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ABSTRACT

The standard source for pre-WWII global freight rate trends is the Isserlis British tramp shipping index. We think it is flawed, and that its sources offer vastly more information than the Isserlis aggregate contains. The new data confirm the precipitous decline in nominal freight rates before the World War I, but it also extends the series to the 1940s. Furthermore, our new series is linked to the post-World War II era (documented by David Hummels), so that we can be more precise about what has happened over the very long run. We also create route-specific deflators by using the prices of commodities transported. Previous scholars have deflated their nominal freight rate indices by a price 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. Using the pricedual method and new indices for factor prices, we then calculate total factor productivity growth pre-war and interwar for five global routes. Finally, we identify the sources of the total factor productivity growth.

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I. Introduction

The period between 1850 and the First World War saw increasingly integrated global commodity markets. Economists commonly use the trade-to-GDP share to demonstrate this trend (Maddison 1995), but this index can be very misleading. After all, outward shifts in import demand or export supply can also lead to trade expansion even in an anti-global policy environment. A better measure is the narrowing of price differentials between markets. That pre-war agricultural and non-agricultural prices did indeed converge within Atlantic markets, within non-Atlantic markets, and between them has been shown in a number of recent works (Harley 1980; O'Rourke and Williamson 1999; Williamson 2002; Findlay and O'Rourke 2002). While integration was hindered by tariff barriers, world markets were far better integrated just before the First World War than ever before.

Economists have mistakenly concentrated on trade policy to explain this globalization trend prior to the First World War. Albert 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 (Coatsworth and Williamson 2002). 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.

This paper focuses on the developments in the British tramp shipping industry up to the Second World War. There is already enough published material to show that freight rates declined precipitously before the First World War (Isserlis 1938; North 1958, 1965, 1968; Stemmer 1989; Harley 1980, 1988, 1989; Fischer and Nordvik 1986; Yasuba 1978). This paper fills in some of the gaps from a well-known source (Angiers) that has been incompletely mined. It also replaces the famous but, we think, flawed Isserlis (1938) global tramp shipping index, the standard source on global freight rate trends. In addition, the paper also fills a gap in the shipping literature for the 1920s, 1930s and 1940s, decades that saw policy-induced de-globalization. Finally, our global index is linked to that of David 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. Douglass 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. Knick 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.

[1] Harley has not been alone. Yasukichi 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.

II. Freight Rate Indices

The Need for New Indices

It is surprising that the Isserlis global freight rate index has remained the standard source on global freight rates for 1869-1936 given that 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 Isserlis 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). Isserlis 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 Isserlis index, however, lies with the way the data were aggregated[3] and with the deflator used to convert from nominal rates. We think it is time to return to Isserlis' original source and reconstruct the global index.

The Angier Data

Isserlis 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 Isserlis 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 Isserlis, they can be found in Isserlis' 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

[3] Isserlis 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

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 Isserlis 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* included 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.[4]

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.

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rebased this chain index in a single year, 1869. There are significant problems with this method of construction. See Appendix 1.

[4] There are over 8,000 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 unites. These too were standardized by combing through Angier's reports, the contemporary shipping literature, and the *Oxford* dictionary.

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, 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 sixty-four pounds per cubic foot or displaces thirty-five 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."

Thus, freight rates for commodities with different stowage factors behaved very differently, and they responded very differently to changes in shipping technology. Because the tramp shipping industry was competitive and because the time charter party was part of it (e.g. shippers could take any commodity the ship would carry), freight rates for commodities with similar stowage factors behaved similarly. Thus, we construct our regional indices 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) 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. The results are plotted in Figures 1A and 1B.[5]

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 Isserlis index with our new Global Index makes a difference. The new index (Figures 1A and 1B) falls faster than the Isserlis index before and after 1884, suggesting that Isserlis understated the fall in freight rates. After the War, Isserlis again understates the fall in global tramp freights.

Important differences in the behavior of tramp freights in different regions emerge when the regional freight rate indices are examined. 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 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

[5] Details on the construction of the route and "global" indices are supplied in Appendix 2.

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% in this period. 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 Baltic freights 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 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 only slowly in the interwar period. It was only around 1933/4 that nominal freight rates fell to 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.

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 our purposes since it includes non-tradables and many tradables not carried on all routes. As an alternative, we constructed route-specific deflators by taking the unweighted average of the prices of the commodities included in the commodity-routes. Both our preferred real indices and the Sauerbeck deflated indices are discussed in Appendix 3.

Figures 2A and 2B illustrate the impact of the deflators by plotting both 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 index deflated by Sauerbeck. Deflating by Sauerbeck thus understates the fall in real transport costs. The difference is less pronounced in the ENA-grain route, perhaps because wheat prices get a large weight in the Sauerbeck index.

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. Figure 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.[6] The nominal freight rates seem to trace out a U-shaped pattern: while the pre-World War I decades saw a continuous fall in nominal freight rates, the trend was reversed during the war years; and while the pre-war nominal freight rates were briefly recovered by the middle of the great depression, they have traced out a trend rise ever since. However, these nominal series need to be deflated by commodity prices. We do so in Figure 4 where the trend in real tramp freight rates is documented for over 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.

[6] Appendix 2 explains exactly how these indices are linked.

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 (Figure 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 Figure 4 are, after all, deflated by commodity prices. The key, therefore, to long run trends in freight rates was and is total factor productivity growth. Any retardation in the fall in freight rates plotted in Figure 4 must reflect a slow down in the rate of productivity advance.

III. Total Factor Productivity Growth

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

$$A^{*} = P\mathrm{i}^{*} - P\mathrm{f}^{*} = Q^{*} - Q\mathrm{i}^{*} \qquad (3.1)$$

where A is total factor productivity, Pi is an index of factor prices weighted by factor shares, Pf is the freight rate index, Q is the quantity index of outputs (i.e. amount of goods carried), and Qi 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 not unreasonable, 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 (1988; 1985; 1989; 1990), we depart from North's 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 legs of journeys. 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 have to return to their homeports for repairs and to return their crews. The simplest case is where demand and marginal cost are the same on both legs. Given the competitive conditions of the tramp shipping industry on any route,

$$Ph = MCh = ATCh \qquad (3.2)$$

$$Po = MCo = ATCo \qquad (3.3)$$

where P is the freight rate, MC is the marginal cost of undertaking the voyage, ATC is the average total cost for each unit space or weight of the carried good, h denotes the homeward journey, and o the outbound journey. It is not necessarily true that the more full the ship, the lower the average total cost. Filling a ship beyond a certain level may undermine stability or increase the average fuel cost, and this level may be defined as full capacity. Of course, in competitive equilibrium, ships would be filled to this full capacity. Given all of these assumptions, freight rates in both directions would be equal, and to the marginal cost along each leg.

Now suppose that the demand for shipping in the two directions is different, as would be the marginal costs of the voyage. In the 19th and early-20th centuries, Britain was the primary supplier of much of the world's coal used as bunker fuel, and the cost of bunker coal thus increased the farther one was from Britain. Fuel costs on the voyage back to Britain were higher than on the outbound voyage. Marginal costs could also have been different because crew costs were different in the two directions. 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 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* to or at their destination. Likewise ships and crewmembers could agree to part company at low-wage ports of call along the journey.

If freight rates in the two directions were determined separately, we would expect that competitive pressures would have driven freight rates on each leg to the point where they would equal marginal cost per unit space or weight (and average total costs) for that leg. The demand and freight rate for shipping on the two legs would have been equal only by chance. Assuming that the demand for shipping on the homeward leg exceeded the demand on the outbound leg, one of two cases would have arisen, given that the supply of shipping in the both directions had to be equal. If the entire demand for shipping on the homeward leg was met by supply (at some competitive freight rate), then there would excess supply available on the outbound leg. Thus, some, if not all, ships plying the homeward route would be filled to less than full capacity, and the cost of carrying these goods would not be covered for these ships. In long run competitive equilibrium, ships making losses would leave the route. Then, the entire demand on the homeward route would not be met, and there would be a shortage of shipping space in the outbound route. Alternatively, suppose the entire demand was supplied by shipping space on the outbound route. In this case, there would be a shortage of shipping in the homeward direction, and we would see shippers bidding freight rates up. Freight rates would exceed the marginal cost of making that leg of the voyage. Thus ships on the homeward route would be making excess profits.

However, barriers to entry on any route were insignificant in the long run. Ships setting freight rates on the two legs jointly could still earn profits on the journey as a whole. If <u>x</u> were the profit per unit earned by the ships on the homeward direction, a profit could be earned by setting freight rates in the following manner:

$$Ph = MCh + ax \qquad a<1 \qquad (3.4)$$

$$Po = MCo - abx \qquad b<1 \qquad (3.5)$$

Ships setting freights separately would have to lower rates to get any cargo. Again, given the absence of barriers to entry, ships could take away all business on the outbound route from these ships charging rates according to (3.5) by further lowering the freight rate by setting a new b, denoted b* such that 1<b*<b in equation 3.5. The argument can be repeated so that in the competitive equilibrium, b will in fact equal 1. Thus Po = MCo – ax.

As long as demand for shipping in one direction is greater than demand in the other, ships will continue to face inelastic demand on the voyage leg with greater demand. The argument above can be repeated, until at the combination of rates Ph* and Po* where the demand in both directions will be equal. By the argument here,

$$Ph^* = MCh + x^* \qquad (3.6)$$

$$Po^* = MCo - x^* \qquad (3.7)$$

Obviously, Ph* + Po* = MCh + MCo, which will be equal to the average total cost of the journey taken as a whole. No profits are earned for the journey taken as whole and marginal costs on both legs are just covered even though the freight rates do not equal marginal (and average total) costs on either leg of the journey.

Finally, there is a possibility that demand on the outbound leg will be lower than demand on the homeward route no matter what the freight rates are. When the freight rate is zero on the outbound route, demand for shipping is infinite. Ships have the option of either taking the cargo for free, or undertaking the outbound voyage in ballast. Since there are costs associated with loading and unloading cargo, ships may prefer to travel in ballast, since loading and unloading ballast was generally less expensive than handling cargo. If some ships do decide 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 roundtrip voyage less the marginal cost of carrying outbound cargo. Total costs of the journey still equal total revenue.

Two minor adjustments complete the analysis. First, in the long run, owners will want to use their ships with "optimal" qualities fitting the specification of the trade and the route so that the cost of operation is minimized. Costs included the interest paid on the price of the ship. Larger, faster and more specialized ships were more expensive to build. This tradeoff 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).

The second adjustment is only cosmetic, and it has to do with our assumption that all ships originated from a single homeport. The competitive conditions still hold even if ships originate at different homeports at the two ends of the shipping route, given the need for ships to return to their origins. The sum of the freight rates on the different legs will still equal the sum of marginal costs. Thus, changing this assumption would only require changing the wording of the exposition here.

The analysis 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 of the journey. 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.

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 our analysis above demonstrates, 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.

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.[7] First, we redid Harley's calculations for the period between 1871-3 and 1887-9 using much improved factor price data, in particular new wage and coal price data (Appendix 3). Second, we extended the calculations to 1909-11. 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 freight rates can be explained by the decline in 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

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

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 his inclusion of the unusual years 1874 and 1890 in the 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.

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 growth rates similar to those along the Bombay route, where rates had been maintained.

