Suez

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Abstract: For all of its importance, there still is no complete quantitative assessment of the Suez Canal's opening in 1869. Here, we find that it led to a 72% increase in bilateral exports for affected country pairs, suggesting a 12% permanent increase in world trade. We also consider the composition of trade, finding that Suez led to narrowly concentrated changes in export shares and increased the extensive margin of exports. Finally, shipping cost calculations show that the relative cost of using steamships fell dramatically and immediately after 1869, pointing to a vital role for Suez in the diffusion of steam technology.

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Introduction

From its opening in 1869, the Suez Canal has been hailed as an engineering marvel, a major contributor to the process of globalization in the 19th Century, and a means for consolidating European imperial reach worldwide (Huber, 2015). Of course, the reasons are straightforward: this single 195 kilometre cut from Port Said in northern Egypt to Suez in the south effectively reduced the distance separating Liverpool and Mumbai from 21,409 to 10,699 kilometres (Fletcher, 1958). Thus, Suez served to pull Asia and Europe closer together with presumably profound implications for international mobility, relations, and trade. What is more, it remains one of the critical chokepoints of international commerce with 80% of all maritime trade between Asia and Europe transiting the Suez Canal in the present day and representing roughly 15% of all world trade (Øiestad, 2019).

But for all this, over 150 years later, we still do not have a full assessment of the quantitative effects of the canal's opening and subsequent operation. To be sure, there are measures of the uptake of the canal's services which indicate prodigious rates of growth until the outbreak of World War I: thus, Adams (1971) reports a forty-fold increase in tonnage passing through the canal between 1870 and 1910. However, metrics like these give us no indication as to whether the canal: (1) increased the volume of trade for all country-pairs through its implicit increase in shipping capacity or only those most immediately affected through its explicit reduction in trade costs; (2) affected the volume of trade of all goods or had an outsized impact on narrower categories of goods; and (3) influenced the diffusion of new transport technology and, thus, altered the global pace of the sail-to-steam transition. Advances in data collection, econometric modelling, and economic theory now allow us to answer these questions.

Using multiple sources of data on bilateral trade, we find that the country-pairs that relied on the Suez Canal to lower shipping costs/times (e.g., British India and the United Kingdom) witnessed significantly faster growth in trade relative to pairs that were unaffected by the opening of the canal (e.g., the United Kingdom and the United States). We do so by running an event study on the canal's opening, ruling out the role of pre-trends and finding that the rise in trade for these pairs is persistent over time but took roughly five years to come into effect. More specifically, we find that its introduction led to a 72% increase in bilateral exports for affected country-pairs. This effect also persisted decades later, suggesting a 12% permanent increase in world trade. For our preferred sample of bilateral trade, this estimate is consistent across different time horizons and different sub-samples of relevant country-pairs. Across larger – but potentially less reliable – samples of bilateral trade, we find quantitatively similar results and additionally demonstrate how the Suez canal was effectively a global public good.

We also use new sources of data on product-level bilateral trade data for British India, the United Kingdom, and the United States to explore changes in the composition of trade due to the canal. We do so by running a set of difference-in-difference regressions on country-level shares of SITC one-digit sections in total exports as well as on the extensive margins of trade. Our results suggest that the Suez Canal was not associated with broad-based changes in the composition of exports (or at least, in our sample of countries). The number of affected sections and divisions were quite small in number both on a country-by-country basis and collectively, suggesting large but narrowly concentrated changes in the composition of trade. We also run a set of difference-in-difference regressions on the extensive margins of trade, finding evidence that the Suez Canal did, however, increase the probability of exporting activity at the destination-section level for both British India and the United Kingdom.

To better understand the mechanisms behind some of these results, we revisit the theory-informed shipping cost calculations underlying Harley (1971, 1972). In so doing, we seek to move beyond the truism that reductions in maritime distances lead to reductions in trade costs by highlighting the more subtle role of distance in the process of technological choice and change in the maritime industry. As distance was the key mediating variable governing the diffusion of steam technology, we consider the shock of Suez by first calculating shipping costs across multiple cost components, routes, and years. We then consider relative costs across destinations and means of propulsion to assess Suez's potential role in the transition from sail to steam. The results of this exercise are clear in their implications: immediately after 1869, the relative cost of shipping by steam fell in general, but did so even more dramatically on Suez-affected routes. Thus, not only was the mode-of-shipping choice of merchants affected, but also the fleet deployment choice of shipowners now favored the use of steamships on Suez-affected routes for the very first time.

This paper first relates to a burgeoning literature on the role of trade costs in the creation of a global economy from the mid-19th Century (Jacks, Meissner, and Novy, 2010). The papers in this literature seek to re-evaluate the sources of the so-called first wave of globalization in light of state-of-the-art techniques in causal inference. Thus, Jacks and Pendakur (2010) along with Pascali (2017) consider the role of the maritime transport revolution in driving global trade flows while also accounting for the endogeneity of bilateral trade and freight rates. Likewise, Juhasz and Steinwender (2018) and Steinwender (2018) respectively examine the role of improvements in communication technology in fostering the fragmentation of production and commodity market integration.

This paper also speaks to a smaller set of papers which consider the effects of Suez on other aspects of international trade. In the paper closest to ours, Pascali (2017) estimates the effects of changes in shipping times in the late 19th Century on bilateral trade flows and, from there, the effects of country-level openness (i.e., export-to-GDP ratios) on economic growth. Critically for our purposes, his estimates never separately distinguish between changes in shipping times arising from the opening of the Suez Canal and from the transition from sail to steam. However, as we later argue, the mass adoption of steam technology east of Suez itself was dependent upon the opening of the canal in 1869, given the critical role of distance in influencing the choice across sail versus steam by merchants and shipowners alike.

Following this work, Xu (2022) examines a 1866 banking crisis originating in London but with worldwide effects as sources of trade credit dried up and trade flows were permanently altered. As part of this exercise, the two variables capturing the difference in shipping times under sail and steam from Pascali (2017) are used as controls in a robustness exercise, but no separate estimate of the effect of Suez's opening on bilateral trade is reported. Hugot and Umana Dajud (2016) also use the opening of the Suez Canal – along with that of the Panama Canal – to estimate a time-varying elasticity of bilateral trade with respect to distance. On this basis, they argue that while the distance elasticity may have well increased since the 1950s (Disdier and Head, 2008), it remains a relatively modest determinant of bilateral trade flows. But yet again, no separate estimate of the effect of Suez's opening on bilateral trade is reported.

Finally, our paper speaks to and suggests new directions for a well-established literature linking changes in economic geography to improvements in transportation technology. Donaldson (2018) explores the introduction and articulation of British India's railroad network from 1870 to 1930, finding that rail technology reduced external and internal trade costs, increased external and internal trade flows, and raised real income levels. Fajgelbaum and Redding (2022) consider the combined effects of improvements in steam technology for maritime and overland transportation in the case of Argentina from 1869 to 1914, demonstrating that these improvements affected location's disposition towards trade and, from there, their long-run structural transformation. A set of other papers document similar effects occurring in Canada (Galiani, Jaramillo, and Uribe-Castro, 2022), Colombia (Belmar, 2023), and the United States (Maurer and Yu, 2008; Maurer and Rauch, 2023) in the wake of the opening of the Panama Canal. Notably, all of these papers emphasize the degree to which the location of economic activity responds to exogenous changes in transport technology. In contrast, we emphasize the degree to which the diffusion of a particular technology – the application of steam to maritime transport – itself responded to the singular change in economic geography arising from the opening of the Suez Canal.

The rest of the paper proceeds as follows. Section 2 lays out the historical context related to the opening of the Suez Canal and its subsequent operation. Section 3 introduces our data. Section 4 presents our results awhile Section 5 relates considers their potential mechanisms which arose from the opening of the Suez Canal and its interaction with the diffusion of technological change in the shipping industry. Section 6 concludes.

2. Historical background

Conceptually, there was nothing new about the Suez Canal. The advantages of connecting the Mediterranean and Red Seas had been clear to various Pharaonic, Persian, Roman, and Arabic leaders and observers. However, these long-standing aspirations never quite materialized. They were, however, actively revived during the brief period around 1800 when the French occupied Egypt in an attempt to subvert British interests in India and the Middle East. Critically, this episode also took place when the formidable, but not insurmountable technological barriers to punching a hole in the desert were slowly dissipating thanks to the industrial revolution. Here, we briefly discuss the features of the Suez Canal and its opening in November 1869 that are important for purposes of establishing our working hypotheses as well as identifying assumptions and variation.[1]

As was noted earlier and many times before by others, the power of the Suez Canal came in its ability to dramatically decrease the distances separating the main population centers of the Eurasian landmass. What is also very important for our purposes is the degree to which certain locations – or more precisely, country-pairs – were in affected by the opening of the Suez Canal whereas others remained entirely removed from the process. In what follows, we make comparisons between countries or regions which saw increased connectivity with other parts of the world due to the Suez Canal versus countries or regions which saw no change in their connectivity at this time. Thus, we implicitly contrast the varying experiences of Australia versus New Zealand, East versus West Africa, and North versus South America as the latter countries/regions belong to the set of locations which the Suez Canal effectively by-passed.[2]

[1] Naturally, there is a very large literature charting the development of the Suez Canal from the middle of the century which we need to side-line for the moment. At the heart of the entire endeavour was Ferdinand de Lessep who leveraged personal ambition, contacts, and entrepreneurial skills to see the project through to completion. In Baer's words (1954, p. 361), "de Lesseps was not a politician, a financier, an engineer, a promoter, or a businessman, [yet] he succeeded brilliantly in a venture requiring consummate mastery of all these professional fields."

[2] Future work could also exploit the significant variation within countries. Thus, while Suez reduced the maritime distance from Bombay to Liverpool by 4,393 nautical miles, it "only" reduced that of Calcutta to Liverpool by 3,817 nautical miles (Rabino, 1887). In the context of the gravity model, it is not only declines in the level of trade costs like these across country-pairs which matter but also the relative changes across potential export destinations. Thus, prior to 1869, Calcutta suffered from a +12% "distance penalty" with respect to Bombay. After 1869, this penalty increased to +29%. A similar dynamic can be observed on a west-to-east gradient for Australia: Fremantle/Perth experienced the largest decline in maritime distance to European markets while Sydney experienced the smallest.

Another critical element to consider is that successful year-round navigation of the Suez Canal – as well as the Red Sea – was predicated on adoption of steam technology. Inauspiciously, the first sailing ship to traverse the canal in December 1869 promptly wrecked just south of Suez (Fletcher, 1958). This foreshadowed a very modest uptake by sailing ships as they represented less than 0.2% of canal clearances in the years from 1876 to 1886 (Rabino, 1887).

However, the historical literature is also clear that the mass adoption of steam technology east of Suez was heavily constrained by the ready availability of British coal (Fletcher, 1975, Barak, 2022) and was greatly accelerated by the opening of the Suez Canal (Fletcher, 1958; Sargent, 1918). Here, the historical literature is clear that distance was the key mediating variable governing the diffusion of steam technology at any given point in time. This is a theme which we pursue in more detail in Section 5. Critically for purposes of estimation, we note that this implies an absence of anticipation as mercantile firms were unlikely to engage in beachhead activity prior to November 1869 given the significant expense involved in traversing the Cape of Good Hope and the uncertainty over when the canal would become fully operational. Thus, in a standard event study framework, we would not expect the presence of any significant pre-trends.

Another consideration which we explore below is the degree to which the Suez Canal acted as a global public good. In the 1850s and 1860s, the British Foreign Office was resolutely opposed to any potential canal, seeing a worrying parallel to Napoleon's attempt to establish ports on the two ends of the Isthmus of Suez. The Foreign Office had come to fear that a canal would jeopardize its grip on British India, lead to the demise of the Cape Colony as it would be relegated to also-ran status in global commerce, and open up the dangerous possibility of French imperial expansion in East Africa. This British concern and that of other nations led to the Canal's Second Concession of 1856 to repeatedly emphasize its eventual neutrality (Piquet, 2004).[3]

[3] To quote, Article 14 states: "The great maritime canal from Suez to Tina [Plain, east of Said] and the ports belonging to it shall be open forever, as neutral passages, to every merchant vessel."

