April 19, 2022

Dear Editors Raymond Fisman, Will Dobbie, and members of editorial board at REStat :

I am writing to apply for the Review of Economics and Statistics Fellowship for the NBER Summer Institute, announced on the journal website. I have been an Assistant Professor working in international economics at North Dakota State University (NDSU) since 2016, after completing a Ph.D. in economics from Virginia Tech. My research focuses on globalization and innovation, international trade patterns, and trade policy impacts. As I am housed in the Department of Agribusiness and Applied Economics, I am enthusiastic about the unique opportunity this fellowship would bring me in sharing and receiving feedback on my work from a broader academic community related to my research area.

Below, I discuss my most current research activity, where I hope to benefit the most from this fellowship.

The current wave of globalization overlaps with an increase in within-country income inequality across many countries worldwide. To what extent can we generalize differences in market and wage income across countries? In one strand of my work, I use micro-level data for 149 countries and quantify the relationship between trade, immigration, and technological innovation on their impacts on productivity and wages. I find that (i) market income inequality looks more similar at the end of the tail (top 1 and 0.2 percentile) across regions and countries than elsewhere in the distribution (ii) innovative firms outperform other firms conditional on R D spending in terms of productivity (iii) however, wages respond positively to productivity only for the firms in the tenth decile of the productivity and only with a certain threshold of skilled labor to capital ratio. Based on the empirical regularities in my data, I then develop a theoretical framework to study the connection between globalization and inequality with trade, technology, and immigration at the center. Related to my theoretical framework, firms with a certain threshold skilled labor to capital ratio innovate. Given this threshold ratio is met, firms can substitute between skilled immigrants and (skilled) native workers at different rates depending on their ratio. An implication is that competition has no effect on innovation for both entrants and incumbents with high productivity draw. Given that the current literature connecting trade and innovation predicts either positive or negative impact of competition on innovation, feedback along this line would help me explore the full implication of my prediction further beyond this research. Along this line of research, I am most interested in attending the summer research institute in **Productivity, Innovation, and Entrepreneurship** from July 19 to July 20, 2022.

Along with this letter are my curriculum vitae, and my recent research paper. I look forward to hearing from you. Thank you for your time and consideration.

Sincerely,
Anupa Sharma
North Dakota State University, ND, Fargo 58102
anupa.sharma@ndsu.edu

Anupa Sharma

North Dakota State University
Dept. of Agribusiness and Applied Economics
400G Barry Hall
811 2nd Ave N
Fargo, ND 58102
anupa.sharma@ndsu.edu | 540-394-0466

Current Academic Positions

Assistant Professor, North Dakota State University (NDSU), 2016-present.

Visiting Scholar, the Graduate Center, the City University of New York, Fall 2021

Past Employment

Economist, Department of Livestock Services (DLS), Government of Nepal, 2007-2010

Education

Ph.D. Economics, Virginia Tech, 2016.

M.Sc. Agricultural Economics, Tribhuvan University, 2007.

B.Sc. Agricultural Economics, Tribhuvan University, 2005.

Publications in Referred Journals

1. Sharma, Anupa, Jason Grant, and Kathryn Boys. "Truly Preferential Treatment? Reconsidering the Generalised System of (Trade) Preferences with Competing Suppliers." *Journal of Agricultural Economics* 72, no. 2 (2021): 500-524. https://doi.org/10.1111/1477-9552.12414

2. Miljkovic, Dragan, Miguel Gomez, Anupa Sharma, and Sergio Puerto."Testing the Alchian - Allen Theorem for Three Goods Using the Pseudo Poisson Model." *Agricultural Economics* 55, no. 6 (2019): 793-802. https://doi.org/10.1111/agec.12525

3. Sharma, Anupa, Kathryn Boys, and Jason Grant. "The Bright Side of the Generalized System of (Trade) Preferences: Lessons from Agricultural Trade." *Journal of Agricultural and Resource Economics* 44, no. 1 (2019): 32-61. Available here

Working Papers (Papers available upon request)

5. "Distance Effect in International Trade Across Three Waves of Globalization."

6. "Acknowledging Consumption in Production Technology."
(previously circulated as "Acknowledging Consumption in Production Function.")

7. "Trade and Welfare Effects of African Growth and Opportunity Act: Evidence from Africa's Domestic Value-Added content of Exports," with Joseph Mwagura.

8. "Manufacturing Productivity Spillover across Agricultural and Non-Agricultural Sectors."

