	27.1%	26.8%
Average TFP change	2.83%	1.27%	1.05%
1923/5–1932/4			
Average change in nominal freight rates	−3.61%	−1.39%	−1.57%
Contribution of			
Wages	1.98%	5.17%	1.87%
Ship prices	48%	124%	45.2%
Coal prices	23.43%	72.3%	28.3%
Average TFP change	0.96%	−1.4%	0.95%

Sources: Appendix 3 (see footnote 8) for Factor Prices. Factor shares are as follows: Coal 28.6%, Capital costs 57.1%, Wages 14.3%. Port costs and other factors have not been included for lack of data. See Appendix 3. Homeward Bombay–UK freights for 1923/5 are for wheat, and for 1932/4 for Marmagao (ore/manganese). Coal freights are for Port Said; see section on joint-production for explanation.

World War induced substantial—but temporary—improvements in productivity, no doubt due to full capacity demands in wartime. Had TFP growth rates from the First World War been maintained in the interwar period, nominal freight rates would have been able to overcome the rise in factor prices and real freight rates wound have demonstrated a clear downward trend.

4. Explaining productivity gains

The revolution in shipping technology has been recounted many times (e.g., Pollard and Robertson, 1979, pp. 9–24). This revolution rested on two developments: the decrease in iron, and later steel, prices that made economical the introduction of new metallic hulls in ship construction in the second half of the 19th century, and the advances in engine technology that saw vast increases in fuel efficiency. These changes were related to changes in the metallurgical, chemical and engineering sciences that spilled over into the shipbuilding industry. The results were lower ship prices for larger and faster ships allowing British firms to wrest leadership in shipping from the Americans by the 1860s. Britain maintained this leadership unchallenged until the First World War, when British ship owners rejected the more efficient diesel engine for the older, trusted steam engine.

How did changes in shipping technology affect the industry? We are told (e.g., Pollard and Robertson, 1979) that iron and steel allowed for larger ships with bigger steam engines that reduced coal consumption and increased speeds. These changes also made it possible to reduce crew sizes, and to take advantage of economies of scale. Given all these benefits, why the big differences in adoption and diffusion between routes?

We have the input data for the period between 1869 and 1913 that will help us seek answers to these questions. Much of the data documenting the quantity of labor used, time spent at sea and in port, the size of vessels and engines on various routes come from the impressive Atlantic Canada Shipping Project (ACSP) dataset constructed recently at the Memorial University of Newfoundland. The ACSP data come from the *British Agreements and Accounts of Crews*, official documents that had to be filled by any British ship whenever a crewmember joined its ranks. The data includes a 1% random sample of all voyages by British ships between 1863 and 1914. The rest of the pre-1890 data utilized here, particularly the coal consumption data mainly come from Harley, and we have extended these series up to 1913 by scouring contemporary shipping sources. We have much less information about the interwar period, though Sturmey's (1962) study of British shipping was quite useful.

4.1. Cargo capacity (hull weight)

Using ship, steel and iron price data, Harley (1972, p. 311) estimates that average hull weight fell by about 10% between 1870 and 1890. Pollard and Robertson (1979, p. 14) report that the introduction of steel, largely after 1890, reduced hull weights by 15%. Most new ships constructed on the Clyde in 1890 were made of steel. Allowing for the diffusion of steel in the tramp shipping industry, as well as the slight increase in cargo capacity generated by the improvement in coal consumption, it seems likely that two-thirds of this 15% increase in cargo capacity took place between 1890 and the First World War, while the rest took place in the interwar period.

4.2. Crew size

Harley (1972, p. 255) admits that his crew size data are suspect.[15] Using the new ACSP data, we can do better. The ACSP reports the number of crewmembers that ships intended to hire for over 4500 individual journeys between 1869 and 1913. After dividing the prewar years into nine five-year periods, we regressed the intended number of crewmembers per gross registered tonnage on the period, the square of the period, the gross tonnage (to take into account ship size) and horsepower per gross tonnage (to take into account the size of engines). The results are statistically significant at the 99% confidence interval. The number of crewmembers per gross registered ton decreased over time, though this fall gradually leveled off. Having more powerful engines increased crew size, possibly because more firemen and coal trimmers were required. The coefficient on gross tonnage is also statistically significant, and negative, telling us that ship operators took advantage of economies of scale by shedding labor per tonnage. We use these regression results to calculate crew sizes along all routes between 1869 and 1913.[16]

4.3. Ship size

We also use the ACSP data to estimate the increase in ship size along various routes. Again dividing the period between 1869 and 1913 into 9 five-year periods, we regress ship size on period, controlling for regions. The regional coefficients on all but West Africa are statistically significant. Furthermore, average ship size increased over time on all routes. There were, of course, pronounced regional differences, with the largest ships being used in the North Atlantic trade.[17] Larger ships were also used along South African and Australian routes. In the Baltic and Spanish

[15] Using figures for total tonnage and total employment in the British merchant fleet taken from the *Trade and Navigational Returns*, he finds average employment per gross registered ton for every year. He then uses these figures in his productivity calculations. His method does not control for the size of ships and engines, both of which varied by route.