The availability of outbound coal freight rates for Alexandria and North America make it possible to extend these calculations up to 1932-4, 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 conduct 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. Thus, even though post-war nominal factor prices declined, they never recovered their pre-war levels in the 1920s. It was the inflated factor prices that prevented freight rates from falling, not slow productivity advance. Indeed, interwar TFP growth rates 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.

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 World War induced substantial – but temporary -- improvements in productivity, no doubt due to full capacity demands in wartime.

IV. 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 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.

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.

Crew Size

Harley (1972: p. 255) admits that his crew size data are suspect.[8] Using the 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 regressions results to calculate crew sizes along all routes between 1869 and 1913.[9]

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

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[8] 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.

[9] 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.

trade.[10] Larger ships were also used along South African and Australian routes. In the Baltic and Spanish trades, smaller vessels were used, lending support to the contemporary literature's description of the former as a backwater for older vessels.

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.

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[10] 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.

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.

Port Turnaround Times

The ACSP data was 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.

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 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 to 1932/4 and the higher rates over the longer period 1909/11 to 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.

V. Conclusion

Revisiting the Isserlis index confirms that nominal tramp shipping freights did fall drastically in the period between 1869 and 1913. Indeed, the Isserlis index understates the fall in freight rates in both this and the interwar period. Our new global index however 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 exact behavior of rates depends on these route-specific factors, not just distance.

Deflating regional indices constructed here by actual commodities carried on these routes rather than by the Sauerbeck index that includes non-tradables and tradables not carried on these routes also makes a difference. The Sauerbeck-deflated indices often understate the fall in real transport costs in this period.

Linking with David Hummels' (1999) research on post-Second World War shipping, we are for the first time able 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 is 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 freight rates during the age of steam has not been matched 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-1880's. 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 ports did not always keep up with increasing ship sizes and capacities. 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.

Appendix 1: Construction of the Isserlis Index

Implicitly, Isserlis assumes the following statistical process for the movement of any commodity-routes freight rates:

$$F\text{xn}/F\text{xn-1} = A(\text{x,n}) + U\text{xn} \qquad \text{(A1.1)}$$

where Fxn and Fxn-1 are freight rates in the nth and n-1th year respectively for route x. A(x,n) is some route- and time-specific function formed from the set of conditions that caused freight rates to change year to year. Uxn is a random error term distributed around 0 and it is introduced because Isserlis Fxn and Fxn-1 are really the simple arithmetic averages of the highest and lowest freight rates made available to Isserlis from the Angier data.

Isserlis then takes the average of all the commodity-route chain indices available for each year. Thus the global freight rate chain index for the year n+1 relative to the year n is:

$$G\text{n+1} = [\Sigma A(\text{x,n}) + U\text{xn}]/k \qquad \text{(A1.2)}$$

where k is the number of commodity-route ratios that are available for that year. Isserlis then implicitly uses large sample averages to claim that ΣUxn goes to zero. He is thus left with:

$$G\text{n+1} = \Sigma A(x,n)/k \qquad \text{(A1.3)}$$

To derive an index based in the first year in the dataset, one would of course use the following:

$$In+1 = \Pi\ Gi \qquad \text{(A1.4)}$$

where In+1 is the index entry for the year n+1 based on the level of freight rates in the year 1. The index can then be rebased in any single year.

A number of problems with this method of construction are immediately obvious. First, for Gn+1 to be representative of the level of global freight rates relative to rates in the previous year, the sample of commodity-routes included in the years average will have to be representative of the distribution of global trade in shipping. Isserlis makes no attempt to confirm this. Second, Isserlis' implicit invocation of large sample properties seems inappropriate. The largest number of observations Angier has in any year is around seventy (not all of whom have corresponding entries in the previous years). In early years, sample sizes are around thirty. In some years, sample sizes are around fifteen or twenty. For the First World War years, sample sizes hover around ten.

Small sample sizes may lead to a bias in the final index because ΣUxn does not go to zero. Because of the way that Isserlis' final index is derived, if this bias exists in any year, it persists in all subsequent years, and is even multiplied. Suppose Cn is the correct index entry for the nth year, and bn is a bias. Then, in the chain index:

$$Gn = Cn + bn \qquad \text{(A1.5)}$$

In Isserlis' final index, the entry for the n+1th year is:

$$In{+}1 = \Pi(Ci+bi) \qquad \text{(A1.6)}$$

Thus if $bi \neq 0$ for all years before n+1, the bias persists in all subsequent years, and even increases, as it is multiplied with the index entries in the subsequent years.

Finally, for the index to preserve the long-run behavior of global freight rates, the method in which the index was constructed requires that freight rates on different commodity-routes move more or less similarly to each other from year to year. This is easy to verify. Suppose there were two freight rate series, both of which started at the same level and ended up at the same level at the end of two years, but one of which had the fall taking place in only the first year and the second seeing the fall in only the second year. Obviously, the final freight rate index constructed *a la* Isserlis would not preserve the long run movement of these two freight rate series. In fact, the aggregate index, in this case, would have fallen slower at the end of two years than either series used in its construction. This problem is only compounded by the fact that Isserlis deals with quite small samples. Freight rates were extremely volatile, and it is unreasonable to assume that they would move lockstep with each other. Clearly, Isserlis' index must be replaced.

Appendix 2: Construction of the Regional and Global Freight Rate Indices

Angiers 1869-1950

The Angier dataset was broken up into smaller regional datasets based upon the location of ports and the availability of data. Wherever possible, ports that were included in a region were not separated from each other by more than 10% of the distance from Europe.[11] We also separated outbound from homeward routes. Consulting contemporary sources that reported commodity stowage factors, we identified commodities with similar stowage factors for each region.

Starting with the first year in this restricted regional dataset, we took a segment of the dataset covering all years in which the freight rates for the same commodity-routes were quoted. We then took the simple average of these quoted freight rates for each year, and formed an index from these averages. We then took the year that immediately followed the last year in the first segment, and formed a new segment covering all years which contained the same commodity-routes. Again, we took the simple average of the freight rates quoted for each year, and formed an index from these averages. If the first and second segments had some commodity-routes in common, we linked them in the following manner: We first take the simple average of the freight rates on the shared commodity-routes in the last year of the first segment in which this overlap takes place. We mark this as *A*. We then take the simple average of the freight rates on the shared commodity-routes in the first year of the second segment in which this overlap takes place. We mark this as *B*. We rebase the second segment index in *B*s year. We form the ratio of *B* to *A*. We multiply all the entries in the rebased second index with this ratio. This rebased second segment is then grafted to the first segment to form an index covering the full period.

[11] For two regions out of seventeen – East Asia (comprising of the Philippines, Japan and China) and West Africa – data limitations forced us to violate this condition.

If the first and second segment have no commodity-routes in common, we form a third segment with all years where the freight rates of exactly the same commodity-routes as the year immediately following the last year of the second segment were quoted. We form a index for this segment in the same manner described above. We then see if the segment shared commodity-routes with the first segment. If so, we link the first and third index in the manner described in the last paragraph. To link this combination index formed from the first and third segment indices ("first-third combination index") to the second segment index we first link the second and third indices in the manner described in the last paragraph (to form the "second-third combination index"). We rebase the second-third combination index in the year (call it year *X*) in the third segment that was used for linking the third segment to the second segment. We then multiply all entries in this rebased second-third combination index with the entry for year *X* in the first-third combination index.

Obviously, if the first, second and third segments do not share commodity-routes, the procedure can be repeated until segments with some overlapping commodity-routes are found. Of course, the procedure does not guarantee that each segment with have overlapping commodity-routes with some other segment. If this happens, we are forced to find new freight rate data that will allow us to carry out the linking.

Note that it does not matter what year within segments is taken as the base year. The ratio of the average of nominal freight rates at any year to the average of nominal freight rates at another year within the segment is preserved independent of the choice of base year. We are thus able to rebase segments at the linking years and not introduce any biases. To link across segments, it is assumed that had Angier been consistent in his choices of commodity-routes, the missing data would not substantially change the ratio of the average nominal freight rate in one segment's linking year to the average nominal freight rate for another segment's linking year from the ratio calculated from the incomplete data. The competitive nature of the tramp shipping industry and the fact that we are including routes where only commodities with comparable stowage factors were carried allow us to feel somewhat comfortable with this assumption.

Our global index of long distance tramp freight rates between Europe and the rest of the world requires us to weight the different regional indices according to the importance of trade to and from that region. We use the *Board of Trade* figures (Mitchell 1992) to compute the value of trade between Britain and the different regions in the dataset, and find the percentage of total trade to these regions to Britain being carried from individual regions. These percentages formed the weights for the homeward routes. For outbound coal freights on various routes, the limitations of the Angier data forced us to take the simple average of available indices of coal freights along the routes. The outbound coal freight and the homeward freight indices were then aggregated taking their simple average.

Linking Angiers with the Post-WW II Era

The Norwegian Shipping News (NSN) index for tramp voyage charter party freight rates reported by Hummels (1999) is based in 1947, but has a gap between 1947 and 1952. Since our Angiers-based global freight rate index has an entry for 1945-49, the NSN index can be easily linked to it. To fill the gap between 1947 and 1952, the Italian freight index reported by Sturmey (1962: p. 179) is used.

Even though the three indices used here relate to tramp shipping from different countries and are weighted up differently, they are highly correlated. Hummels (1999: p. 27) reports a correlation of 0.87 between British and Norwegian charters rates, and we computed a correlation of 0.99 between the Italian and Norwegian indices.

Appendix 3: Deflated Regional Freight Rate Indices

Table A3A: Non-Atlantic Routes Deflated by the Sauerbeck Index

Table A3B: Atlantic Routes Deflated by the Sauerbeck Index

Table A3C: Non-Atlantic Routes Deflated by Commodity Prices in Britain

Table A3D: Atlantic Routes Deflated by Commodity Prices in Britain

Appendix 4: Productivity Growth Calculations

Wages

Nearly a century after they were compiled, Bowley's indices of income and wages remain standard sources for the late-19th and early-20th century Britain.[12] Bowley included in his work a wage index for British able-bodies seamen (ABS) covering the years between 1870 and 1890. The information is taken from 11 voyages started each from year from each of the major ports in Great Britain. Harley used this index in his productivity gains calculations. For the period between 1890 and 1913, the Board of Trade collected wage rates for various classes of seamen. It is easy to construct an index of wage rates for seamen by taking unweighted averages (i.e., fixed weights) of wage rates for various classes of seamen.

However, crew composition must have changed drastically in this period. Due to economies of scale and increasing steam engine efficiency, the number of ABS, firemen and coal trimmers would have decreased. The share of officers in the crew would thus have increased, as the number of officers would have remained more or less fixed. Given the fact that officers were paid more than ABS, Bowley's index would have overstated the fall in average crew wages. It is easy to see that taking an unweighted average of wage rates for the various classes of mariners does precisely the same thing.

The Atlantic Canada Shipping Project (ACSP) at the Memorial University of Newfoundland has compiled a 1% random sample of *British Agreements and Accounts of Crews* between 1863 and 1913. These were official documents mandated by law and were required to be completed whenever a crew signed onto a ship, regardless of the port. The documents included such information as ship and voyage details, as well as rank and personal information of individual crewmembers, including the wage rates agreed upon by them. Overall, we have information on about 80,000 seamen of all ranks in this sample. Taking the simple average of wage rates for all seamen – regardless of rank – in a particular year and forming an index from these averages improves upon Bowley's and Feinstein's in two ways.