9. "Role of Institutions and Policies in Immigration, Innovation, and Growth."

Work in Progress

10. "Globalization and Inequality: International Trade, International Migration, and Technology."
(Draft manuscript available upon request)

11. "Value-Added Trade and Non-Reciprocal Trade Agreements."

12. "International Trade and Global Land Use Patterns," with Sandip Ghimire.

13. "Endogenous Money and the Discovery of Liquidity," with James Caton.

14. "Deglobalization: Can We Gain Insights From International Trade Disputes?
(previously, "Deglobalization: Can We Gain Insights From Agricultural Sector?")

Selected Invited Seminars, Conference Presentations, and Panel Invitations

1. 2021: Globalization and Inequality: International Trade, International Migration, and Technology. Invited Paper Presentation at the Graduate Center, the City University of New York, Nov 11, 2021.

2. 2020: Deglobalization: Can We Gain Insights From Agricultural Sector? Selected paper presentation at 2020 International Agricultural Trade Research Consortium's Annual Meeting, Virtual. Dec 15, 2020.

3. 2020: Role of Institutions and Policies in Immigration, Innovation, and Growth: A Global Trade Perspective. Invited Talk. Department of Agribusiness and Applied Economics, Virtual. Dec 4, 2020.

4. 2019: Consumption Pattern and International Trade. Selected paper presentation at International Agricultural Trade Research Consortium's Annual Meeting, Washington, DC. Dec 8-10, 2019.

5. 2018: Manufacturing Productivity Spillover. Invited talk, Department of Agribusiness and Applied Economics, NDSU. March 23, 2018.

6. 2017: International Trade and Global Land Use Patterns. Selected paper presentation at 2017 International Agricultural Trade Research Consortium's Annual Meeting, Washington, DC. Dec 3-5, 2017.

7. 2017: Manufacturing Productivity Spillover in Agricultural Exports in the Post-Liberalization Context. Selected paper presentation at Agricultural and Applied Economics Association and Western Agricultural Economics Association Annual Meeting, Chicago, IL. Jul 30-Aug 1st, 2017.

Departmental, and College Level Committees Served at NDSU

September, 2017-present: Graduate Program Committee.

September, 2017-present: Applied Economics PhD committee.

March, 2019-present: Technology and Instructional Services Committee.

Professional Service

Trade Topic Leader: International Trade section, AAEA Annual Meetings, 2017 & 2018.

Internal Reviewer: International Trade Section, AAEA Conference, 2017-2021.

Junior Mentoring: Mentoring-match up program, ASSA Meeting Philadelphia, 2018-2019.

Professional Membership

American Economics Association, Agricultural and Applied Economics Association, Nepalese Economics Society

Honors, and Awards

Fall 2021: Distinguished Visiting Scholarship, Advanced Research Collaborative, the Graduate Center, the City University of New York

Nov, 2019-present: Faculty Fellow, Challey Institute for Global Innovation and Growth

2019: Research and Education Grant Award, ND Established Program to Stimulate Competitive Research

2016: Research Development Travel Award, NDSU

2012: Work Life Grant Award from the Dean of the Graduate School, Virginia Tech

2005: Top Student of the Department, Department of Agricultural Economics, Tribhuvan University

2001-2005: University Merit Scholarship for Academic Excellence

Personal

Citizenship: Nepal (U.S. Permanent Resident)

Languages

English (fluent), Nepali (native), Hindi (fluent), Tamil (basic)

The Measuring Tape: Diminishing Distance Effect Across Three Waves of Trade Globalization

By ANUPA SHARMA*

Globalization has integrated the world economy. Has this led to the distance between trading countries becoming less relevant? We develop a search and trade model that results in an interesting feature -with no natural autarky equilibrium and instead economy leapfrogs to open equilibrium as firms sell their products. We also conduct a counterfactual analysis with a sub-sample by combining modern-day bilateral trade data with the historical distance sailor ships navigated between ports from 1762 to 1810. If the distance effect remained constant despite globalization: (i) international trade wouldn't be possible for 49 of 52 countries (ii) in almost all cases, trade prohibition emanates from a huge increase in outward multilateral resistances that translate into adverse shocks to factory-gate prices and GDPs relative to baseline.
JEL: F00, F1, F14
Keywords: globalization, distance, search & trade

The past three waves of globalization have exposed countries to an unprecedented flux of goods across international borders. This has generated much effort in understanding how and through which channel globalization affects economic growth and international trade, in particular (Goldberg and Pavcnik, 2004; López-Córdova and Meissner, 2005; Goldberg and Pavcnik, 2007; Grossman and Helpman, 2015; Antràs, De Gortari and Itskhoki, 2017). Contextually, one valuable and presumably straightforward way to see the impact of globalization would be to examine if bilateral distance has become less relevant in international trade. Empirical trade economists have done that precisely, using the reduced form gravity equation, which is consistent with widely different general equilibrium theories of international trade (see Costinot and Rodríguez-Clare, 2014). Surprisingly, however, the trade literature fails to deliver consistent empirical support for the diminishing effect of distance on bilateral trade.

