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ABSTRACT

What is the role of transport improvements in globalization? We argue that the nineteenth century is the ideal testing ground for this question: freight rates fell on average by 50% while global trade increased 400% from 1870 to 1913. We estimate the first indices of bilateral freight rates for the period and directly incorporate these into a standard gravity model. We also take the endogeneity of bilateral trade and freight rates seriously and propose an instrumental variables approach. The results are striking as we find no evidence that the maritime transport revolution was the primary driver of the late nineteenth century global trade boom. Rather, the most powerful forces driving the boom were those of income growth and convergence.

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I. Introduction

In 1995, Krugman noted that the question of "Why has world trade grown?" was then an open issue. The most commonly held perception was that this growth was strongly associated with relentless technological improvement in the communication and transport sectors—roughly, computers, containers, and supertankers. However, academics and policy-makers were prone to associate the explosion of global trade in the post-World War II period to the decline in protectionist commercial policies. Particularly dramatic in this sense was the succession of GATT negotiations which achieved a reduction of average tariffs in industrialized countries from roughly forty percent in 1950 to less than five percent in 1995 (Irwin, 1995).

More than ten years later, the issue has still not been conclusively resolved. In one of the main contributions to the literature, Baier and Bergstrand (2001) argue that a general equilibrium gravity model of international trade implies that roughly two-thirds of the growth of world trade post-1950 can be explained by income growth, one-fourth by tariff reductions, and less than one-tenth by transport-cost reductions. Given that there are few sources for consistent data on the cost of international freight for the post-war period (Hummels, 2001; Levinson, 2006), their general equilibrium approach allows the economics of supply-and-demand to "fill in the holes".

An alternative approach is to use data on the actual cost of international shipping to determine whether or not declining freight costs drive increasing international trade. In this paper, we use data on over 5000 maritime shipping transactions in the period from 1870 to 1913 to address this question. We argue that the late nineteenth century is an ideal testing ground: from 1870 to 1913, maritime freight rates fell on average by 50% as a result of productivity growth in the shipping industry (Mohammed and Williamson, 2004) while global trade increased by roughly 400% (Cameron and Neal, 2003). This feature of the late nineteenth century global economy sets it apart from the post-World War II period where the joint trajectory of freight rates and bilateral trade is less clear and the data are sparse. Thus, if maritime transport revolutions matter, then the nineteenth century is the place to start looking.

This paper addresses some of the issues raised by the recent work of Estevadeordal et al. (2003). They use a gravity model of bilateral trade for the years 1913, 1928, and 1938 to indirectly decompose the forces driving the change in country-level aggregate trade volumes between 1870 and 1939. However, in contrast to Estevadeordal et al. (2003), we focus only on the initial upsurge of trade from 1870 to 1913 and accordingly bring new, direct panel data to bear on the issue. More specifically, we are able to provide the first indices of country-pair specific freight rates for this earlier period and incorporate these into a standard gravity equation of bilateral trade. That these indices are country-pair specific is important as it is well-known that technological innovation in the maritime shipping industry reduced long-haul freight rates more than short-haul ones.

We also address a major and previously unnoticed identification issue: freight rates are endogenous to bilateral trade. This is due to the fact that freight rates are the price for shipping services and are, thus, partially determined by import demand. Although one would expect that lower freight rates would stimulate higher volumes of trade, this simultaneity is as likely to generate a positive correlation between the two variables of interest. In the short-run, increases in import demand could interact with capacity constraints in the shipping industry to create higher freight rates. Disentangling these two forces via standard IV panel methods is one of the paper's main contributions.

In our empirical work, we are able to document such correlations. OLS estimates generate a positive coefficient on freight rates in a standard gravity equation. But by using a plausible set of instruments ranging from shipping input prices to weather on major shipping routes, we are able to identify a negative, but statistically insignificant relationship between the two variables. In sum, the results are striking: we find little systematic evidence suggesting that the maritime transport revolution was a primary driver of the late nineteenth century global trade boom. Rather, the most powerful forces driving the boom were those of income growth and convergence. Finally, we suggest that a significant portion of the observed decline in maritime transport costs may have been induced by the trade boom itself. In this view of the world, the key innovations in the shipping industry were induced technological responses to the heightened trading potential of the period.

In the following section, we explore the relationship between freight costs and trade flows more fully. In the third section, we discuss our data and introduce the means by which the bilateral freight indices are constructed. The fourth section presents our main empirical results while the fifth section presents a decomposition exercise in the spirit of Baier and Bergstrand (2001). The sixth section concludes.

II. Transportation Costs and Trade Flows

There is a strong impression in both popular and professional opinion that the late twentieth century—just like the late nineteenth century—witnessed drastic improvements in transport technology which are assumed to have necessarily spilled over into international trade flows. Lundgren (1996, p. 7) writes that “during the last 30 years merchant shipping has actually undergone a revolution comparable to what happened in the late nineteenth century.” In these accounts, identifying the sources of such improvements is relatively straightforward and is seen in the movement towards containerization and increased port efficiency (Levinson, 2006). Thus, “the clearest conclusion is that new technologies that reduce the costs of transportation and communication have been a major factor supporting global economic integration” (Bernanke, 2006).

However, this view has not gone unchallenged. Hummels (1999) strongly argues against a twentieth century maritime transport revolution and accompanying declines in shipping costs. In reviewing the limited data on maritime freight rates dating from 1947, Hummels concludes that “there is remarkably little systematic evidence documenting [such a] decline” (p. 1). Yet he does find considerable evidence of changes in the composition of transport medium and in the trade-off between transport cost and transit time. The most marked development in this regard has been the increasing reliance on air shipments in international trade. As of 2000, these shipments had grown from negligible levels in the 1940s to roughly one-third (by value) of all U.S. trade. These developments point to the fact that the late nineteenth century offers a much simpler context in which to study the effect of rapidly declining maritime freight rates on global trade.

As to the most widely-held view of the nineteenth century, it is generally supposed that the railroad and telegraph take pride of place in promoting economic integration within countries while the wholesale adoption of steam propulsion in the maritime industry plays a similar role in spurring trade between countries (cf. Frieden, 2007, p. 19; James, 2001, pp. 10-13). While analytically sound, this interpretation overlooks many critical elements of the late nineteenth century. The first would be the development of a host of commercial and monetary institutions, chief among them the classical gold standard. More importantly, this view fails to condition on the economic environment in which this global trade boom occurred: this was a period of both significant income growth and convergence (Taylor and Williamson, 1997).

What is needed then is evidence on the relationship between transport costs and trade flows. Of course, this is traditionally proxied within the context of gravity models of trade as the mapping of distance into bilateral trade flows. Almost always this is formulated as a log-linear equation which allows for potential fixed costs in shipping and a concave relationship between distance and transport costs. This seems to be a reasonable procedure, especially in the cross-section. But, of course, this approach suffers from the fact that distance is a time-invariant variable, so the instrument to gauge the contribution of changes in transport costs to changes in trade flows is decidedly blunt.