First, the index does not depend solely upon wages quoted in major British ports. True, the crew on British vessels was mostly hired in Britain, and hiring most of the necessary crew in one location was more efficient than stopping at a number of ports to add crewmembers and incurring associated costs. Large ports like Liverpool and London were also centers of the shipping labor market, but expanding the wage estimates to include non-British seamen hired in non-British ports is a significant improvement. Second, taking a simple average of wage rates for all seamen takes into account changing crew composition. As crew composition changes, the number of observations for each rank relative to the total number of observations for that year in our sample also changes. In effect, the simple average of wage rates is weighted, according to crew composition. The wage rate index created does not have a fixed-weight bias toward the wages for a particular rank

The ACSP sample ends in 1913. For the period between the two World Wars, we turn to Chapman's average earnings data collected from the *Annual Yearbook of the National Maritime Board* (summary of Agreement) and the quinquennial censuses of seamen. This index is a weighted average of monthly rates for various ranks of seamen, and controls for different sizes of vessels. The wage rates reported do not include overtime pay.

Cost of Capital

The cost of capital in each period was calculated from the following formula:

$$CKt = PKt\ (r + d)$$

[12] Feinstein (1972) improved on these data recently by revisiting Bowley's sources.

where CKt is the cost of capital in time t; r is the interest rate; d is the rate of depreciation; PK is the price of the ship per gross ton in that period. As has been standard in the literature, we assume that r and d remain unchanged in this period.

A number of studies have examined ship prices in the age of steam. We use data from Harley (1972: pp. 250-57) to estimate average ship price per ton for the period between 1871 and 1889. Pollard and Robertson use data from *Fairplay* magazine to trace the price of "representative" ships in the period between 1887 and 1913. It is unclear to what degree the Pollard-Robertson index controls for increasing vessel size, but we assume that it represents ship prices per gross ton, with a standard engine attached, allowing for changes in engine quality. For the interwar period, we use the Maywald index of British ship prices, also used by Feinstein (1972: p. T137) in his construction of an index of British capital expenditure.[13]

Price of Coal

Ideally, we would have liked to have taken into account the price of coal at bunker (refueling) ports on each route. However, reliable bunker coal price series are unavailable. Instead, we construct a bunker coal price index in two steps. First, we take the sum of the freight rate for coal shipped to the destination and the average price of British exported coal (reported by Sauerbeck) as a initial proxy for the price of bunker coal. Second, the initial bunker coal proxy price index is then multiplied by 1.25 to take into account port costs during refueling.

Port Charges

Urquhart published a review of charges and dues in non-British ports regularly in the second half of the 19th century. This work was continued by Ritherdon in the first half of the 20th century. While these publications suggest that port charges per gross registered ton may have

[13] Both Pollard-Robertson and Harley note serious problems with this index, especially since it does not control for the increasing complexity of navy ships whose prices Maywald used to construct the index.

fallen over the period, it is difficult to say by how much. Therefore port charges are ignored in our TFP calculations.

Factor Shares

We use Harley's (1972: p. 312) estimates of factor shares for the period between 1869 to1890. These were mined from contemporary sources. Roberts (1947: p. 297) presents the shares of various inputs in coal-burning steamers in the early 1920s. These factor share estimates are comparable to Harley's for the late 19th century. Griffiths' (1995: pp. 323-26) reports of operating costs in 1922 and 1926 agree with this assessment. Fayle's comparative figures for a ship voyage from Cardiff, to Algiers, New Orleans and Rotterdam in 1913 and 1920 also suggest that it is reasonable to use Harley's factor share estimates for the period between 1890 and 1913 as well as for the 1920s. These factor share estimates are presented in table following:

Factor Shares (%)

Capital Costs (interest, depreciation, repairs)	40
Fuel Costs (Coal)	20
Labor Costs (Wages + Provisions)	10
Port Charges	25
Others	5

These factor shares are used as fixed weights for the entire period in the productivity calculations.

Appendix 5: Explanation of the TFP Growth Calculation

The explanation for TFP growth using quantities of factors used is derived as follows:

$$A^* = Pi^* - Pf^* = Q^* - Qi^*$$

where A* is the percentage change in total factor productivity, Pi* is the percentage change in the index of factor prices weighted by factor shares, Pf* is the percentage change in the freight index, Q* is the percentage change in the quantity of goods carried, and Qi* is the percentage change in the index of quantities of inputs weighted by factor shares. The percentage change in quantity of goods carried, $Q^* = K^* + F^*$, where K^* is the rate of increase in the size of ships, F^* is the rate of increase in cargo capacity (the load factor).

Given factor shares from the previous appendix:

$$A^* = K^* + F^* - (0.4K^* + 0.2C^* + 0.1L^* + 0.25\, Qt^* + 0.05O^*)$$

where C^* is the rate of change in the quantity of coal consumed on the journey, L^* the rate of change in the quantity of labor, Qt^* the quantity of usage of port facilities, and O^* the quantity of other inputs.

We have figures for the number of seamen and the amount of time spent at sea and port in the voyage, the amount of labor in labor-hours is $L^* = Ln^* + (S+T)^*$, where S is the amount of time spent at sea, T is the amount of time spent at port, $(S+T)^*$ is the rate of change in the length of the voyage, and Ln^* is the rate of change in the number of workers. Similarly, port charges would have been calculated per day spent at port. So the correct quantity of the port input takes into account the number of days spent at port. Port usage thus changes at the rate of $QT^* = (QT/day)^* + T^*$. It is assumed that Qt/day and O are directly proportional to the ship size and load factor.

Similarly, coal consumption figures are per hour. Coal is assumed to have been consumed only at sea, and $C^* = (C/day)^* + S^*$. Similarly, the price of capital is expressed per unit time. Thus,

$$A^* = 0.3K^* + 0.7F^* - [(0.2C/day)^* + (0.1L/day)^* + + 0.2S^* + 0.25\, T^* + 0.5(S+T)^*]$$

Table A3A: Real Freight Rate Indices Deflated by Sauerbeck - Baltic and Non-Atlantic Routes (1884 = 1.00)

Year	Baltic - Grain	Baltic - Deals	Coal to Baltic	Coal to Genoa	Black Sea - Grain	Alexandria - Cottonseeds	Coal to Egypt	W. India - Grain and General	Bay of Bengal - Grain and similar	Bay of Bengal - Lighter goods	Coal to Colombo	SE Asia - Grain, Sugar
1869	1.421	1.311	1.055	1.244	2.029	1.390	1.536	1.579	1.425		1.168	1.200
1870	1.755	1.547	1.112	1.341	2.163	1.644	1.567	2.222	1.317		1.106	1.121
1871	1.470	1.372	0.877	1.054	2.085	1.629		1.811	1.687	2.076	1.021	1.399
1872	1.360	1.334	1.168	1.045	1.690	1.444	1.316	1.556	1.623	1.531	0.965	1.336
1873	1.506	1.457	0.883	1.107	1.616	1.621	1.309	1.681	1.618	1.726	0.895	1.523
1874	1.433	1.434	0.949	1.196	1.609	1.516	1.369	1.827	1.888		1.078	1.776
1875	1.392	1.361	0.913	1.004	1.562	1.557		1.939	1.755		0.955	1.652
1876	1.563	1.558	1.301	1.021	1.912	1.958	0.985	1.688	1.580		0.913	1.487
1877	1.518	1.423	1.171	1.025	2.072	1.448	1.231	1.663	1.487		0.935	1.528
1878	1.435	1.400	1.096	1.090	1.851	1.372	1.305	1.133	1.115		1.104	1.209
1879	1.318	1.391	1.120	1.141	1.392	1.586	1.189	1.302	1.265	1.573	1.166	1.366
1880	1.184	1.137	1.122	1.140	1.174	1.187	1.290	1.534	1.398	1.795	0.998	1.463
1881	1.334	1.176	1.318	1.098	1.538	1.715	1.185	1.649	1.514	1.729	0.867	1.562
1882	1.311	1.137	1.067	1.038	1.311	2.908	1.080	1.278	1.387	1.360	0.868	1.360
1883	1.371	1.328	1.024	0.979	1.182	0.989	1.194	1.200	1.272	1.393	0.964	1.241
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
1885	1.327	1.233	1.021	0.982	1.153	0.976	0.989	1.052	1.119	1.121	0.970	1.085
1886	1.144	1.255	0.983	1.004	0.974	0.727	1.038	0.965	1.018	0.902	0.940	1.036
1887	1.205	1.333	0.914	1.059	1.315	1.057	1.023	0.958	1.067	0.977	1.045	1.033
1888	1.477	1.669	0.953	0.980	1.621	1.409	1.007	1.053	1.251	1.206	1.306	1.004
1889	1.200	1.455	0.896	1.068	1.305	1.161	1.158	1.073	1.177	1.092	1.074	0.977
1890	0.921	1.173	0.801	0.847	1.127	1.138	0.941	0.980	0.986	0.900	0.855	0.978
1891	1.227	1.321	0.707	0.751	1.465	1.045	0.801	1.049	1.133	1.092	0.479	1.044
1892	0.946	0.995	0.798	0.815	0.970	1.032	0.925	0.899	0.859	0.861	0.110	0.921
1893	1.016	1.137	0.798	0.713	1.038	0.983	0.737	0.682	0.773	0.825	0.794	0.832
1894	0.926	1.130	0.824	0.637	1.108	1.139	0.642	1.023	0.962	1.001	0.613	0.966
1895	1.229	1.349	0.728	0.636	1.028	1.117	0.689	0.925	0.813	1.028	0.649	0.835
1896	1.251	1.292	0.629	0.759	1.335	1.326	0.884	0.660	0.586	0.702	1.047	0.683
1897	1.136	1.208	0.783	1.093	0.977	1.077	0.973	0.817	0.679	0.702	0.970	0.708
1898	1.263	1.318	0.794	0.941	1.080	1.122	1.057	1.461	1.004	0.988	0.915	0.937
1899	1.188	1.347	0.964	0.947	0.906	0.983	1.157	0.964	0.873	0.897	0.855	0.834
1900	1.221	1.534	0.939	0.986	1.064	0.980	1.152	0.879	0.794	0.807	1.084	0.781
1901	0.915	1.112	0.856	0.722	0.848	0.836	0.765	0.752	0.689	0.742	0.748	0.655
1902	0.844	1.019	0.705	0.542	0.812	0.848	0.577	0.690	0.592	0.676	0.663	0.602
1903	0.914	1.132	0.705	0.592	0.791	0.775	0.623	0.789	0.634	0.655	0.578	0.645
1904	0.977	1.059	0.662	0.554	0.721	0.752	0.690	0.817	0.711	0.842	0.534	0.684
1905	0.930	1.126	0.644	0.597	0.816	0.813	0.664	0.719	0.592	0.681	0.537	0.604
1906	0.921	1.106	0.711	0.605	0.708	0.751	0.591	0.659	0.559	0.656	0.587	0.515
1907	0.890	1.035	0.671	0.591	0.653	0.631	0.624	0.677	0.570	0.559	0.483	0.598
1908	0.828	0.958	0.620	0.589	0.575	0.527	0.618	0.493	0.481	0.520	0.587	0.513
1909	0.837	1.026	0.634	0.583	0.594	0.602	0.599	0.683	0.615	0.697	0.433	0.626
1910	0.856	0.981	0.545	0.553	0.710	0.721	0.601	0.628	0.611	0.555	0.474	0.560
1911	0.876	1.110	0.629	0.651	0.712	0.786	0.750	0.730	0.664	0.776	0.560	0.618
1912	0.851	1.366	0.883	0.929	1.129	1.072	0.891	0.893	0.780	0.867	0.620	0.786
1913	0.796	1.223	0.567	0.800	0.738	0.672	0.854	0.714	0.688	0.755	0.567	0.661
1914					0.626	1.013	1.190	0.615	0.571	0.714		0.629
1915		2.393				3.052	3.090	2.092	1.774	1.983		1.452
1916		3.835				5.855	4.603	3.324	2.999	2.960		2.822
1917						4.073	4.980	4.396	5.162	8.036		5.648

