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Centre for Economic Policy Research
33 Great Sutton Street, London EC1V 0DX, UK
Tel: +44 (0)20 7183 8801
www.cepr.org

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JEL Classification: F1, N7

Keywords: distance, Empire, Gravity

David Jacks - dsjacks@gmail.com
Simon Fraser University and CEPR

Kevin O'Rourke - ko37@nyu.edu
NYU Abu Dhabi and CEPR

Alan M. Taylor - amtaylor@ucdavis.edu
University of California, Davis and CEPR

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The Gravitational Constant?[⋆]

David S. Jacks[†] Kevin Hjortshøj O'Rourke[‡] Alan M. Taylor[§]

October 2020

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[†]Department of Economics, Simon Fraser University; CEPR; and NBER (dsjacks@gmail.com).

[‡]Department of Economics, NYU Abu Dhabi; CEPR; and NBER (kevin.orourke@nyu.edu).

[§]Department of Economics and Graduate School of Management, University of California, Davis; CEPR; and NBER (amtaylor@ucdavis.edu).

1 Introduction

A key finding of a now vast literature is that bilateral trade patterns are determined by the so-called forces of gravity: trade is enhanced by the attractive (multiplicative) force of economic mass in two locations – along with other destination and origin characteristics – but it is reduced by frictions due to bilateral trade costs, some of which increase with distance. Over four decades, from its early formalization to incorporation in basic textbooks, gravity has been found to operate in a wide range of empirical settings, and can be rationalized by many underlying theoretical models of international trade (Anderson, 1979; Bergstrand, 1985; Leamer and Levinsohn, 1995; Eaton and Kortum, 2002; Anderson and van Wincoop, 2003; Feenstra, 2004; Chaney, 2008). Very recent research in this area has furthered our understanding of many of the mechanisms involved and the underlying drivers of gravity (Eaton and Fieler, 2019; Redding and Weinstein, 2019; Allen, Arkolakis, and Takahashi, 2020).

However, precisely how far and to what extent gravity held in the past remains unclear.[1] This gap in our knowledge persists for a simple reason: the scarcity of high quality, sufficiently detailed trade data prior to the mid-19th century. In this paper, we introduce a new and large hand-collected dataset on British exports at the bilateral, commodity-level for the two centuries from 1700 to 1899.

This was a period of momentous and almost continuous change. Politically, England and Wales were united with Scotland in 1707, forming the new state of Great Britain. In 1801 Britain and Ireland merged to form the United Kingdom. The 18th century saw England, and later Britain, fighting a series of wars in Europe, India, and the Americas, culminating in the American Revolutionary War and the quarter century struggle against France that only ended in 1815. While the loss of the United States was a major blow, the Empire resumed its expansion in the 19th century in Africa and Asia. Settler colonies were established in Oceania and consolidated in what remained of British North America, while formal empire was supplemented with informal empire in Latin America and elsewhere. Economically, the UK was the first country to undergo an industrial revolution; a more urban and liberal society eventually emerged, and mercantilism was decisively abandoned

[1] In a recent contribution, Barjamovic et al. (2019) explore trade patterns in the Bronze Age. They find that certain features of commercial travel between Assyrian settlements described in primary records see well-approximated by an arbitrage-based model of trade. They then use estimates of the elasticity of the probability of commercial travel between settlements with respect to distance to infer the location of so-called lost cities.

in the mid-19th century. The UK was at the heart of the nascent global economy, importing food and raw materials from around the world, and exporting capital, manufactured goods, people, and services. Were the determinants of trade constant across these two centuries that saw such dramatic shifts in the geopolitical environment, information transmission, trade policies, and transport costs?

A basic problem we confront in the data is that British trade flows were valued at constant "official" prices during the 18th and early 19th century. This means that it makes little sense to estimate trade models for that period using aggregate data, given that relative prices were changing over time and that aggregate values are therefore mismeasured. By working with commodity-level data, we are able to reliably estimate cross-sectional gravity models, as industry-specific price levels can be absorbed by fixed effects. We are thus able to estimate both the trade-diminishing effects of bilateral distance, and the trade-enhancing effects of membership in the British Empire, as far back as 1700 – more than a century earlier than any existing study to date (Mitchener and Weidenmier, 2008; Jacks, Meissner, and Novy, 2011; Fouquin and Hugot, 2016).

We find that gravity exerted its pull as early as 1700, but that the distance effect then attenuated significantly. It had almost vanished by the 19th century, becoming statistically indistinguishable from zero. Meanwhile the empire effect peaked sometime in the late 18th century before significantly declining in influence. An analysis of aggregate data from 1870 to 2010 confirms our findings for the late 19th century, and shows that distance only started to matter again for UK exports from the middle of the 20th century onwards. Thus, the forces of gravity were operational more than three centuries ago, but they were far from being constant over time.

Section 2 introduces the new data underlying this paper and considers the various advantages and limitations inherent in such a long panel of bilateral trade flows. Section 3 revisits the gravity model of trade and introduces our empirical model. Section 4 explores some basic contours of the data and presents our baseline results, while Section 5 concludes.

2 Data

One of the chief outputs of this paper comes in the form of a new and comprehensive dataset of bilateral, commodity-level British exports from 1700 to 1899. The primary sources of the data are the ledgers of exports compiled by the Customs and Excise

Department under various titles from 1697 to 1899. These were entirely hand-written until the mid-19th century, and remained partly hand-written thereafter, thus, precluding the use of optical character recognition software. Appendix A details the sources used on a year-by-year basis and includes some images of the ledgers themselves.

All told, 424,551 lines of raw data from over 7,000 pages of ledgers were scanned, digitized, and then (painstakingly) cleaned by hand, a process that took more than a decade from start to finish. For our present purposes we focus our attention on British exports. Our reasons for doing so relate to: (i) concerns over smuggling activity and under-reporting which primarily apply to imports and re-exports; and (ii) potential concerns over market versus official valuations of trade flows which ease considerably earlier in the case of exports rather than imports (see below).

The first objective of the original data collection by the British government was to determine bilateral trade flows for taxation purposes. By 1697 there was already an extensive set of excises and tariffs in place which provided a significant fraction of central government revenue and which required close observation and detailed accounting of exports and imports of goods in British ports (O'Brien, 1988). At the same time an increasingly mercantilist understanding of the role of trade in shaping the domestic economy had developed. The ledgers provide annual summaries of bilateral exports and imports, plus re-exports, as well as annual outflows of gold and silver. Thus, a secondary objective of the original data collection was to use the balance of trade as a key indicator for the British economy, and to measure net bullion flows which were a potential objective of economic policy.

The ledgers themselves contain a line-by-line account of Britain's commodity-level bilateral trade flows with locations in the rest of the world. Both the primary and secondary literature provide reassurance that the ledgers represent the full population of British trade flows. They are, however, presented in an inconsistent welter of detail – in some years, for instance, distinguishing between trade with London versus "outports", trade carried out on British versus foreign ships, or the trade of sub-national units like England versus Scotland. There are also changes over time with respect to the reporting unit: thus, trade flows are captured for England and Wales up to 1780, for Great Britain (including Scotland) up to 1830, and for the United Kingdom (including Ireland) up to 1899.[2]

[2]These breaks in the reporting unit somewhat obscure the overwhelming dominance of England throughout. In 1790, the first year in which exports are reported for England and Scotland, the former accounted for 95% of all British exports. In 1840, the first year in which exports are reported for England, Ireland, and Scotland, the first accounted for 90% of all UK exports.

The ledgers are the sources underlying such classic studies of British trade as Schlote (1958) and Schumpeter (1960). However, this pioneering work was mostly concerned with the compilation of aggregate trade statistics, reflecting the scholarly interest of the period in macroeconomic aggregates, as well as technological constraints on data storage. In consequence, despite the tremendous time and effort which was expended on compiling and aggregating these statistics, most of the resultant figures gave little sense of the important shifts in the commodity-by-country composition of British trade which occurred over this period.

A notable advance came with the lifelong work of Ralph Davis, summarized in Davis (1979). In this slim but dense volume, Davis details British exports and imports using a classification scheme of roughly 20 commodity groups across 15 geographical designations for the period from 1785 to 1855. This is one of the only attempts to provide early British trade data at the commodity-country level, with most studies reporting total trade figures for a particular commodity or a particular geographic entity, but not their cross-tabulation. Our project is thus a continuation of and improvement on the path-breaking work of Davis, with no further systematic evidence having been collected over the past four decades.

Our goal was to digitize the export ledgers at 10 year intervals from 1700 to 1899.[3] However, in any project like this there are a number of caveats regarding the data – in particular relating to aggregation – which should be addressed head-on:

1. Going back as far as Clark (1938), some critics have disparaged the use of the ledgers as accurate guides to British trade. In particular, commentators have criticized the reliability of such statistics due to the lack of effort and misaligned incentives of government agents, smuggling activity, and the under-reporting of imports in particular. Although these concerns are undoubtedly valid, the scale of this type of activity was almost certainly dominated by the volume of trade legitimately recorded and is more likely even smaller in the case of export activity. What is more, there is nothing in the historical record suggesting that any systematic bias across countries, industries, or industry-by-country combinations (which will form our basic observational unit).

2. Before 1904 (that is, during our entire period of interest), British exports were reported for those countries to which they were directly shipped. Thus, trans-

[3]The full set of years in the final dataset are 1700, 1710, 1720, 1730, 1740, 1750, 1760, 1770, 1780, 1790, 1800, 1807, 1820, 1830, 1840, 1850, 1860, 1869, 1880, 1890, and 1899. The inclusion of "off years" like 1807 was driven by data availability in certain benchmark years.

shipment trade went unreported (and, as a consequence, land-locked nations are absent in the data). Additionally, while the goods categories that were reported in the ledgers were generally becoming more aggregated, the level at which destinations were reported was generally becoming more disaggregated. What this means is that in using the most geographically disaggregated data available in any given year to examine the extensive margin of British exports we run the risk of conflating the "real" extensive margin with changes in the process of data collection and coding.

Our proposed solution is to aggregate the bilateral, commodity-level export data up to the smallest area which can be consistently tracked through time. For example, we merge all observations on China and Hong Kong. In what follows, this amounts to having 99 geographic areas (or "countries") for every year in our gravity regressions. Appendix B describes the geographic distribution of the 99 destinations in our final dataset. The average distance from the UK across the countries in our sample is 6,304 kilometers, ranging from 322 (for Belgium) to 18,327 (for New Zealand).

3. The evolving structure of the British economy over these two centuries implied corresponding changes in the structure of the trade data reported in the ledgers. Some goods categories suddenly emerge in the data (like railway carriages) while others disappear (like human hair). The chief problem this raises is how to assign consistent goods categories across years.

   Our first step in arriving at a consistent classification was to apply more or less modern and consistent country-grouping definitions as discussed in above. Thus, from the original 424,551 raw observations of disaggregated exports from 1700 to 1899, we arrive at 231,209 observations of exports for the whole of England, Britain or the UK (depending on the year being considered), rather than from individual ports or sub-national units; of these we can assign consistent country identifiers to 223,523 observations. We then assign SITC-2 codes to each observation: given that the commodity headings that were used were often quite imprecise, it is easier to assign exports to broader than to narrower categories. We obtain:

   - 223,523 observations that can be classified at the 1-digit level (e.g, beverages & tobacco);
   - 217,082 observations that can be classified at the 2-digit level (e.g, beverages);

- 13,399 observations that can be classified at the 3-digit level (e.g, alcoholic beverages);
- 13,335 observations that can be classified at the 4-digit level (e.g., beer made from malt);
- 64 observations that can be classified at the 5-digit level (e.g., ale).