In an effort to empirically assess the much-touted "death of distance" in the late twentieth century, researchers have tried to tease out any time-variant properties of the relationship among distance, trade costs, and trade flows. One of the first to explore this relationship was Leamer and Levinsohn who wrote "that the effect of distance on trade patterns is not diminishing over time. Contrary to popular impression, the world is not getting dramatically smaller" (1995, p. 1387). Taking this view as a starting point, a string of papers has strongly confirmed their results. Berthelon and Freund (2004) find corroborating evidence in highly disaggregated trade data, suggesting that distance-related trade costs have been on the rise in recent years, rather than falling as has often been assumed. Likewise, Carrère and Schiff (2004) argue that a measure of the distance separating trade partners (or distance-of-trade) has been falling from the 1960s. Finally, Disdier and Head (2008) conduct a meta-analysis of over 1000 estimated distance coefficients from 78 previous studies. They find that the estimated distance coefficient has been on the rise from 1950, suggesting that there has been an exaggerated sense of the death of distance.

This paper can make a contribution to the debate on several fronts. First, it provides economists with a different testing ground for assessing the interaction between transport costs and trade flows. Second, and much more importantly, it is the first study for any period to tackle this question with the aid of direct information on country-pair specific freight rates rather than proxies such as the ratio of declared cost-insurance-freight to free-on-board prices as in Baier and Bergstrand (2001) or a single world-wide index of global freight rates as in Estevadeordal et al. (2003). Finally, freight rates are almost certainly endogenous to trade flows. Freight rates are the price of shipping services and, thus, are determined by supply and demand in the shipping industry where demand obviously depends on international trade flows. The identification strategy employed in this paper is to isolate the supply curve of shipping services from changes in demand with a wide-ranging set of instrumental variables. This approach yields a small, negative, but statistically insignificant relationship between freight rates and trade volumes, leaving little independent role for the maritime transport revolution in explaining the late nineteenth century trade boom.

III. Data

One of the first issues which must be addressed is how to separate out the effects of changes in maritime transport from changes in other modes of transport. Our approach is to identify a country which might be thought of as representative and for which all trade was maritime by definition. The choice here is obvious. The United Kingdom loomed large in developments in the global economy of the time and is conveniently separated from all of its trading partners by water. Thus, we will explore the evolution of maritime freight rates and trade flows through the lens of the United Kingdom's experience during the late nineteenth century.

Figure 1 gives a rough sense of the changes involved. The trends in the two variables are clear—freight rates decline appreciably while trade volumes explode, suggesting a negative correlation between these variables. At the same time, Figure 1 also demonstrates that trade volumes only take off after 1895 by which time the maritime transport revolution has essentially played itself out.

Our data are an unbalanced panel on twenty-one countries (UK trading partners) for the period 1870 to 1913. Table 1 provides the share of our sample in total trade with the United Kingdom, the share of the United Kingdom in global trade, and the share of our sample in global trade during the period. Here, we see that, although the sample's share of UK trade is slightly rising through time, the UK share in global trade is effectively halved over this period from 30% to 15%. Consequently, our sample falls from 21% to 11% of global trade in the period. However, the UK was the primary trading partner of not only the fastest growing economies of the time (e.g. Germany, Japan, and the United States) but also those economies experiencing the most rapid decline in maritime freight rates (e.g. Australasia, India, and Japan). Finally, Table 2 summarizes the coverage of matched bilateral trade, freight, and GDP data. It should be noted that, in general, the limiting variable here is GDP—by comparison, the bilateral trade data are complete and the freight data have only a few breaks in coverage.

Our underlying gravity equation of bilateral trade flows is the following:

$$(1)\ Trade_{UK,i,t} = \alpha f_{UK,i,t} + X_{UK,i,t}\beta + \delta_t + \theta_i + \varepsilon_{i,t}$$

where *i* indexes countries; *t* indexes years; *Trade* is the trade flow between the United Kingdom and country *i* in year *t* and is equal to $(\ln(\text{Exports}_{\text{UK,i,t}}) + \ln(\text{Imports}_{\text{UK,i,t}}))/2$; *f* is the freight cost index to ship one ton of a generic commodity from Great Britain to country *i* in year *t*; and *X* is a vector of covariates suitable to a gravity model of trade. The third-to-last term is a decade fixed effect to control for secular changes in world GDP and other variables. The second-to-last term is a country fixed effect to control for time-invariant multilateral barriers and/or price effects which capture the average trade barrier facing countries (Anderson and van Wincoop, 2003).[1] In addition, these country fixed-effects absorb all other time-invariant factors which affect international trade volumes including the geographical distance between trading partners, membership in the British Empire, use of the English language, and other cultural factors.

The freight cost index used in (1) constitutes a primary contribution of this paper and varies across countries and over time. All extant freight cost indices are either commodity- and city-specific as in Mohammed and Williamson (2004) or invariant across countries as in Isserlis (1938). We use information on 5247 shipments of 40 different commodities during the period 1870 to 1913 between the United Kingdom and our sample of 21 countries. These shipping data were collected from a number of sources, detailed in Appendix I, while Appendix II delves in greater length into the composition of the underlying freight rates series in terms of country, commodity, and route coverage.

We model the freight index as $f_{UK,i,t} = f_{UK,i}(t)$ where $f_{UK,i}(t)$, $i = 1,...,21$ are country-specific freight rate indices, each of which is estimated as part of the function:

$$(2)\ \ln F_{UK,i,s,t} = \delta_i + f_{UK,i}(t) + \phi_{i,s} + u_{UK,i,s,t}\,.$$

[1] Appendix III considers other formulations of the gravity equation which address the identification problem highlighted by Baldwin and Taglioni (2006). Specifically, they incorporate country-specific time dummies. The results presented in the following section remain qualitatively unaltered by the addition of country-specific decade dummies. In the body of this paper, we present results with country fixed-effects and decade fixed-effects, but without their interaction as these diminish the identifying power of the *freight* variable.

Here, $F_{UK,i,s,t}$ is the shipment cost in Great British pounds per ton, *i* indexes shipments between a given country *i* and the United Kingdom in a given year *t* for a given commodity *s*, and δ_i is (the log of) a country fixed effect capturing the 1870 freight cost separating Great Britain and country *i*. In addition, $f_{UK,i}(t)$ are commodity-independent smooth functions of time normalized to have a mean of zero (i.e., the log of one), and $\phi_{i,s}$, $s = 1,\ldots,40$ are commodity fixed effects which vary across countries. The function is estimated separately for each country *i* and is implemented as a semiparametric model, using a penalized B-spline smoother for $f_{UK,i}(t)$ with partially linear effects for commodities.

The motivation for using semiparametric estimation is to let the data determine the shape of $f_{UK,i}(t)$, rather than imposing a parametric structure *a priori*. The penalized spline approach uses polynomial functions of *t* over separate "windows" covering different time periods (the spline functions) to approximate the unrestricted function $f_{UK,i}(t)$, with additive commodity effects in this case. We implement quadratic B-splines: quadratic splines for the curvature within windows and B-splines which optimize the spacing and placement of the windows to minimize the collinearity of spline functions across windows. To maintain degrees of freedom, a roughness penalty is added to restrict the change in curvature from window to window, resulting in greater smoothness. The spline functions are cross-validated to achieve the semiparametrically optimal smoothness. We use quadratic splines with cross-validated roughness (λ) of 2 and implement the model in S-Plus using the "GLASS" routines of Eilers and Marx. See Eilers and Marx (1996) for a description of the software and Ruppert et al. (2003) for a survey of semiparametric spline methods.