This conundrum is aptly described as "distance puzzle" in Disdier and Head (2008), which spurred a wave of discussion about why the gravity equation, a workhorse model in empirical trade literature, fails to reveal the globalization effect in its estimate of distance coefficient. Since then, many economic studies have focused on statistical misspecification, theory-empirics mismatch, or identification issues in structural gravity estimation to resolve the 'distance puzzle' (Arribas, Pérez and Tortosa-Ausina, 2011; Yotov, 2012; Lin, 2013; Carrère, De Melo and Wilson, 2013; Buehler and White, 2015; Yilmazkuday, 2017; Borchert and Yotov, 2017; Li et al., 2018; Chaney, 2018).

In this paper, we answer a novel question pertinent to the distance effect on interna-

* North Dakota State University, Fargo, ND 58102 (email:anupa.sharma@ndsu.edu)

tional trade: what would have happened to world trade if the distance effect on bilateral trade remained constant despite globalization. We build a new search and trade framework (discussed further below) that allows us to examine the distance effect by considering the two primary means of transport in global trade: maritime and air transport. Jointly, these two modes of transportation account for 95% of the international trade. We use a large collection of data that spans three waves of globalization from 1750 to 2010. To the best of our knowledge, this is also the longest data used in studying the distance effect on international trade. The oldest data slice in our collection corresponds to the pre-globalization period and provides distances recorded in logbooks of sailing voyages between 1750 to 1850. The second slice of the data spans 1850-1900, overlaps the first wave of globalization, and covers the era of major innovation in steam engines. The third slice of data from 1962 to 2010 covers the widespread adoption of jet engines in air cargo freights in international trade. It also covers advances via containerization and trade liberalization through policy interventions internationally.

We find that our framework reveals the declining effect of distance in international trade, and even better when using the shortest or actual maritime distance between ports. The intuition is relatively simple. Because most international trade occurs by water, the sea distance also represents a more accurate distance the goods travel in international trade. Second, there is a decline in the actual navigable distance or time traveled between ports as globalization unfolds. Before the steam engines were invented, voyages depended extensively on wind velocity and wind patterns on ocean surfaces, which affected bilateral distance traveled and trade routes in international trade. With the adoption of steam engines in the mid-nineteenth century, the navigable distance between ports and shipping time were reduced drastically, albeit unevenly across countries and routes (see Pascali, 2017 for details). Yet, the point-to-point great circle distance or physical crow-fly distance commonly used in the structural gravity estimation does not change over time and thus may not entirely capture the effective fall in the transportation barrier. The effect of globalization is not limited to steam engines alone in maritime trade. The invention and adoption of shipping containers in the 20th century brought in another wave of transformation to the maritime transportation (Levison, 2006; Bernhofen, El-Sahli and Kneller, 2016). A key to this revolution is the design of the containers; they are designed to internationally known standard dimensions. Therefore, ships could be built to fit these containers. The uniformity in size also meant containers could be easily transferred between ships, trucks, and trains for inroad transportation (Notteboom and Rodrigue, 2008; Hummels, 2007). On a more granular level, it implies ships could spend less time on docks and more on water opening up the possibility to ship time-sensitive products (Notteboom, 2006). Further, as these containers are sealed at factory gates, they are less permeable to theft, which reduces the insurance cost on freight (see, for example, Acciaro and Serra, 2013). As a result, perhaps, the containers affected the distance traveled and the range and volume of goods traded.

Equally impressive institutional changes accompany the technological changes in the maritime industry. Container shipping incentivized ships to grow in size. The maritime industry now operates with fewer but larger ports globally. The top 20 container ports

together handle about 45% to 50% of the world's total container cargo (UNCTAD, 2011; Brooks and Faust, 2018). Did the industry harness the benefit of economies of scale? More precisely, did the freight rate decline over the recent decades? The answer is no, and the transportation cost is still an obstacle in maritime trade (Hummels, 2007).