Given the dramatic reduction in the number of observations when we move from the 2-digit to the 3-digit level, we settle on the 2-digit level as our preferred level of analysis as it provides the best compromise between disaggregation and observation count. We then aggregate individual observations at the 2-digit level to form our measure of export activity at the country-industry level. We further interpret the ledgers as representing the universe of British trade and rectangularize the data by assigning zero values to observations for particular country-industry combinations for which there are no recorded values.

4. Another obstacle to the use of the ledgers is the aforementioned fact that the underlying prices used to value bilateral trade flows were initially fixed – from 1702 to 1813 in the case of exports and from 1702 to 1853 in the case of imports. These "official prices" were based on average prices prevailing in or around 1694 and were presumably used in an attempt to minimize bargaining over customs valuations and, thereby, maximize compliance. For many researchers, this implicit fixed price index was seen as a chief attraction of the data, in that it provided a consistent measure of real quantities exported and imported. For example, Deane and Cole (1962) famously made use of these data to construct their indices of industrial production. On the other hand, aggregating across such real quantities to obtain aggregate export values, required in order to estimate standard gravity models, is clearly problematic. In what follows, in order to address this issue we estimate gravity models using cross-sections of data on exports at the country-industry level along with industry-level fixed effects, thus capturing potential differences in relative price levels in individual years.

All told, our final panel of data for the 21 years between 1700 and 1899 consists of English/British/UK exports to 99 consistently-defined countries for 57 industries recorded at the SITC 2-digit level. The final observation count is then 118,503 in total (with an average of 5,643 observations per year).

3 Gravity in the very long run

Over the past 20 years, the gravity model has emerged as the uncontestable workhorse of empirical international trade research. A very large literature has built up and documented its applicability to particular episodes in the history of globalization and over longer run periods (Estevadeordal, Frantz, and Taylor, 2003; Jacks, Meissner, and Novy, 2011). Moreover, it has been shown that gravity equations can be derived from a wide range of leading trade models. Although the driving forces behind trade differ across these models, they all predict a gravity equation for international expenditure patterns. Grossman (1998, pp. 29–30) nicely summarizes this situation: "specialization lies behind the explanatory power [of gravity], and of course some degree of specialization is at the heart of any model of trade... this is true no matter what supply-side considerations give rise to specialization, be they increasing returns to scale in a world of differentiated products, technology differences in a world of Ricardian trade, or large factor endowment differences in a world of Heckscher-Ohlin trade."

Anderson and van Wincoop (2003, henceforth AvW) derive a structural gravity equation of the form

$$x_{ij} = \frac{y_i y_j}{y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} . \tag{1}$$

The value of bilateral exports (x_{ij}) represents the nominal demand for country i's good in country j, which can be written as price times quantity ($p_{ij}\ q_{ij}$), where the delivered price of export goods (p_{ij}) equals the home price (p_i) times an iceberg trade cost (t_{ij}). The value of bilateral exports is also a function of output (y_i, y_j) – or equivalently, expenditure – in countries i and j relative to world output (y_w); bilateral trade costs (t_{ij}) relative to indices of outward and inward trade costs (Π_i and P_j) which AvW label the two countries' outward and inward multilateral resistance; and the elasticity of substitution for traded goods (σ). Thus, bilateral trade flows are a function of factors common to all countries, factors within particular countries, and factors which are specific to country-pairs (that is, bilateral trade costs).

Based on Equation 1, an estimating equation for gravity models in the cross-section which is consistent with AvW then takes the form of

$$\ln x_{ij} = \delta + \alpha_i + \beta_j + z_{ij}\,\gamma + \epsilon_{ij}\,, \tag{2}$$

where x_{ij} again represents bilateral exports from country i to j; δ is a constant; the α_i and

α_j terms represent exporter and importer fixed effects intended to capture multilateral trade barriers, productivity, resource endowments, and any other country-level attributes which might determine a country's propensity to trade; z_{ij} is a set of gravity variables representing various bilateral factors that impede or promote the flow of goods between countries i and j; and ϵ_{ij} is an error term. Note that the exporter and importer fixed effects absorb both countries' output (a standard proxy for which is country-level GDP) and the multilateral resistance terms.

In the context of more disaggregated trade flows, the basic structural gravity equation for industries is given by

$$x_{ij}^k = \frac{y_i^k y_j^k}{y_w^k} \left(\frac{t_{ij}^k}{\Pi_i^k P_j^k} \right)^{1-\sigma_k}, \tag{3}$$

which features the same variable definitions as Equation 1, simply indexed at the industry k level (see Redding and Weinstein, 2019). Thus, disaggregated bilateral trade flows are a function of industry-level factors common to all countries, factors within particular industries in particular countries, and factors specific to particular industries in particular country-pairs (that is, industry-specific bilateral trade costs).

This suggests an estimating equation featuring industry fixed effects, exporter and importer fixed effects for all country-industry combinations, and proxies for industry-specific bilateral trade costs, or

$$\ln x_{ij}^k = \delta^k + \alpha_i^k + \beta_j^k + z_{ijk}\,\gamma^k + \epsilon_{ijk}\,. \tag{4}$$

Importantly, the second term on the right hand side, α_i^k, can accommodate instances in which bilateral trade is measured in real rather than nominal terms, as is the case for British exports prior to 1813. In this case we would simply have (from Equation 3 and the fact that $x_{ij}^k = p_{ij}^k q_{ij}^k = p_i^k t_{ij}^k q_{ij}^k$)

$$\alpha_i^k = \ln y_i^k - (1-\sigma_k) \ln \Pi_i^k - \ln p_i^k\,,$$

where the additional term p_i^k represents the price index of industry k in the exporting country i. In other words, the exporter-industry fixed effects absorb industry-specific price levels, which may be changing from cross-section to cross-section.

Furthermore, as we are dealing with a single exporter (that is, i indexes only Britain)

the exporter subscript can be dropped. We then have

$$\ln x_j^k = \alpha^k + \beta_j^k + z_{jk}\,\gamma^k + \epsilon_{jk}\,. \tag{5}$$

Note however that the importer-industry fixed effects β_j^k cannot be estimated, as they would absorb all the variation in our data. We therefore use the log of country-specific real GDP (from the Maddison 2010 database) to absorb as much variation as possible in both destination countries' output and the (unobserved) multilateral resistance terms at the industry level, thereby assigning any residual variation in the importer-industry fixed effects to the error term.

Additionally, while Equation 5 suggests estimating industry-specific distance and empire coefficients, we prefer estimating coefficients that are common to all industries. This makes the exposition easier, and facilitates later comparisons with coefficients estimated using aggregate trade data (moreover, Appendix C shows that the trends in estimated coefficients are similar across 1-digit industries).

Summing up, our proposed estimating equation is

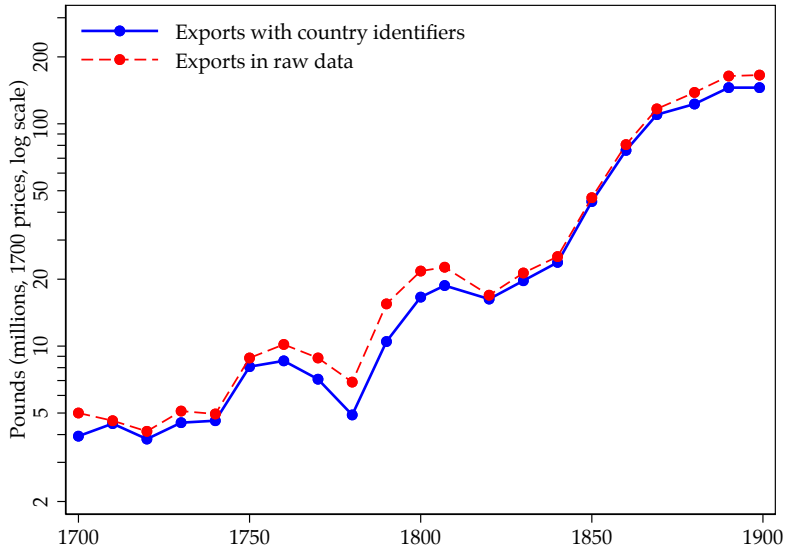
$$\ln x_j^k = \alpha^k + \beta \ln(GDP_j) + z_j\,\gamma + \epsilon_{jk}\,, \tag{6}$$

where the x_j^k are British exports (real before 1813, nominal thereafter) in industry k to country j; α^k are industry fixed effects (defined at the 2-digit level); z_j is a set of gravity variables impeding or promoting the flow of goods between Britain and j (that is, the logged physical bilateral distance separating country j from Britain and an indicator for country j's contemporaneous membership in the British Empire), and ϵ_{jk} is an error term.[4]

We estimate Equation 6 using PPML (Fally, 2015; Santos Silva and Tenreyro, 2006) since it fully uses the information contained in our zero observations (roughly 80% of our sample) and since, in the presence of heteroskedasticity, OLS is biased. Throughout we cluster our standard errors at the country level, ensuring that residuals are appropriately adjusted for arbitrary within country-year serial correlation.

[4]The GDP coefficient in Equation 6 is common across industries. We also ran regressions with industry-specific GDP coefficients, on the basis that this might be more consistent with Equation 5. The results were unchanged (details available on request).

Figure 1: Aggregate British exports, 1700–1899



Notes: See text.

4 Empirical findings

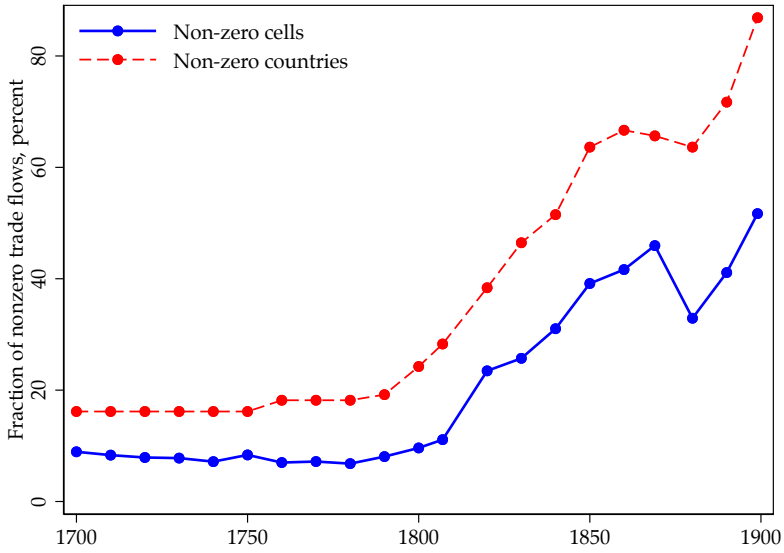
4.1 Overview of British exports

As stressed above, the use of constant official prices to value exports prior to 1813 means that aggregating trade figures is not ideal. Nevertheless, creating such an aggregate can give a rough indication of overall export trends. Figure 1 thus plots the log of real aggregate British exports (in pounds sterling) by year from 1700 to 1899. Up to 1813 these are the sum of all exports, valued at official (fixed) prices. From then on they are the sum of all exports valued at market prices, but deflated by the Bank of England's composite price index.[5] The two series represent the sum of all observations in the raw data (the dotted red series) and the sum of all observations for which we can assign commodity and country identifiers and which we use in the analysis below (the solid blue line). The very high degree of correspondence between the two series is reassuring.