There are three crucial assumptions embodied in our semiparametric estimation of freight rate indices. First, we use country-specific, but time-invariant coefficients for the 40 different commodities we observe in our sample. This implies that, in any given country, the prices for shipping different commodities must be related by the same proportionate differences over the entire period. Historically, this restriction may be justified by considering freight rates in the North Atlantic, the most heavily traveled route. In 1870, grain could be transported between Britain and the US at 30% of the cost per ton of cotton. Likewise, wheat could be transported at 20% of the cost. In 1913, the respective figures were 25% and 16%. Given that the overall maritime freight rate index for this route fell by 45% between 1870 and 1913, the above changes on the order of 5% are relatively small and likely of second-order importance. Second, the penalized splines employ a small number of windows and a roughness penalty that delivers a freight index which varies smoothly over time and does not allow for discrete jumps or falls in freight costs. Both of these assumptions are imposed to deliver a tractable empirical model. If either is relaxed, the resulting model has too many parameters to feasibly estimate.

Finally, since we are interested in the total volume of trade between country *i* and the United Kingdom, i.e. imports plus exports, we estimate equation (2) using information on both UK-bound and -originated freight rates. In this sense, the $f_{UK,i}(t)$ term can be thought of as the commodity-independent average freight rate separating country *i* and the United Kingdom. This method also avoids the problem that indices derived from freight rates in only one direction, e.g. *from* the United States *to* the United Kingdom, are likely to be biased as back-haulage rates were vitally affected by both outward-bound rates and the composition of trade between two countries.

Figure 2 gives the reader a rough sense of this approach by plotting all available per-ton freight rates between the United States and the United Kingdom against our UK-US freight rate index as estimated from equation (2). The results are reassuring as the main trends in the data seem to be captured well. From 1870 to 1913, the index registers a 45% decline for the UK-US as compared to the 34% decline reported in the standard source on freight rates for this period (Isserlis, 1939). Again, we emphasize that this Isserlis series which was used by Estevadeordal et al. (2003) among others is simply a chained, unweighted average of a large number of disparate freight rate series with no controls for commodities or routes and is, thus, country-invariant. We believe that explicitly modeling the structure of freight rates as in equation (2) as well as allowing for cross-country differences in the evolution of freight rates is an important step in the right direction.

Next, we incorporate the country-specific freight indices into the vector of covariates *X* of equation (1) which includes standard gravity model variables: GDP, income similarity, average tariff intensities and exchange rate volatility for the United Kingdom and the twenty-one sample countries, plus an indicator for gold standard adherence by each trading partner.[2] The data are described and summarized in Table 3 while the sources are detailed in Appendix IV.

IV. Results

In what follows, we take a very agnostic approach to our estimation strategy. Since our main task is in exploring the co-movement of maritime freight rates and global trade flows, we have avoided at the moment the issue of developing a fully specified, micro-founded model of international trade in which to ground our gravity equation. And as our concern does not lie in utilizing the gravity equation as a means of testing the empirical validity of any particular

[2] The United Kingdom was, of course, on the gold standard for the entire period from 1870 to 1913.

modeling approach (Feenstra et al. 2001; Evenett and Keller, 2002), we are then on safe ground in making the following assumptions about the gravity equation: simply, that the level of bilateral trade flows should be increasing in economic size and in income similarity. Notably, accounting for time-invariant unobservables with country fixed effects "knocks out" classic gravity variables such as distance.[3]

Our first exercise is to simply run a very naïve regression of bilateral trade flows on nothing more than a constant and our measure of bilateral freight rates. These results are reported in column A of Table 4 and strongly confirm the traditional story of the role of the maritime transport revolution in the nineteenth century global trade boom. The estimated elasticity between the two variables is precise, large, and negative. A ten percent drop in freight rates is associated with an increase in trade volumes of over four percent. Thus, the drop in average freight rates between 1870-75 and 1908-13 is predicted to explain approximately fifty percent of the change in U.K. trade volumes in the same period.

Of course, this is the wrong exercise for evaluating the relationship of interest in light of the considerable body of research into gravity models of international trade flows. Thus, we include standard gravity variables—GDP, income similarity, tariff intensity, the gold standard, and nominal exchange rate volatility. GDP is defined as $(\log GDP_{UK} + \log GDP_i)$ while income similarity is measured by $\log\left(\frac{GDP_{UK}}{GDP_{UK}+GDP_i} \times \frac{GDP_i}{GDP_{UK}+GDP_i}\right)$. Tariff intensities are defined as

[3] The use of country fixed effects also allows us to avoid the issue of making the freight rate indices—which are estimated at the country level as mean-zero series—strictly comparable across countries. Thus, identification of the effects of the maritime transport revolution will instead solely come from the proportionate changes in trade and freight rates *within* countries.

$\log\left(\text{average}\left[\frac{\text{Tariff revenue}}{\text{Imports}}\right]_{UK,i}\right)$. We note that we lack country-pair specific information on tariff barriers—that is, these measures capture the general level of protection afforded in the UK and US markets, for example, but not the protection afforded against British goods in US markets and vice versa. At the same time, these same measures have been shown to correlate in sensible ways with such things as trade costs and flows (Jacks et al., 2006). Likewise, adherence to fixed exchange rate regimes as a stimulus to bilateral trade has a fairly long provenance in the literature (Rose, 2000) and especially in the context of the gold standard of the late nineteenth century (López-Córdova and Meissner, 2003).

When we incorporate these variables, the picture changes radically. Column B of Table 4 reports the results of OLS estimation of the gravity equation. Conforming to our priors, we find significant positive coefficients for GDP, income similarity, and the gold standard as well as significant negative coefficients for average tariffs and exchange rate volatility. But by far, the most striking result is that for the freight rate term. Whereas in Column A the relationship was decidedly negative, here in column B the relationship is decidedly positive.[4]

What explains this divergence from the previous results and, more pointedly, the traditional narrative of the nineteenth century? In this take, the relationship should be a negative one as lower freight rates drive down the costs of international trade and, thus, stimulate an increase in observed trade volumes. Such a result would be consistent with the findings of Baier and Bergstrand (2001) in company with Estevadoreal et al. (2003), both of which invoke the exogeneity of transportation costs in explaining the growth of world trade.

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[4] We note that this finding is not affected by the inclusion of time-variant fixed effects or other freight indices. Appendix III reports the results of this sensitivity analysis.

We believe there is another explanation, namely that freight rates are not exogenous. One of our key arguments is that there has been insufficient appreciation of the following facts: 1.) freight rates are nothing but the prices for transport services and as such are a function of the supply of shipping and the volume of trade demanded; and 2.) the volume of trade is a function of traded prices and the quantity of goods shipped. In other words, the two variables—trade volumes and freight rates—are simultaneously determined.