Year	Baltic - Grain	Baltic - Deals	Coal to Baltic	Coal to Genoa	Black Sea - Grain	Alexandria - Cottonseeds	Coal to Egypt	W. India - Grain and General	Bay of Bengal - Grain and similar	Bay of Bengal - Lighter goods	Coal to Colombo	SE Asia - Grain, Sugar
1918							7.580			8.214		5.919
1919						2.301	2.204	2.083	1.618	2.001		1.820
1920					1.132	1.060	1.433	1.028	1.119	0.950		0.861
1921					0.987	0.612	0.852	0.624	0.591			0.610
1922					0.521	0.550	0.787	0.546	0.514			0.455
1923		0.907			0.537	0.565	0.668	0.644	0.518			0.501
1924		0.853			0.465	0.561	0.615	0.530	0.528			0.479
1925		0.764			0.452	0.734	0.558	0.518	0.492			0.410
1926		0.918			0.705	1.563	0.664	0.603	0.582			0.450
1927		0.973			0.511	0.916	0.711	0.615	0.615			0.506
1928		0.964			0.422	0.817	0.704	0.575	0.540			0.510
1929		1.125			0.520	0.951	0.700	0.550	0.472			0.412
1930		1.236			0.525	1.030	0.558	0.566	0.457			0.414
1931		1.197			0.590	1.077	0.612	0.701	0.655			0.604
1932		1.070			0.564	1.173	0.617	0.748	0.719			0.602
1933					0.591	1.152	0.576	0.772	0.742			0.597
1934					0.568	1.166	0.619	0.755	0.740			0.591
1935					0.591	0.943	0.740	0.649	0.675			0.525
1936		1.072			0.681	1.616	0.557	0.996	0.904			0.679
1937		1.280			0.908	1.781	0.746	0.975	1.007			0.826
1938		0.985			0.612	1.326	0.570	0.748	0.833			0.655
1939		0.930			0.760	2.310	1.161		1.429			0.982
1940					1.548	3.305	2.601		1.498			1.756
1941							3.586					
1942							3.859					
1943							4.231					
1944							4.102					
1945							2.980	1.563	1.476			
1946					1.146							
1947						1.746		0.740				
1948						1.339	0.712					
1949					0.510	0.936	0.706					
1950					0.711		0.708					

Sources: Angier in *Fairplay*; Coal to Colombo from Jevon (1962) and Angier.
Sauerbeck index was taken from Sauerbeck (various years) in the Journal of the Royal Statistical Society.

Table A3B: Real Freight Rate Indices Deflated by Sauerbeck - 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	Western Mediterranean - Ore
1869	0.875	0.792	1.073	1.668	1.129	1.374	1.398		0.975		
1870	0.749	0.943	0.965	1.136	1.131	1.314	1.255		0.968		
1871	0.890	1.087	0.976	1.137	1.127	1.359	1.059		0.937		1.328
1872	0.857	1.036	0.979	1.180	1.091	3.134	1.459		0.925		
1873	0.894	1.108	1.084	1.082	1.399	1.421	1.619		1.191		1.686
1874	0.915	1.236	1.008	1.179	1.539	1.393	1.569		1.219		
1875	0.982	1.110	0.882	0.728		1.554	1.163				
1876	0.920	1.037	0.855	0.830		1.347	1.342				1.451
1877	0.862	0.984	0.838	0.808		1.367	0.969				1.323
1878	0.854	0.830	0.904	0.797		1.475	1.112	1.133			
1879	0.871	0.918	0.976	0.869		1.355	1.341	1.146			1.034
1880	0.933	0.958	0.933	0.848		1.211	1.493	0.989			1.211
1881	0.989	1.109	0.921	0.810		1.010	2.034	0.946			
1882	1.000	1.253	0.985	0.863		1.181	1.465	1.074			1.231
1883	0.905	0.953	1.013	0.914	1.197	1.120	1.107	1.000			1.136
1884	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1885	0.986	0.787	0.933	1.046	1.021	0.984	1.013		1.122	1.048	1.023
1886	0.914	0.768	0.892	1.049	0.973	1.168	0.961	0.971	1.170	1.015	1.044
1887	1.130	0.892	0.987	1.100	0.973	0.969	0.877	0.997	0.961	0.927	1.292
1888	1.078	0.925	1.223	1.616	1.279	1.256	0.947	1.177	1.126	1.163	1.526
1889	1.218	0.984	1.508	1.486	1.407	1.425	0.995	1.184	1.496	1.247	1.357
1890	1.343	1.057	1.122	1.400	0.987	1.242	1.161	0.875	1.242	1.068	1.355
1891	1.628	0.872	0.856	0.629	0.926	1.222	1.105	0.931	1.068	1.003	1.288
1892	1.395	0.446	0.818	0.695	1.002	1.248	0.819	0.824	1.145	1.030	1.134
1893	1.226	0.816	0.783	0.883	0.962	0.992	0.799	0.927	1.159	0.852	1.225
1894	1.390	0.821	0.662	0.749	1.006	1.188	0.895	1.036	1.234	1.016	1.478
1895	1.221	0.707	0.639	0.742	1.038	1.158	1.067	0.902	1.254	1.175	1.397
1896	1.103	0.671	0.814	0.908	1.070	1.422	0.868	0.917	1.274	1.247	1.683
1897	1.014	0.907	0.840	0.894	1.022	1.303	1.017	0.869	1.207	1.180	1.502
1898	1.258	0.990	0.869	0.995	1.141	1.380	0.962	0.970	1.470	1.426	1.636
1899	1.507	0.964	0.614	0.937	1.046	1.116	1.132	0.865	1.265	1.228	1.389
1900	1.168	1.020	0.798	0.813	1.191	1.224	1.218	0.881	1.228	1.365	1.564
1901	0.982	0.851	0.631	0.858	0.962	0.835	1.246	0.658	1.071	0.977	1.239
1902	0.904	0.648	0.555	0.536	0.836	0.673	0.902	0.566	0.919	0.879	1.322
1903	1.037	0.492	0.469	0.810	0.906	0.760	0.603	0.597	0.926	0.839	1.271
1904	1.108	0.655	0.413	0.558	0.797	0.835	0.718	0.541	0.920	0.791	1.164
1905	0.841	0.609	0.488	0.543	0.789	0.854	0.763	0.585	0.855	0.846	1.259
1906	0.743	0.536	0.581	0.554	0.692	0.770	0.769	0.540	0.802	0.702	1.178
1907	0.756	0.435	0.551	0.966	0.762	0.655	0.976	0.525	0.779	0.709	1.075
1908	0.749	0.482	0.477	0.817		0.596	0.853	0.507	0.810	0.714	1.034
1909	0.640	0.541	0.474	0.713		0.587	0.828	0.562	0.750	0.628	1.038
1910	0.608	0.540	0.649	0.699		0.529	0.819	0.549	0.750	0.662	1.082
1911	0.642	0.556	0.736	0.905		0.705	0.939		0.761	0.648	1.114
1912	1.112	0.677	0.803	1.016		0.944	1.130		1.070	0.983	1.277
1913	0.944	0.702	0.677	1.031		0.804	1.130		0.902	0.826	1.100
1914	1.174	0.639	0.607			1.293	0.980		0.852	0.767	1.017
1915	2.469	1.330	1.024		1.827	2.737	1.788	1.798	1.595	0.602	2.145
1916	3.492	2.044	1.399		3.313	3.267	2.477		2.834	0.580	2.387
1917	7.096	2.006	2.231			4.841					3.672

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	Western Mediterranean - Ore
1918	4.567	2.539	0.920								2.699
1919	3.831	2.199	0.683		2.249	1.506			1.374	3.442	1.741
1920	1.805	0.757	0.230		1.509	1.057	1.182		0.899	0.944	1.865
1921	0.905	0.731	0.337		1.235	0.520	0.987		0.963	0.765	1.084
1922	0.848	0.523	0.353		0.816	0.613	0.655		0.786	0.532	1.057
1923	0.696	0.521	0.453		0.813	0.550	0.626		0.776	0.479	1.067
1924	0.761	0.408	0.294		0.770	0.570	0.580		0.732	0.487	0.942
1925	0.582	0.384	0.291		0.716	0.475	0.578		0.715	0.428	0.898
1926	1.037	0.422	0.378		0.756	0.909	0.640		0.612	0.482	1.204
1927	0.897	0.532	0.348		0.897	0.536	0.647		0.830	0.495	0.926
1928	0.776	0.442	0.249		0.803	0.631	0.599		0.719	0.453	0.935
1929	0.680	0.447	0.250		1.011	0.505	0.563		0.779	0.437	1.053
1930	0.670	0.477	0.307		1.064	0.422	0.490		0.857	0.375	1.021
1931	0.907	0.567	0.347		0.987	0.500	0.635		0.872	0.436	1.078
1932	0.860	0.572	0.349		0.988	0.551	0.602			0.651	1.124
1933	0.815	0.557	0.380		0.964	0.483	0.563			0.644	1.219
1934	0.789	0.467	0.440		0.976	0.439	0.540			0.605	1.175
1935	0.785	0.471	0.450		0.953	0.511	0.500			0.610	1.223
1936	1.048	0.422	0.586		1.084	0.567	0.645			0.689	1.655
1937	1.225		1.142		1.370	0.937	0.827			0.811	2.194
1938	1.114		1.453		1.103	0.807	0.672			0.634	1.709
1939	1.626		1.741		1.667	1.993	0.954			1.350	4.466
1940	3.280		1.531		3.575	2.484	1.651			2.335	7.819
1941			1.383								
1942			1.117								
1943											
1944											
1945			0.527			1.767	1.515			1.605	4.565
1946			0.729			1.416	1.166			1.425	3.908
1947		0.877	0.606			1.195	0.962			1.250	2.946
1948		0.682				0.879	0.776			0.971	2.325
1949		0.588				0.785	0.564			1.152	1.932
1950		0.364				0.773	0.663			0.768	1.855

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 (1962) and Angier. Sauerbeck index was taken from Sauerbeck (various years) in the Journal of the Royal Statistical Society.