For the solid blue line, the 1.4 log point difference between 1700 and 1800 suggests that British exports increased by a factor of 4.2 in real terms. The figure also suggests that much of this increase occurred between 1740 and 1750, and again after the independence of the United States in 1783. Likewise, the 2.2 log point difference between 1800 and 1899

[5] https://www.bankofengland.co.uk/monetary-policy/inflation/inflation-calculator

Figure 2: The extensive margins of British exports, 1700–1899

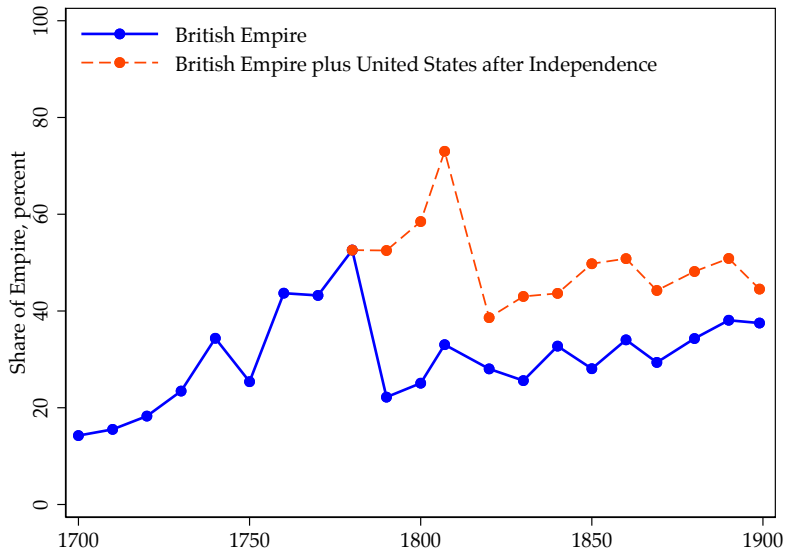


Notes: The solid blue line depicts the share of non-empty cells in our matrix of 99 countries by 58 industries recorded at the SITC 2-digit level on a year-by-year basis. The dotted red line depicts the share of 99 countries for which British exports (in any industry) are positive on a year-by-year basis.

suggests that British exports increased by a factor of 8.8 in real terms during the 19th century. The vast majority of this export growth is concentrated in the period from 1840 to 1869 (1.5 log points or 361%), with relatively modest growth in real exports between 1869 and 1899 (0.3 log points or 33%).

Figure 2 turns to the extensive margin of trade. The solid blue line depicts the share of non-zero cells in our matrix of 99 countries by 57 industries recorded at the SITC 2-digit level on a year-by-year basis. The dotted red line depicts the share of 99 countries for which British exports (in any industry) were positive in a given year. Both series are relatively flat throughout the 18th century (averaging 7.8% for the solid blue series and 17.1% for the dotted red series), suggesting that most of the export growth depicted in Figure 1 occurred on the intensive margin, within a relatively fixed set of importer-industry combinations. In contrast, the 19th century was marked by a steady increase in both the share of non-zero cells (from 9.6% in 1800 to 51.7% in 1899) and the share of non-zero countries (from 24.2% in 1800 to 86.9% in 1899), suggesting that British exports grew on the extensive as well as the intensive margin after 1800. Finally, the (undepicted) ratio of the two shares (that is, non-zero cells to non-zero countries) provides us with the average share of industries with positive trade flows for those countries which actually imported goods from Britain.

Figure 3: British export share with the Empire, 1700–1899



Notes: The solid blue line represents the share of British exports going to destinations in the contemporaneously-defined British Empire. The dotted red line represents this share plus the share of the United States after Independence.

Somewhat curiously, this ratio displays only a relatively small, upward trend from 1700 to 1900, hovering around an average value of 0.51.

Finally, Figure 3 depicts the importance of trade with the British Empire over these two hundred years. The solid blue line represents the share of observed exports going to destinations in the contemporaneously-defined British Empire.[6] The dotted red line adds the United States (at one time a very prominent part of the British Empire) to the total. The difference between the two lines thus represents the US share of British exports. With regards to the share of the British Empire, we can see that this was on the rise until 1780 (from 14.3% in 1700 to 52.6% in that year). In 1783 the United States became independent, initiating a precipitous decline in the empire share to 22.2% in 1790 and a subsequent, albeit partial recovery over the 19th century, reaching 38.1% in 1890. The second series (in red) shows the importance of the United States post-independence as a destination for British trade flows. Exports to what would become the United States had been very important prior to independence. They represented on average 10.8% of the total between 1700 and 1780, peaking at 22.4% in 1760. The dramatic rise in the US share between 1790 and 1807 reflects the resumption of normal trading relationships between ex-colony and

[6]The figures prior to 1813 come with the same caveat as before: they are based on trade flows valued at fixed official prices.

coloniser, as well as the diversion of British exports in light of the war with France (at least until the US Embargo Act of 1807 came into effect in December of that year). The figure also highlights the importance of the United States as a destination for British exports after 1815 (representing on average 14.0% of the total between 1820 and 1899).

4.2 The impact of distance and empire on British exports

We now explore the impact of distance and empire on how much Britain exported to the 99 countries across the 57 industries in our data. We obtain time-varying distance and empire coefficients by estimating Equation 6 using cross-sectional data and PPML for our 21 benchmark years.

Figure 4a depicts the coefficient point estimates and associated 95% confidence intervals for (logged) bilateral distance and a binary indicator for contemporaneous membership in the British Empire. Turning first to distance, the elasticity of British exports is estimated in 1700 to be equal to −1.11, very much in line with results for the post-World War II era (Head and Mayer, 2014). This point estimate is also precisely estimated and statistically significant at conventional levels ($z = 3.53$). Abstracting from the values of the standard errors, we see that from 1710 to 1780 the distance elasticity is roughly constant, with an average value of −1.03. From this point on, however, things change dramatically: the distance elasticity collapses in absolute value, averaging just −0.11 over the entire 19th century. It is also statistically insignificant throughout this period. Thus, we are confronted with the curious result that the (near) death of distance had already effectively been achieved by 1800, at least in the case of British exports to the rest of the world.[7]

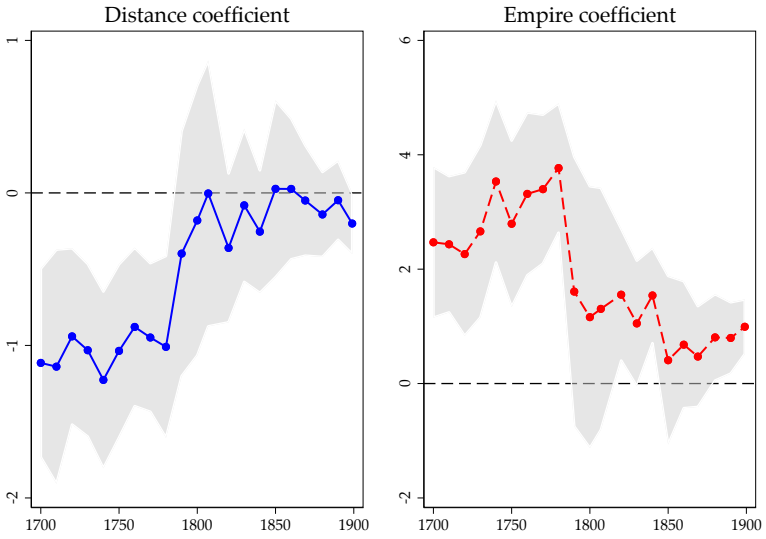
One obvious possibility is that distance came to matter less because trade became dominated by membership of the British Empire, a notably far-flung enterprise. It is therefore important to note that our distance coefficients were estimated controlling for membership in the British Empire. Moreover, Appendix C shows that we obtain roughly the same results when we allow for the distance elasticity to vary according to membership in the British Empire. That is, the overall decline shown in Figure 4a is driven by both subsets of countries, Empire and non-Empire.

Turning to the impact of Empire, Figure 4a shows that this coefficient was strongly positive at the outset of our period. The point estimate in 1700 is +2.47 and it is precisely estimated ($z = 3.68$). The Empire effect then slowly drifted upwards, peaking at +3.77 in

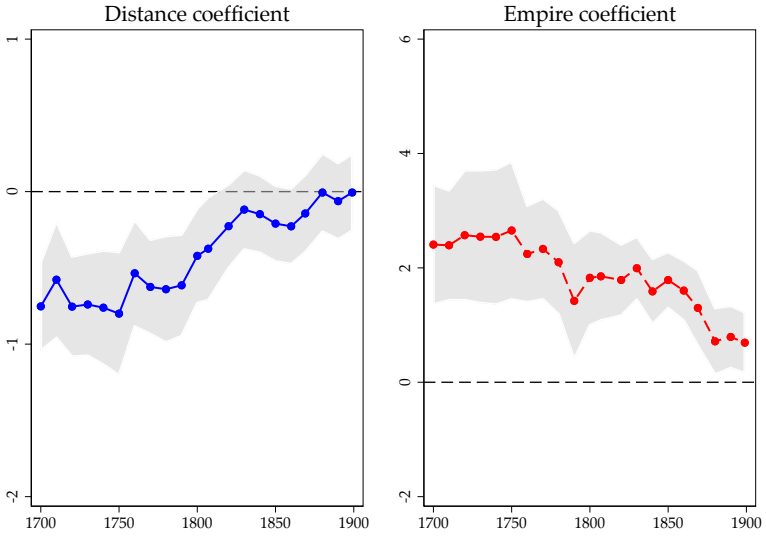
[7] Estimates of Equation 6 by 1-digit sector in Appendix C show broadly similar patterns across sectors over time.

Figure 4: Distance versus Empire, British exports, 1700–1899

(a) Distance and Empire coefficients, PPML estimation



(b) Extensive margin of exports, Probit estimation



Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire from Equation 6. All point estimates generated on a year-by-year basis via PPML (a) or probit (b). Standard errors clustered at the country level.

1780. It then declined dramatically, presumably as a result of American independence. The average point estimate between 1790 and 1840 was +1.37, with the coefficient drifting in and out of statistical significance. The year 1850 saw another dramatic drop in the empire coefficient, to +0.41, suggesting a potentially large role for the repeal of the Corn Laws and mercantilist Navigation Acts in the 1840s (Munzur, 2019). While the coefficient subsequently recovered, and eventually became statistically significant, it never regained the levels experienced prior to the 1840s, averaging just +0.75 between 1860 and 1899.

Summarizing, we have found that the trade-diminishing effects of distance declined sharply from 1780. The distance elasticity for British exports was very small and statistically indistinguishable from zero throughout the 19th century. Furthermore, this pattern is not driven by imperial trade alone, as it occurs for both the British Empire and the rest of the world (see Appendix C). The trade-enhancing effects of the British Empire peaked during the late 18th century, declined sharply after 1780, and fell again around 1850, when the UK abandoned what remained of its traditional mercantilist policy framework. Thus, the forces of gravity were alive and well as early as 1700, but somewhat puzzlingly they became much weaker throughout the 19th century.

4.3 The extensive margin of British exports

One concern may be that we are pushing the data too hard. Apart from the accuracy of the historical data collection process, there is the issue of constant official prices being used to value trade flows before 1813. Despite the fact that we are estimating gravity models at the 2-digit industry level, the relative imprecision of some of the point estimates in Figure 4a might be due to measurement error in our dependent variable, especially prior to 1813.