In the next battery of regressions, we address this endogeneity by instrumenting for the freight price indices $f_i(t)$ using a vector of instruments which includes the log of Norwegian sailors' wages, log of the prices of coal and fish, the log of the average tonnages of sail and steamships registered in the United Kingdom, the log of the (once- and twice-lagged) net tonnage of British sail and steamships, and the annual mean and variance of barometric pressures in four quadrants around the United Kingdom (the Baltic and North Seas, the Mediterranean Sea, and the North and South Atlantic). The basic idea here is to isolate the supply curve of shipping services from changes in demand, and we can motivate out instruments as follows.

Wage bills constituted a significant portion of variable costs in shipping. However, using British sailors' wages would be inappropriate as these wages are likely correlated with the British business cycle and, thus, import demand. We exploit a different source of exogenous variation in sailors' wages. Hiring Norwegian sailors was a common occurrence on merchant ships of all flags throughout this period, so their wages are likely to be highly correlated with, but not wholly dependent upon those prevailing in the British shipping industry as their labor was, in effect, an internationally traded commodity (Grytten, 2005). Such wages are likely to be a suitable instrument in that they should be correlated with freight rates but not with the error term, i.e. they only affect trade volumes indirectly through freights. Likewise, coal was a major input to the production of shipping services during the period, but the share of coal consumed by the industry was relatively small with 1.3% and 1.2% of British coal output in 1869 and 1903, respectively, being allocated to coaling stations which acted as the depositories for coal consumed in maritime transport (Griffin, 1977).

The measures of fish prices and route-specific barometric pressures are intended to capture climatic effects on the supply of shipping with the idea being that inclement weather over a year should have an adverse effect on the level of freight rates. The average tonnage of sail and steamships is intended to capture exogenous technological change in the shipping industry. As refinements in steamship technology were adopted and the physical size of steamships ballooned, the cost advantages of steam versus sail mounted and shifted out the supply curve of shipping over the long-run. And as these average tonnages enter logarithmically, these variables capture the ratio of the average steamship size to that of the average sail ship which should not be contemporaneously correlated with prevailing freight rates. We have measures of the stock of net tonnage in the sail and steam fleets of the United Kingdom at our disposal. Capacity constraints should vitally affect freight rates. However, we only include lagged values of these measures to avoid the simultaneity between what is the quantity supplied (net tonnages) and price (freight rates) of shipping service. Finally, as freight rates are dependent on the distance separating ports, we also interact all instruments with the distance between country *i*'s chief port and London.

The use of instrumental variables may also correct for the endogeneity of freight rates due to correlated missing variables. One such correlated missing variable is unobserved declines in overland shipping costs within the partner countries, particularly the introduction and extension of railroad networks. These costs bear on the alternative to maritime trade with the

United Kingdom, i.e., domestic trade. Our instruments are based on the weather, sail and steam tonnages, sailors' wages, fish prices and UK coal prices. Noting that coal is a relatively small input to rail and other overland transport, all these instruments are plausibly uncorrelated with overland freight costs. Consequently, our IV regressions can be thought of as dealing with unobserved declines in overland freight costs.

The instruments we chose are reasonably correlated with our endogenous variables of interest. In our baseline model, the R-squared of the first stage regression is 0.84, and the Shea partial R-squared of excluded instruments is 0.21. In addition, these instruments are plausibly exogenous: the test of overidentifying restrictions has a p-value of about 10%. The results of the instrumental-variables exercise are reported in Column C of Table 4. The coefficient on *freight* is now small, negative, and statistically indistinguishable from zero.[5] Taking together, these results suggest that we are correctly identifying the relationship between trade flows and freight rates, namely that freight rates are partially determined by the volume of trade—or more broadly, the degree of economic integration—demanded by nations. However, once these demand-induced changes in freight rates are accounted for, freight rates seem to have little independent bearing on the volume of trade as the coefficient on *freight* in Column C is effectively zero.

[5] The z-test statistic on an exclusion restriction for a constructed, endogenous regressor is asymptotically normally distributed. This is because the semiparametric estimate of our constructed regressor is consistent under the model and because the constructed regressor is not in the model under the null hypothesis. See Section 6.2 of Newey and McFadden (1994).

V. What Drove the Nineteenth Century Trade Boom?

In the preceding, we have presented the evidence on the relationship linking trade flows and freight rates with the view of determining the sources of globalization, both in the past and the present. As of yet, we have reached a seemingly negative conclusion: there is little evidence suggesting that the maritime transport revolution was a primary driver of the late nineteenth century global trade boom.[6]

If this conclusion is warranted, it raises the issue of what might be the other, true drivers. In order to provide an answer, we turn to the work of Baier and Bergstrand (2001). There, they argue that a general equilibrium gravity model of international trade implies that roughly two-thirds of the growth of world trade post-1950 can be explained by income growth, one-fourth by tariff reductions, and less than one-tenth by transport-cost reductions while virtually none of the growth in trade can be explained by income convergence. In the following, we suggest implicitly

[6] At the same time, there is a voluminous body of work on commodity price convergence throughout the nineteenth century (O'Rourke and Williamson, 1994, and Jacks, 2005). In the most influential contribution to this literature, O'Rourke and Williamson write that the "impressive increase in commodity market integration in the Atlantic economy [of] the late nineteenth century" was a consequence of "sharply declining transport costs" (1999, p. 33). However, O'Rourke and Williamson (1999) are quick to point out that a host of other factors could also be responsible for the dramatic boom in international trade during the period, chief among them being increases in GDP and import demand.

invoking their underlying model of world trade and explicitly following their lead by estimating the following equation[7]:

$$
\begin{aligned}
(3)\ \Delta(Trade_{UK,i}) = {} & \beta_1 \Delta \log(Freight_{UK,i}) + \beta_2 \Delta(\log GDP_{UK} + \log GDP_i) \\
& + \beta_3 \Delta \log\left(\frac{GDP_{UK}}{GDP_{UK} + GDP_i} \times \frac{GDP_i}{GDP_{UK} + GDP_i}\right) \\
& + \beta_4 \Delta \log\left(\text{average}\left[\frac{\text{Tariff revenue}}{\text{Imports}}\right]_{UK,i} \right) \\
& + \beta_5 \Delta Gold_i + \beta_6 \Delta(Exchange\ rate\ volatility_{UKi}) + \varepsilon_i ,
\end{aligned}
$$

where Δ denotes the change in a variable over a ten year period. What we are trying to achieve here is comparability of results for the nineteenth and twentieth centuries as well as provide another test of the independent role of freight rates in determining the volume of trade.

The results of this exercise are presented in Table 5. Once again, the instrumented *freight* variable fails to register—whether by sign or significance—in a manner consistent with prevailing narratives of a transport-led global trade boom in the late nineteenth century. However, the variables capturing changes in income growth, convergence, tariffs, gold standard adherence, and exchange rate volatility are all highly statistically significant and signed consistently with the results of Table 4.