[16] Crew sizes differed somewhat by route, as contemporary accounts inform us. Certainly the composition of the crew differed by route. A large segment of the British tramp ship labor force was comprised of Asians (known as "lascars" in contemporary accounts) from South and Southeast Asia, hired primarily on Indian ocean routes because they were better able to withstand the tropical heat. However, a crew size regression with regional controls was not statistically significant.

[17] Harley (1989, pp. 153–4) tells us that North Atlantic tramps competed fiercely with large liners for grain freights, explaining the larger tramp ship sizes along this route.

trades, smaller vessels were used, lending support to the contemporary literature's description of the former as a backwater for older vessels.

4.4. Coal consumption

Harley (1972, p. 273) uses well-respected contemporary engineering sources to conclude that coal consumption was reduced from 2.1 to 1.6 lbs per Indicated Horse Power per hour (IHP) between 1871 and 1885. Henning and Trace (1975, p. 365) tell us that coal consumption fell more slowly thereafter, to about 1 lb per IHP hour in the late 1930s. The quadruple compound engine had not been introduced in 1885, but when it was, it resulted in a significant reduction in coal consumption, to about 1.25 lbs per IHP per hour in 1914 (Pollard and Robertson: p. 20). Harley (1972, p. 261) also provides estimates for the ratio of IHP to Net Horse Power (NHP). NHP was a statistic of engine volume, and the ratio is needed to insure comparability across periods. According to Harley, the ratio increased from 5 in 1875 to 6 in 1885. Cage (1997, pp. 150–60) reports that "typical" tramp steamers of around 4000 gross registered tons bought by Burrell & Sons of Glasgow around 1910 carried engines of about 300–320 NHP. The Hughes (1917, p. 310) handbook, a well-respected shipping manual of the period, estimates that the IHP on the typical ship was around 2000. All of this implies that the ratio of IHP to NHP stood at a bit less than 7 in 1913.

Engine volume for 1869–1913 can also be estimated from the ACSP data by regressing it on gross tonnage, period and square of period. The results are statistically significant at the 99% confidence interval. Engine volumes decreased over time, but increased with ship size, implying that improved engine technology and fuel efficiency allowed a tradeoff between smaller engines and larger ships.

4.5. Time spent at sea

ACSP data reporting days at sea per gross ton were regressed on period, period squared, gross tonnage, horsepower per gross ton and the number of ports visited along the way. The results showed that days at sea per gross ton fell with increasing ship size, implying economies of scale. However, time spent at sea was not falling, holding ship size constant. Along the ENA route, the coefficient on the period variable was positive and significant. Along the Alexandria route, the positive coefficient on the period-squared variable was so large that days at sea per gross ton actually increased by the second period. For the Riga and Bombay routes, the positive coefficient on the period-squared variable was large enough for days spent at sea per gross ton to be increasing up to 1914. Days spent at sea per gross ton would have been decreasing over time only if speed was chosen over ship size. For a route such as ENA, where tramp ships would have to compete with larger liner vessels, it seems that larger ships were always chosen. Voyage charter parties did not stipulate fixed routes or schedules for hired tramp vessels. This implies that there was no premium for speed in the tramp shipping business, which carried mostly low value commodities. Clearly, ship owners would lean toward size rather than speed, as the data confirm for the other routes.

4.6. Port turnaround times

The ACSP data were also used to determine by regression time at port. Days in port per gross ton decreased with increasing ship size, implying economies of scale. However, for the port of Antwerp, the coefficient on the period variable was positive. For Bombay, Alexandria and Riga, the period-squared variable was positive, and large enough for time at port per gross ton to be increasing by the fourth period, implying that technology may not have kept up with the increasing volume of trade at every port.