In response to such concerns we now turn to the impact of distance and the British Empire on the extensive margin of British exports. The extensive margin of trade is of interest in its own right, but in addition the ledgers are almost certainly a highly accurate representation of what Britain exported to whom (as opposed to the value of what Britain exported to whom). We thus obtain time-varying distance and empire coefficients by running annual gravity regressions with probit. The dependent variable of the estimating equation is an indicator variable for positive British exports in a particular country-by-industry cell. As before, we include industry fixed effects, GDP, and country-specific measures of bilateral distance and contemporaneous membership in the British Empire, and cluster the associated standard errors at the country level.

Figure 4b depicts the point estimates and associated 95% confidence intervals for bilateral distance and membership in the British Empire. Turning first to bilateral distance, the point estimate for British exports in 1700 is −0.75. This estimate is highly statistically significant ($z = 5.08$). We see that the point estimates follow a similar pattern to those in Figure 4a: relative stability until the mid- to late 18th century, a rapid subsequent decline, and very low absolute values throughout the 19th century, ending in 1899 with a point estimate of −0.01 ($z = 0.05$).

The interpretation of these probit point estimates is of course not as straightforward as is that of the PPML estimates discussed earlier. The point estimate of −0.75 in 1700 corresponds to an average marginal effect of distance on the probability of positive British exports of −0.063, while the point estimate of −0.01 in 1899 corresponds to an average marginal effect of distance on the probability of positive British exports of −0.001. Regardless, the results from the extensive margin are qualitatively consistent with those in the previous sub-section, once again suggesting a 19th century demise of distance in the case of British exports to the rest of the world. Appendix C shows that the results are broadly similar for both the Empire and the rest of the world, and for individual sectors defined at the 1-digit level, so they are robust across all these subsamples.

As for the empire effect, also depicted in Figure 4b, it starts out with a precisely estimated point estimate of +2.41 in 1700 ($z = 4.51$). The coefficient then increases slightly, peaking at +2.65 in 1750. There follows a long, steady decline, once again with a pronounced drop in the late 19th century. The coefficient averages just +0.73 in the period 1880–1899. Hence, the broad conclusions from the last section apply to the extensive margin also, although with an earlier peak: the trade-enhancing effect of the British Empire was at its greatest in 1750 and then fell sharply, particularly from 1850.

To sum up, it would seem that from the late 18th century onwards Britain gradually escaped the pull of gravity, at least as mediated via physical distance. Instead, and somewhat ironically – given that the late 19th century is thought to epitomize classical free-trade principles – the country ended up with trading patterns at the end of the 19th century that were primarily influenced not by distance, but rather by the political construct of the British Empire. At the same time, this empire effect was itself much smaller than it had been in the 18th century. As already noted these results survive a number of robustness checks. Appendix C shows that they hold for both Empire and non-Empire countries; for separate 1-digit sectors; and when excluding individual continents.

4.4 British exports into the present day and a global perspective

The results thus far were obtained using disaggregated data. This makes sense, since it allows us to side-step some of the problems caused by official valuations prior to 1813, but it makes our results less directly comparable with the distance and empire effects commonly estimated in the literature, which typically make use of aggregate data (Head and Mayer, 2014). Might our results merely be an artifact of our disaggregated data?

We answer this question in two ways. First, for the years after 1813 when direct aggregation is justified (i.e., the fixed "official" prices are no longer in use) we computed aggregate exports to our 99 countries, and estimated distance and empire coefficients in the standard fashion (controlling as before for destination GDP). Appendix C shows that we obtain almost identical results to those reported in the text.

Second, for a later sample window 1870 to 2010 we have bilateral trade data for a large number of country pairs worldwide (Jacks, Meissner, and Novy, 2011; Jacks and Novy, 2018). This allows us to estimate distance and empire coefficients using successive annual cross-sections, and importantly it also allows us to do so with a full set of exporter/importer fixed effects. We also allow for different coefficients on distance and the British Empire for UK and non-UK exports, to see if there is any difference between UK exports and exports more generally. Our chief interest is in the distance coefficient, and the period prior to 1900, rather than in the evolution of the empire effect in the 20th century, and so *for these exercises* the empire variable is time-invariant and defined as the British Empire in effect in 1910 (i.e., roughly its post–U.S. Independence peak), so it captures current and legacy Empire effects.

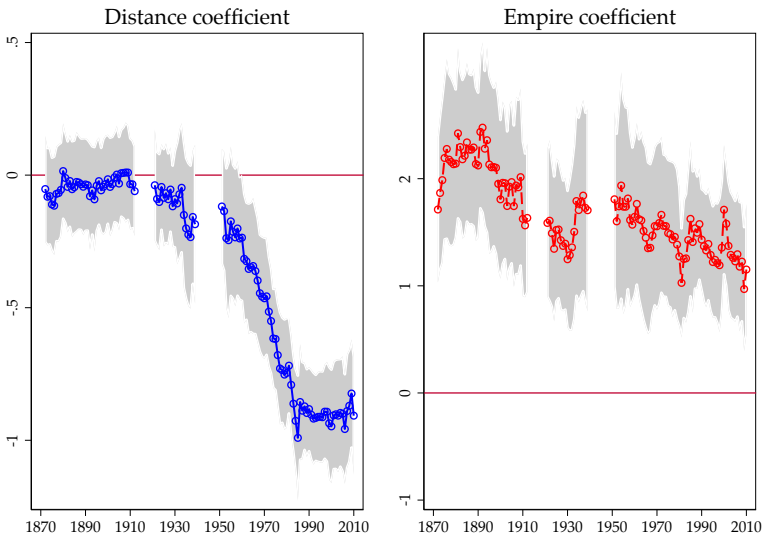
The results for UK exports, comparable to our earlier results, are given in Figure 5a. As can be seen, the distance coefficient is very small and statistically insignificant during the 29 years overlapping with our own estimates (1870–99) and presented above, suggesting that our earlier results are comparable with more standard gravity estimates using aggregate data and a full set of fixed effects.[8] Indeed, we see that the distance coefficient continued to remain extremely low in peacetime years from 1900 to 1950 (the mean value was just -0.07 over these years). It was only from 1950 onwards that it started to increase in absolute value, reaching −0.91 in 2010.

The empire effect for UK exports is also plotted in Figure 5a: it is larger than that estimated earlier. Between 1870 and 1899 the empire effect averaged +2.14 using aggregate

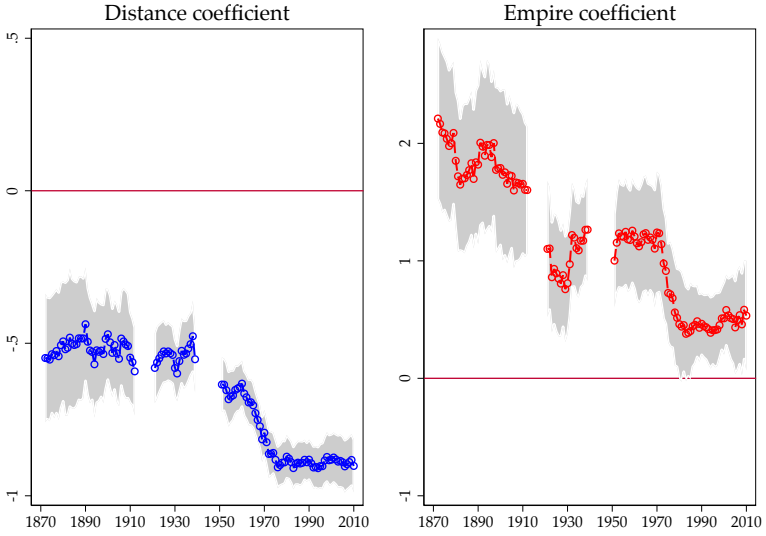
[8]The average value for 1870–99 is -0.06 using aggregate bilateral trade data, as compared with -0.11 using our disaggregated data.

Figure 5: Distance versus Empire, World sample, 1870–2010

(a) UK exports only, PPML estimation



(b) Non-UK exports, PPML estimation



Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire from Equation 2. All point estimates generated on a year-by-year basis via PPML. Standard errors clustered at the country level.

data, as opposed to +0.87 using our disaggregated data. It fell until the mid-1920s when, not surprisingly, given the geopolitical tension of the time and discriminatory trade policies favouring intra-Empire trade, it started to rise (de Bromhead et al., 2019; Arthi et al., 2020; Jacks and Novy, 2020). It remain elevated immediately following World War II, but declined from the mid-1950s onwards, consistent with Head, Mayer, and Ries (2010).

Finally, one might wonder whether it is not our pre-1900 dataset, but the UK itself, that is unrepresentative. Figure 5b therefore plots coefficients for bilateral distance and the British Empire for non-UK exports after 1870. As can be seen, the UK experience was not atypical: it was just more extreme when it came to distance in particular. The distance coefficient estimated on all trade flows hovered at a low level during the late 19th century, averaging just -0.52 between 1870 and 1899. It then increased in absolute value only after the 1950s, as in the UK case. As for the worldwide British Empire effect: it was roughly the same as for UK exports in the late 19th century (averaging +1.92 between 1870 and 1899, as opposed to +2.14), but declined sharply after World War I and dropped much more dramatically from the 1960s onwards.

Combining our results, it would appear that distance started to become less important for British exports in the late 18th century, and that by the late 19th century at the latest this pattern was somewhat generalized. It was only from 1950 onwards that the forces of gravity converged to their current values, which strongly – and paradoxically – most resemble those of the early 18th century.

5 Conclusion

Drawing on a new dataset on British exports at the bilateral, commodity-level for the period from 1700 to 1899, we have documented two striking empirical patterns. First, the trade-enhancing effect of the British Empire peaked sometime in the mercantilist mid- to late 18th century, before significantly declining in value. Second, the trade-diminishing effect of bilateral distance declined sharply in the late 18th century, remaining very small in magnitude – and statistically indistinguishable from zero – throughout the 19th. Furthermore, the latter finding is not an artifact of our commodity-level data. The relationship between distance and UK exports in 1700 seems to more closely resemble the present day than 1800 or 1900. And while world trade flows in general never broke the tyranny of distance as decisively as British exports, they were moving in the same direction in the late 19th and early 20th centuries.

It is tempting to speculate that this 19th century death of distance for UK exports was due to British imperialism, but that argument sits uneasily with the fact that the distance coefficient fell just as much for countries outside the Empire. The argument might perhaps be resurrected by arguing that informal imperialism was boosting UK exports in distant markets such as Argentina, even though they were formally outside the Empire (Cain and Hopkins, 1987), but it is unclear how to test such a claim. European protectionism cannot explain the finding on its own since the result survives the exclusion of European destinations from the sample (Appendix C). And as Appendix C also shows, the result is consistent across 1-digit industries, making it less likely that changes in the composition of traded goods were responsible.

We are thus left with a puzzle. On the other hand, time-varying estimates of gravity model parameters are perhaps to be expected. These two centuries saw enormous changes in commercial policy, the composition of trade, geopolitics, information transmission, and the technology of goods handling/storage and maritime transport. All of these presumably affected the degree to which bilateral trade flows responded to differences in bilateral distance and imperial status. Perhaps it would have been more surprising if the impact of distance and Empire had remained constant throughout such a period of flux. Thus, despite the frequent invocation in policy debates of the so-called "iron law of trade models" – in which trade halves as distance doubles – and the fact that physical distances are indeed exogenous, we also can acknowledge that traded distances themselves are a policy outcome and are therefore influenced by geopolitics, technology, and trade policy, all of which vary greatly over time. What is true in one era may not be true in others. An economist estimating gravity models in 1700 would have been wrong to assume that their lessons would hold a century later, and there may be a lesson there for economists today.