Coupled with the sample means of the variables reported in Table 3, the point estimates allow us to decompose the relative contribution of these variables. Clearly, the overwhelming majority (>75%) of the change in trade volumes is explained by the growth of economies in this period—a result which compares well with the 65% figure from O'Rourke and Williamson (2002) for 1500 to 1800, the 67% figure from Baier and Bergstrad (2001) for 1958 to 1988, and

[7] We have slightly augment the model of Baier and Bergstrand by incorporating terms for secular changes in the gold standard and exchange rate volatility.

the 76% figure from Whalley and Xin (2007) for 1975 to 2004. Unlike Baier and Bergstrand (2001), we are also able to associate income convergence with the growth of trade volumes as this variable explains 18% of the variation of the dependent variable—a result which might be explainable by the greater convergence forces in effect for the pre-World War I era (O'Rourke et al., 1996). Finally, we find significant but relatively mild trade-enhancing effects for the gold standard (+6.23%) and the decline in nominal exchange rate volatility (+2.26%) as well as trade-diminishing effects for average tariffs (-1.40%).[8]

VI. Conclusion

As seen above, this paper has established two important facets of global trade which are likely to be just as applicable to the post-WWII trade boom as the pre-WWI one. First, greater care must be taken in future work considering the relationship between transportation costs and trade volumes as they are simultaneously determined. Second, and more fundamentally, once this endogeneity is dealt with in appropriate fashion there is potentially little room for maritime transport revolutions to be the primary drivers of the two global trade booms of the nineteenth and twentieth centuries. Rather, the most powerful forces driving the boom were those of income growth and convergence—a finding established here and congruent with a mounting

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[8] Partially controlling for the potential endogeneity of GDP by netting out the balance of trade (i.e., X+M in the GDP equation) leaves the results largely unchanged. And since most of the countries in our sample ran large, persistent trade surpluses with the United Kingdom, this direct (accounting) effect of trade on GDP probably dominates any second order effects on, for instance, scale and efficiency.

body of research on the sources of trade growth spanning not only the late twentieth century but all the way back to the beginning of the global trading system in 1500.

In balance, these results allow for a potential revision of the first wave of globalization—one in which the maritime transport revolution is substituted by the general progression and convergence of incomes and in which freight rates are driven by the "demand" for globalization. In this view of the world, the key innovations in the shipping industry, e.g. iron hulls and the screw propeller, were induced technological responses to the heightened trading potential of the period (see Peet, 1969, for an earlier statement of this view). Analogously, the movement towards containerization of the world mercantile fleet was strongly conditioned upon agents' expectations of commercial policy in light of attempts to re-establish the pre-war international economic order (Levinson, 2006). In short, exploring this potential causal connection between technological innovation and the diplomatic and political environment surrounding world trade remains an important task for future research.

Another possibility that our results suggest is that focusing solely on the secular decline in freight rates across the nineteenth century may be misleading. Aggregate trade costs of the countries in our sample fell on average by around 15% from 1870 to 1913 (Jacks et al., 2006). How can such a finding be reconciled with the very well-documented decline in maritime freight rates in the period? First, transportation costs are only one input into trade costs, as emphasized by Anderson and van Wincoop (2004). A broader look at the factors contributing to declines in trade costs should include overall shipping and freight rates, the rise of the classical gold standard and the financial stability it implied, and improved communication technology. There were also countervailing effects of tariffs. These rose on average by 50 percent between 1870 and 1913 (Williamson, 2006). In addition, new non-tariff barriers were erected (Saul, 1967).

At the same time, the results also warrant some caution. First, it could be argued that the United Kingdom might well be a peculiar unit of observation. Given the heavy share of raw materials and especially food stuffs in its imports, it may have found itself on an inelastic section of its demand curve, i.e. the level of freight rates would not affect the decisions of importers. However, given that separate gravity equations estimated for imports and exports (not reported) yield symmetric results, it seems unlikely that this is generating our findings.

Second, more work needs to be done in documenting and testing the complementary decline in overland freight rates during this period. In some instances, the introduction of the railroad and the telegraph led to declines in transportation costs on the order of 90% (but this number was subject to wide variation). This point can be seen in the example of the grain trade between the UK and US after 1850. Much of the decrease in the price differential between the UK and US markets came through a narrowing of price gaps separating the Midwest and the East coast of the US (O'Rourke and Williamson, 1994). The ever-expanding networks of railroads and telegraphs lowered transportation costs between the Midwest and the Atlantic ports at a faster rate than the observed decline in maritime freight rates. Jacks (2005) documents a similar pattern based on commodity price data for a large set of countries which shows much faster within country integration than cross-border integration over the period from 1800 to 1913. Thus, the differential decline in overland and maritime freight rates across countries might tell a different story, and we encourage others to follow our lead. Yet as we have argued before, to the extent that within-country freight costs are uncorrelated with the supply-side instruments we use, our instrumental variables strategy corrects for such excluded changes in overland transportation costs.

Finally, recent research has suggested that the period prior to 1870 might have, in fact, been the "big bang" period for the maritime transport revolution. Again, Jacks (2006) documents a decline in the price gap for wheat separating London and New York City from 1830 to 1913 of 88%. Yet this decline was highly concentrated—of that 88%, the period from 1830 to 1870 witnessed a 74% decline with the remaining 14% decline being contributed in the period from 1870 to 1913. It stands to reason that if maritime transport revolutions matter we should also be looking at the early nineteenth century for clues. Unfortunately, systematic freight, output, and trade data are all lacking for this earlier period. But there are some fragments at our disposal: real US trade with 10 European countries and Canada grew 449% between 1870 and 1913 but only 412% between 1830 and 1870 (Treasury Department, 1893). Of course, one needs to condition on standard gravity variables as argued above, but *prima facie* this suggests that if anything the response of trade in the face of an even steeper decline in freight rates from 1830 to 1870 was more muted. Only ongoing work by economic historians piecing together the trade history of the early nineteenth century will allow us to test this hypothesis directly.

Appendix I: Sources of Freight Rates

The richest single source for nineteenth century freight rates is Angier (1920). This provided 3049 of the 7923 observations in the global freight rate dataset available from the authors. Of these 7923 observations, 5247 comprise either UK-destined or –originated freights and were used in this paper. The following comprises the full list of sources.

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Angier, E.A.V. (1920), *Fifty Years' Freights 1869-1919*, London: Fairplay.

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Appendix II: Composition of Freight Rates

Of primary concern in constructing freight rate indices as above is the composition and, thus, representativeness of the underlying series. Table A.1 details the dataset of individual freight rate observations along three dimensions. The first column considers the frequency with which countries are represented in the data. At the top of the list, we find that a very substantial proportion of the freight rates are taken from the United States. This is probably not surprising as the United States was the United Kingdom's largest trading partner (and the two were the largest trading partners in the world throughout the period). At the same time, one can see that most countries are very well-represented, including a number (e.g. Australasia, Ceylon, and India) which witnessed the most dramatic drops in freight rates in the period under consideration. The second column considers the commodities for which the freight rates were contracted. The number one commodity was coal which, of course, was a primary export of the United Kingdom at the time. Of the remaining twenty commodities, only the "General" and "Provisions" categories could be interpreted as capturing manufactured goods. Thus, the freight rate indices should capture the maritime transport revolution reasonably well to the extent that it vitally affected high-bulk, low-value commodities. Finally, the third column details the most prominent country and commodity pairings.