On the other hand, as was famously – and one presumes approvingly – written in *The Economist* (1869, p. 1367), a widely held opinion at the time was that the Suez Canal "had been cut by French energy and Egyptian money for British advantage."[4] This suspicion was naturally only heightened when in 1875 Disraeli engaged in a secret purchase of the Khedive of Egypt's 44% stake in the company. Seemingly overnight, this move effectively reversed the Foreign Office's long-standing opposition, further giving the impression that the Suez Canal was fundamentally a British affair. And while British ships – if not necessarily British goods – later dominated the traffic of the Suez Canal (Issawi, 1982), it remains an open question the degree to which the canal differentially affected trade between the United Kingdom and its Empire to the east of Suez versus other country-pairs which were also linked via Suez.

3. Data

For our results in Section 4, our data are drawn from three main sources: existing datasets on annual bilateral (directed) trade values for large numbers of country-pairs in the latter half of the 19th Century; a new dataset on product-level bilateral exports from British India, the United Kingdom, and the United States for select years from 1866 to 1899; and a new indicator regarding the use of the Suez Canal for shipping between country-pairs after 1869 drawn from a contemporary source. These are discussed along with details of data construction in sections 3.1, 3.2, and 3.3, respectively.

3.1 Dependent variable, part I

There now exists a wide number of datasets on historical bilateral trade which can be used to determine the degree to which the opening of the Suez Canal increased the volume of trade for affected country-pairs. Our primary focus and baseline results will be drawn from the data underlying Jacks, Meissner, and Novy (2011). The sample comprises bilateral trade

[4] At the same time, the writers might have also been off in their assessment of the larger effects of the Suez Canal: "The balance of probabilities therefore is that the canal will be kept in working order for many years to come, but we cannot on that account believe that any very marked effect will be produced either on the politics or the commerce of the world..." (p. 1366).

from 27 countries and 148 country-pairs across the Americas, Asia, Australasia, and Europe, representing over 70% of world exports and GDP in the late 19th Century (Jacks and Tang, 2021). The original sample was fully balanced, but its extension back to 1850 entails a loss of data for some country-pairs. As a consequence, the final observation count is 9,439 for our preferred sample from 1865 to 1900, relative to a hypothetically possible, balanced observation count of 10,656 (i.e., a "coverage ratio" of 89%).

Critically, all the data is drawn from contemporary official sources documenting exports and imports at the individual country level (e.g., the various statistical abstracts of the United Kingdom) or works directly derived from the same (e.g., the retrospective historical data released by the Japan Statistical Association). That is, at no time does this dataset rely upon third-party accounts of bilateral trade occurring between other states (e.g., French consular reports on the state of trade between Brazil and Paraguay) or other sources of unclear provenance. This partially ensures that our baseline data and results are of the highest quality. In Section 4.1 below, we trace out larger trends in the export data by non-Suez- and Suez-affected routes from 1860 to 1900.

Alternative datasets are available which allow for higher observation counts. However, data quality issues come to the fore as many of these additional observations are drawn from third-party accounts and other sources. Moreover, it is unclear precisely what additional information is conveyed via the introduction of – oftentimes very small – countries and country-pairs constituting the remainder of world exports and GDP. Consequently, these datasets are reserved for purposes of assessing the robustness of our main results. Chief among these alternative datasets is Pascali (2017) which is comprised of exports from 95 countries and 413 country-pairs. The final observation count in this dataset is 21,258 from 1865 to 1900, relative to a theoretically possible, balanced observation count of 29,736 (i.e., a "coverage ratio" of 71%).

Likewise, Fouquin and Hugot (2016) and Dedinger and Girard (2017) are respectively comprised of exports from 208 regions[5] and 2,337 region-pairs and exports from 173 countries and 1,453 country-pairs. For the former, the final observation count is 41,865 from 1865 to 1900, relative to a theoretically possible, balanced observation count of 168,264 (i.e., a "coverage ratio" of 25%). For the latter, the final observation count is 45,556 from 1865 to 1900, relative to a theoretically possible, balanced observation count of 104,616 (i.e., a "coverage ratio" of 44%). Finally, all these datasets express bilateral export values in nominal Great British Pounds throughout the sample period.

3.2 Dependent variable, part II

To determine the degree to which the opening of the Suez Canal increased the volume of trade of all goods or had outsized effects on narrower categories of goods, we move beyond existing and easily accessible datasets on historical bilateral trade flows. To this end, we have collected and collated new data on bilateral, product-level exports from British India, the United Kingdom, and the United States in 1866, 1869, 1875, 1880, 1885, 1890, and 1899. These years were chosen to provide us with at least two pre-period years (1866 and 1869) and a viable match across countries over the longest span of years possible as the British records abruptly end in 1899 after 200 years of continuous publication.

As this is a data-intensive task, we are limited in the number of origin countries we can consider, but we note that these three countries alone represented roughly 30% of world exports and 40% of world GDP in the late 19th Century (Jacks and Tang, 2021). They are also distinguished by their varying levels of economic development and their differential exposure to the opening of the Suez Canal (e.g., the whole of British Indian exports to the rest of Asia remained unaffected – at least directly – by Suez).

The product-level export data for British India was extracted from the variously titled colonial yearbooks on the trade and navigation of British India detailed in Appendix A.

[5] We distinguish regions from countries here as the Fouquin and Hugot dataset includes sub-national entities like the provinces of Canada or states of Australia whereas all the other datasets aggregate such units to the country level.

Altogether, these yield 11,153 lines of raw data. From these, we assign consistent country identifiers and one-digit SITC codes to 7,578 observations (with further assignment to 6,907 observations at the two-digit and 6,187 observations at the three-digit SITC levels).

The product-level export data for the United Kingdom was extracted from the variously titled ledgers of exports for the United Kingdom detailed in Appendix A.
This is the same data underlying Jacks, O'Rourke, and Taylor (2020). Altogether, these yield 216,761 lines of raw data. From these, we assign consistent country identifiers and one-digit SITC codes to 206,932 observations (with further assignment to 202,063 observations at the two-digit and 188,561 observations at the three-digit SITC levels).

The product-level export data for the United States was extracted from the variously titled Department of Treasury reports for the United States detailed in Appendix A. Altogether, these yield 106,243 lines of raw data. From these, we assign consistent country identifiers and one-digit SITC codes to 97,967 observations (with further assignment to 97,310 observations at the two-digit and 97,171 observations at the three-digit SITC levels).

Finally, we identify 70 mutually consistent destinations across the three national datasets on product-level exports. Next, all observations at the one-digit SITC section (two-digit SITC division) level are collapsed by origin-country, creating 10 (66) observations for each destination country and year combination. In total, this process generates a fully balanced sample of 16,800 observations at the section level (= 3 origin countries * 8 years * 10 SITC one-digit sections * 70 destination countries) and 110,880 observations at the division level (= 3 origin countries * 8 years * 66 SITC two-digit sections * 70 destination countries). Of these, 16,080 and 106,128 observations can be assigned unambiguous "treatment" status vis a vis the opening of the Suez Canal.[6] In Section 4.2 below, we trace out larger trends in the export data by country and section.

[6] That is, three composite destinations ("British Africa", "German Oceania and Africa", and "Portuguese Possessions in Africa") are too coarse for our purposes of assigning a Suez "treatment".

3.3 Independent variable

Throughout, we rely on the sharpest difference in the Suez Canal "treatment" possible: an indicator variable, S_{ij}, for whether *i* and *j*'s main ports were connected via Suez after 1869. Our source for this information comes from *Philips' Centenary Mercantile Marine Atlas* (1935) which not only reports the maritime distances separating ports of the world but also indicates which canals and passages ships actually used in conducting international trade allowing us not to rely on imputations of minimum voyage duration as in Pascali (2017).

In our preferred sample of bilateral trade flows drawn from Jacks, Meissner, and Novy (2011), there are 148 unique country pairs. Of these, 28 (of 19%) were affected by the opening of the Suez Canal. In 1869, trade among affected country pairs accounted for 17% of the value of exports in the sample. In our new sample of bilateral, product-level exports from British India, the United Kingdom, and the United States, there are 201 unique country pairs. Of these, 62 (of 31%) were affected by the opening of the Suez Canal. In 1869, trade among affected country pairs accounted for 27% of the value of world exports in the sample.

4. Results

Our results are presented in two main parts, corresponding to the two forms of trade data at our disposal, namely aggregate bilateral trade flows for a large number of countries and product-level bilateral export flows for British India, the United Kingdom, and the United States. First, we consider our main event study on the effects of the Suez Canal on aggregate bilateral trade flows. This is followed by a battery of difference-in-differences estimates which aid the interpretation of magnitudes as well as demonstrate that our results are robust to different definitions of our sample and alternative datasets. Finally, we explore potential heterogeneity in our main results along the lines of the British Empire and the size of the Suez shock with respect to its proportional reduction in maritime distances.

Second, we consider the effects of the Suez Canal on the composition of trade by using our new product-level bilateral export data for British India, the United States, and the United Kingdom. There, we present difference-in-differences estimates which differentiate the effects of the Suez Canal on the exports shares of SITC one-digit sections and two-digit divisions on a country-by-country basis as well as on the extensive margin of exports.

4.1 Bilateral flows

We begin with a presentation of underlying trends in bilateral trade flows. We do so by plotting the sum of annual trade for those country-pairs in the Jacks, Meissner, and Novy (2011) dataset which were connected by the Suez Canal post-1869 versus those which were not. In this instance, we only consider those country-pairs for which there are uninterrupted export data from 1860 to 1900. The resulting series are presented below in Figure 1 with non-Suez-affected country pairs (n = 120) depicted in grey and Suez-affected country-pairs (n = 28) depicted in black.

Here, the two series are normalized to a value of 100 in 1860 and their subsequent growth to 1900 is tracked.[7] For the period prior to 1870, there are a few interesting features: for one, Suez-affected country-pairs seem to have experienced a trade boom and bust between 1863 and 1867 which is likely related to the American Civil War. More importantly, the difference in the two series is essentially trendless, suggesting that the parallel trends assumption might be satisfied. From 1870, the trade between country-pairs which were unaffected by the opening of the Suez Canal grew tremendously in the early 1870s but essentially flat-lined over the next 20 years. Curiously, from 1870, trade between country-pairs which were affected by opening of the Suez Canal initially declined in the 1870s but then commenced on a steady trajectory of growth for the next 20 years.

Of course, this type of analysis is purely impressionistic as it does not condition on changes in the size and structure of national economies which may have been occurring for reasons apart from the opening of the Suez Canal. Instead, the empirical framework outlined below allows us to more rigorously assess the potential effects of Suez through a panel

[7] In the 1860s, the nominal value of exports for country-pairs not affected by the opening of the Suez Canal was roughly five times higher than for those affected by Suez, reflecting the dominance of both intra-European and trans-Atlantic trade at this time.

model with a large battery of fixed effects which are intended to control for a wide range of unobservables.

4.1.1 Event study

In this section, we conduct an event-study analysis in the context of a difference-in-differences research design that exploits the differential exposure to the opening of the Suez Canal in November 1869. Again, we do so using the data from Jacks, Meissner, and Novy (2011) for all country-pairs in the years from 1860 to 1900. Our regression specification is given below. There, we estimate a standard structural gravity equation[8] wherein the value of bilateral exports depend on factors common to all countries, factors within particular countries, and factors which are specific to country-pairs (that is, the costs of conducting trade between two countries):

$$ln(X_{ijt}) = \sum_{l=-10, l\neq -1}^{30} \alpha_l S_{ij1870+l} + \beta_{ij} + \gamma_{it} + \delta_{jt} + \zeta_t + \varepsilon_{ijt}$$

That is, the log of bilateral exports from origin country *i* to destination country *j* in year *t*, X_{ijt}, is a function of treatment effects associated with the opening of the Suez Canal in late 1869, α_l, with 10 lags and 30 leads along with fixed effects:

(a) for time-invariant productivity/trade cost factors at the country-pair level, β_{ij}

(b) for time-varying productivity/trade cost factors at the origin-country level, γ_{it}

(c) for time-varying productivity/trade cost factors at the destination-country level, δ_{jt}, and

(d) for time-varying productivity/trade cost factors which affect all country-pairs, ζ_t.