4.7. Explaining TFP growth in the age of steam

The ACSP data allow us to say something about the components of productivity growth during the age of steam. True, the total factor productivity growth implied by the ACSP data in Table 6 does not always reproduce the calculations of the previous section, but we only use Table 6 to identify which forces accounted for most of the pre-war productivity advance along four major routes, not to get another estimate of aggregate TFP growth.

In the first two decades (1871/3–1887/9), increasing ship size contributed significantly to total factor productivity growth, ranging from about a quarter along the Bombay route to about a third along the ENA and Alexandria routes. Increasing ship size contributed to about half of TFP growth along the Riga route. We have already alluded to the increase in vessel size along Baltic routes as ship size

Table 6
Explaining TFP growth before World War I

	ENA	Alexandria	Riga	Bombay
A. 1871/3–1887/9				
Contribution to TFP growth				
Ship size	30.8%	32.5%	59.4%	25.9%
Relative to contribution of ship size				
Load capacity	1.98	1.20	0.51	1.01
Coal consumed	0.44	0.38	0.27	0.45
No. of Seamen	1.09	0.55	0.16	0.48
Time at Sea	−0.62	0.06	0.26	2.93
Time at Port	0.48	0.84	0.33	1.47
B. 1887/9–1909/11				
Contribution to TFP Growth				
Ship size	28.4%	76.1%	86.62%	47.98%
Relative to contribution of ship size				
Load capacity	0.76	0.50	0.26	0.46
Coal consumed	−0.12	−0.27	0.40	−0.24
No. of Seamen	0.17	−0.02	−0.22	−0.03
Time at Sea	−0.28	−0.24	0.09	−0.80
Time at Port	1.17	0.39	−0.21	−0.22

Sources: See text. The calculations can be found in Appendix 4 (see footnote 8).

converged to the British fleet average, and Table 6 confirms its importance to TFP growth. The increase in load capacity contributed about the same to the increase in productivity. This was particularly true of the ENA route (60.9%), where vessels were so much larger. Scale economies made possible reductions in crew size, a force that accounted for a tenth to almost a third of productivity growth. As predicted, the strongest effect (33.6%) was along the ENA route, plied as it was by the largest ships.

There seems to have been a tradeoff between size and speed along some routes, particularly ENA. For Bombay, the sharp decline in voyage time was no doubt facilitated by faster passages through the Suez Canal. The fact that coal consumption decreased along this route, supports this hypothesis. Had speeds increased at the rate that would have created the observed drop in voyage time, coal consumption would likely have increased. Decreasing coal consumption on all routes contributed to about a tenth of the productivity increases in this period. In any case, the big surprise is the major decrease in port turnaround times. For the Bombay and Alexandria routes, its contribution to productivity growth was almost as high as the direct effect of the increase in ship size.

For the second two decades (1887/9–1909/11), the causes of TFP growth are less uniform, although rising ship sizes and load capacity are still dominant forces. Indeed, the increase in ship size contributed even more to the growth on three routes: for Riga and Alexandria they contributed between 76 and 86% of the increase in TFP, and for Bombay about half. The effect along the ENA route decreased only a little, from 30 to 28%. The contribution of improved load capacity was similar to the previous periods, except along the ENA route. Gains from improved fuel efficiency fell between the first and second periods before the War. In the shorter Baltic route, coal consumption still managed to fall due to improvements in engines. In the longer routes like Alexandria and Bombay, however, the tradeoff between coal consumption and ship size favored the latter. Ship speeds seem to have decreased considerably as well. On the Baltic and Bombay routes, increased ship sizes led to increases in port turnaround times. On the other routes, it seems that ports were able to keep up with the demands placed upon them by larger ships carrying larger loads. Labor savings did not contribute prominently to TFP growth.

The results for the period immediately before the First World War suggest explanations for the discrepancy between the ENA and Alexandria interwar TFP growth (Table 5). Perhaps the port of Alexandria could not keep up with increasing ship size. Improvements in steam engine technology had slowed down by the First World War, and as we have seen, even before the War, steam technology could not keep up with increased ship sizes on some routes. The new diesel technology held promise, but British ship owners were slow in adopting the more efficient diesel engine for reasons that are hotly debated in the shipping history literature. Griffiths (1995, p. 318) has drawn a connection between negative perceptions of the diesel engines by many industry leaders and their sympathies for the faltering giant coaling industry. He notes that industry leaders believed that British domination of long-range coal exports contributed significantly to its pre-war dominance in long distance shipping. Griffiths than argues that prior dependence on cheap coal freights led to a slow adoption of diesel technology. If Griffith's argument is correct, ship owners on the ENA route would let go of their old ways more easily since that route was less dependent upon the transportation of coal (Harley, 1972, p. 318). Tramp ships along the ENA route had to compete fiercely with liner companies for freights on bulk commodities. These conditions, not prevalent elsewhere, may have forced ship owners on the ENA route to adopt faster and larger ships as well as diesel engine technology.