Table A.1: Composition of freight rate series

By country:	N	%	By commodity (top 21 only):	N	%	By country & commodity (top 21 only):	N	%
United States	1627	30.76	Coal	2037	38.51	United States, grain	537	10.23
Russia	794	15.01	Grain	770	14.56	Italy, coal	449	8.56
India	518	9.79	Wheat	567	10.72	United States, wheat	251	4.78
Italy	450	8.51	General	303	5.73	France, coal	247	4.71
Argentina	317	5.99	Deals	213	4.03	United States, flour	210	4.00
France	247	4.67	Flour	210	3.97	Argentina, coal	188	3.58
Spain	237	4.48	Provisions	149	2.82	Russia, wheat	188	3.58
Germany	180	3.40	Cotton	139	2.63	Germany, coal	180	3.43
Chile	120	2.27	Ore	114	2.16	Russia, grain	179	3.41
Australasia	116	2.19	Rice	76	1.44	India, coal	167	3.18
Ceylon	115	2.17	Sugar	63	1.19	Spain, coal	165	3.14
Brazil	101	1.91	Beef	58	1.10	Russia, coal	157	2.99
Sweden/Norway	91	1.72	Pork	58	1.10	United States, provisions	149	2.84
Canada	86	1.63	Phosphate	57	1.08	India, general	143	2.73
Philippines	71	1.34	Hemp	44	0.83	United States, cotton	137	2.61
Portugal	48	0.91	Nitrate	40	0.76	Russia, deals	136	2.59
Denmark	42	0.79	Bacon	38	0.72	Ceylon, coal	101	1.92
Dutch East Indies	41	0.78	Jute	38	0.72	Chile, coal	80	1.52
Japan	39	0.74	Wood	36	0.68	Brazil, coal	78	1.49
Uruguay	31	0.59	Oats	35	0.66	Sweden/Norway, coal	72	1.37
Colombia	19	0.36	Mutton	32	0.60	Argentina, wheat	64	1.22

Appendix III: Sensitivity Analysis

The following tables present the results of some sensitivity analysis. The inclusion of decadal country fixed effects (i.e., there are five separate fixed effects for each of the twenty-one sample countries) in the second column of Table A.2 is intended to capture any remaining unexplained variation coming from time-varying country attributes. The specification preserves the sign of the *freight* variable while decreasing its magnitude and significance. This does little to change our basic story. This specification also destroys most of the explanatory power of remaining variables, but the GDP and GDP shares remain large and highly significant. Additionally, this specification comes closest to addressing the identification problems highlighted in Baldwin and Taglioni (2006). The results are much the same for the IV specification presented immediately below.

Table A.2: Regressions with time-varying country fixed effects

Dependent variable: Average bilateral volume of trade

OLS with fixed effects:	Country and decade fixed effects			Decadal country fixed effects		
	Estimate	Std Error	p-value	Estimate	Std Error	p-value
Freight	**0.2463**	**0.1047**	**0.019**	0.0692	0.0674	0.305
GDP	**0.7549**	**0.1650**	**0.000**	**0.8308**	**0.1250**	**0.000**
Income similarity	**0.9095**	**0.1556**	**0.000**	**0.7300**	**0.1973**	**0.000**
Average tariffs	**-0.1556**	**0.0645**	**0.016**	-0.0306	0.0755	0.686
Gold standard	**0.2019**	**0.0396**	**0.000**	0.0633	0.0447	0.157
Exchange rate volatility	**-1.7926**	**0.8069**	**0.026**	-0.1466	0.6822	0.830
Observations		671			671	
R-squared		0.4789			0.7800	

IV with fixed effects:	Country and decade fixed effects			Decadal country fixed effects		
	Estimate	Std Error	p-value	Estimate	Std Error	p-value
Freight	-0.0146	0.1754	0.934	0.0572	0.1546	0.712
GDP	**0.5470**	**0.1532**	**0.000**	**0.7357**	**0.1421**	**0.000**
Income similarity	**0.8498**	**0.1529**	**0.000**	**0.5185**	**0.1984**	**0.009**
Average tariffs	**-0.2211**	**0.0618**	**0.000**	-0.0812	0.0561	0.148
Gold standard	**0.2178**	**0.0358**	**0.000**	**0.1037**	**0.0304**	**0.001**
Exchange rate volatility	**-1.5656**	**0.8346**	**0.061**	-0.0431	0.6535	0.947
IV relevance (p-value)		152.185 (0.000)			226.696 (0.000)	
IV overidentification test (p-value)		29.871 (0.095)			45.324 (0.002)	
Observations		671			671	
R-squared		0.4837			0.7801	

NB: All estimation with first-order auto-regressive and heteroskedastic robust standard errors; fixed effects not reported.

Table A.3 shows that the results presented in the text are robust to the inclusion of other freight rate indices, whether they be variants of our preferred index or the Isserlis (1938) index. Across the board, the coefficients on the *freight* variable are statistically indistinguishable from the results discussed above.

Table A.3: Regressions with alternate freight indices

Dependent variable: Average bilateral volume of trade

OLS with country fixed effects	Estimate	Std Error	p-value	Estimate	Std Error	p-value	Estimate	Std Error	p-value	Estimate	Std Error	p-value
Freight (λ=2)	**-0.4457**	**0.0590**	**0.000**									
Isserlis index				**-0.5020**	**0.0676**	**0.000**						
Alternate Freight (λ=1)							**-0.4363**	**0.0587**	**0.000**			
Alternate Freight (λ=3)										**-0.4513**	**0.0592**	**0.000**
Observations		671			671			671			671	
R-squared		0.1937			0.1856			0.1878			0.1976	
OLS with country and decade fixed effects	Estimate	Std Error	p-value	Estimate	Std Error	p-value	Estimate	Std Error	p-value	Estimate	Std Error	p-value
Freight (λ=2)	**0.2463**	**0.1047**	**0.019**									
Isserlis index				**0.1904**	**0.0821**	**0.020**						
Alternate Freight (λ=1)							**0.2397**	**0.0942**	**0.011**			
Alternate Freight (λ=3)										**0.2486**	**0.1121**	**0.027**
GDP	**0.7549**	**0.1650**	**0.000**	**0.6447**	**0.1446**	**0.000**	**0.7499**	**0.1606**	**0.000**	**0.7572**	**0.1681**	**0.000**
Income similarity	**0.9095**	**0.1556**	**0.000**	**1.0133**	**0.1665**	**0.000**	**0.9092**	**0.1568**	**0.000**	**0.9100**	**0.1549**	**0.000**
Average tariffs	**-0.1556**	**0.0645**	**0.016**	**-0.1854**	**0.0649**	**0.004**	**-0.1576**	**0.0644**	**0.014**	**-0.1548**	**0.0646**	**0.017**
Gold standard	**0.2019**	**0.0396**	**0.000**	**0.1878**	**0.0389**	**0.000**	**0.2002**	**0.0396**	**0.000**	**0.2027**	**0.0395**	**0.000**
Exchange rate volatility	**-1.7926**	**0.8069**	**0.026**	**-1.7378**	**0.8002**	**0.030**	**-1.8173**	**0.8051**	**0.024**	**-1.7802**	**0.8080**	**0.028**
Observations		671			671			671			671	
R-squared		0.4789			0.4810			0.4791			0.4786	
IV with country and decade fixed effects	Estimate	Std Error	p-value	Estimate	Std Error	p-value	Estimate	Std Error	p-value	Estimate	Std Error	p-value
Freight (λ=2)	-0.0146	0.1754	0.934									
Isserlis index				0.1653	0.1151	0.151						
Alternate Freight (λ=1)							-0.0195	0.1838	0.915			
Alternate Freight (λ=3)										-0.0734	0.1913	0.701
GDP	**0.5470**	**0.1532**	**0.000**	**0.5703**	**0.1314**	**0.000**	**0.5301**	**0.1522**	**0.000**	**0.4993**	**0.1587**	**0.002**
Income similarity	**0.8498**	**0.1529**	**0.000**	**0.8833**	**0.1477**	**0.000**	**0.8479**	**0.1716**	**0.000**	**0.8591**	**0.1700**	**0.000**
Average tariffs	**-0.2211**	**0.0618**	**0.000**	**-0.1943**	**0.0622**	**0.002**	**-0.2062**	**0.0636**	**0.001**	**-0.2151**	**0.0634**	**0.001**
Gold standard	**0.2178**	**0.0358**	**0.000**	**0.2323**	**0.0368**	**0.000**	**0.2317**	**0.0369**	**0.000**	**0.2288**	**0.0371**	**0.000**
Exchange rate volatility	**-1.5656**	**0.8346**	**0.061**	-1.3195	0.8458	0.119	-1.3140	0.8588	0.126	-1.3105	0.8549	0.125
IV relevance (p-value)		152.185 (0.000)			468.905 (0.000)			137.162 (0.000)			135.872 (0.000)	
IV overidentification test (p-value)		29.871 (0.095)			22.952 (0.347)			29.030 (0.113)			29.659 (0.099)	
Observations		671			671			671			671	
R-squared		0.4837			0.4846			0.4767			0.4717	