Importantly for our purposes, this specification captures all unobserved, general-equilibrium effects arising from Suez, inclusive of any trade diversion which the canal may have induced.

[8] The structure referenced here comes from the general equilibrium properties of international trade: what we observe with respect to exports between two countries actually depends on changes in the costs of trade between all potential trading partners worldwide (that is, the exports of British India to the UK depends on what is happening not only in and between these two countries but also what is happening in and between the UK and the US).

Following best practice in the literature, our empirical model is estimated in levels of the dependent variable via PPML. Doing so fully utilizes the information contained in zero observations while PPML also yields unbiased estimates even in the presence of heteroskedasticity unlike OLS (Santos Silva and Tenreyro, 2006). Furthermore, PPML automatically eases the "adding-up constraints" presented by reduced form approaches like ours (Fally, 2015). Finally, we cluster standard errors at the country-pair level, ensuring that residuals are appropriately adjusted for arbitrary within country-pair/year serial correlation.

Figure 2 presents our event-study using the 120 never-affected country-pairs (out of 148) in the sample as the control group. Naturally, in the case of the Suez Canal, we expect to see non-zero effects emerge after 1869 but not before, provided that the canal is not confounded with pre-trends. We summarize these results in three parts:

(1) Nearly all of the point estimates for $t < -1$ (before 1869) are statistically insignificant, and collectively, they are inconsistently signed. Reassuringly, there is a lack of a discernible, positive pre-trend.[9] This suggests that there were no anticipation effects or effective beachhead activity by firms prior to Suez's opening in light of the significant expense involved in traversing the Cape of Good Hope and the uncertainty over when the canal would become fully operational.

(2) All of the point estimates for $-1 < t < +5$ (from 1870 to 1875) are also statistically insignificant, and collectively, they are inconsistently signed but trending upwards. This suggests that there was a transition period of roughly five years as final work on the canal was only completed in 1871, the hazards of traversing the canal were progressively diminished, and the commercial advantages of the route became more apparent.[10]

(3) All of the point estimates for $t > 5$ (after 1875) are positive and statistically significant at the 1% level, showing no sign of decline even as late as 1900. This

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[9] Indeed, for $t < -5$, there seems to be something of a negative pre-trend, but this is likely related to the disruptions and particular circumstances emanating from the American Civil War.

[10] Another factor that could be at work here was the high tolls initially levied by the Suez Canal Company for the use of its services (Yousri, 1968, p. 296).

> suggests that the Suez Canal was responsible for a more or less permanent increase in bilateral trade for affected country-pairs after an initial period of transition as certain problems related to information and navigation were ironed out and trade costs fell.

Is there any other evidence which might corroborate this last claim? For one, we can consider the trajectory of bilateral trade costs using the same dataset. Fortunately, the approach used by Jacks, Meissner, and Novy (2011) explicitly takes into account the general equilibrium forces underlying structural gravity models. Somewhat unfortunately, this approach also requires annual information on not only aggregate and bilateral exports but also country-level GDP. The last element is not consistently available prior to 1870. However, we can document the trajectory of this measure of bilateral trade costs from 1870, using the same distinction between non-Suez-affected and Suez-affected country-pairs as in Figure 1.

The unweighted averages of bilateral trade costs are presented in Figure 3 with non-Suez-affected country pairs (n = 120) depicted in grey and Suez-affected country-pairs (n = 28) depicted in black. These series indicate that the former declined by 20% from 1870 to 1900 while the latter declined by 35% in the same.[11] They also indicate that after a period of potential teething pains in the early 1870s, Suez-affected country-pairs saw greater rates of decline in their trade costs relative to their non-affected peers.

4.1.2 Difference-in-differences estimates and robustness

Having shown that there were no discernible pre-trends in bilateral export flows in Figure 2, we turn to a consideration of the equivalent difference-in-differences estimates to aid the interpretation of magnitudes as well as demonstrate that our results are robust to other definitions of our sample and alternative datasets. In Table 1, the specification for Column 1 corresponds to the event study in Figure 2, where bilateral exports from 1860 to 1900 are a function of country-pair, time-varying exporter, and time-varying importer fixed

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[11] This result is materially unaffected whether we consider the series on a GDP-weighted, trade-weighted, or unweighted basis as depicted here.

effects. We find a statistically significant (at the 1% level) increase in bilateral exports of 0.56 log points (or 75%) for those country-pairs which were directly affected by the opening of the Suez Canal in 1869.

The remainder of Table 1 establishes the robustness of our results to various other specifications. Column 2 considers a longer time horizon, extending the sample from 1850 to 1900. While it does so by making the sample more unbalanced, the results are not significantly different (statistically speaking) from those in Column 1. Likewise, Column 3 only uses data from 1865 to 1900, thereby excluding the years of the American Civil War, but with materially the same result as in Columns 2 and 3. Finally, Column 4 retains the sample from 1865 to 1900 and focusses our attention on a smaller "high quality" sample. This sample excludes country-pairs for which there are fewer than 10 observations and/or the minimum recorded value of exports is less than 1,000 GBP. Regardless, this restriction yields results which are highly consistent with those of Columns 1 through 3.

Thus, we conclude that the opening of the Suez Canal led to a 0.54 log point (or 72%) increase in bilateral exports for affected country-pairs. We also know from Figure 2 above that effect persisted decades later. What effect did this have the on the level of trade worldwide? As a back of the envelope calculation, we can combine our preferred estimated from Column 4 with the 17% share of world bilateral trade flows in the 1860s emanating from Suez-affected country-pairs. This product suggests that the Suez Canal led to a 12% permanent increase in world trade.

We can also consider what happens to our results when we use the three alternative datasets described in Section 3.1. In what follows, we take the period from 1865 to 1900 as our preferred sample for two reasons. First, it excludes the volatile years of the American Civil War in the early 1860s. Second, and more importantly, it most closely corresponds to the sample period we employ in Section 4.2. With this in mind, we reproduce our baseline results in Column 4 of Table 1 in Column 1 of Table 2 below. Columns 2, 3, and 4 then report the results of using Pascali (2017), Fouquin and Hugot (2016), and Dedinger and Girard (2017), respectively. Again, for purposes of comparability, we exclude country-pairs in all datasets for which there are fewer than 10 observations and/or the minimum recorded value of exports is less than 1,000 GBP. In sum, while the coefficients differ due to different sample countries, we note that all of them are positive and significantly different than zero while none of them are statistically significantly different from our baseline results in Column 1 or from one another.

4.1.3 Heterogeneity analysis

We can also consider the possibility that the Suez Canal differentially affected trade on the basis of belonging to the British Empire and the degree to which it proportionally changed maritime distances across country pairs. Table 3 below directly contends with the suspicion that the Suez Canal had been cut "for British advantage" and the possibility that this spilled over to the trade between the United Kingdom (as metropole) and its colonial possessions east of Suez. Columns 1 through 4 use the same "high quality" samples as in Table 2. They also include an interaction term for Suez-affected routes which involved the United Kingdom as an origin or destination. They suggest that while British metropole trade was enhanced by the introduction of the Suez Canal, non-metropole trade saw an even greater proportional increase. Thus, while the British Empire may have gained geopolitical or other strategic advantage from the Suez Canal, this did not necessarily register in its pattern of bilateral trade relations. In this particular sense, it may then be argued that the Suez Canal was a global public good — or at least, one for the dominant powers of the day.

Of course, our baseline results through their use of a simple indicator for maritime trade via Suez only captures the average treatment effect of the canal. Another form of heterogeneity that might be informative comes from variation in the proportional declines in maritime distances induced by the opening of the canal. Here, we use the maritime distances separating country-pairs – both before and after 1869 – reported in Hugot and Umana Dajud (2016) to construct the variable, "Suez factor". This is simply the proportional decline in maritime distances following in the wake of Suez at the country-pair level. From there, we construct four indicator variables for the interaction between Suez's opening and the first (-0.10, 0.00), second (-0.23, -0.10), third (-0.39, -0.23), and fourth quartiles (-0.56, -0.39) of the "Suez factor". That is, Table 4 considers the differential effect of Suez on the basis of the smallest (first quartile) to largest (fourth quartile) proportional declines in maritime distances.

All of the results suggest positive and significant treatment effects for the Suez Canal. Moreover, the effects of Suez are increasing in the size of the proportional decline in maritime distances, but only up to the third quartile. Indeed, for those country-pairs which witnessed the largest proportional declines, the estimated coefficient is roughly one-tenth the size of that for the third quartile. Somewhat surprisingly, all of the country-pairs in the fourth quartile feature British India as either the origin or destination in our sample. But they also primarily feature countries with ports in the Mediterranean Sea like Italy and Turkey for which there were high hopes related to Suez's opening that never materialized (Barak, 2022; Huber, 2015). In the third quartile, British India steadily appears again as does the Dutch East Indies. However, the majority of country-pairs in this quartile feature Japan as either the origin or destination. Thus, concurrent with its dramatic re-engagement with the world and nascent industrialization (Meissner and Tang, 2018), Japan was able to fully seize the opportunity of Suez's opening to firmly establish itself as one of the world's premier trading nations by the end of the 19th Century. This result, thus, amplifies the message of Table 3 above in which the British were not the primary beneficiary of the Suez Canal with respect to its promotion of bilateral trade flows.

4.2 Bilateral, product-level exports

In this section, we address the possibility that the Suez Canal not only had an effect on the volume of trade but also its composition. We do so in the context of the product-level export data discussed in Section 3.2. Before proceeding to the analysis, we first lay out some broad trends in the export flows emanating from British India, the United Kingdom, and the United States in this period. Panels A through C of Figure 4 below respectively chart British India's: (1) total exports; (2) share of manufacturing goods in its total value of exports; and (3) share of non-zero observations on the basis of destination-country/one-digit SITC section cells. These series are also delineated across trades routes for British India which were and were not affected by the opening of the Suez Canal. Panels D through F and Panels G through I respectively do the same for the United Kingdom and the United States.

For British India, total exports grew considerably rising 62% from 1866 to 1899. Its Suez-affected routes also notably dominated its exports throughout the period with a 71% share on average while export growth rates for its non-Suez- and Suez-affected routes were similar at 65% and 61%, respectively. Its share of manufacturing sections (5 through 9) declined in aggregate from 35% in 1866 to 26% in 1899. Primarily, this reflects a large decline of 10 percentage points for non-Suez affected routes as manufacturing goods on Suez-affected routes actually managed to marginally increase their share of total exports. Over time, its exports also grew on the extensive margin as the fraction of non-zero observations for destination-country/one-digit SITC section cells grew. Notably, this growth was somewhat faster for Suez-affected routes than non-Suez affected routes.

For the United Kingdom, total exports grew more modestly in the period rising 40% from 1866 to 1899, albeit from a higher base (roughly 4x that of British India). Here, Suez-affected routes were in the minority with a 30% share on average. However, they were gaining ground: the growth rate for exports for Suez-affected routes (62%) outstripped that for non-Suez-affected routes (32%), reflecting the burgeoning potential of Asia in world trade. Curiously, its share of manufacturing sections actually declined in aggregate from 91% in 1866 to 82% in 1899. But there is also a clear asymmetry here: whereas as manufacturing goods on non-Suez-affected routes saw their share decline by 15 percentage points those on Suez-affected routes saw their share increase by 5 percentage points. Finally, in 1866, the fraction of non-zero observations for destination-country/one-digit SITC section cells was considerably higher for non-Suez-affected routes than Suez-affected routes, but this gap entirely disappeared – indeed, it was even reversed – by 1899.