Technological innovations are spectacular in air transportation as well. The introduction of jet engines made flights faster. Newer jet engines can pump in more air and achieve more air thrust and thus travel further per unit of fuel. As noted in Sun and Smith (2022), the higher fuel economy is also linked to a maximum threshold speed. Adjustments in wing design could make an aircraft faster. But, such wings would require more materials, which means aircraft would be heavier and thus would burn more fuel (Chaudhari and Takahashi, 2022). Therefore, fuel economy is a significant concern for commercial air flights. Despite the concern, the air transportation cost declined sharply, especially between 1980 and 2001 (Hummels, 2007). Even with this decline in air freight cost, 80% to 90% of trade in volume terms still occurs by ocean freight (UNCTAD, 2011; Brooks and Faust, 2018; UNCTAD, 2021). However, the remaining small fraction of the tonnage that crosses borders via air carries a much higher value per pound than those sent through the water. It is estimated that about 30% of the value of world trade occurs through air transportation (UNCTAD, 2021).

We develop an integrated framework by combining search, transport, and trade models. In the search model, firms follow sequential searches to identify trade partners at some intervals of distance from their loci in direction $[0, 2\pi)$. Firms incur probabilistic search costs based on the derived distribution of firms' spatial distribution. That is, firms face variable fixed costs of search. To deliver their products to a partner, firms incur transport costs in addition to this search cost. Goods are sorted into different modes of transport such that the total transport expenditure is also minimized at an aggregate level. When these search and transport elements are taken to the trade model *à* la Krugman (1980), the model predicts no natural autarky equilibrium and thus we are able to leapfrog to open equilibrium as firms attempt to sell their products. Necessary for our purpose, the integrated model allows us to account for different yet relevant measures of actual distance goods traveled in international trade within the single framework. The model lends to the counterfactual exercise, where we ask what would have happened to international trade assuming no technological breakthrough ever occurred in the maritime industry. We combine the distance ships navigated between 1762 and 1810 with bilateral trade data for 1962 to 2010 to answer whether bilateral distance has become less relevant with globalization. As the question begs, our focus is on the cumulative impact globalization has had on the distance effect of international trade since it unfolded, starting in 1810. Nevertheless, we also examine the instantaneous or evolving effect of bilateral distance on trade with globalization. As a result, we are able to compare our model and outcomes across many studies in this literature.

Our results are novel. Time-constant elasticity estimates of distance effect on trade with distance measured as a point-to-point great circle distance[1] are closer to one than

[1] We refer to point-to-point great circle distance also as crow-fly distance or air distance non-discriminately throughout the paper.

zero. In contrast, the elasticity estimates with sea distance, where distance is measured based on actual trips ships make in international trade, produce coefficients closer to zero than one. These results are robust to the inclusion of intranational trade and internal distance. Second, the coefficients with sea (maritime) distance become less relevant over time. For example, the estimate declined by 19.4% from 1870 to 1900, with the bulk (97%) of the decline occurring in 1900. Further, in the latest wave of globalization from 1970 to 2010, the coefficients with sea distance turn out non-significant. However, within the same specification, air distance reveals a non-monotonic effect from 1970 to 2010.

In a counterfactual analysis, we examine what would be the effect on trade, assuming port to port distance countries would have to travel in international trade stayed constant as they were from 1762 to 1810 for each of the next two hundred years. We find that the outward multilateral resistances increase markedly–up to 14 times their baseline values, factory gate prices for producers declined by approximately 50% for an average country, and 49 out of 52 countries in the sample would show zero international trade at equilibrium.

The rest of the paper is as follows. Section I contains related literature, Section II presents the theoretical model, Section III describes the data, and Sections IV and V provide an empirical model and regression results. Section VI lays out the counterfactual scenario, details the implementation technique, and presents the counterfactual results. Section VII concludes.

I. Related Literature

Our paper relates to the growing literature on the effect of globalization on economic growth across economies (see Federico and Tena-Junguito, 2017 and Pascali, 2017). Particularly, we contribute to the branch of this literature that addresses the question of how globalization has affected international trade of goods. One robust finding of this literature is that bilateral trade decreases with distance. Intuitively, if distance reflects the transportation cost in international trade, the distance effect is expected to decline over time with globalization. In contrast, several studies that draw on year-by-year cross-sectional estimates suggest that the distance elasticity of trade tends to increase over time. Results along this line are reflected in the work of Frankel, Stein and Wei (1997), Soloaga and Wintersb (2001), Coe et al. (2002), Brun et al. (2005), and Berthelon and Freund (2004). A related literature examines distance effect of trade across countries and goods. Carrère, De Melo and Wilson (2013) find that the distance effect is increasing for less developed countries. Distance is a curse even for developed countries in the sense that it decreases their market access (Boulhol and De Serres, 2010). Blum and Goldfarb (2006) show that distance matters even in digital goods, such as music that are consumed over the Internet. The authors categorize goods into taste-dependent and non-dependent categories and find that the results hold only for the goods that are taste-dependent.