NB: All estimation with first-order auto-regressive and heteroskedastic robust standard errors; fixed effects not reported.

Appendix IV: Sources of Gravity Variables

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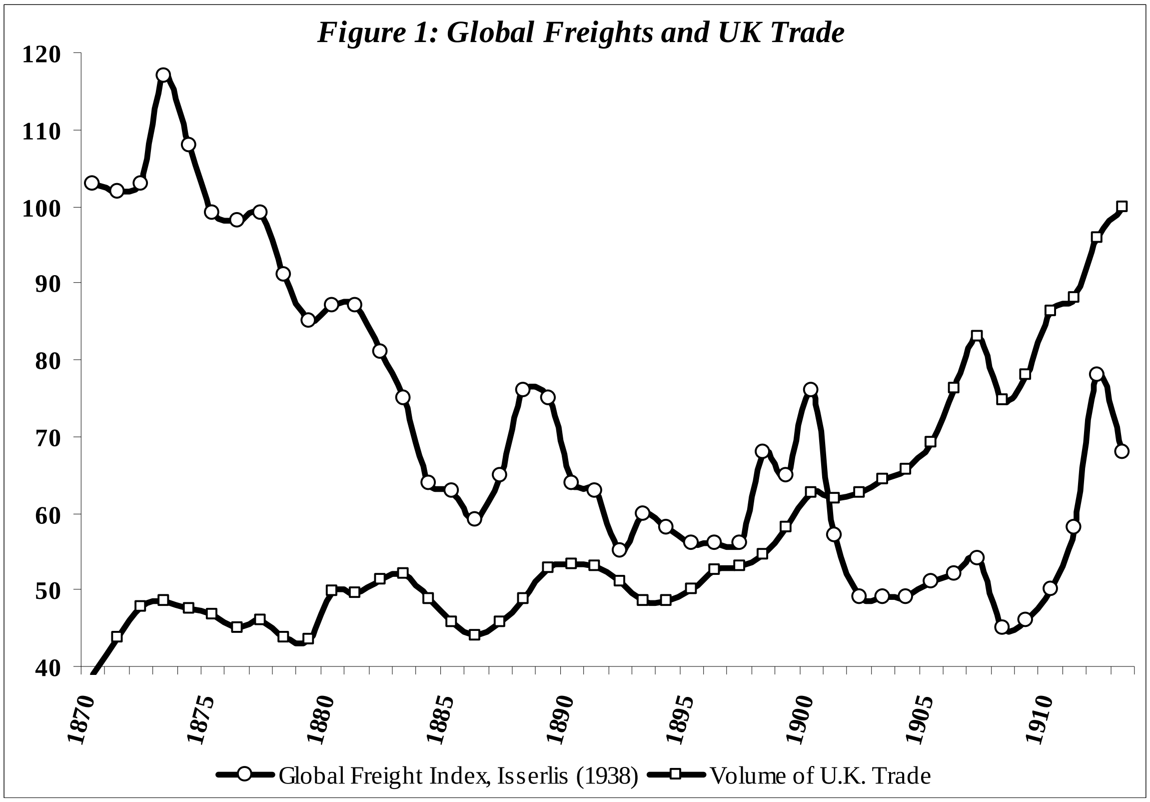
Figure 1: Global Freights and UK Trade
120
110
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1895
1900
1905
1910
Global Freight Index, Isserlis (1938)
Volume of U.K. Trade

Table 1: Trade Ratios

	Sample to UK trade ratio	*UK to global trade ratio*	*Sample to global trade ratio*
1870-1875	0.7116	0.2969	0.2111
1875-1880	0.7264	0.2629	0.1909
1880-1885	0.7369	0.2310	0.1703
1885-1890	0.7456	0.2193	0.1635
1890-1895	0.7508	0.2098	0.1575
1895-1900	0.7607	0.2013	0.1532
1900-1905	0.7657	0.1940	0.1486
1905-1910	0.7539	0.1692	0.1276
1910-1913	0.7412	0.1514	0.1122

Sources: Estevadeordal et al. (2003); *Statistical Abstract for the United Kingdom* .

Table 2: Sample Countries and Coverage

Countries with a full panel of GDP and freight data from 1870:

Brazil	Japan
Canada (ends 1907)	Portugal
Ceylon	Russia
Dutch East Indies	Spain
France	United States
Germany	Uruguay (ends 1907)
Italy	

Countries with a full panel of GDP and freight data from 1884:

Australasia	India
Denmark	Norway & Sweden

Countries with a full panel of GDP and freight data from 1900:

Argentina	Colombia
Chile	Philippines

NB: Australia and New Zealand do not enter as separate trade entities before 1887; likewise, Norway and Sweden do not enter seperately until 1891.