Somewhat anomalously, the United States experienced explosive export growth in this period of 154%.[12] And while its Suez-affected routes massively outperformed its non-Suez-affected routes in terms of export growth (at 541% and 145%, respectively), the United

[12] Base year effects might matter here as the US was only emerging from its Civil War in 1866. However, using 1869 as the base, its export growth was even more pronounced at 208%. Even using 1875, its export growth was 110%, underlining the growing stature of the American economy on the world stage. Thus, its cumulative export growth lead the United States to catch up with the United Kingdom by 1899 when the value of the former's exports was 94% of that of the latter.

States is exceptional here in that the former only commanded a 3.5% export share on average. Here, greater economic activity and lower internal trade costs in the eastern United States along with the sheer economic mass of Europe virtually guaranteed that trade with Suez-affected export destinations would remain marginal at this time. Furthermore, its share of manufacturing sections in aggregate increased from 8% in 1866 to 23% in 1899 with nearly all of this increase coming from a 13 percentage point increase in the share of manufacturing goods on non-Suez affected routes. We do, however, see another narrowing of the gap in the fraction of non-zero observations across non-Suez- and Suez-affected routes.

4.2.1 DiD on export shares before and after the opening of the Suez Canal

As a reminder, the data used in this section are two fully balanced samples of 16,080 observations of bilateral exports at the SITC one-digit section level and 106,128 observations of bilateral exports at the SITC two-digit division level. We then form the respective shares of total exports by goods category, origin country, Suez/non-Suez routes, and year. In total, this process generates a fully balanced sample of 480 observations at the section level (= 2 routes * 3 origin countries * 8 years * 10 SITC one-digit sections) and 3,168 observations at the division level (= 2 routes * 3 origin countries * 8 years * 66 SITC two-digit divisions).

Against this backdrop, we now assess the degree to which the opening of the canal changed the distribution of export shares for particular goods by origin country across non-Suez- and Suez-affected routes. That is, we would like to learn whether the opening of the Suez Canal affected the volume of trade of all goods or had an outsized impact on narrower categories of goods and, thereby, changed the composition of trade. To do so, we estimate a battery of difference-in-differences regressions for each origin country, successively drilling down from the level of the manufacturing/non-manufacturing sectors to one-digit sections and then two-digit divisions. The intent of this progression from broadest to narrowest good categories allows us to easily see the largest movers in the underlying data by making use of the additive properties of these shares. That is, because the shares must sum to one for any origin country/year, the changes in shares within appropriately defined sectors, sections, and divisions must equal one another.

In particular, we estimate the following two-way fixed effects model:

$$Share_{iskt} = \alpha_{ik} S_{ist>1869} + \gamma S_{isk} + \delta_{kt} + \varepsilon_{iskt}$$

where $Share_{iskt}$ is the share of total exports for a single origin country (*i*) to destinations which are/are not affected by the Suez Canal (*s*) in a particular sector, section, or division (*k*) and year (*t*). Thus, the indicator variable, S_{isk}, simply delineates the set of destinations which were ever affected by the Suez Canal but varies by *k*. As an example, our first regression is ran on the data underlying Panel B of Figure 4 for British India. That is, we evaluate whether the gap in the share of manufacturing goods in total exports between non-Suez- and Suez-affected routes increased, narrowed, or remained the same after the opening of the Suez Canal in 1869.[13] Likewise, we do the same for the share of non-manufacturing goods in total exports.

Panel A of Figure 5 depicts the estimated coefficients and related confidence interval for this regression. There, we see that the opening of the Suez Canal is associated with a (significant) 7.04 percentage point increase in the share of total exports which were manufacturing goods shipped to destinations affected by Suez in 1869. Here, it is important to remember that this estimate – like all DiD estimates – only speaks to the difference in relative baseline mean outcomes and is not necessarily a statement about the change in levels of these shares. Thus, it captures the fact that while British India's share of manufacturing goods declined in aggregate, its share of total exports in the form of manufacturing goods on Suez-affected routes held its own throughout.

Panel B of Figure 5 helps us pin down the sources of this result by considering the 10 SITC one-digit sections. There, we see statistically significant results of greater than three percentage points magnitude associated with the opening of the Suez Canal in the following:
+8.17 percentage points for 0 ("Food and live animals");
-9.15 percentage points for 2 ("Crude materials");
+11.31 percentage points for 5 ("Chemicals and related products"); and

[13] Ideally, we would do so in the context of an event study as in Figure 2 to evaluate the validity of the parallel trends assumption. However, this would require collection of annual export data for the three origin countries which is a far from trivial task given the dimensions of the raw data. Therefore, some degree of caution is warranted in ascribing a truly causal role for Suez in our discussion below.

-4.72 percentage points for 6 ("Manufactured goods classified chiefly by materials"). Interestingly, six of the sections register coefficient values very near zero (μ = 0.09 percentage points), suggesting that for a large range of goods there was no difference in export performance across routes after 1869. Instead, any effects of the Suez Canal on the composition of trade seem to be limited to a relative handful of sectors.

This impression is further affirmed in Panel C of Figure 5 which turns to SITC two-digit divisions as there is a similar pattern of a large number of near zero coefficients (36 of the 54 divisions estimated with non-zero observations for British India). More strikingly, there is a small number of economically and statistically significant coefficients in the following:
+5.39 percentage points for 07 ("Coffee, tea, cocoa, spices, and manufactures thereof");
+4.75 percentage points for 21 ("Hides, skins and furskins, raw");
-21.25 percentage points for 26 ("Textile fibres and their wastes");
+6.59 percentage points for 29 ("Crude animal and vegetable materials");
+12.72 percentage points for 54 ("Medicinal and pharmaceutical products"); and
-4.85 percentage points for 65 ("'Textile yarn, fabrics, and made-up articles").[14]
Again, this suggests that the effects of the Suez Canal on the composition of trade was likely significant but also highly concentrated.

Turning to Panels A through C of Figure 6 for the United Kingdom, we repeat the exercise above moving from sectors to sections and then divisions. In this case, the opening of the Suez Canal is associated with a (significant) 5.89 percentage point decrease in the share of total exports which were non-manufacturing goods shipped to destinations affected by Suez in 1869 and a (significant) 18.57 percentage point increase in the share of the same coming from manufacturing goods. Again, this last result is noteworthy for the fact that the UK's share of manufacturing goods in aggregate was in decline as seen in Panel E of Figure 4.

[14] The second-to-last result requires some explanation as this might not be a product category which immediately springs to mind in the context of trade in the late 19th Century. However, this division critically includes "Opium alkaloids and their derivatives": over our sample period opium represented roughly 13% of all exports from British India.

With respect to the section shares for the United Kingdom, we can see how the effect of Suez on manufacturing exports was even more concentrated in the following sections:
-3.89 percentage points for 3 ("Mineral fuels and lubricants");
+20.62 percentage points for 6 ("Manufactured goods classified chiefly by materials").
These results are also fully mirrored and likewise narrowly defined at the division level:
-4.65 percentage points for 32 ("Coal, coke and briquettes"); and
+11.03 percentage points for 65 ("'Textile yarn, fabrics, and made-up articles").

Finally, we arrive at the equivalent results for the United States in Figures 7a through 7c. Here, the effects of Suez seem more muted with respect to the effects on both non-manufacturing and manufacturing goods. However, within the non-manufacturing sector, there were large, countervailing, and narrowly concentrated changes as seen in Figure 7c:
-5.51 percentage points for 01 ("Meat and preparations");
-11.49 percentage points for 04 ("Cereals and cereal preparations");
+3.02 percentage points for 12 ("Tobacco and tobacco manufactures"); and
+25.34 percentage points for 26 ("Textile fibres and their wastes").

In sum, these results underline the message that the Suez Canal was not associated with broad-based changes in the composition of exports for our three sample countries. And not only were the number of affected sections and divisions small in number on a country-by-country basis, they were also collectively small in number with only ten divisions significantly at play. This figure contrasts with the 66 possible divisions for which we observe positive trade values in this period, suggesting that there might have been more systematic forces at play like the interaction of capacity constraints in the maritime shipping industry and value-to-weight ratios for goods in determining the canal's effect on the composition of trade.

4.2.2 DiD on the extensive margins of trade

As Panels C, F, and I of Figure 4 show, there were also appreciable changes in the extensive margins of trade as the fraction of non-zero cells at the origin-destination-section level increased from 1866 to 1899. In order to assess the potential role of Suez's opening in this process, we run a set of two-way fixed effects probit regressions of the following form:

$$probit(Y_{ijkt}) = \alpha_i S_{ijt>1869} + \gamma S_{ij} + \delta_t + \varepsilon_{ijkt}$$

where Y_{ijkt} equals to one if an origin country (*i*) exports to a destination (*j*) in a particular section (*k*) and year (*t*). Thus, the indicator variable, S_{ij}, simply delineates whether a destination was ever affected by the Suez Canal.

Panel A of Table 5 reports the average marginal effects of this difference-in-differences exercise. Column (1) does so for the full sample of 16,080 observations, finding the opening of the canal was associated with a statistically significant 6% higher chance of exporting activity for Suez-affected routes across all origin countries. Columns (2) through (4) do so on a country-by-country basis. Statistically, the strongest marginal effects come from British India with a 7% higher chance of exporting activity and a z-score of 2.47 (which is highly significant at the 1% level). Quantitatively, the largest average marginal effects come from the United Kingdom with a 12% higher chance of exporting activity and a z-score of 1.62 (which is only marginally statistically significant at the 10% level). In contrast, the marginal effects for the United States are negative and grossly statistically insignificant.

Panel B of Table 5 repeats this exercise but does so by aggregating the treatment up to the destination-country level. That is, it now evaluates Y_{ijt} which equals to one if an origin country (*i*) exports to a destination (*j*) in a particular year (*t*), leaving all other variables and the probit specification otherwise the same. For British India, the average marginal effects are quantitatively and statistically negligible. Somewhat as a contrast, the marginal effects for the United Kingdom are large and statistically significant (but again, only marginally so). This suggests that the results for British India and the United Kingdom in Panel A – although quantitatively similar – might be driven by slightly different forces. In combination, the two panels imply that the increase in the probability of export activity from British India came from an increase in the number of exported products but not necessarily the number of export destinations. At the same time, the results for the United Kingdom imply that the Suez Canal may have allowed it to export a roughly similar bundle of goods but to a larger set of countries. In the interests of space, we leave this potentially disparate pattern of export diversification for future work.

5. Suez and the transition from sail to steam

In this section, we consider potential mechanisms underlying the some of the effects identified in the wake of the Suez Canal's opening. In particular, we would like to move beyond the truism that reductions in maritime distances are associated with reductions in trade costs. On the one hand, it is obvious that distance is a key determinant of a wide range of variable cost components like capital, fuel, and labor costs. On the other hand, its role in the process of technological choice and change in the maritime industry is more subtle.

Purely in terms of timing, we know that the opening of the Suez Canal was closely linked to the transition to steam propulsion in maritime transport, coming at a time when roughly 80% of world shipping was still under sail (Jacks and Stuermer, 2021). For one, its opening contributed to a veritable boom in steamship construction (Girard, 1966). What is more, this boom itself reflected not only expectations about the commercial potential of the canal but also the fact that sailing ships were unsuitable for using the Suez Canal. At the same time, the historical literature has long pointed to a potential role of the Suez Canal in shaping the diffusion and development of steam technology in the maritime shipping industry, but quantitative evidence to this effect has been thin on the ground.

Harley (1971, 1972) and others have made clear that distance was the key mediating variable governing the diffusion of steam technology at any given point in time. That is, the prodigious fuel requirements of steam engines necessarily reduced the size of potential cargoes and, thus, determined the distance threshold of profitability for shippers. This fact along with technological change in the industry helps us understand why steam was limited to carrying high value-to-weight cargoes over short distances at the beginning of this period but was carrying low value-to-weight cargoes over long distances at the end of this period.

Thus, to assess the role of the Suez in the transition from sail to steam, we need to understand the factors that shaped the relative costs of shipping in the late 19^{th} Century and, in particular, how the opening of the canal and technological change interacted with one another. Our starting point is the set of calculations underlying Harley (1972) which estimate the costs of shipping via sail and steam over the period from 1850 to 1890 for a large number of maritime routes. We revise these calculations to allow for additional known costs to the production of shipping services and validate them against observed freight rate data for nine trade routes. Appendix B details the assumptions and data going into these calculations along with the full results of our validation exercise.