The big gap between the lower TFP growth rates over the years 1923/5–1932/4 and the higher rates over the longer period 1909/11–1932/4 need explanation. The discrepancy implies that the First World War saw very sharp increases in TFP growth, and that these transitory rates were not only unsustainable, but even reversed in the interwar period. Sturmey (1962, p. 51) informs us that war profits in tramp shipping were high, even taking into account higher insurance and replacement costs. The need for quick delivery of war material implied a push for fast turnaround times, a price the market was willing to pay in a wartime cost-plus environment. Faster and larger ships would also have minimized the time spent at sea exposed to enemy attack and to maximize the amount that could be carried per journey. The ship's capacity would also be pressed beyond free-market optimal levels during wartime when governments were willing to pay very high prices for the fastest delivery possible. The influx of speculative capital (Sturmey, 1962, p. 53) would have allowed ship owners to purchase more advanced steam technology, when previously they had opted for less advanced but cheaper ships. The collapse of speculative profits at the end of the war, and in the decline of global trade in the interwar period reversed the productivity advances of the war period. With the break in ship prices in 1920, British ship owners over-invested in second-hand ships, hoping that the boom in freights would continue (Sturmey, 1962, p. 58). The interwar period was "troubled" (Sturmey, 1962, pp. 61–97) by idle tonnage. These low-capacity handicaps were imposed by nationalistic policies of foreign competitors, by the inability of British ship owners to take advantage of new trades—such as tankers, and by their inability to exploit new technologies—such as diesel engines, either due to lack of capital or to technological conservatism.

5. Conclusion

Revisiting the Isserliss index confirms that nominal and real tramp shipping freights did fall drastically in the period between 1869 and 1913. Indeed, the Isserliss index understates the fall in freight rates in both this and the interwar period. However, our new Global Index masks wide regional variation in the behavior of freight rates in the age of steam. Differences can be explained by joint production of shipping freights, among journey-legs and commodities carried on routes. Freight rates did fall globally, but the magnitude and timing depended on these route-specific factors. They did not just depend on distance.

Linking our Global Index with David Hummels' (1999) research on post-Second World War shipping, we are able for the first time to take a long-run view of oceanic transport costs. The decline in nominal freight rates in the pre- First World War period slowed down in the interwar period, and actually reversed after the Second

World War. Hummels (1999) has shown that even though real freights fall sharply over the half century following 1950 when deflated by a GDP deflator, commodity-deflated real freight rates hardly fall at all. In short, the fall in real freight rates during the age of steam has not been matched in the century since.

Our TFP calculations, explicitly taking into account joint-production, corroborate the results of previous research and confirm that the decline in global freight rates was not driven just by falling input prices. Indeed, while ship prices did fall throughout the pre-First World War period, coal prices and wages actually rose after the mid-1880s. Rapid technological change drove the steep fall in real freight rates before the First World War, and a marked slow down in technological change contributed to the stability in those rates during the interwar years. The intensity of this technological experience varied across routes, based, no doubt, upon different rates of diffusion of new steam technologies.

Not all types of technological change in the shipping industry were equal in their impact. Nor did these changes have a uniform impact across routes. Ship-owners tried to balance the tradeoff between increasing ship size and capacity, increased speeds, lower coal consumption and smaller crew sizes, and route-specific factors determined their decisions. Port turnaround times affected TFP growth as well, and not always positively, since some ports were not always able to keep up with increasing ship size, increasing ship capacity, and trade volume. The literature on the port development and costs is virtually non-existent, and it needs attention.

While David Hummels has examined the post-World War II period in some detail, we feel that more work needs to be done on the interwar period. While the interwar years saw a slow-down in TFP growth in British tramp shipping, the paucity of compiled data on factor costs and quantities has limited our ability to examine the causes of the slow down. Why British tramp shipping—for so long at the forefront of technological innovation—failed to embrace the emerging diesel technology in this period is a question that requires further examination. If the rapid fall in shipping costs, whose causes we have examined here, lies at the heart of pre-First World War globalization, then the interwar deceleration in the fall of freight rates can perhaps help shed more light on the contrasting interwar retreat from globalization.

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