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Online Appendix

A Sources of British trade dataset by year

All sources are held by UK National Archives, as follows:

1700: Ledgers of Imports and Exports, CUST 3/4
1710: Ledgers of Imports and Exports, CUST 3/13
1720: Ledgers of Imports and Exports, CUST 3/22
1730: Ledgers of Imports and Exports, CUST 3/30
1740: Ledgers of Imports and Exports, CUST 3/40
1750: Ledgers of Imports and Exports, CUST 3/50
1760: Ledgers of Imports and Exports, CUST 3/60
1770: Ledgers of Imports and Exports, CUST 3/70
1780: Ledgers of Imports and Exports, CUST 3/80
1790: States of Navigation, Commerce and Revenue, CUST 17/12
1800: States of Navigation, Commerce and Revenue, CUST 17/22
1807: States of Navigation, Commerce and Revenue, CUST 17/26-29
1820: Ledgers of Exports of British Merchandise under Countries, CUST 8/11
Ledgers of Imports under Countries, CUST 4/15
1830: Ledgers of Exports of British Merchandise under Countries, CUST 8/31-32
Ledgers of Imports under Countries, CUST 4/25
1840: Ledgers of Exports of British Merchandise under Countries, CUST 8/51-52
Ledgers of Imports under Countries, CUST 4/35
1850: Ledgers of Exports of British Merchandise under Countries, CUST 8/71-72
Ledgers of Imports under Countries, CUST 4/45
1860: Ledgers of Exports of British Merchandise under Countries, CUST 8/91-92
Ledgers of Imports under Countries, CUST 4/55
1869: Ledgers of Exports of British Merchandise under Countries, CUST 8/109-110
Ledgers of Imports under Countries, CUST 4/64
1880: Ledgers of Exports of British Merchandise under Countries, CUST 8/121
Ledgers of Imports under Countries, CUST 4/75
1890: Ledgers of Exports of British Merchandise under Countries, CUST 8/131
Ledgers of Imports under Countries, CUST 4/85
1899: Ledgers of Exports of British Merchandise under Countries, CUST 8/140
Ledgers of Imports under Countries, CUST 4/94

Sample ledger pages are shown in Figure A1 to Figure A4. A total of 424,551 raw lines of entries from over 7,000 such ledger pages were scanned and digitized.

Figure A1: Sample ledger page: 1700, exports to France, all handwritten

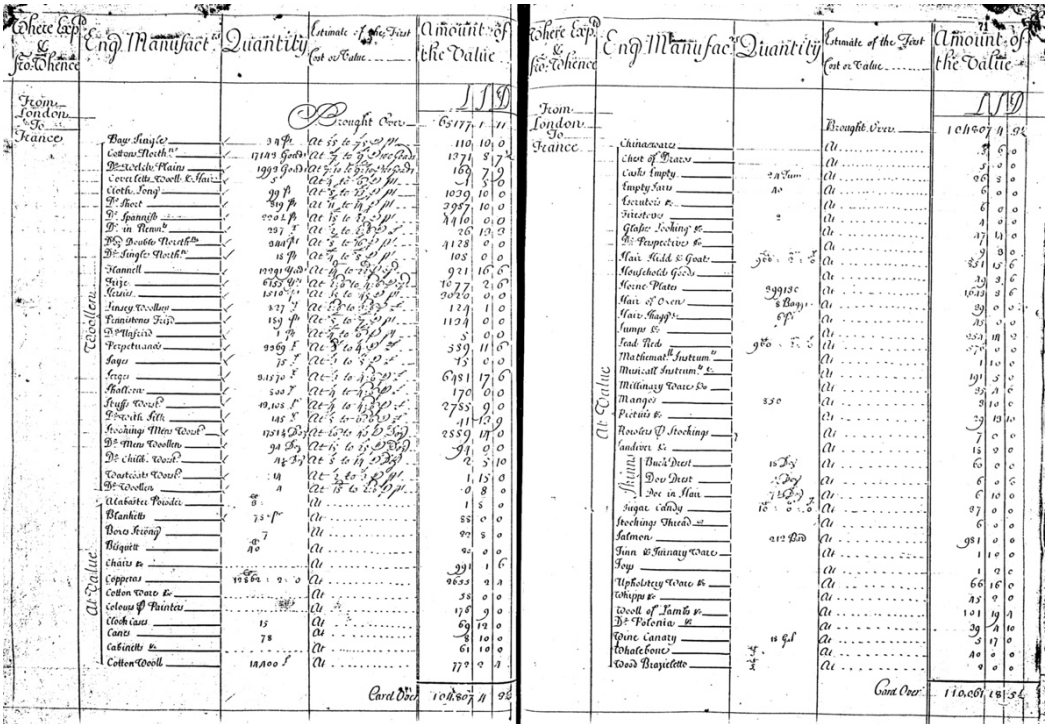


Figure A2: 1820, exports to Hudson's Bay, all handwritten

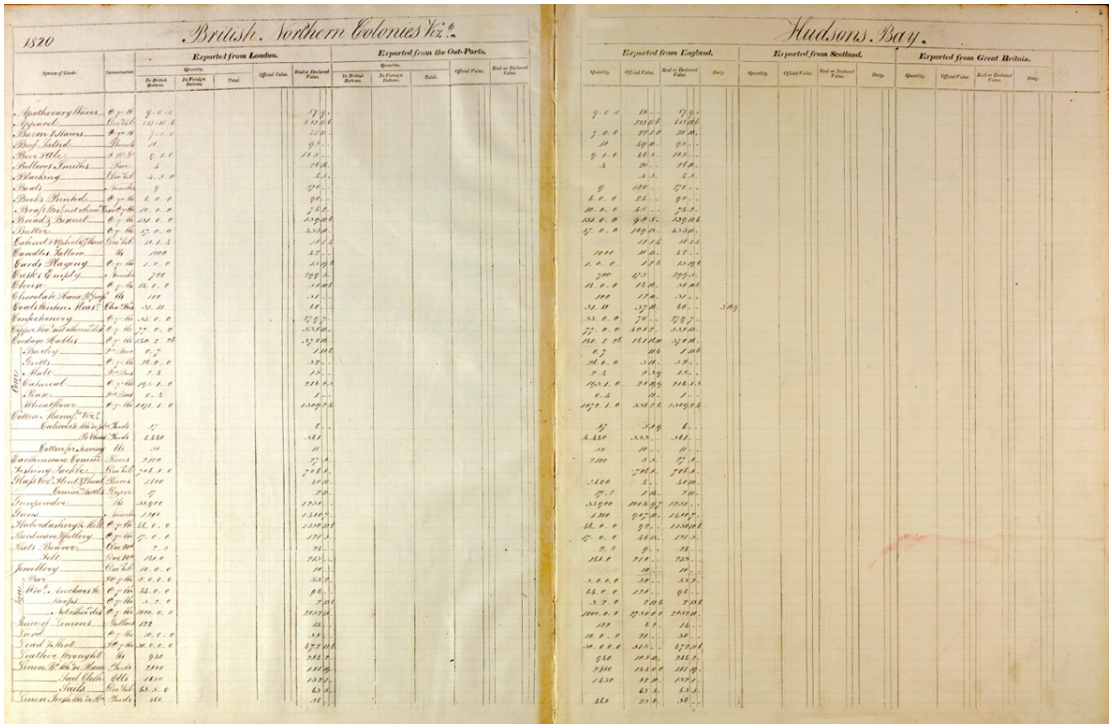


Figure A3: 1869, exports to Bolivia, mix of printed and handwritten

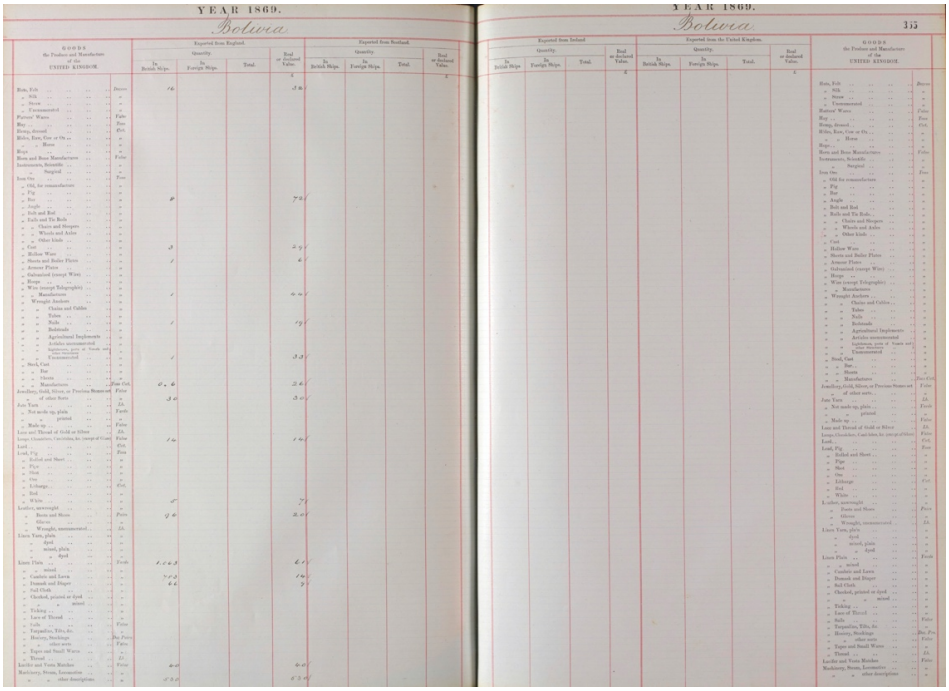
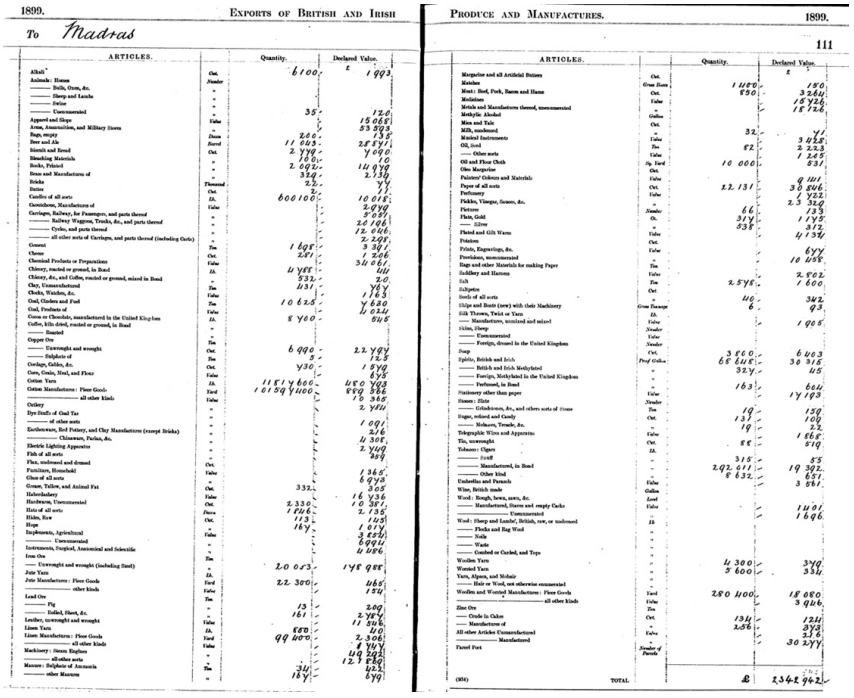