Given the very high correlation between calculated shipping costs and observed freight rates (>0.95), our next step is then to extend this approach to 201 routes, corresponding to the usable origin-destination combinations found in our bilateral, product-level data for British India, the United Kingdom, and the United States. These cost calculations allow us to decompose total shipping costs on a per ton basis into the contribution of capital and labour (for both sail and steam) as well as the price of coal and Suez passage (for steam). Critically, at any given point in time, variation in shipping costs across routes for both sailing and steam ships arises from variation in distance, conditional on ship size. And of course, the opening of the Suez Canal in late 1869 represented a large, discrete shock to the distances travelled by merchant ships. Thus, the canal should have had very large effects on the relative costs of shipping via sail versus steam but only for a limited number of origins and destinations.

Figure 8 below depicts the evolution of average calculated shipping costs across two dimensions: sail versus steam propulsion and non-Suez- versus Suez-affected routes. A few general observations are in order. First, shipping costs were decreasing across the board, ranging from a decline of 22% for sail on non-Suez affected routes to a decline of 66% for steam on Suez-affected routes. Also for our sample of origins and destinations, shipping costs for Suez-affected routes were always higher than non-Suez-affected routes, regardless of the means of propulsion or year. The average premium on Suez-affected routes (+126%), of course, partially reflects the greater distances involved prior to the opening of the canal (+154%). However, this premium declined over time from 153% in 1860 to 109% in 1890. Another important development in this period is the convergence in the two series for shipping costs under steam to the respective series for shipping costs under sail. Indeed by 1890, shipping costs via steam were lower than those sail across both the non-Suez and Suez-affected routes in our sample.

Apart from these broad trajectories, is there a means to perhaps more clearly see the role of the Suez Canal in driving the diffusion of steam technology? We begin with the observation that the demand for sail versus steam ships will depend on their relative cost from the perspective of an individual merchant. That is, while merchants may be willing to pay a premium for the greater speed and reliability of steamships, too great of a divergence in relative shipping costs will limit the appeal of employing steam. Likewise, from the perspective of a shipowner, they are unlikely to deploy steamships to locations where the market will not bear the price of their services on both the outward and homeward journeys and will rely on sail to get the job done instead. Of course, this constraint is particularly binding for more far-flung destinations.

Along these lines, Figure 9 uses the same raw data as that underlying Figure 8, but instead considers the ratio of steam-to-sail shipping costs across non-Suez- and Suez-affected routes. Thus, in 1860 steam shipping was 40% and 61% higher than sail for non-Suez- and Suez-affected routes, respectively. Not surprisingly, these ratios also decline over time with steam shipping consistently being cheaper than sail on the two routes from 1875. However, this bird's eye view misses a very important reversal in the rank ordering of the two series. Up to 1869, the relative cost of steam was higher for Suez-affected routes than non-Suez-affected routes. Immediately after the opening of the Suez Canal in 1869, the relative cost of shipping by steam fell in general, but did so even more dramatically on Suez-affected routes: the relative cost of steam was now higher for non-Suez-affected routes than Suez-affected routes. Thus, not only was the mode-of-shipping choice of merchants affected, but also the fleet deployment choice of shipowners now favored the use of steamships on Suez-affected routes for the very first time.

6. Conclusion

This primary purpose of this paper has been to provide a first and full assessment of the quantitative effects of the Suez Canal's opening and subsequent operation in the late 19th Century. As such, it finds that the canal increased the volume of trade for affected country pairs, had an outsized impact on a fairly narrow range of goods while also increasing the extensive margin of exports, and vitally influenced the diffusion of new transport technology and, thus, altered the global pace of the sail-to-steam transition.

One open question – naturally, outside the scope of the present paper – is whether the opening of the Suez Canal also influenced the direction of technical change in maritime shipping itself. Many historians have alluded to this possibility, citing key innovations in engine and hull design which occurred after 1869 and which arose to address specific issues related to the operation of steamships to the east of Suez (cf. Fletcher, 1958; Girard, 1966; Harley, 1971). In this way, endogenizing the process of technological change in the sail-to-steam transition could further amplify the impression that the opening of Suez was one of the key catalysts in intensifying the first wave of globalization.

APPENDIX A: PRODUCT-LEVEL EXPORT DATA SOURCES

For British India, the full title is *Annual Statement of the Trade and Navigation of British India with Foreign Countries and of the Coasting Trade of the Several Presidencies and Provinces* (*ASTNBI*):

1866 – *ASTNBI*. Calcutta: Superintendent of Government Printing, 1869.
1869 – *ASTNBI*. Calcutta: Superintendent of Government Printing, 1871.
1875 - *ASTNBI*. Calcutta: Superintendent of Government Printing, 1877.
1880 - *ASTNBI*. Calcutta: Superintendent of Government Printing, 1881.
1885 - *ASTNBI*. Calcutta: Superintendent of Government Printing, 1890.
1890 - *ASTNBI*. Calcutta: Superintendent of Government Printing, 1895.
1895 - *ASTNBI*. Calcutta: Superintendent of Government Printing, 1899.
1899 - *ASTNBI*. Calcutta: Superintendent of Government Printing, 1901.

For the United Kingdom, the UK National Archives in the following folders of CUST 8:

1866 - *Ledgers of Exports of British Merchandise under Countries*, 103
1869 - *Ledgers of Exports of British Merchandise under Countries*, 109-110
1875 - *Ledgers of Exports of British Merchandise under Countries*, 116
1880 - *Ledgers of Exports of British Merchandise under Countries*, 121
1885 - *Ledgers of Exports of British Merchandise under Countries*, 126
1890 - *Ledgers of Exports of British Merchandise under Countries*, 131
1895 - *Ledgers of Exports of British Merchandise under Countries*, 136
1899 - *Ledgers of Exports of British Merchandise under Countries*, 140

For the United States, the full title is *Annual Report of the Secretary of the Treasury on the Commerce and Navigation of the United States* (*ARSTCNUS*):

1866 – *ARSTCNUS*. Washington: Government Printing Office, 1868.
1869 – *ARSTCNUS*. Washington: Government Printing Office, 1871.
1875 – *ARSTCNUS*. Washington: Government Printing Office, 1877.
1880 – *ARSTCNUS*. Washington: Government Printing Office, 1882.
1885 – *ARSTCNUS*. Washington: Government Printing Office, 1887.
1890 – *ARSTCNUS*. Washington: Government Printing Office, 1892.
1895 – *ARSTCNUS*. Washington: Government Printing Office, 1897.
1899 – *ARSTCNUS*. Washington: Government Printing Office, 1901.

APPENDIX B: SHIPPING COST CALCULATIONS

Following Harley (1972), we assume that all ships use the most efficient technology available. Using data from *Mitchell's Maritime Register*, he assumes that sailing ships have an average (time-invariant) speed of 4.0 knots (p. 281f) while steamships have an average speed that increases from 5.5 knots in 1856 to 7.0 knots in 1890. On this basis, we argue that at any given point in time, all variation in shipping costs across routes for both sailing and steam ships arises from variation in distance, conditional on ship size. Necessarily, the opening of the Suez Canal dramatically altered shipping costs through its effect on maritime distances. For each route, we calculate shipping costs in UK shillings on the basis of two measures of shipping capacity: (1) per ton of carrying capacity and (2) per ton of usable cargo space. The latter measure takes into account that steamers needed to carry coal as fuel which necessarily limited their cargo space.

Capital costs

Capital costs for sailing ships are simply determined by the purchase price per gross ton multiplied by an annual rate of return to take depreciation, insurance, management, profit, and repairs into account. Harley sets this to 30%, following Giffen (1882). Ship prices per gross ton are taken from the engineering firm of Stephen and Sons Limited of Glasgow (Harley 1972, p. 233f.). For ship sizes, we take route- and year-specific data from the *Annual Return on Trade and Navigation* (various years).

Calculating capital costs for steamships is more involved, because cargo capacity, coal consumption, displacement, and speed played off one another. From the technical literature, Harley (1972, p. 214) refers to the Admiralty constant (A) to establish the relationship between engine power, displacement of a ship, and speed:

$$A = \frac{\frac{D^{2/3}}{V^3}}{IHP}$$

where *D* is displacement, *V* is speed in knots, and *IHP* is indicated horsepower. Assuming a proportional relationship between displacement and hull weight and calculating the weight of coal as a function of indicated horsepower, we can calculate the cost of the ship (engine plus hull) for a given cargo capacity, level of steam technology, and route-specific distance.[15]

The prices for engines and hulls are taken from several sources including Stephen and Sons Limited and Maywald (1956). Data on coal consumption is taken from several contemporary

[15] Formally, the relationship is

$$D = (F + DH) + \frac{D^{2/3}V^3}{A} + \left(\frac{D^{2/3}V^3}{A} C \frac{d}{V}\right)$$

where *F* is cargo capacity (ship size), *H* is hull size, *C* is coal consumption per IHP, and *d* is distance. This relationship can be approximated using a Taylor series expansion.

engineering sources (Harley 1972, p. 274, fn 20) while route- and year-specific ship sizes are from the *Annual Return on Trade and Navigation*. The annual return for steamships is set slightly higher than for sailing ships at 35%, following Giffen (1882). Note that coal consumption per IHP is declining from 5.0 pounds per IHP in 1855 to 1.6 lbs per IHP in 1890. (Harley 1972, p. 219, p. 273). Thus, this reduced the cost of capital, but also – and more so – the cost of coal as discussed below.

Labor Costs

We use data on man-ton ratios, ship size, and wages to calculate labor costs. We follow Harley and use wage data from Bowley (1895). We update his data on man-ton ratios with more recent work by Sager (1989) and Kaukiainen (1995) as Harley (1972) acknowledges that his data on crew sizes "are undoubtedly the worst figures here" (p. 277). It is broadly understood that steam ships had larger crew size than sailing ships, due to the need for an engine crew. We follow Sager's man-ton ratios for sailing ships together with data on ship sizes and adjust this for steamships as suggested by Kaukiainen (1995).

Coal

The calculation of the cost of coal for steamships is, in comparison, relatively straightforward: given the state of technology in a particular year (measured in terms of coal consumed per IHP per hour) and data on distances and steaming speed, we can calculate coal consumption per day by route. This can be multiplied by the average f.o.b. export price at Cardiff, Newport, and Swansea from Harley (1972, p. 278) to derive the cost of coal per route. The majority of coal used on British steamships was Welsh, even after coal mining was established in other quarters such as India and South Africa, due to its cleaner burn and higher caloric content (Barak, 2022; Gray, 2018). However, the question remains where that coal was purchased and loaded.

In the 19th Century, countries like the UK suffered from an imbalance in terms of the physical volumes of traded goods as they exported high value, less bulky goods and imported low value, more bulky goods. Consequently, coal was often used as ballast (Allan, 2020; Jevons, 1866; Palmer, 1979) with lower than average outward freight rates which were effectively subsidized by higher homeward freight rates (Klovland, 2006). To give a sense of the scale of this phenomena, Fletcher (1975) reports that whereas coal represented 10% of the total value of British exports in 1913, it took up over 85% of the total volume of the same. However, due to high costs of loading and unloading coal, Harley argues that it was rarely profitable for UK-originated ships to use coaling stations along the way and even less so over time with the advent of more efficient steam engines.

In the absence of systematic data on coaling station activity, we assume that steamships from the UK carried enough coal for the outward journey. For the homeward journey, we assume that coal is purchased at the foreign port at the prevailing price for Welsh coal plus the freight to reach the Mediterranean side of the Suez Canal (Port Said). Steamships would refuel after passage to Port Said to save on canal dues which were assessed partially on tonnage and on coal prices which were cheaper at Port Said. It should be noted that both improvements in steam technology and the reduction in distance due to Suez's opening reduced the cost of steamships in two ways. First, they directly reduced coal consumption and hence the cost of purchasing coal. Second, they freed up more cargo space which previously would have been used for bunkering coal. To account for these changes, we calculate all shipping costs per ton of carrying capacity and per ton of available cargo space, which is simply carrying capacity less tonnage dedicate to hauling coal.