Table A3C: Real Commodity Deflated 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	Alexandria - Cottonseeds	Coal to Egypt	W. India - Grain and General	Bay of Bengal - Grain and similar	Bay of Bengal - Lighter goods (Jute)	Coal to Colombo	SE Asia - Grain, Sugar
1869	1.384	1.516	1.307	1.540	1.926	0.720	1.901	1.499	1.475		1.446	1.042
1870	1.804	1.719	1.346	1.624	2.070	1.001	1.897	2.126	1.336		1.339	0.953
1871	1.358	1.794	1.087	1.307	1.716	1.443		1.491	1.721	1.559	1.266	1.198
1872	1.412	1.782	0.975	0.872	1.505	1.079	1.099	1.386	1.771	1.435	0.806	1.260
1873	1.505	1.566	0.569	0.713	1.423	1.494	0.843	1.481	1.892	1.875	0.577	1.554
1874	1.280	1.353	0.683	0.861	1.375	1.499	0.985	1.561	1.930		0.776	1.681
1875	1.304	1.405	0.802	0.882	1.550	1.541		1.923	2.050		0.839	1.657
1876	1.500	1.591	1.375	1.080	1.837	2.131	1.041	1.622	1.674		0.965	1.391
1877	1.301	1.389	1.316	1.152	1.603	1.353	1.384	1.286	1.403		1.052	1.246
1878	1.308	1.470	1.228	1.221	1.623	1.248	1.462	0.993	0.975		1.237	1.009
1879	1.247	1.622	1.293	1.317	1.234	1.361	1.372	1.154	1.103	1.403	1.346	1.136
1880	1.146	1.161	1.343	1.365	1.090	1.027	1.545	1.424	1.362	1.491	1.195	1.278
1881	1.269	1.207	1.523	1.269	1.350	1.722	1.369	1.447	1.554	1.407	1.002	1.340
1882	1.235	1.109	1.196	1.163	1.143	2.928	1.210	1.115	1.581	1.350	0.972	1.237
1883	1.219	1.370	1.096	1.047	1.091	1.083	1.277	1.108	1.299	1.373	1.031	1.089
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
1885	1.283	1.179	0.992	0.954	1.172	0.846	0.961	1.069	1.147	1.180	0.943	1.062
1886	1.136	1.205	0.970	0.990	1.006	0.721	1.024	0.996	1.064	0.951	0.927	1.111
1887	1.244	1.291	0.903	1.046	1.277	1.033	1.010	0.930	1.059	0.952	1.032	1.063
1888	1.563	1.588	0.958	0.985	1.653	1.303	1.013	1.074	1.232	1.119	1.314	0.995
1889	1.314	1.279	0.763	0.910	1.464	1.038	0.986	1.204	1.165	0.920	0.915	0.900
1890	0.952	1.098	0.552	0.584	1.179	1.065	0.648	1.025	0.976	0.858	0.589	1.008
1891	1.134	1.323	0.506	0.537	1.322	1.185	0.573	0.946	1.027	1.061	0.343	1.019
1892	0.916	0.920	0.594	0.606	1.011	1.199	0.689	0.938	0.760	0.685	0.082	0.851
1893	1.080	1.076	0.657	0.587	1.244	0.961	0.607	0.817	0.850	0.758	0.654	0.822
1894	1.024	0.969	0.599	0.462	1.420	1.402	0.466	1.311	1.038	0.887	0.445	1.025
1895	1.456	1.194	0.586	0.511	1.283	1.292	0.554	1.155	0.916	1.019	0.522	0.962
1896	1.360	1.074	0.525	0.634	1.447	1.342	0.737	0.715	0.579	0.615	0.874	0.715
1897	1.091	0.955	0.654	0.913	0.933	1.118	0.813	0.780	0.623	0.695	0.811	0.758
1898	1.130	1.075	0.620	0.734	0.944	1.472	0.825	1.277	0.895	1.011	0.714	0.972
1899	1.348	1.118	0.739	0.726	1.113	1.245	0.887	1.185	0.826	0.857	0.656	0.903
1900	1.485	1.244	0.514	0.540	1.392	0.910	0.631	1.150	0.820	0.755	0.594	0.915
1901	1.004	0.895	0.522	0.441	1.030	0.864	0.467	0.912	0.730	0.715	0.457	0.809
1902	0.850	0.825	0.478	0.368	0.925	0.812	0.391	0.786	0.661	0.669	0.449	0.838
1903	1.027	0.865	0.502	0.422	0.946	0.664	0.444	0.944	0.602	0.588	0.412	0.771
1904	1.112	0.869	0.503	0.421	0.826	0.539	0.524	0.936	0.754	0.739	0.406	0.821
1905	1.032	0.950	0.530	0.491	0.918	0.721	0.546	0.809	0.630	0.465	0.442	0.702
1906	1.100	0.937	0.614	0.522	0.905	0.623	0.510	0.843	0.598	0.381	0.507	0.687
1907	1.047	0.878	0.514	0.453	0.800	0.588	0.478	0.830	0.556	0.378	0.370	0.741
1908	0.883	0.789	0.428	0.406	0.608	0.457	0.427	0.522	0.461	0.430	0.405	0.591
1909	0.828	0.852	0.508	0.467	0.559	0.474	0.480	0.643	0.649	0.705	0.347	0.752
1910	1.007	0.812	0.443	0.450	0.820	0.485	0.488	0.726	0.662	0.521	0.386	0.674
1911	1.013	0.941	0.538	0.556	0.843	0.542	0.641	0.865	0.655	0.544	0.479	0.697
1912	0.933	1.168	0.721	0.758	1.293	0.908	0.727	1.022	0.661	0.622	0.506	0.843
1913	0.970	0.996	0.421	0.594	0.924	0.519	0.635	0.895	0.721	0.429	0.421	0.874
1914					0.462	0.976	0.903	0.454	0.537	0.397		0.720
1915		1.647				3.874	2.387	1.801	1.448	1.787		1.463
1916		2.117				5.870	3.093	2.789	2.434	2.297		2.711
1917						2.765	3.909	4.940	3.597	6.323		5.019

Year	Baltic - Grain	Baltic - Deals	Coal to Baltic	Coal to Genoa	Black Sea - Grain	Alexandria - Cottonseeds	Coal to Egypt	W. India - Grain and General	Bay of Bengal - Grain and similar	Bay of Bengal - Lighter goods (Jute)	Coal to Colombo	SE Asia - Grain, Sugar
1918							5.783			7.010		5.467
1919						1.654	1.193	2.750	1.293	1.451		1.674
1920					2.769	1.002	0.547	2.517	0.673	0.940		0.581
1921					1.692	0.839	0.460	1.069	0.498			0.675
1922					0.649	0.465	0.520	0.680	0.456			0.553
1923		0.539			0.621	0.377	0.418	0.745	0.453			0.507
1924		0.585			0.613	0.365	0.445	0.698	0.440			0.511
1925		0.510			0.551	0.468	0.460	0.631	0.420			0.524
1926		0.653			0.781	1.313	0.549	0.668	0.454			0.527
1927		0.661			0.582	0.693	0.590	0.701	0.471			0.564
1928		6.215			0.528	0.581	0.653	0.718	0.431			0.610
1929		0.721			0.659	0.727	0.605	0.698	0.381			0.523
1930		0.706			0.693	1.005	0.395	0.748	0.342			0.510
1931		0.722			0.956	1.005	0.388	1.136	0.566			0.808
1932		0.689			0.845	1.001	0.370	1.121	0.600			0.801
1933					0.958	1.040	0.346	1.253	0.762			0.946
1934					1.082	1.030	0.385	1.438	0.797			1.004
1935					1.048	0.756	0.465	1.151	0.646			0.813
1936		0.722			0.911	1.434	0.352	1.333	0.889			1.084
1937		0.761			1.080	1.948	0.485	1.159	0.988			1.273
1938		0.566			0.890	1.678	0.293	1.089	0.712			0.912
1939		0.491			1.558	2.539	0.628		1.217			1.301
1940					2.165	3.492	1.491		1.251			2.383
1941							1.922					
1942							2.030					
1943							2.157					
1944							2.032					
1945							1.472	1.930	0.892			
1946					1.566							
1947						1.272		1.109				
1948						1.010	0.305					
1949					0.656	0.645	0.323					
1950					0.972		0.379					

Sources: Angier in *Fairplay*; Coal to Colombo from Jevon (1962) and Angier.

Note: All UK commodity prices are taken from Sauerbeck (various years) from the Journal of the Royal Statistical Society. Alexandria - Cottonseeds has been deflated by Cotton (Fair Dhollerah) prices for data availability. Baltic - Grain has been deflated by average of oat and wheat prices. All other routes carrying grain are deflated by wheat prices.

Table A3D: Real Freight Rate Indices Deflated by Commodity Prices - 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	Western Mediterranean - Ore
1869	0.863	0.613	1.328	2.066	1.305	1.355	1.378		1.127		
1870	0.744	0.692	1.169	1.376	1.257	1.305	1.247		1.076		
1871	0.761	0.831	1.210	1.409	1.474	1.162	0.905		1.225		1.167
1872	0.756	0.875	0.818	0.985	1.458	2.767	1.288		1.236		
1873	0.752	0.984	0.698	0.696	1.503	1.196	1.363		1.280		1.001
1874	0.783	1.278	0.725	0.849	1.453	1.192	1.343		1.150		
1875	0.940	1.082	0.776	0.640		1.489	1.114				
1876	0.872	1.065	0.904	0.877		1.277	1.273				1.276
1877	0.706	0.821	0.942	0.909		1.120	0.793				1.236
1878	0.743	0.600	1.013	0.893		1.283	0.968	1.266			
1879	0.723	0.633	1.126	1.003		1.126	1.114	1.187			1.004
1880	0.773	0.677	1.118	1.016		1.002	1.237	0.987			1.061
1881	0.776	0.810	1.064	0.936		0.793	1.597	0.984			
1882	0.830	0.991	1.104	0.967		0.980	1.217	1.073			1.113
1883	0.792	0.867	1.083	0.978	1.236	0.981	0.970	1.124			1.090
1884	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1885	0.965	0.667	0.906	1.016	0.977	0.963	0.992		1.073	1.026	1.006
1886	0.858	0.655	0.881	1.035	0.934	1.096	0.901	1.020	1.123	0.953	1.038
1887	1.077	0.789	0.975	1.087	0.943	0.923	0.835	0.962	0.931	0.883	1.266
1888	0.971	0.800	1.230	1.624	1.217	1.131	0.853	1.155	1.072	1.047	1.460
1889	1.192	0.921	1.285	1.265	1.236	1.395	0.974	1.119	1.314	1.220	1.042
1890	1.296	1.106	0.773	0.964	0.924	1.198	1.120	0.819	1.163	1.030	1.020
1891	1.394	0.886	0.612	0.449	0.928	1.046	0.947	1.115	1.070	0.859	1.098
1892	1.368	0.429	0.609	0.517	0.926	1.224	0.803	1.044	1.059	1.011	0.935
1893	1.443	0.741	0.644	0.727	0.910	1.167	0.941	1.064	1.097	1.004	1.111
1894	1.776	0.692	0.480	0.544	0.863	1.518	1.144	1.338	1.059	1.298	1.275
1895	1.415	0.658	0.514	0.596	0.918	1.343	1.237	1.138	1.109	1.362	0.734
1896	1.106	0.633	0.679	0.758	0.889	1.427	0.870	1.007	1.059	1.251	1.371
1897	0.869	0.898	0.702	0.747	0.808	1.117	0.871	1.078	0.954	1.011	1.184
1898	1.037	1.012	0.678	0.776	0.930	1.138	0.793	1.464	1.199	1.176	1.271
1899	1.626	1.045	0.471	0.718	0.869	1.205	1.222	1.288	1.050	1.325	0.869
1900	1.340	1.196	0.437	0.445	0.966	1.404	1.397	0.954	0.996	1.566	0.879
1901	1.090	0.818	0.385	0.523	0.775	0.927	1.383	0.756	0.863	1.084	0.889
1902	0.974	0.566	0.376	0.364	0.677	0.725	0.971	0.629	0.744	0.947	0.993
1903	1.099	0.430	0.334	0.577	0.693	0.805	0.639	0.533	0.708	0.889	0.936
1904	1.102	0.553	0.313	0.424	0.654	0.831	0.714	0.448	0.755	0.786	0.886
1905	0.847	0.492	0.402	0.447	0.666	0.860	0.769	0.645	0.722	0.852	0.929
1906	0.847	0.458	0.501	0.479	0.586	0.878	0.877	0.552	0.680	0.801	0.843
1907	0.808	0.386	0.422	0.740	0.646	0.700	1.043	0.505	0.661	0.758	0.772
1908	0.694	0.414	0.329	0.564		0.552	0.790	0.505	0.667	0.661	0.745
1909	0.550	0.488	0.379	0.572		0.504	0.712	0.519	0.623	0.540	0.797
1910	0.626	0.540	0.527	0.568		0.544	0.843	0.423	0.620	0.681	0.875
1911	0.705	0.556	0.629	0.774		0.775	1.033		0.646	0.713	0.942
1912	1.195	0.638	0.655	0.829		1.014	1.214		0.915	1.056	0.990
1913	1.058	0.647	0.504	0.766		0.901	1.267		0.735	0.926	0.811
1914	1.195	0.623	0.461			1.317	0.998		0.678	0.781	0.830
1915	2.130	1.411	0.791		1.258	2.361	1.542	2.592	1.098	0.519	1.476
1916	3.370	1.936	0.940		1.829	3.153	2.391		1.564	0.560	1.585
1917	7.159	1.749	1.751			4.885					3.141