Figure A4: 1899, exports to Madras, mix of printed and handwritten



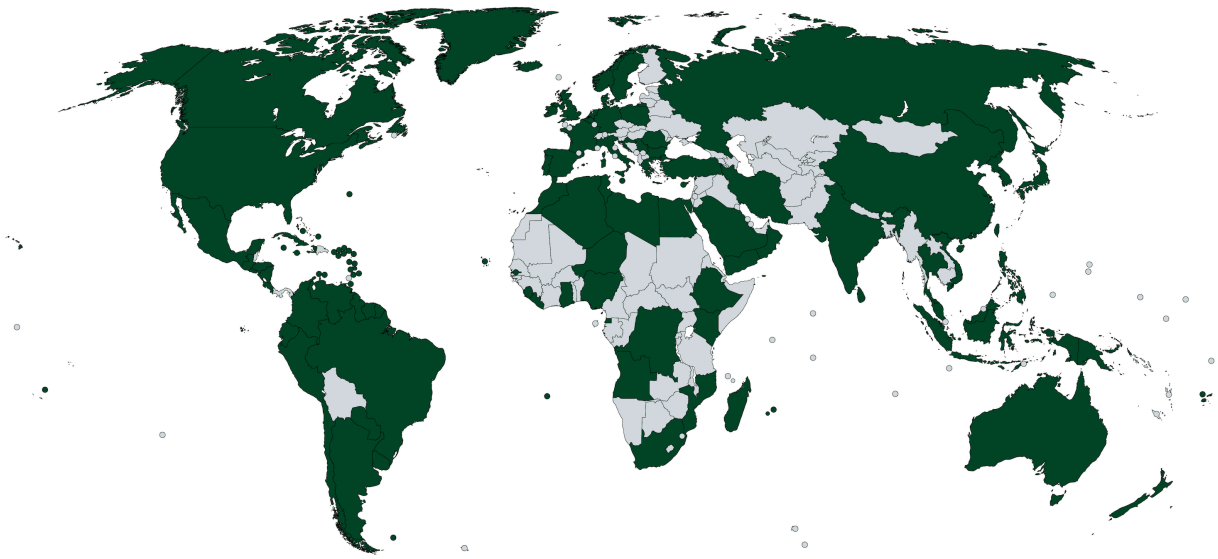
B Coverage of British trading partners in the dataset

Our sample includes the following 99 trading partners recorded as export destinations in the British customs ledgers from 1700 to 1899:

Algeria, Angola, Argentina, Australia, Austria, Belgium, Bermuda, Bonaire, Brazil, British West Indies, Bulgaria, Canada, Cape Verde, Chile, China, Colombia, Costa Rica, Croatia, Cuba, Curacao, Cyprus, DR Congo, Denmark, Ecuador, Egypt, El Salvador, Equatorial Guinea, Ethiopia, Falkland, Fiji, France, French Guiana, Germany, Ghana, Gibraltar, Greece, Greenland, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Iceland, India, Indonesia, Iran, Italy, Japan, Kenya, Korea, Liberia, Libya, Madagascar, Malaysia, Malta, Martinique, Mauritius, Mexico, Morocco, Mozambique, Netherlands, Netherlands Antilles, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Polynesia, Portugal, Puerto Rico, Reunion, Romania, Russia, Saint Helena, Saudi Arabia, Serbia, Sierra Leone, South Africa, Spain, Sri Lanka, Suriname, Sweden, Thailand, The Gambia, Tunisia, Turkey, US Virgin Islands, United States, Uruguay, Venezuela, Vietnam, Yemen, and Zanzibar

The map in Figure A5 shows these destinations.

Figure A5: British export destinations, 1700–1899



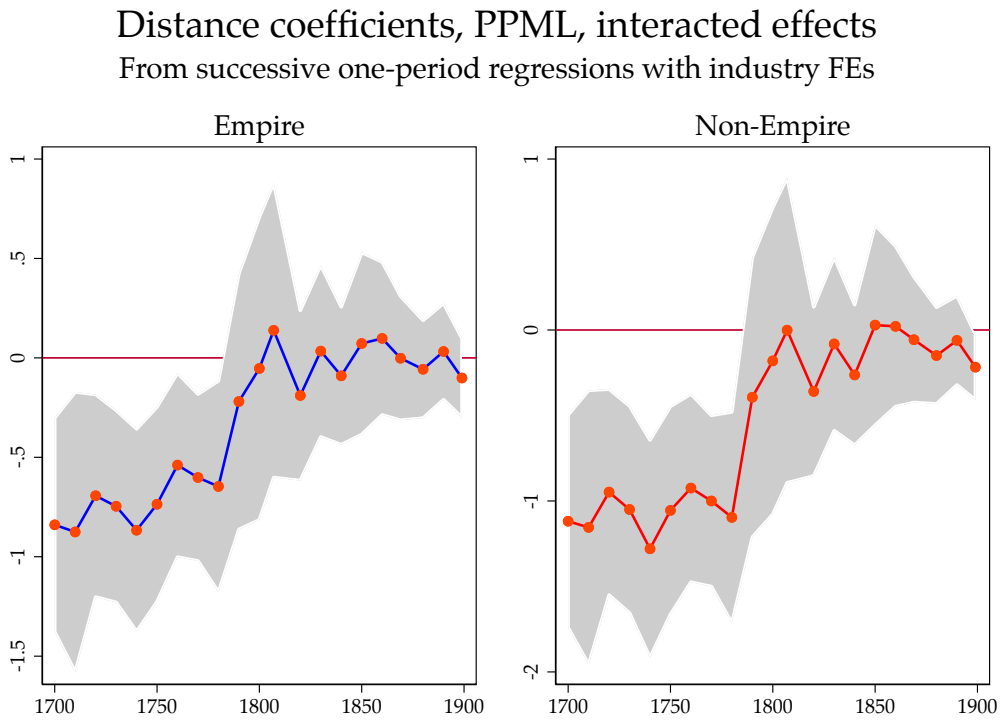
C Robustness exercises

C.1 Empire vs non-Empire and sector-level results

We first ask whether distance elasticities depended on whether or not countries were members of the British Empire. We therefore interact bilateral distance with membership in the British Empire and report both sets of coefficients, along with their associated 95% confidence intervals, in Figure A6. As can be seen the overall drop in the distance elasticity depicted in Figure 4a seems to be equally driven by both sets of countries.

We next ask whether the aggregate results for distance and imperial membership vary across sectors, estimating equation (5) at the 1-digit SITC level. More specifically, we replicate the exercise depicted in Figure 4a by separately considering SITC 0 (food and live animals), SITC 2 (crude materials except fuels), SITC 5 (chemicals and related products), SITC 6 (manufactured goods chiefly classified by material), SITC 8 (miscellaneous manufactured articles), and SITC 1, 3, 4, 7, 9 (everything else). The results are depicted in Figure A7. As can be seen, the results are remarkably consistent across sectors.

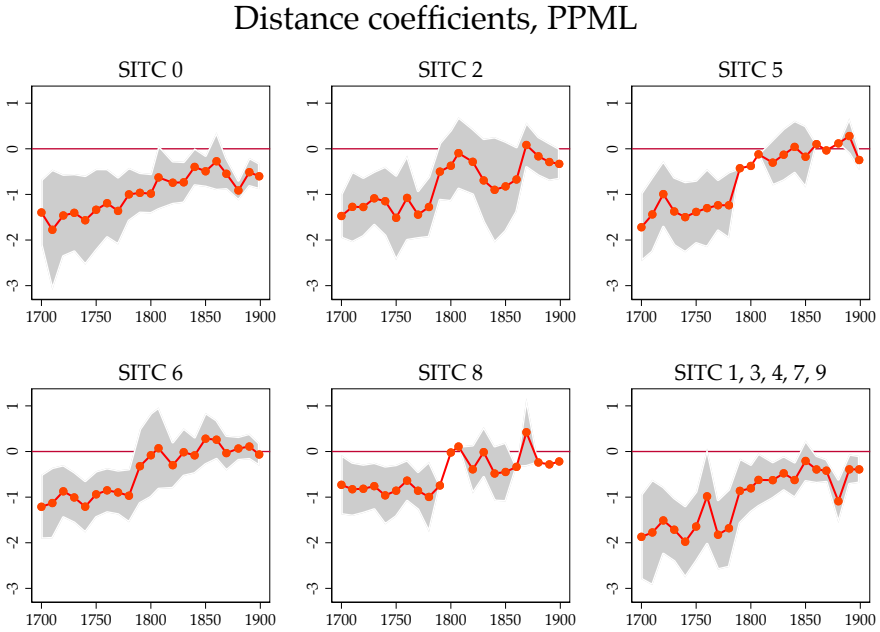
Figure A6: Empire vs non-Empire, 1700–1899



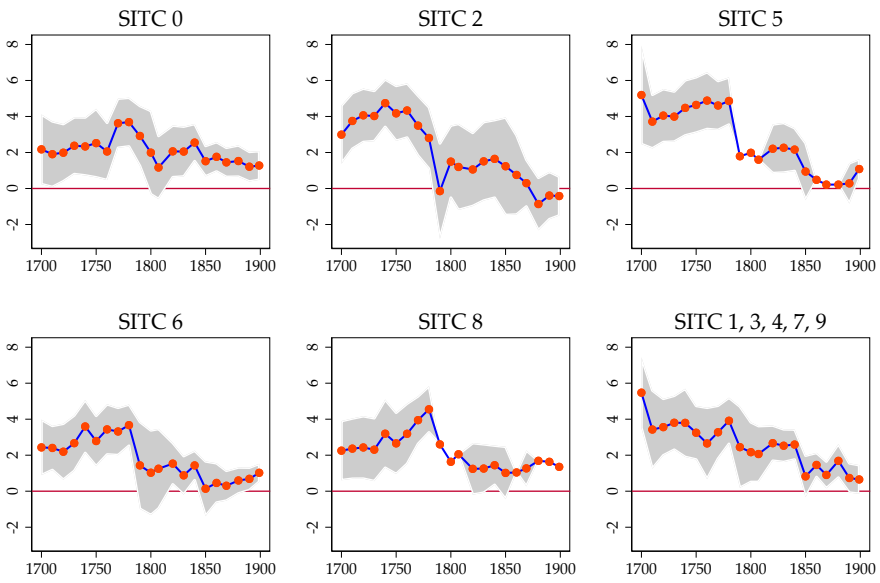
Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire from Equation 6. All point estimates generated on a year-by-year basis via PPML. Standard errors clustered at the country level.