Loading/unloading time in ports, transit fees/times for the Suez Canal

Finally, we need to take into account that both sailing and steam ships had to spend several days in ports due to the cumbersome process of loading and unloading cargoes. We follow Harley and assume that loading/unloading time depended on ship size at an average rate of cargo clearance of 400 tons per day (Hamilton, 1883; Harley, 1972, p. 280). However, bulk loading of coal was typically faster than this, and increasingly so over time. Based on Barak (2015) and Gray (2018), we assume an average rate of cargo clearance of 70 tons per hour for coal.

In the case of steamships, there was also the additional monetary cost for canal transit fees plus the additional opportunity cost for the time it took to transit the canal (as the canal is still subject to congestion given physical limitations on passage). We use transit times reported in Worms (1911). Notably, these were decreasing due to constant improvement in the canal's operation over time. Regarding transit fees, Hansen and Tourk (1978) argued that for a listed, profit-maximizing firm like the Suez Canal Company, fees should have been set to be just below the cost-saving to merchants for avoiding the route around the Cape of Good Hope. However, transit fees actually stayed below this threshold and were reduced over time, notably after Disraeli's purchase of the Khedive's 44% stake in 1875. Consequently, we use the passage fees per ton reported in Worms (1911).

Validation of shipping cost calculations

While our cost calculations demonstrate sensible patterns as discussed in Section 5, they are necessarily based on multiple assumptions so here we validate our approach by comparing them to observed freight rates. We use freight data from Jacks and Pendakur (2010). We are able to match our calculated shipping costs to observed freight rate data in UK shillings per ton for nine trade routes, originating in the southwest of the UK and destined for the following ports: Aden, Bombay, Buenos Aires, Cape Town, the Caribbean, Egypt (Alexandria and Port Said) Hong Kong, the North Atlantic (Halifax and New York), Hong Kong, and San Francisco. As quoted freight rates rarely distinguish between sail and steam, we assume arbitrage/competition between the two types of ships which is easily rationalized in the context of the tramp shipping trade.

To test the validity of our approach, we first regress observed freight rates on the average across sail and steam of our shipping cost calculations for a ton of carrying capacity by route and year. To ease interpretation, we focus on the outward journey from the UK. We then consider a specification using the average across sail and steam of our shipping cost calculations for a ton of cargo space by route and year. The results of this exercise are reported in Panel A of Table B1 below. Next, we use the minimum calculated cost of sail and steam for a ton of carrying capacity and for a ton of cargo space by route and year as regressors. The results of this exercise are reported in Panel B of Table B1 below.

Regardless of specification, our shipping cost calculations predict observed freight rates remarkably well. With no other controls save a constant term, they capture 93% of the variation in freight rates. With respect to levels, we find that observed freight rates are always roughly 20% higher than our calculated shipping costs. This is plausible as we must assume like Harley (1972) that all steamers use the best available technology.

Table B1: Validation exercises for calculated shipping costs

Panel A: Average shipping costs across sail/steam

	(1)	(2)
Per ton of carrying capacity	1.26	-
	(0.20)	
	[6.29]	
Per ton of cargo space	-	1.24
		(0.20)
		[6.21]
N of observations	315	315
Adjusted R^2	0.93	0.93

Panel B: Minimum shipping costs across sail/steam

	(1)	(2)
Per ton of carrying capacity	1.33	-
	(0.20)	
	[6.60]	
Per ton of cargo space	-	1.30
		(0.20)
		[6.43]
N of observations	315	315
Adjusted R^2	0.93	0.93

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Figure 1: Export Growth with and without the Suez Canal, 1860 to 1900

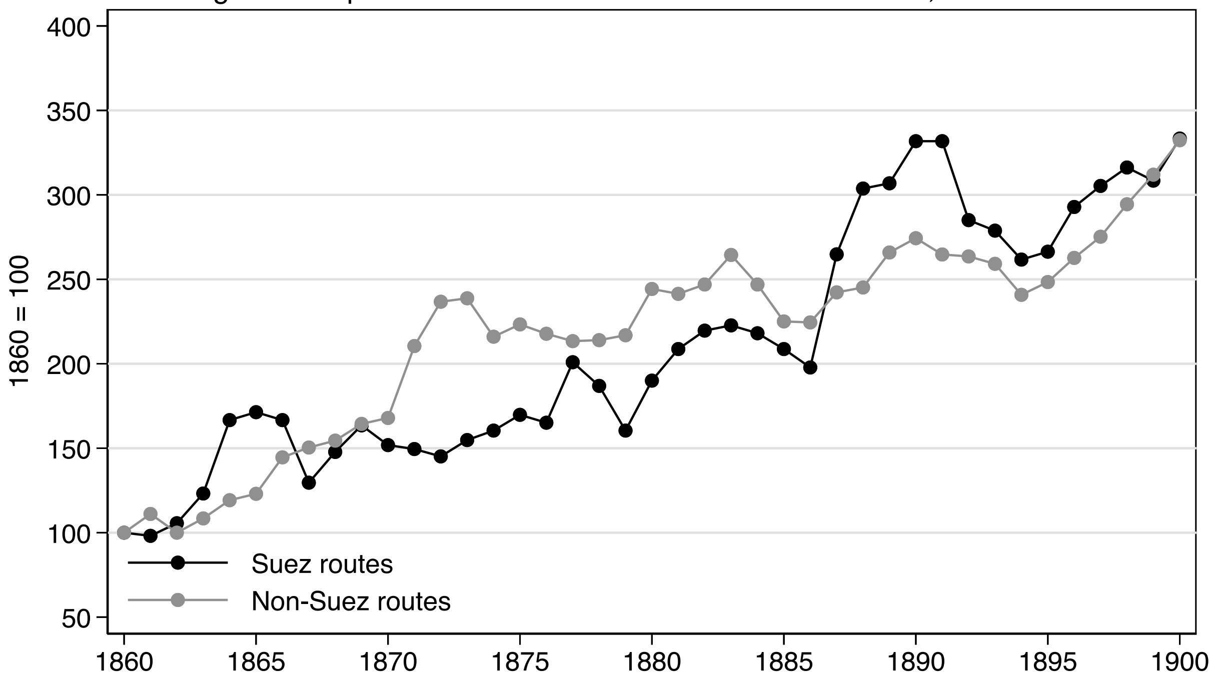

Figure 2: Event Study on Suez's Opening, 1860 to 1900

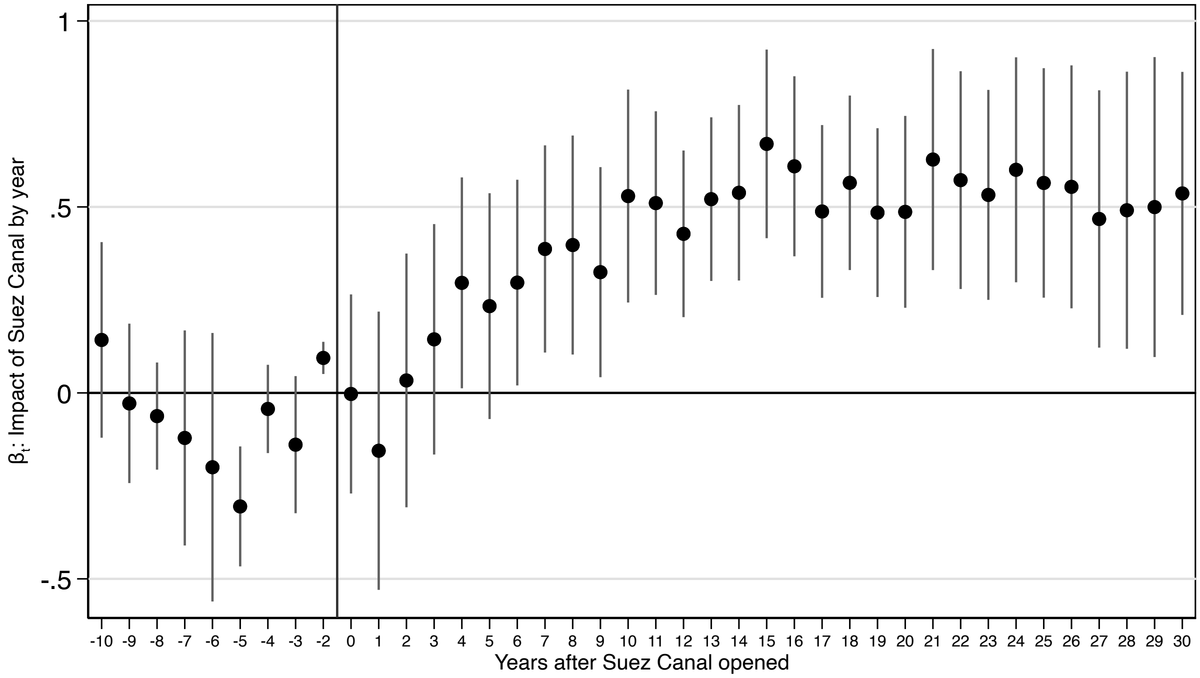

Figure 3: Trade Costs with and without the Suez Canal, 1870 to 1900

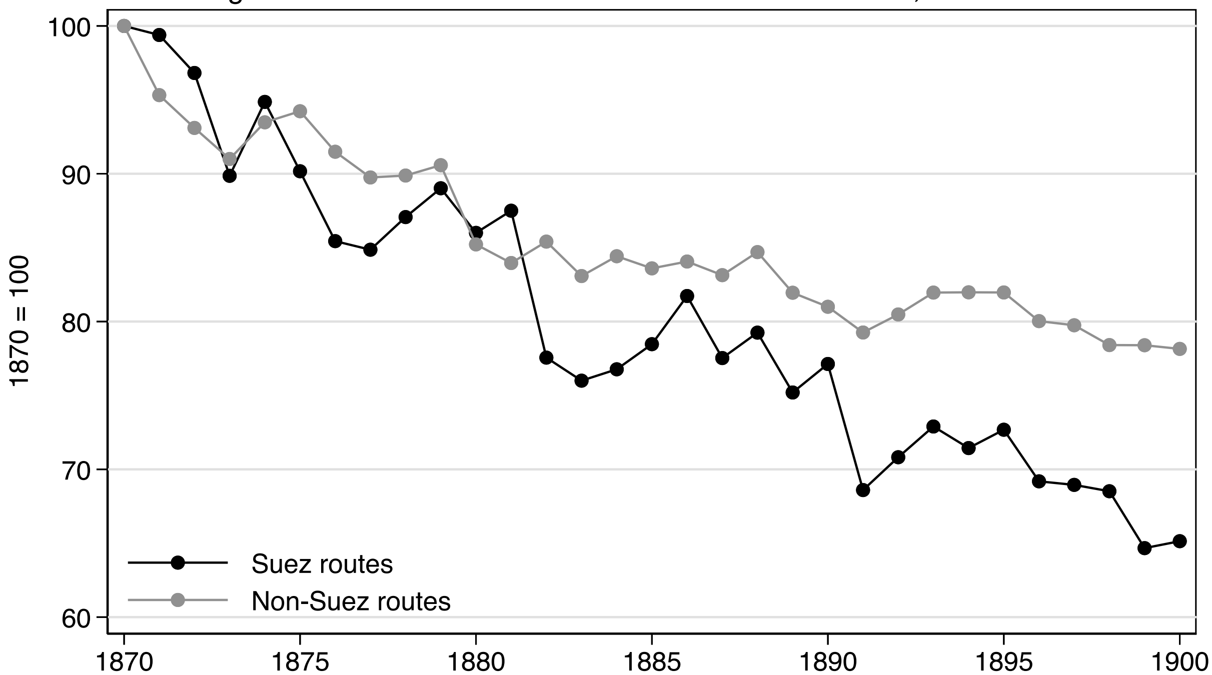

Table 1: DiD estimates for bilateral trade, baseline results

	(1)	(2)	(3)	(4)
	1860 to 1900	1850 to 1900	1865 to 1900	High quality sample
Suez canal (= 1)	0.56	0.50	0.56	0.54
	(0.18)	(0.16)	(0.15)	(0.15)
	[3.14]	[3.16]	[3.79]	[3.65]
N of observations	10,413	12,268	9,439	7,899
Country-pair fixed effects	X	X	X	X
Time-varying exporter effects	X	X	X	X
Time-varying importer effects	X	X	X	X

PPML regression of bilateral trade up to 1900. Columns (1) through (3) vary the sample years while Column (4) uses data from 1865 to 1900 and "high quality" selection criteria as explained in the text. Country-pair fixed effects are defined by the direction of export flows. Standard errors are in parentheses and clustered at the country-pair level. t-statistics are reported below the standard errors in brackets.