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	Western Mediterranean - Ore
1918	5.345	2.224	0.702								2.483
1919	5.044	2.261	0.370		1.198	1.983			0.732	4.532	1.243
1920	2.349	0.954	0.088		0.870	1.375	1.538		0.518	1.228	1.107
1921	0.910	0.742	0.182		0.734	0.523	0.992		0.572	0.769	0.589
1922	1.008	0.595	0.233		0.548	0.728	0.778		0.529	0.632	0.809
1923	0.913	0.623	0.284		0.483	0.721	0.820		0.460	0.628	0.779
1924	0.878	0.518	0.213		0.528	0.657	0.669		0.502	0.562	0.703
1925	0.609	0.486	0.240		0.478	0.497	0.604		0.478	0.448	0.691
1926	1.069	0.500	0.313		0.538	0.937	0.660		0.435	0.496	0.887
1927	0.896	0.639	0.288		0.610	0.535	0.647		0.564	0.494	0.671
1928	0.874	0.598	0.231		5.179	0.710	0.674		4.639	0.510	0.754
1929	0.728	0.622	0.216		0.648	0.541	0.603		0.499	0.468	0.831
1930	0.845	0.584	0.217		0.608	0.532	0.618		0.490	0.473	0.666
1931	1.442	0.644	0.220		0.595	0.795	1.010		0.526	0.693	0.596
1932	1.207	0.683	0.209		0.636	0.774	0.845			0.913	0.606
1933	1.210	0.659	0.228		0.609	0.717	0.837			0.957	0.669
1934	1.111	0.612	0.274		0.609	0.618	0.760			0.851	0.680
1935	1.019	0.647	0.283		0.661	0.664	0.650			0.791	0.718
1936	1.262	0.594	0.370		0.730	0.683	0.776			0.829	0.961
1937	1.205		0.743		0.814	0.923	0.814			0.798	1.217
1938	1.226		0.747		0.635	0.888	0.739			0.697	0.780
1939	2.435		0.943		0.880	2.984	1.428			2.021	2.277
1940	6.019		0.877		1.625	4.559	3.030			4.285	4.702
1941			0.741								
1942			0.587								
1943											
1944											
1945			0.260			2.048	1.756			1.861	2.783
1946			0.337			1.915	1.577			1.927	2.486
1947		1.404	0.357			1.914	1.541			2.003	2.226
1948		1.118				1.496	1.321			1.652	1.913
1949		0.978				1.168	0.840			1.715	1.778
1950		0.675				1.114	0.955			1.107	2.017

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 (1962) and Angier.
Note: All UK commodity prices are taken from Sauerbeck (various years) from the Journal of the Royal Statistical Society. Mediterranean Ore route has been deflated by iron bar prices in UK for lack of data.

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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	Alexandria - Cottonseeds	Coal to Egypt	W. India - Grain and General	Bay of Bengal - Grain and similar	Bay of Bengal - Lighter goods	Coal to Colombo	SE Asia - Grain, Sugar
1869	1.822	1.681	1.353	1.595	2.602	1.783	1.969	2.025	1.827		1.497	1.539
1870	2.205	1.944	1.397	1.685	2.718	2.065	1.969	2.792	1.655		1.389	1.408
1871	1.922	1.794	1.147	1.378	2.726	2.130		2.369	2.207	2.714	1.335	1.829
1872	1.935	1.898	1.662	1.486	2.406	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	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	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	1.783	1.515	2.047	1.830		1.151	1.881
1878	1.637	1.598	1.250	1.243	2.112	1.565	1.489	1.293	1.272		1.259	1.379
1879	1.436	1.516	1.221	1.243	1.517	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	1.370	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	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
1885	1.242	1.154	0.956	0.919	1.079	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	0.652	0.932	0.866	0.914	0.810	0.843	0.930
1887	1.066	1.179	0.809	0.937	1.163	0.935	0.905	0.847	0.944	0.864	0.924	0.914
1888	1.344	1.519	0.868	0.892	1.475	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	1.087	1.083	1.004	1.102	1.022	1.005	0.914
1890	0.862	1.098	0.750	0.793	1.055	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	0.978	0.750	0.981	1.061	1.022	0.449	0.977
1892	0.837	0.880	0.706	0.721	0.858	0.913	0.818	0.795	0.760	0.761	0.097	0.815
1893	0.899	1.006	0.706	0.631	0.919	0.870	0.652	0.603	0.684	0.730	0.703	0.736
1894	0.760	0.927	0.676	0.523	0.909	0.935	0.527	0.839	0.790	0.822	0.503	0.792
1895	0.992	1.090	0.588	0.514	0.830	0.902	0.557	0.747	0.657	0.830	0.524	0.675
1896	0.994	1.027	0.500	0.604	1.062	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	0.870	0.786	0.660	0.548	0.567	0.784	0.572
1898	1.053	1.098	0.662	0.784	0.900	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	0.870	1.024	0.853	0.772	0.793	0.757	0.738
1900	1.205	1.514	0.926	0.973	1.051	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	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	0.761	0.518	0.619	0.532	0.607	0.595	0.541
1903	0.821	1.016	0.632	0.532	0.710	0.696	0.560	0.708	0.569	0.588	0.519	0.579
1904	0.890	0.964	0.603	0.505	0.656	0.685	0.628	0.743	0.647	0.766	0.486	0.622
1905	0.871	1.054	0.603	0.559	0.764	0.761	0.621	0.673	0.554	0.637	0.503	0.565
1906	0.933	1.120	0.721	0.613	0.717	0.761	0.598	0.667	0.566	0.664	0.595	0.521
1907	0.936	1.088	0.706	0.622	0.686	0.663	0.656	0.712	0.599	0.588	0.508	0.629
1908	0.785	0.909	0.588	0.559	0.545	0.500	0.586	0.468	0.456	0.493	0.557	0.487
1909	0.816	1.000	0.618	0.568	0.578	0.587	0.583	0.666	0.599	0.679	0.422	0.610
1910	0.878	1.006	0.559	0.568	0.728	0.739	0.616	0.644	0.626	0.569	0.486	0.574
1911	0.921	1.166	0.662	0.685	0.749	0.826	0.789	0.768	0.698	0.816	0.589	0.650
1912	0.950	1.524	0.985	1.036	1.259	1.196	0.994	0.996	0.870	0.968	0.692	0.877
1913	0.888	1.364	0.632	0.892	0.823	0.750	0.952	0.796	0.768	0.842	0.632	0.737
1914					0.698	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	3.478	4.702	3.376	3.674	3.119		2.826
1921					2.000	1.239	1.726	1.264	1.196			1.236

Year	Baltic - Grain	Baltic - Deals	Coal to Baltic	Coal to Genoa	Black Sea - Grain	Alexandria - Cottonseeds	Coal to Egypt	W. India - Grain and General	Bay of Bengal - Grain and similar	Bay of Bengal - Lighter goods	Coal to Colombo	SE Asia - Grain, Sugar
1922					0.896	0.946	1.351	0.938	0.883			0.781
1923		1.535			0.908	0.957	1.131	1.090	0.877			0.848
1924		1.552			0.846	1.022	1.119	0.964	0.962			0.873
1925		1.361			0.806	1.307	0.994	0.923	0.877			0.731
1926		1.519			1.166	2.585	1.098	0.997	0.962			0.744
1927		1.547			0.812	1.456	1.131	0.977	0.978			0.804
1928		1.507			0.661	1.278	1.101	0.900	0.844			0.797
1929		1.687			0.780	1.426	1.051	0.825	0.709			0.618
1930		1.569			0.666	1.307	0.708	0.719	0.581			0.526
1931		1.305			0.643	1.174	0.667	0.764	0.714			0.658
1932		1.125			0.592	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 Jevon (1962) 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	Western Mediterranean - 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

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	Western Mediterranean - Ore
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
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 (1962) and Angier.

Table 3: Global Nominal and Real Freight Rate Indices
(1884 = 1.00)

Year	Nominal Index	Deflated by Sauerbeck/RPI	Deflated by Commodities
1870-1874	1.88	1.29	1.23
1875-1879	1.53	1.22	1.24
1880-1884	1.24	1.09	1.15
1884	1.00	1.00	1.00
1885-1889	1.05	1.12	1.11
1890-1894	0.87	0.93	0.82
1895-1899	0.87	1.00	0.92
1900-1904	0.81	0.82	0.69
1905-1909	0.74	0.67	0.65
1910-1914	0.94	0.78	0.76
1915-1919	6.79	2.85	2.28
1920-1924	1.89	0.75	0.60
1925-1929	1.05	0.58	0.59
1930-1934	0.78	0.63	0.55
1935-1939	1.27	0.97	0.77
1940-1944	2.98	2.49	1.00
1945-1949	2.41	0.95	0.57
1950-1954	2.21	0.63	0.36
1955-1959	2.72	0.60	0.55
1960-1964	2.00	0.39	0.43
1965-1969	2.03	0.33	0.43
1970-1974	2.84	0.33	0.44
1975-1979	3.16	0.18	0.36
1980-1984	3.95	0.13	0.37
1985-1989	3.90	0.10	0.45
1990-1994	4.32	0.08	0.41
1995-1997	4.44	0.08	NA

Sources: Data for 1870-1950 from Angier. Fairplay;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.