Figure A7: Sector-level results, 1700–1899

(a) Distance coefficients



(b) Empire coefficients

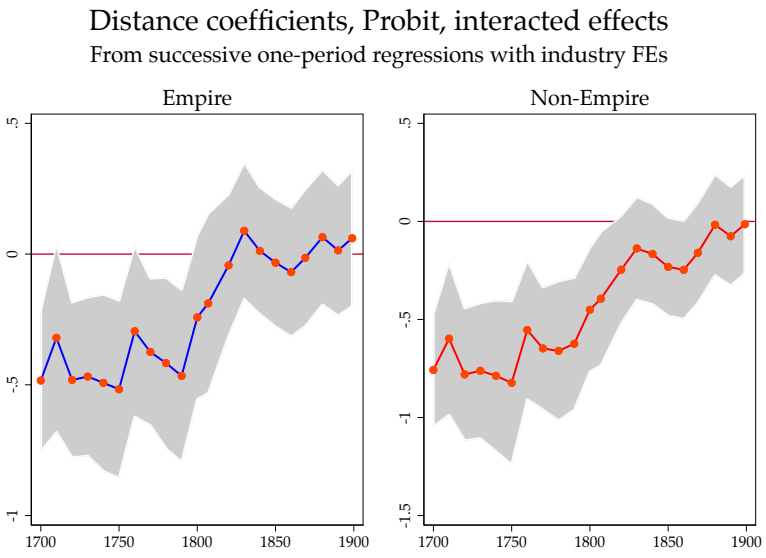


Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire from Equation 6, separately estimated at the 1-digit SITC level. All point estimates generated on a year-by-year basis via PPML. Standard errors clustered at the country level.

C.2 Empire vs non-Empire and sector-level results: the extensive margin

We now repeat the analysis of the previous subsection, but focus on the extensive margin of British exports. Figure A8 suggests that there is a marked decline in the absolute value of the interaction between bilateral distance and both the British Empire and the non-British Empire, mirroring the patterns in Figure 4b. Likewise, the sector-level results depicted in Figure A9 mirror those in Figure 4b.

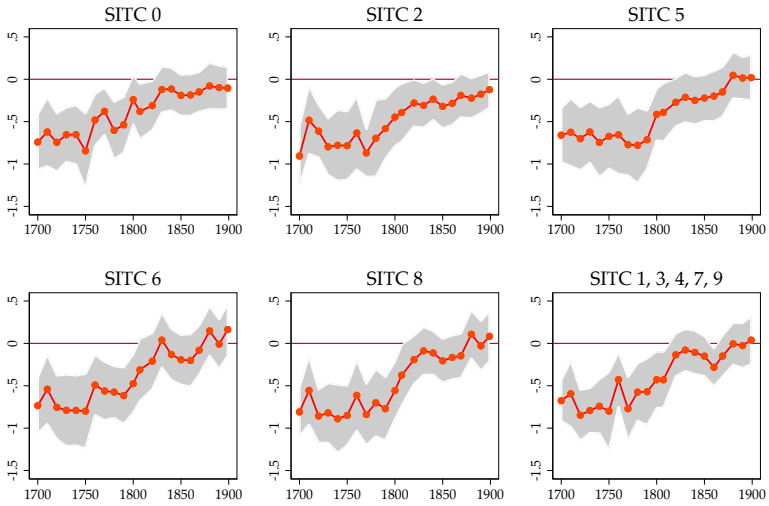
Figure A8: Interacted effects, extensive margin of exports, 1700–1899



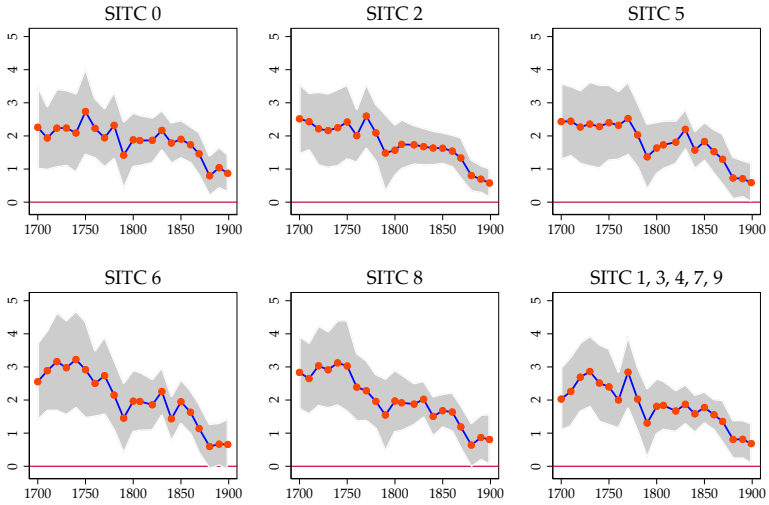
Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire. All point estimates generated on a year-by-year basis via probit. Standard errors clustered at the country level.

Figure A9: Sector-level results, extensive margin of exports, 1700–1899

(a) Distance coefficients



(b) Empire coefficients



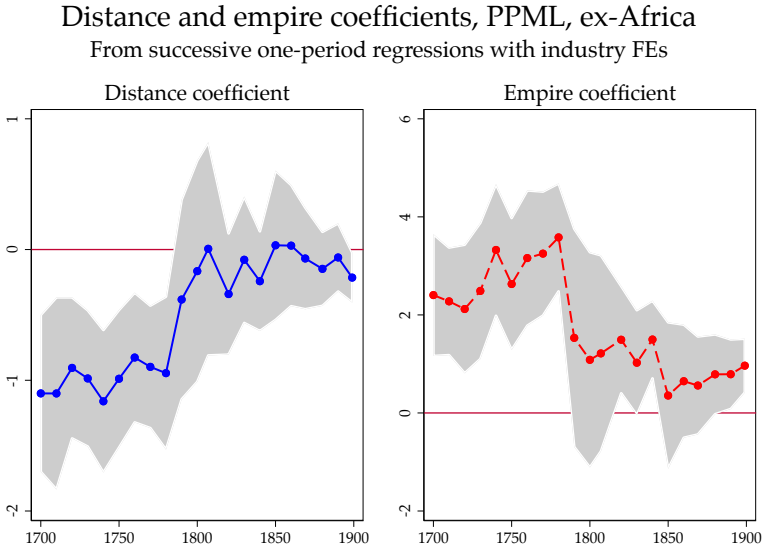
Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire, separately estimated at the 1-digit SITC level. All point estimates generated on a year-by-year basis via probit. Standard errors clustered at the country level.

C.3 Successive exclusion of continents

As a further robustness exercise we consider the sensitivity of the results reported in the main text to the successive exclusion of continents. Figure A10 to Figure A14 respectively show the results when we exclude Africa, Asia & Oceania, Europe, North America, and South America in turn. There are generally only small differences between our main results and those for different sub-samples. One partial exception regards the exclusion of Europe. In earlier years the coefficients are much larger, while the standard errors collapse. We interpret this as being due to the fact that the vast majority of cells in this non-European sample are zero early on, while there are only a handful of cells with very large values like those involving the United States. Nevertheless, the broad patterns documented in the paper survive, with the distance and empire coefficients declining in value in the late 18th century for all sub-samples.

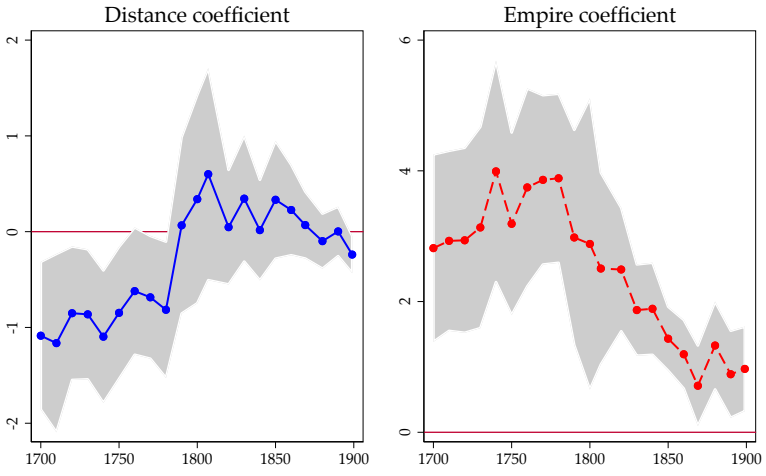
Finally, Figure A15 to Figure A19 repeat this exercise for the extensive margin of trade, using probit as before rather than PPML. The differences between our main results and those for different sub-samples are even less pronounced than in the case of the PPML results.

Figure A10: The impact of distance and Empire, 1700–1899, ex-Africa



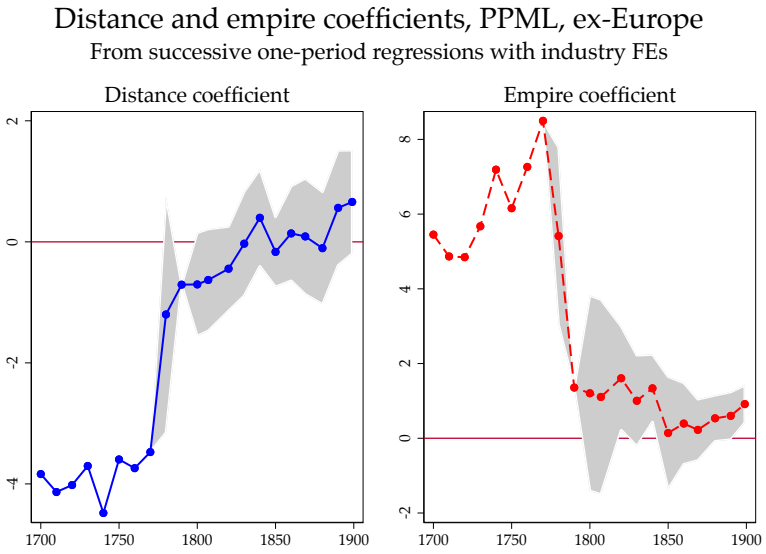
Notes: Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire. All point estimates generated on a year-by-year basis via probit. Standard errors clustered at the country level.

Figure A11: The impact of distance and Empire, 1700–1899, ex-Asia & Oceania



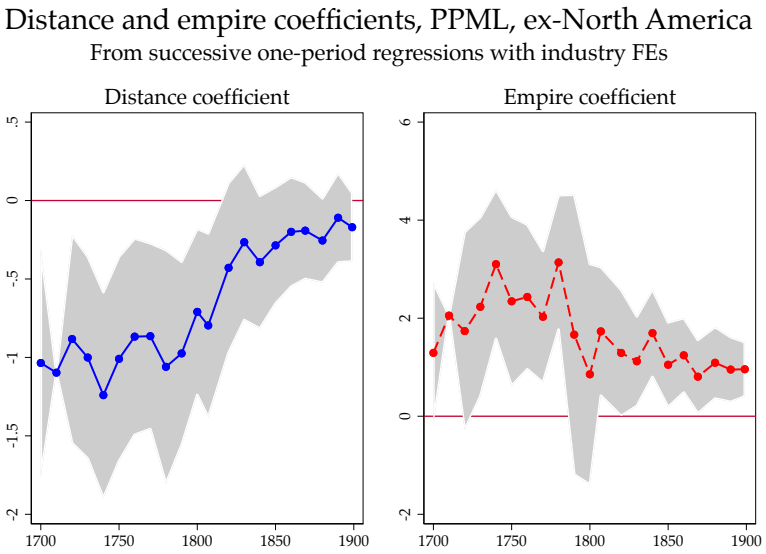
Notes: Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire. All point estimates generated on a year-by-year basis via probit. Standard errors clustered at the country level.