Table 2: DiD estimates, robustness on different samples

	(1)	(2)	(3)	(4)
	JMN	Pascali	F & H	D & G
	(2011)	(2017)	(2017)	(2017)
Suez canal (= 1)	0.54	0.31	0.46	0.22
	(0.15)	(0.09)	(0.13)	(0.11)
	[3.65]	[3.51]	[3.48]	[2.04]
N of observations	7,899	16,363	24,795	27,363
Country-pair fixed effects	X	X	X	X
Time-varying exporter effects	X	X	X	X
Time-varying importer effects	X	X	X	X

PPML regression of bilateral trade for the years from 1865 to 1900. Column (1) reports our baseline results from Table 1 using Jacks, Meissner, and Novy (2011). Columns (2) through (4) are the results from the same specification using the alternative datasets discussed in Section 4.1. Country-pair fixed effects are defined by the direction of export flows. Standard errors are in parentheses and clustered at the country-pair level. t-statistics are reported below the standard errors in brackets.

Table 3: DiD estimates, heterogeneity analysis on British metropole trade

	(1) JMN	(2) Pascali	(3) F & H	(4) D & G
Suez canal (= 1)	1.10	0.51	0.62	0.42
	(0.38)	(0.09)	(0.15)	(0.17)
	[2.92]	[5.40]	[4.00]	[2.41]
Suez canal * British metropole trade (= 1)	-0.62	-0.32	-0.32	-0.34
	(0.35)	(0.13)	(0.14)	(0.23)
	[1.76]	[2.50]	[2.24]	[1.47]
N of observations	7,899	16,363	24,795	27,363
Country-pair fixed effects	X	X	X	X
Time-varying exporter effects	X	X	X	X
Time-varying importer effects	X	X	X	X

PPML regression of bilateral trade for the years from 1865 to 1900. Column (1) through (4) report the results from a specification including the interaction of indicator variables for the Suez Canal being open and trade to or from the United Kingdom. Country-pair fixed effects are defined by the direction of export flows. Standard errors are in parentheses and clustered at the country-pair level. t-statistics are reported below the standard errors in brackets.

Table 4: DiD estimates, heterogeneity analysis on "Suez factor"

	First quartile (smallest)	Second quartile	Third quartile	Fourth quartile (largest)
"Suez factor" (= 1)	1.10	1.71	3.48	0.33
	(0.29)	(0.24)	(0.36)	(0.16)
	[5.81]	[7.03]	[9.57]	[2.15]
N of observations		7,899		
Country-pair fixed effects		X		
Time-varying exporter effects		X		
Time-varying importer effects		X		

PPML regression of bilateral trade for the years from 1865 to 1900. The columns report the results of a single regression which includes the interaction of indicator variables for the Suez Canal being open and the four quartiles of the distribution of the "Suez factor" variable. Country-pair fixed effects are defined by the direction of export flows. Standard errors are in parentheses and clustered at the country-pair level. t-statistics are reported below the standard errors in brackets.

Figure 4: Total exports, manufacturing shares, and extensive margins of trade

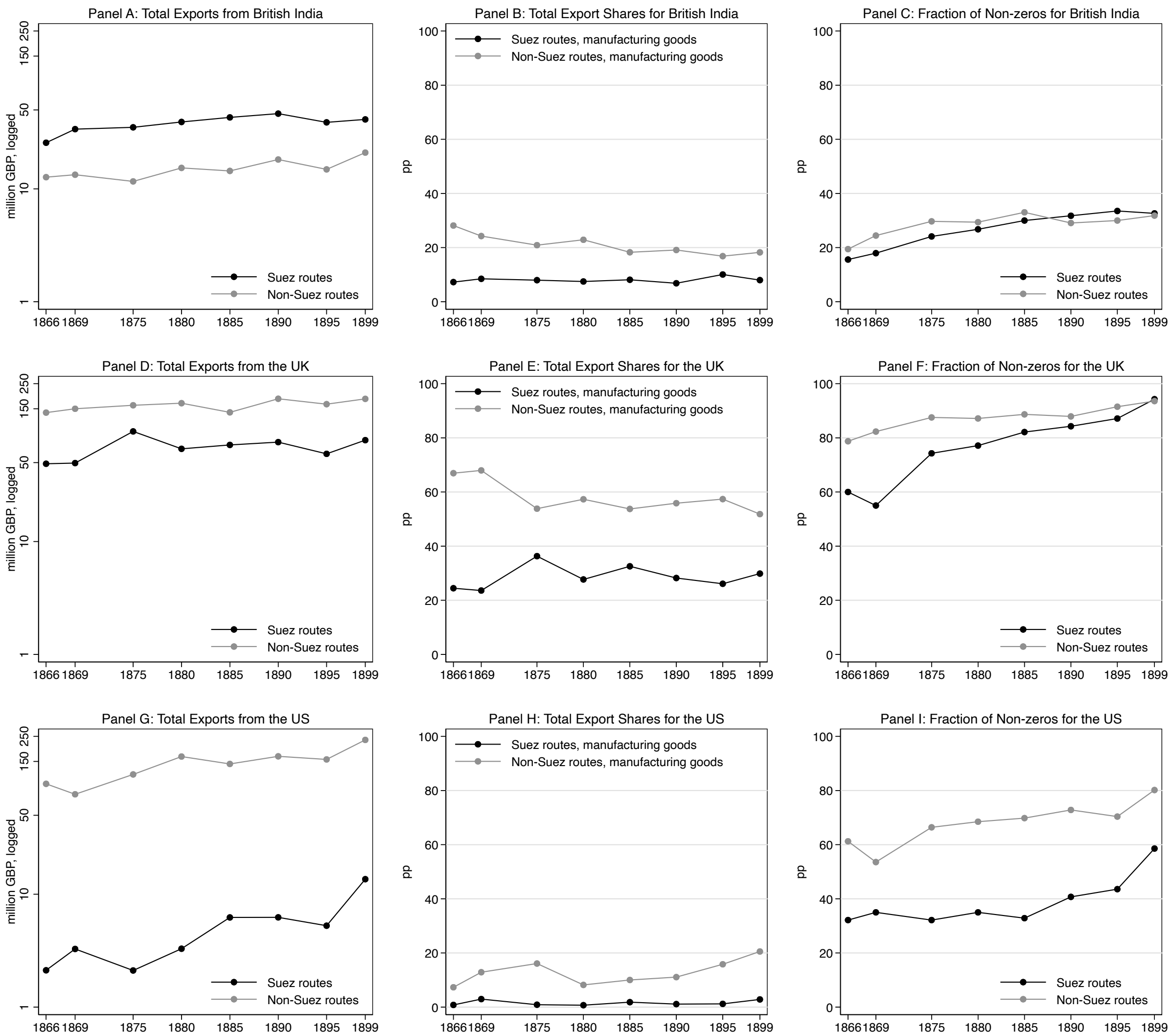

Figure 5: DiD estimates for export shares by sector/section/division, British India