Table 4: TFP Growth before World War I				
	ENA	**Alexandria**	**Riga**	**Bombay**
Distance from UK				
		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 4 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 4.

Table 5: TFP Growth in the Interwar Period

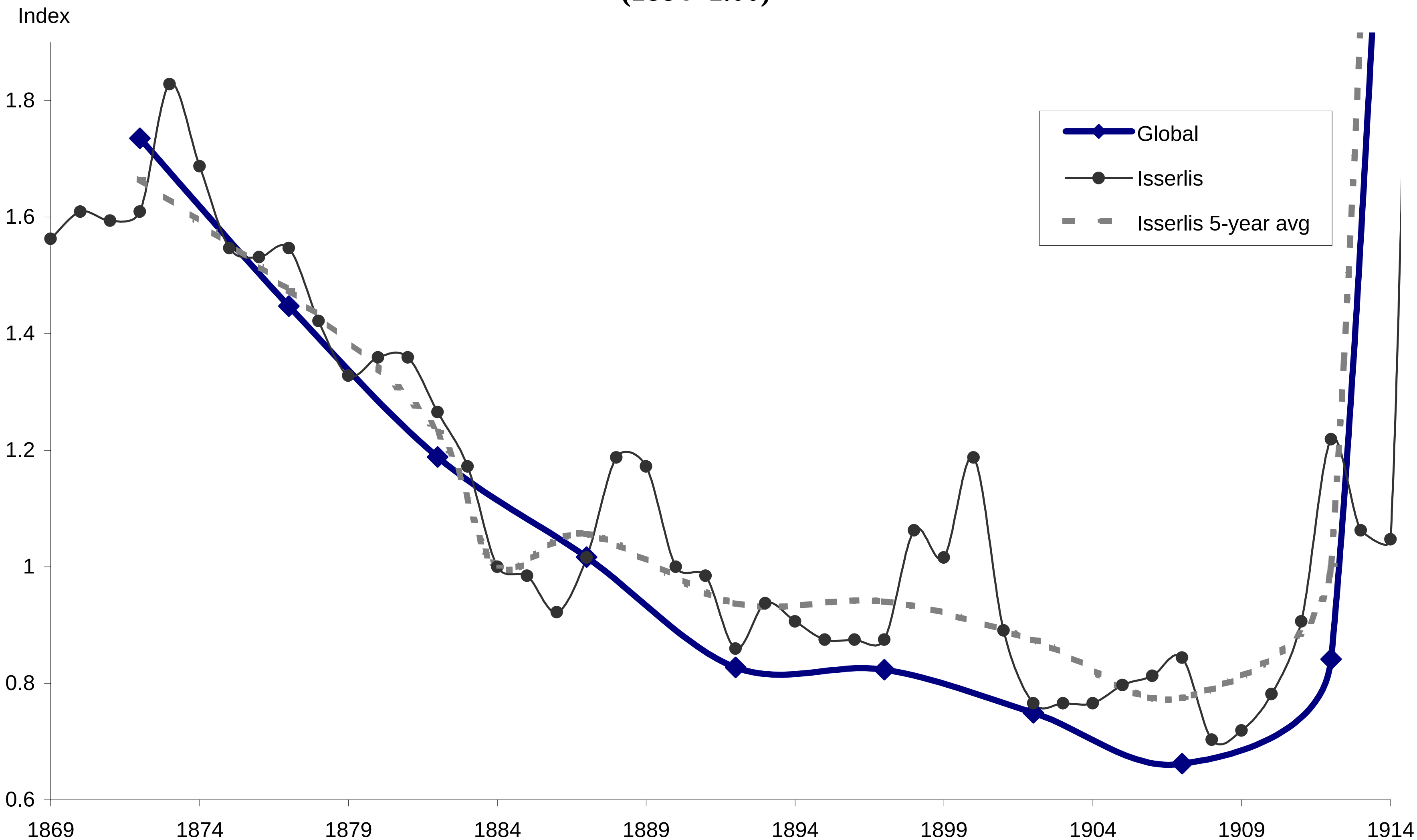
	ENA	Alexandria
Distance from UK		
1909/11-1932/4		
Average Change In Nominal Freight Rates	-1.39%	1%
Contribution of:		
Wages	-100.84%	54.55%
Ship Prices	-268.9%	145%
Coal Prices	-53.4%	27.1%
Average TFP change	2.83%	1.27%
1923/5-1932/4		
Average Change In Nominal Freight Rates	-3.61%	-1.39%
Contribution of:		
Wages	1.98%	5.17%
Ship Prices	48%	124%
Coal Prices	23.43%	72.3%
Average TFP change	0.96%	-1.4%

Sources: Appendix 4 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 4.

Table 6: Explaining TFP Growth before World War I				
	ENA	**Alexandria**	**Riga**	**Bombay**
Distance from UK				
		A. 1871/3 – 1887/9		
Contribution to TFP Growth:				
Ship Size	30.8%	32.5%	59.4%	25.9%
Load Capacity	60.9%	39.0%	30.55%	28.57%
Coal Consumed	13.4%	12.37%	15.93%	11.68%
No. of Seamen	33.6%	18.01%	9.6%	12.31%
Time at Sea	-19.34%	2.01%	15.44%	75.91%
Time at Port	14.7%	27.34%	19.7%	38.1%
Percentage of TFP Explained	133.5%	131.2%	150%	192.4%
		B. 1887/9 – 1909/11		
Contribution to TFP Growth:				
Ship Size	28.4%	76.1%	86.62%	47.98%
Load Capacity	21.5%	37.9%	22.48%	21.94%
Coal Consumed	-3.45%	-20.97%	34.93%	-11.33%
No. of Seamen	4.9%	-2.01%	-19.03%	-1.53%
Time at Sea	-7.86%	-18.37%	7.89%	-38.62%
Time at Port	33.1%	29.76%	-18.39%	-10.38%
Percentage of TFP Explained	76.7%	101.57%	114.5%	7.95%

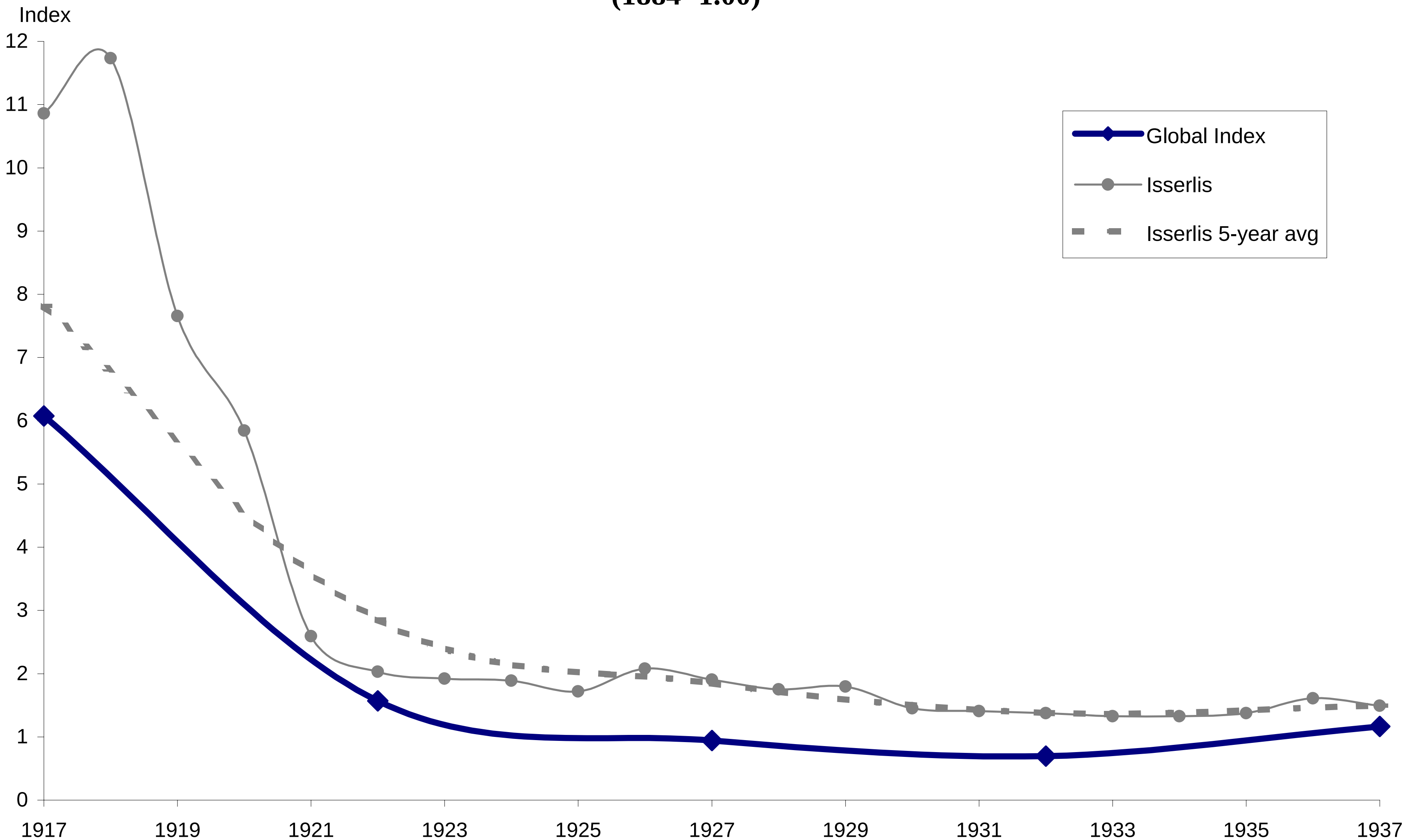
Sources, see text. For calculations, see Appendix 5.

Figure 1A: Nominal Freight Rate Indices 1869-1913
(1884=1.00)



Sources: Table 3 and Isserlis (1938).