Figure 2: Freight Rates and Freight Indices

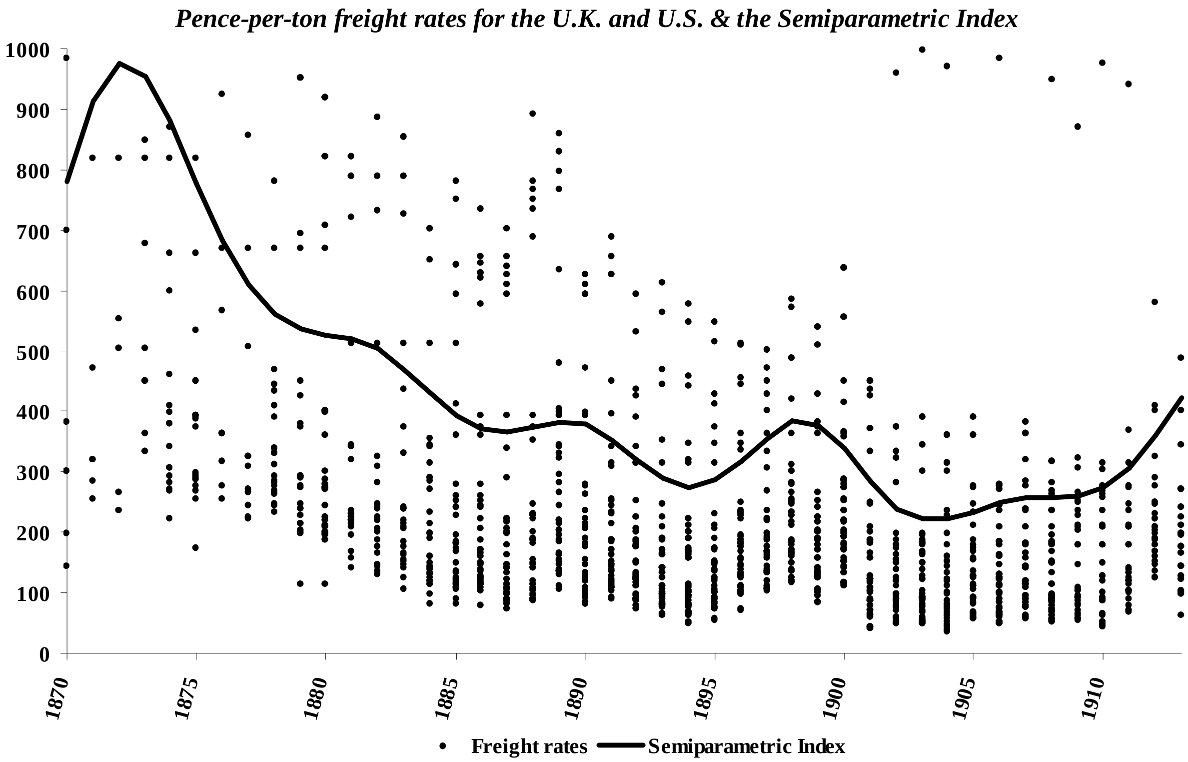

Table 3: Data Summary

	Description:	N	Mean	Stand Dev	Minimum	Maximum
Volume of trade	Average of bilateral imports (log of) plus exports (log of)	671	20.38	1.206	17.22	22.58
Freight	Semiparametric index of country-specific freight rates (log of)	671	4.28	0.368	3.11	5.19
GDP	Sum of UK and partner GDP (log of)	671	12.32	0.334	11.69	13.53
Income similarity	Product of UK- and partner-shares of combined GDP (log of)	671	-2.31	0.860	-4.71	-1.39
Average tariffs	Average of partner and UK tariffs (log of)	671	2.30	0.511	1.25	3.46
Gold standard	Indicator variable for partner adherence to gold standard	671	0.56	0.497	0.00	1.00
Exchange rate volatility	Standard deviation of change in logged nominal exchange rate	671	0.01	0.014	0.00	0.10
Growth of trade	Decadal difference in Volume of trade	463	0.1565	0.3108	-0.9414	1.7904
Change in freight	Decadal difference in Freight	463	-0.2327	0.1814	-0.7567	0.4213
Growth in GDP	Decadal difference in GDP	463	0.1894	0.0532	0.0638	0.4133
Convergence of GDP	Decadal difference in Income similarity	463	0.0300	0.0939	-0.1863	0.5062
Change in average tariffs	Decadal difference in Average tariffs	463	0.0112	0.2444	-0.7258	0.8139
Change in gold standard adherence	Decadal difference in Gold standard	463	0.1102	0.4349	-1.0000	1.0000
Change in exchange rate volatility	Decadal difference in Exchange rate volatility	463	-0.0018	0.0167	-0.0771	0.0930

Table 4: Gravity Regressions

Dependent variable: Average bilateral volume of trade

	Column A - OLS estimates			***Column B - OLS estimates***			***Column C - IV estimates***		
	Estimate	Std Error	p-value	Estimate	Std Error	p-value	Estimate	Std Error	p-value
Freight	**-0.4457**	**0.0590**	**0.000**	**0.2463**	**0.1047**	**0.019**	-0.0146	0.1754	0.934
GDP				**0.7549**	**0.1650**	**0.000**	**0.5470**	**0.1532**	**0.000**
Income similarity				**0.9095**	**0.1556**	**0.000**	**0.8498**	**0.1529**	**0.000**
Average tariffs				**-0.1556**	**0.0645**	**0.016**	**-0.2211**	**0.0618**	**0.000**
Gold standard				**0.2019**	**0.0396**	**0.000**	**0.2178**	**0.0358**	**0.000**
Exchange rate volatility				**-1.7926**	**0.8069**	**0.026**	**-1.5656**	**0.8346**	**0.061**
Decade fixed effects?		*NO*			*YES*			*YES*	
IV relevance (p-value)								152.185 (0.000)	
IV overidentification test (p-value)								29.871 (0.095)	
Observations		671			671			671	
R-squared		0.1937			0.4789			0.4837	

NB: All estimation with first-order auto-regressive and heteroskedastic robust standard errors; fixed effects not reported; freight instrumented with sailors' wages, coal & fish prices, average sail & steam tonnages, lagged sail & steam net tonnages, and barometric means & standard deviations.

Table 5: Differenced Regression

Dependent variable: Change in average bilateral volume of trade

	Coefficient on regressor *A*	Std Error	p-value	Average change in regressor *B*	Predicted effect *C=A*B*	As a percentage of average trade growth *D=(C/.1565)*100*
Change in freight	-0.1786	0.2761	0.518	-0.2327	0.042	26.56
Growth in GDP	**0.6311**	**0.2320**	**0.007**	**0.1894**	**0.119**	**76.36**
Convergence of GDP	**0.9583**	**0.1836**	**0.000**	**0.0300**	**0.029**	**18.38**
Change in average tariffs	**-0.1958**	**0.0851**	**0.021**	**0.0112**	**-0.002**	**-1.40**
Change in gold standard adherence	**0.0854**	**0.0453**	**0.060**	**0.1102**	**0.009**	**6.23**
Change in exchange rate volatility	**-1.9396**	**0.9580**	**0.043**	**-0.0018**	**0.003**	**2.26**
IV relevance (p-value)	86.122 (0.000)					
IV overidentification test (p-value)	11.995 (0.151)					
Observations	463					
R-squared	0.3246					

NB: All variables are differenced over ten year periods in the estimation above; the change in freight is instrumented with changes in sailors' wages, coal & fish prices, average sail & steam tonnages, lagged sail & steam net tonnages, and barometric means & standard deviations.