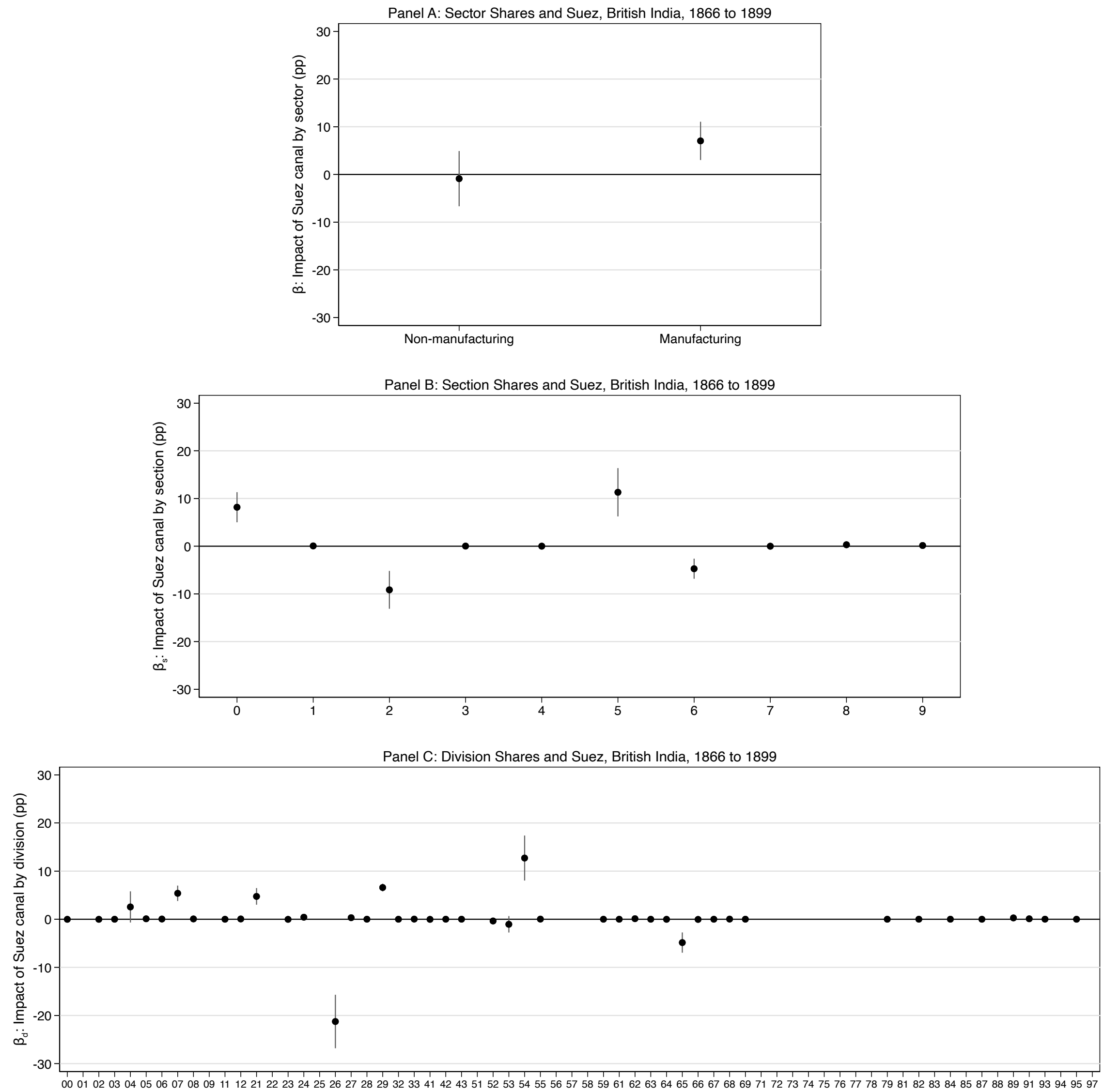

Figure 6: DiD estimates for export shares by sector/section/division, UK

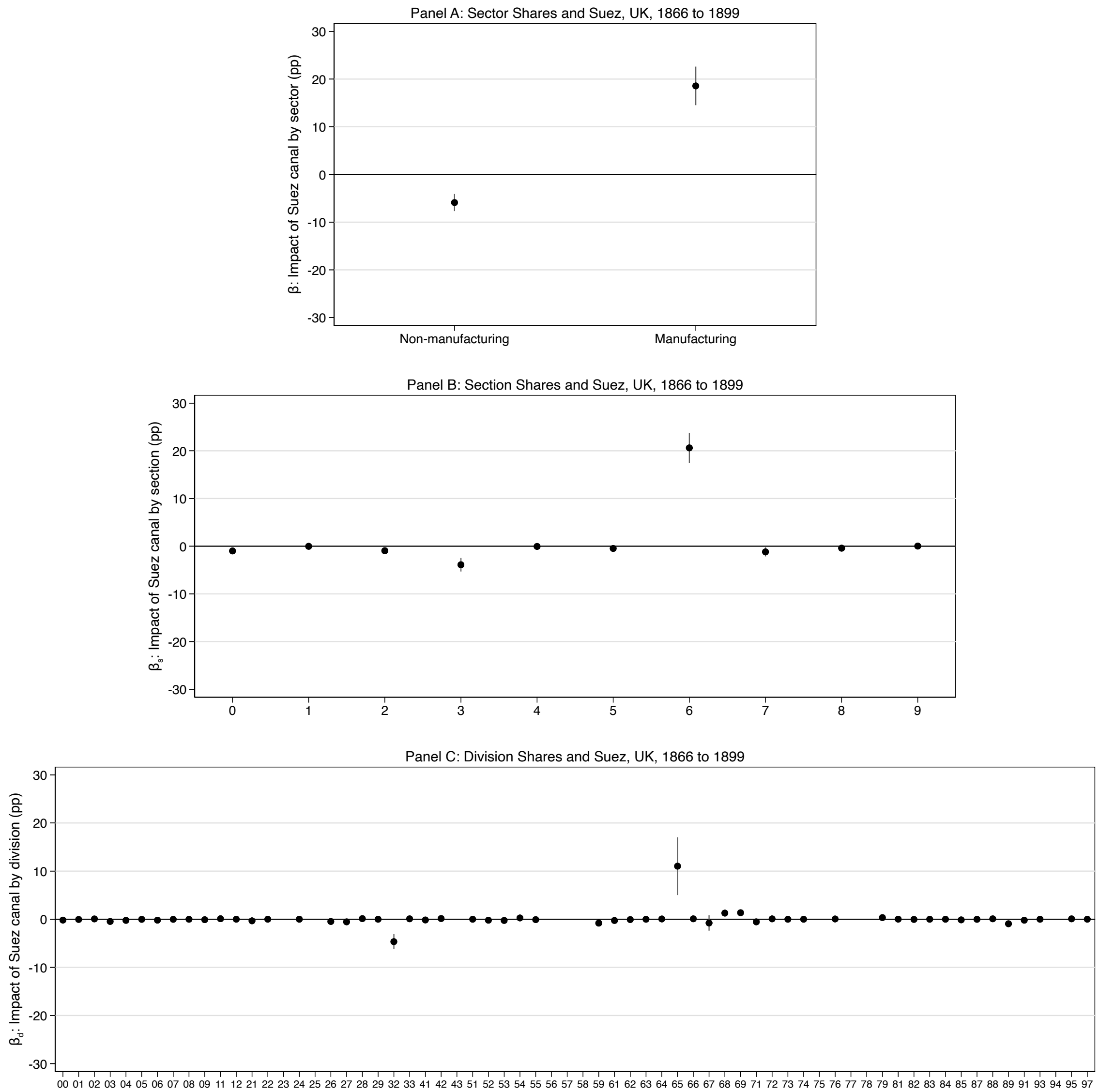

Figure 7: DiD estimates for export shares by sector/section/division, US

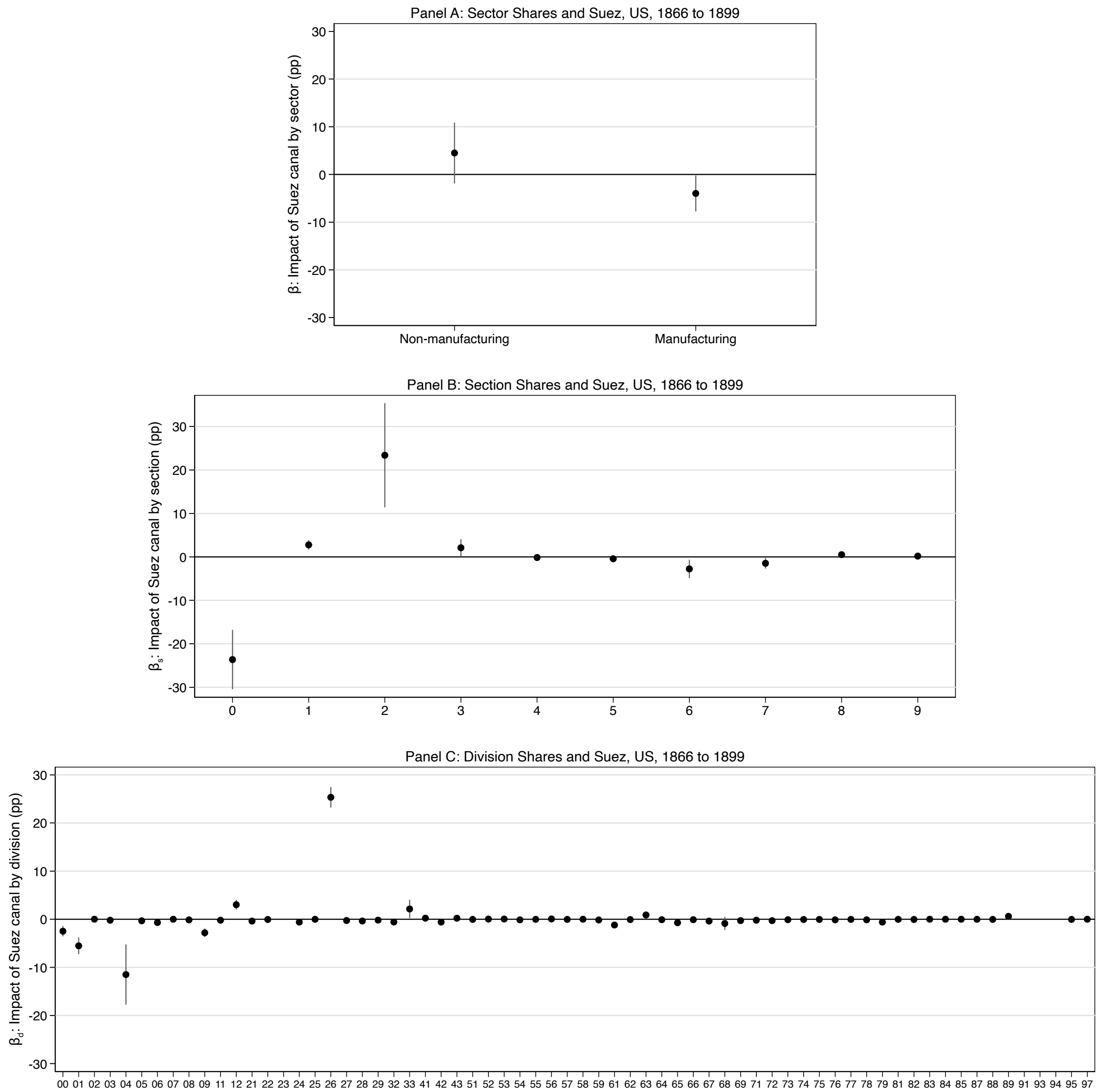

Table 5: DiD estimates for non-zero observations (origin-destination-section cells)

Panel A

	(1) Full sample	(2) British India	(3) United Kingdom	(4) United States
Suez canal (= 1)	0.06	0.07	0.12	-0.06
	(0.03)	(0.03)	(0.08)	(0.04)
	[1.95]	[2.47]	[1.62]	[1.51]
N of observations	16,080	5,360	5,360	5,360
Suez-affected route fixed effect	X	X	X	X
Year fixed effects	X	X	X	X

Panel B

	(1) Full sample	(2) British India	(3) United Kingdom	(4) United States
Suez canal (= 1)	0.03	0.00	0.17	-0.05
	(0.04)	(0.06)	(0.10)	(0.06)
	[0.79]	[0.05]	[1.68]	[0.88]
N of observations	1,608	536	536	536
Suez-affected route fixed effect	X	X	X	X
Year fixed effects	X	X	X	X

Average marginal effects from probit regressions of an indicator variable which takes a value of one for positive trade values in the years from 1865 to 1900, evaluated at the origin-destination-section level. The columns report the results of single regressions which also include an indicator variable for the Suez Canal being open. Standard errors are in parentheses and clustered at the country-pair level. z-statistics are reported below the standard errors in brackets.

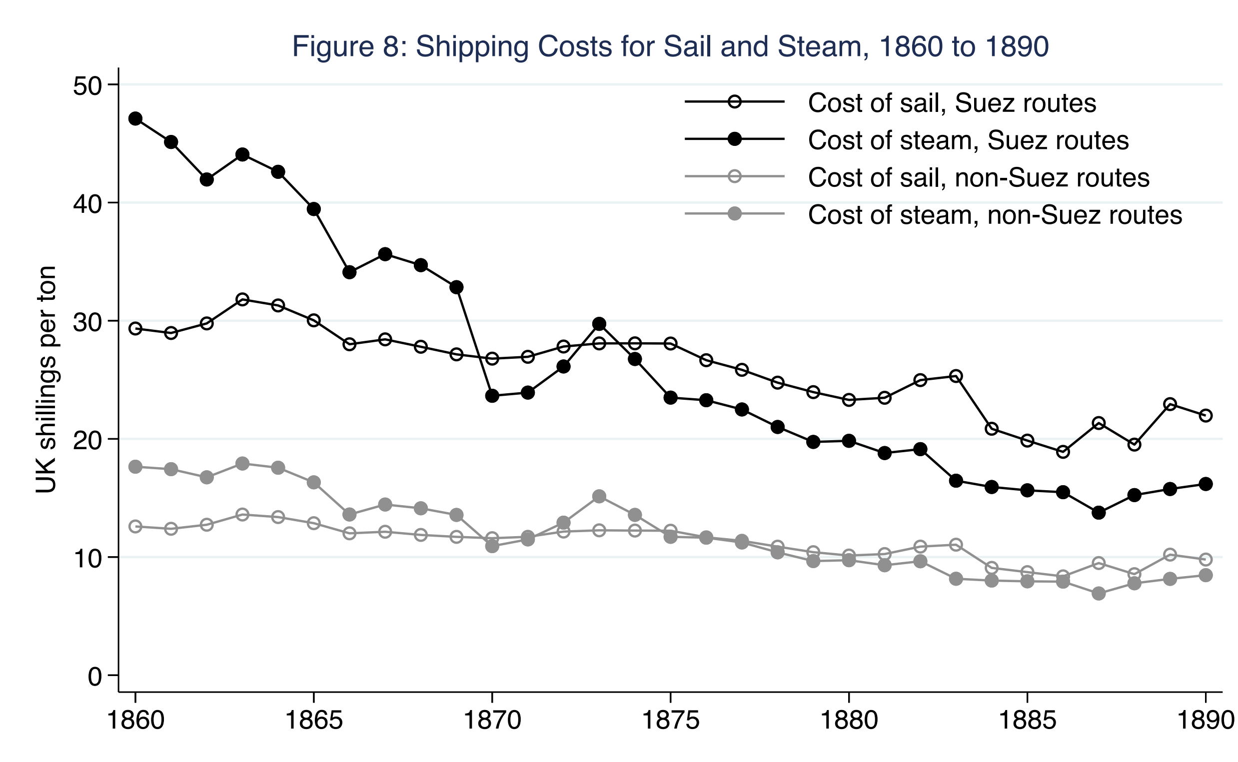
Figure 8: Shipping Costs for Sail and Steam, 1860 to 1890
UK shillings per ton
0
10
20
30
40
50
1860
1865
1870
1875
1880
1885
1890
Cost of sail, Suez routes
Cost of steam, Suez routes
Cost of sail, non-Suez routes
Cost of steam, non-Suez routes

Figure 9: Shipping Cost Ratios with and without the Suez Canal, 1860 to 1890