Figure A12: The impact of distance and Empire, 1700–1899, ex-Europe



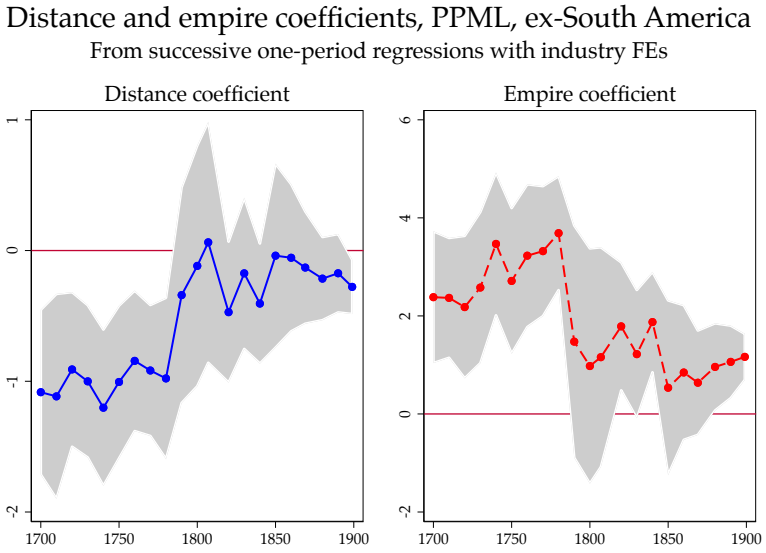
Notes: Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire. All point estimates generated on a year-by-year basis via probit. Standard errors clustered at the country level.

Figure A13: The impact of distance and Empire, 1700–1899, ex-North America



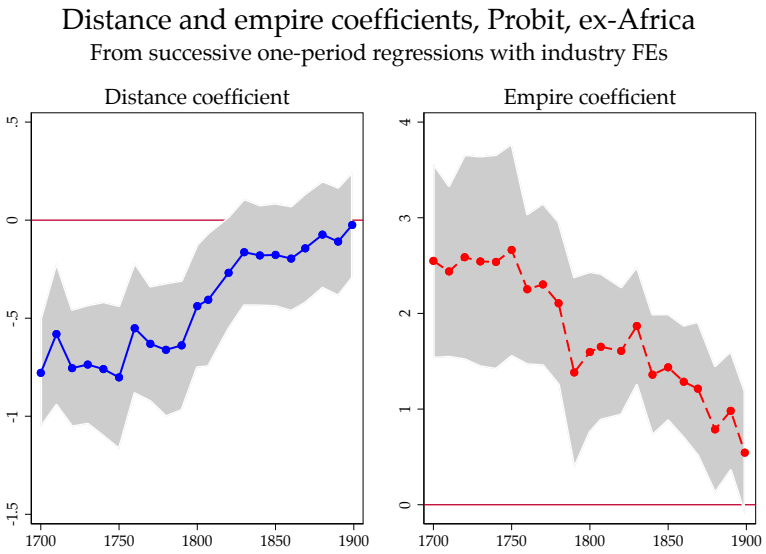
Notes: Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire. All point estimates generated on a year-by-year basis via probit. Standard errors clustered at the country level.

Figure A14: The impact of distance and Empire, 1700–1899, ex-South America



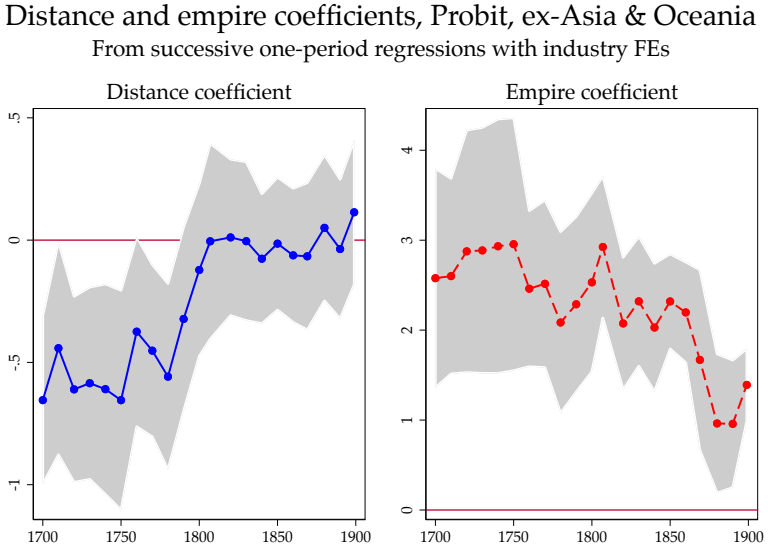
Notes: Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire. All point estimates generated on a year-by-year basis via probit. Standard errors clustered at the country level.

Figure A15: Extensive margin of exports, 1700–1899, ex-Africa



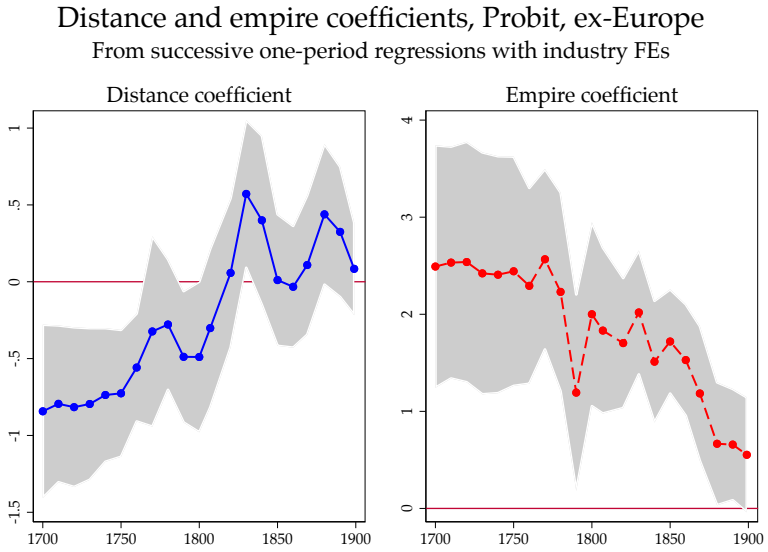
Notes: Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire. All point estimates generated on a year-by-year basis via probit. Standard errors clustered at the country level.

Figure A16: Extensive margin of exports, 1700–1899, ex-Asia & Oceania



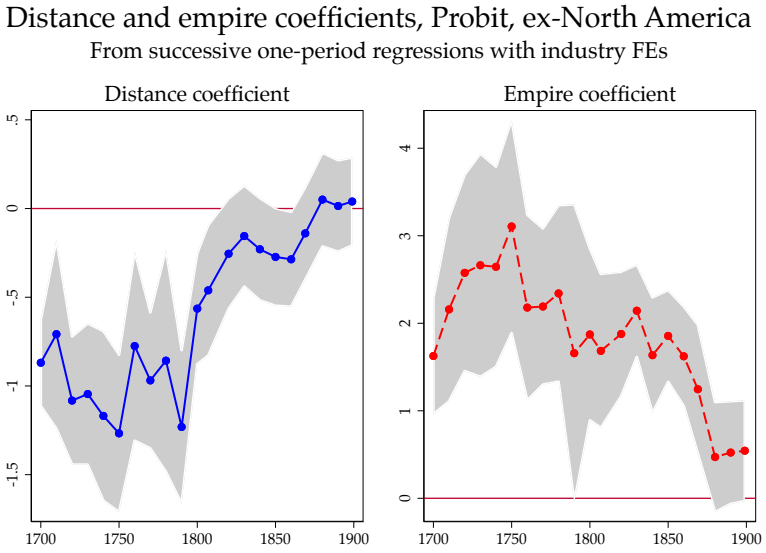
Notes: Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire. All point estimates generated on a year-by-year basis via probit. Standard errors clustered at the country level.

Figure A17: Extensive margin of exports, 1700–1899, ex-Europe



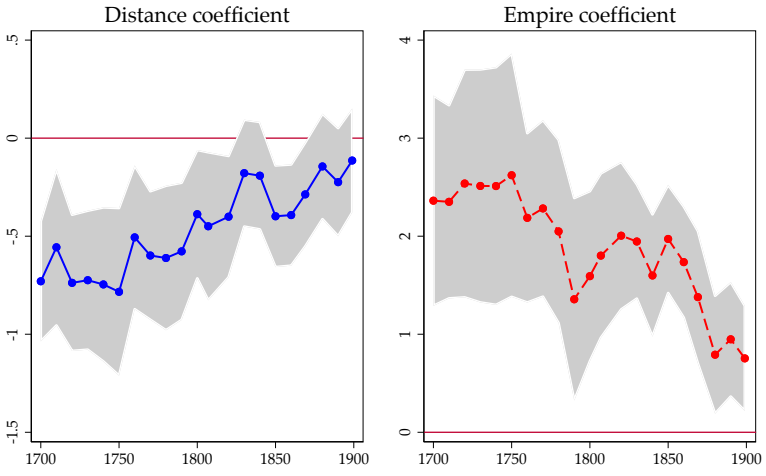
Notes: Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire. All point estimates generated on a year-by-year basis via probit. Standard errors clustered at the country level.

Figure A18: Extensive margin of exports, 1700–1899, ex-North America



Notes: Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire. All point estimates generated on a year-by-year basis via probit. Standard errors clustered at the country level.

Figure A19: Extensive margin of exports, 1700–1899, ex-South America



Notes: Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire. All point estimates generated on a year-by-year basis via probit. Standard errors clustered at the country level.

C.4 Analysis using aggregate trade flows from 1820

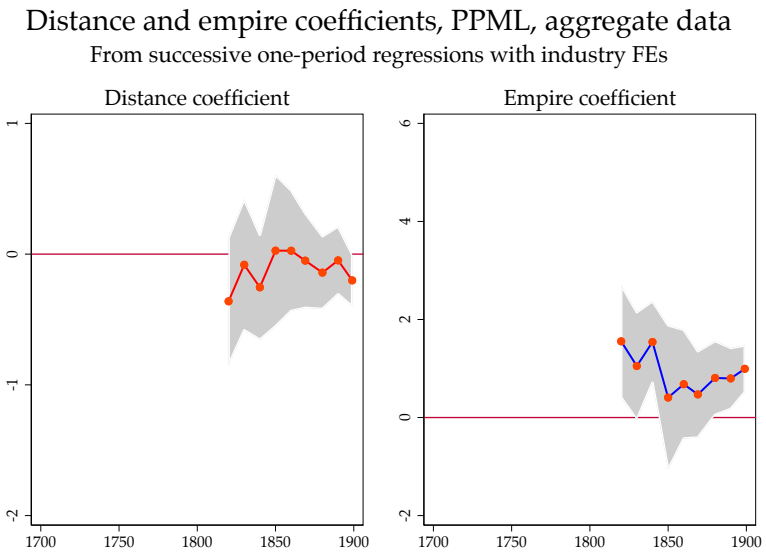
As a final robustness exercise we consider the sensitivity of the results reported in the main text to the highest order of aggregation possible. From 1813 onwards the ledgers reported commodity-level UK exports valued at market prices, and so it is fully appropriate to aggregate them and compute aggregate exports at the country level. We can then estimate distance and empire coefficients for successive cross-sections from 1820, using the specification

$$\ln x_j = \alpha + \beta \ln(GDP_j) + z_j \gamma + \epsilon_j, \tag{7}$$

where x_j represents British exports to country j; α is a constant; z_j is a set of gravity variables impeding or promoting the flow of goods between Britain and j (that is, the logged physical bilateral distance separating country j from Britain and an indicator for country j's contemporaneous membership in the British Empire), while ϵ_j is an error term.

The results are given in Figure A20. As can be seen, they are virtually identical to those reported in the text.

Figure A20: Aggregate-level results, 1813–1899



Notes: Figures depict point estimates and 95% confidence intervals for bilateral distance and membership in the British Empire from Equation 7, estimated at the aggregate level. All point estimates generated on a year-by-year basis via PPML.