Figure 1B: Nominal Freight Rate Indices 1920-1937
(1884=1.00)

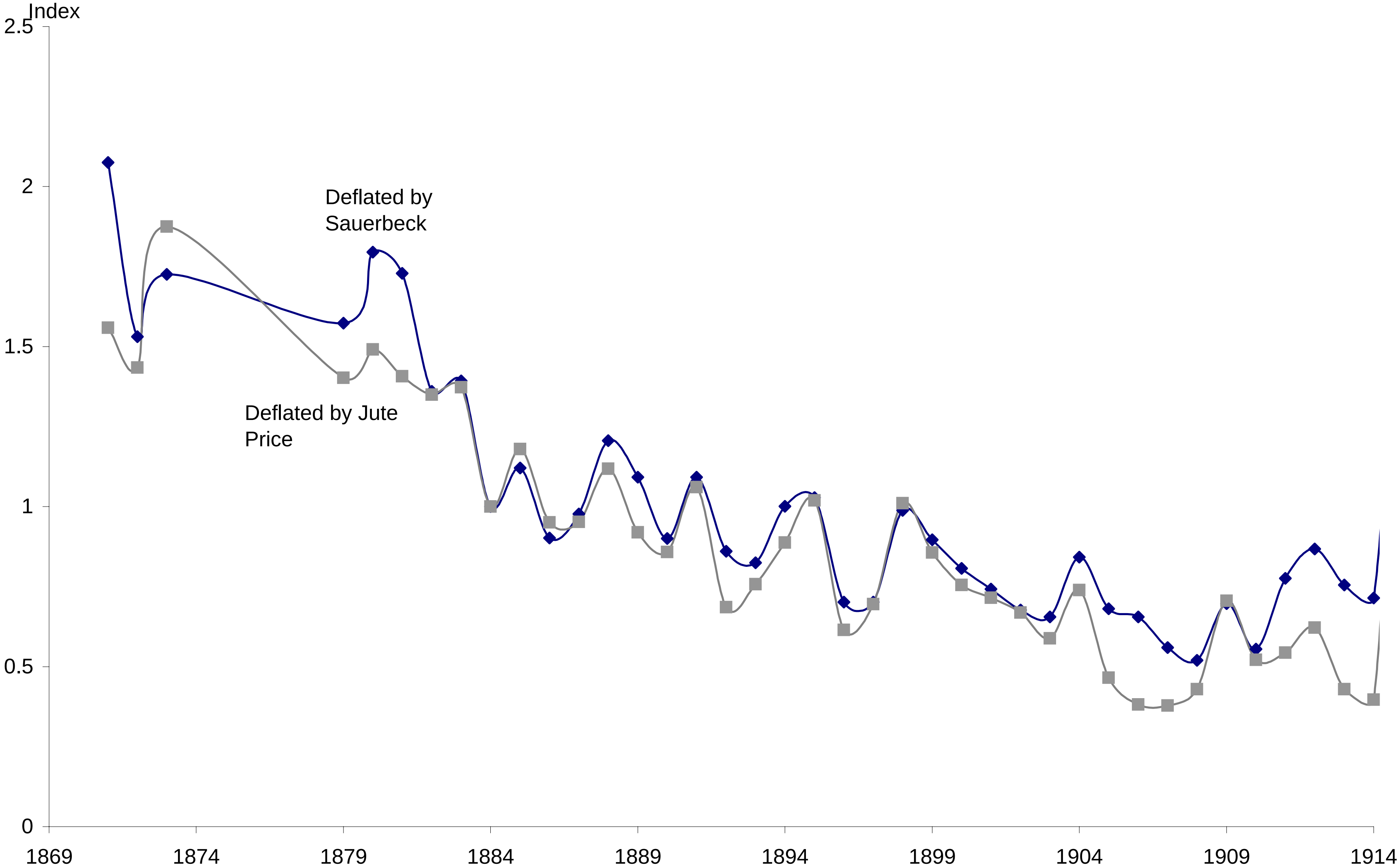


Sources: Table 3 and Isserlis (1938).

Figure 2A: Real Freight Rates for Wheat from Eastern Coast of North America to UK (1884 = 1.00)

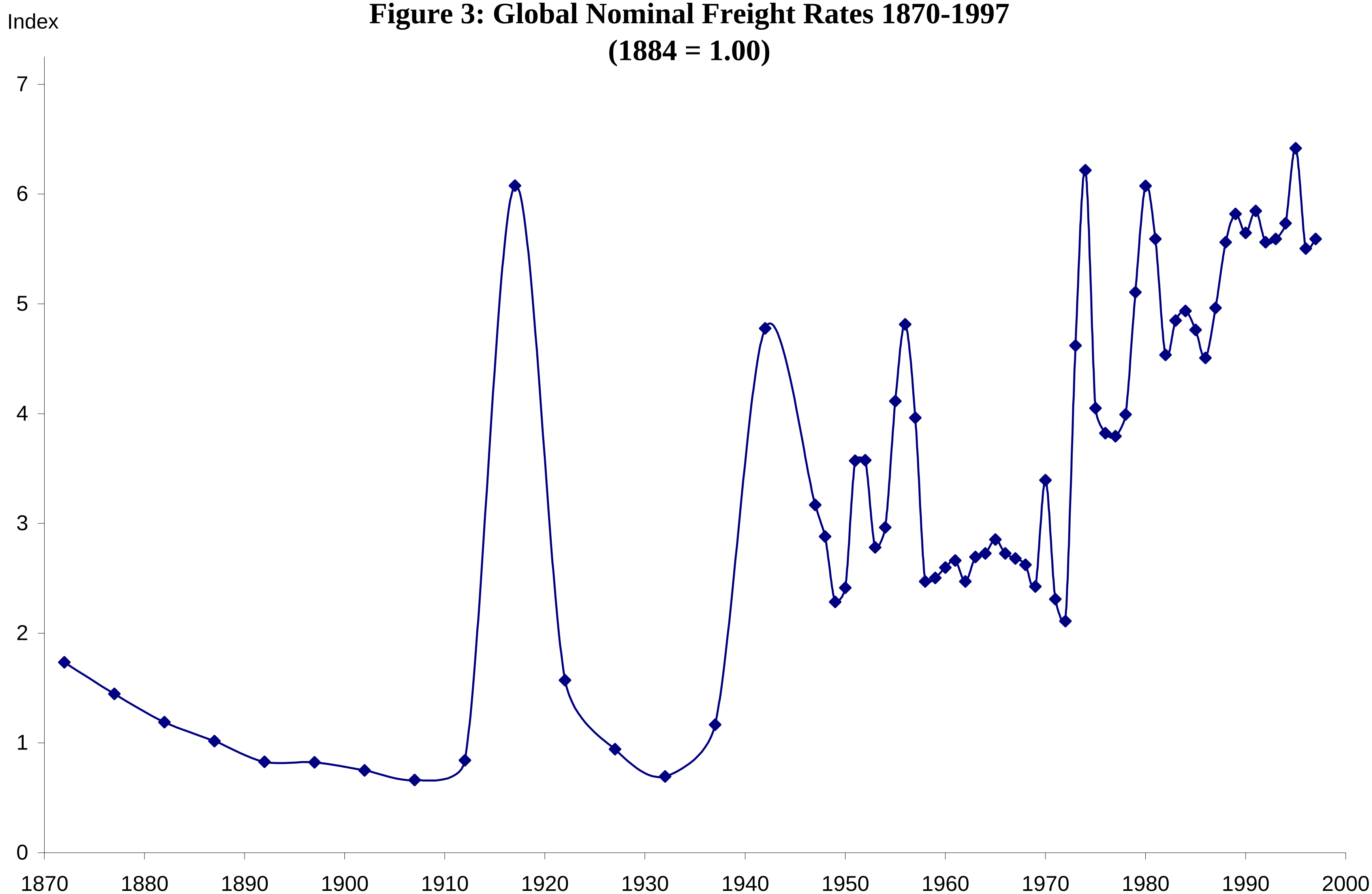
Sources: Table 2 and Sauerbeck (various years).

Figure 2B: Real Freight Rates for Jute from Calcutta to UK (1884=1.00)



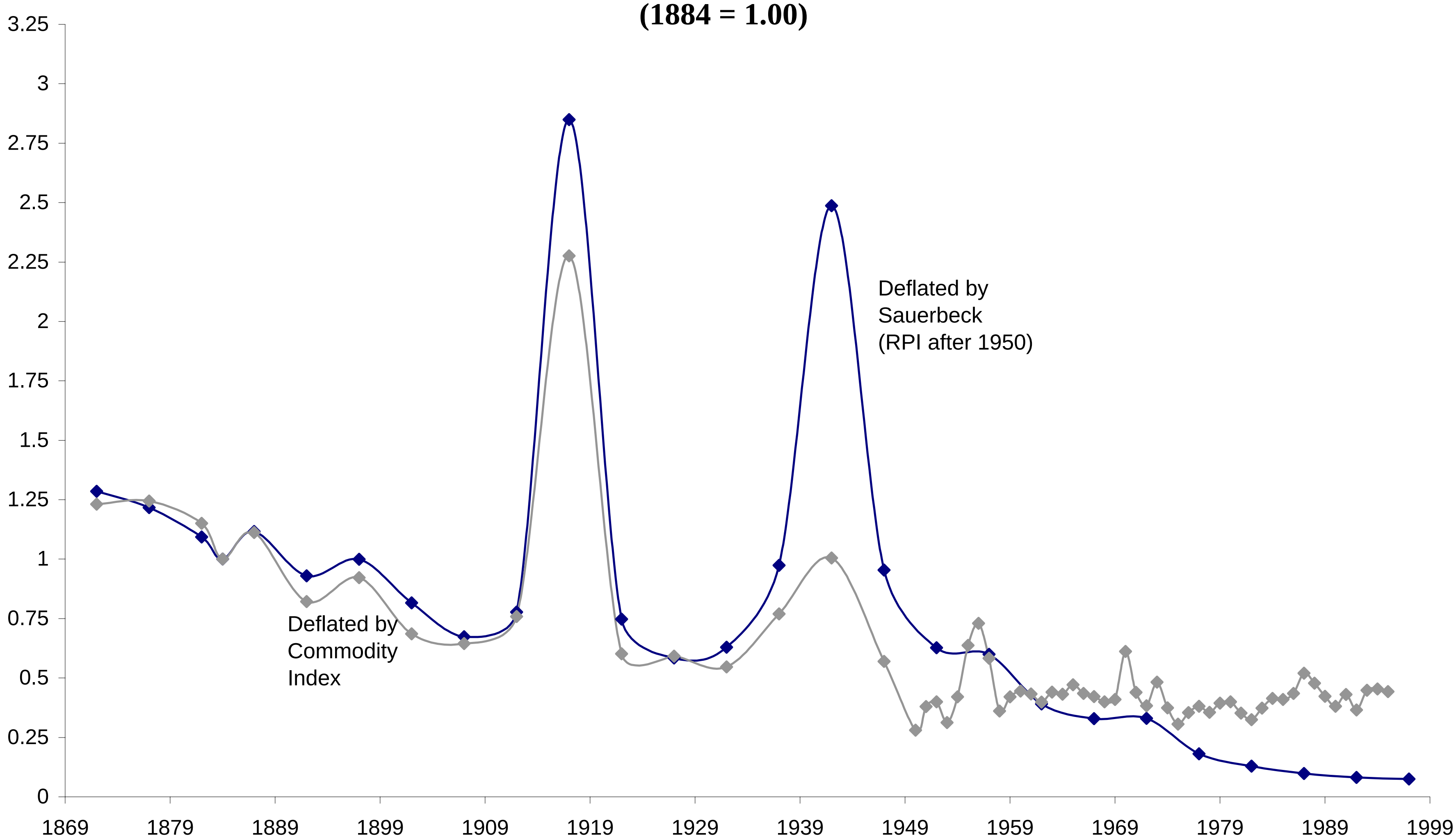
Sources: Table 1 and Sauerbeck (various years)

Figure 3: Global Nominal Freight Rates 1870-1997
(1884 = 1.00)



Sources: Table 3 and Hummels (1999).

Figure 4: Real Global Freight Rate Index (1869-1997)
(1884 = 1.00)



Note: Commodity Index for period before 1950 was constructed using the commodities carried in the Angier data on each route. Each commodity was given the same weight as the route. After 1950, Hummels' index is used.

Sources: Table 3, Sauerbeck (various years), British Office of National Statistics and Hummels (1999).