In a meta-analysis study with 1,467 estimates from 103 papers, Disdier and Head (2008) find that the mean estimate across these studies is 0.9, suggesting a 9% decline in bilateral trade with 10% increase in distance. In an extension, Head and Mayer (2014) use 2508 estimates of the distance coefficients from 159 published papers for another

meta-analysis. They find the mean distance elasticity is -0.92 with a median estimate of -0.89, and a standard deviation of 0.4. Out of the total estimates used, 368 estimates were "structural," in that they use either importer/exporter fixed effects or a ratio-type method in gravity estimation consistent with theoretical underpinnings. In this sense, these results may not be taken as artifacts of estimation techniques.

Studies that offer explanation as to why the expected distance elasticity is close to unity or even constant over time also belong to this strand of literature. This is the case of Rauch (2016), which recommends using scaled harmonic averages of bilateral distances to measure distance elasticity in gravity equation. The argument based on geometric properties of the spread of economic activities from an imaginary center is also found in Karpiarz, Fronczak and Fronczak (2014). The latter study also shows that the distance coefficient in gravity equation is related to the changes in fractal (self-similarity of an expanding system) properties of the global trading system over time and space rather than the trade cost. Relatedly, when firms' size have Pareto distribution, if firms' spatial distribution follows power law, and if the distance of exports rises quicker with firm size, Chaney (2018) find that the distance elasticity of trade is constant. Further, the elasticity is closer to unity if firms' spatial distribution respected Zipf's law. Firms in our model face probabilistic search cost, and this search cost follows a distribution which is derived from firms' spatial distribution. A common thread that connects our paper to these studies is that the derived distribution could result from the mechanisms explored in the above studies. Even with this commonality, ours has an entirely different purpose, namely, of showing distance effect on trade has indeed changed when considering extended scale of time over three waves of globalization.

Along this line, our paper is also related to group of studies that focus on methodological issues in structural estimation of distance elasticity in addressing the distance puzzle. Economic activities such as bilateral trade may increase due to declining distance, but the estimated distance coefficients may remain constant because all countries in the world are similarly affected. This is the argument put forth in Buch, Kleinert and Toubal (2004), where they interpret changes in constant term of the gravity like estimating equation as the reflection of changes to the distance cost. Using structural gravity equation based on Anderson and van Wincoop (2003), Yotov (2012) and Borchert and Yotov (2017) measure crow-fly distance elasticity of international trade with respect to internal distance and intranational trade and find declining distance effect on trade. Lin and Sim (2012) find new bilateral trade relationships that emerged after the 1960s was typically between distant partners. Simultaneously, there was an increase in trade between partners at short distances. In a related study, Larch et al. (2016) compare distance elasticities of trade across different estimation techniques and show that accounting for zero trade flows produces coefficients that generally decrease over time from 1980 to 2003. Our paper has several points of departure from these studies, of which we highlight one. We address the question of what distance is more relevant in examining the distance elasticity of trade over time, given that goods are shipped using different means of transport.

This paper is also a part of the literature that focuses on transportation costs in international trade. Our contribution to this literature comes from introducing endogenous

sorting of products into different modes of transport in international trade. We draw heavily from Dornbusch, Fischer and Samuelson (1977) in that a borderline commodity separates goods that are shipped through maritime and air transport. A modeler observes that this sorting minimizes total trade expenditure in a country. However, what leads to the sorting mechanism is intrinsic to product characteristics. Important for our purpose, the endogenous sorting of goods at firm levels implies that countries adopt both air and maritime transport in international trade at an aggregate level. In this, we also take inspiration from Deardorff (2003). Although without a formal model, the author discusses in length that countries located far from the world market may not have comparative advantages in goods that depreciate fast and that they choose to adopt different means of transportation based on product characteristics. In a recent study, Brancaccio, Kalouptsidi and Papageorgiou (2020) model maritime transportation cost where sellers and ships participate in international trade through a random match process. Allowing goods to sort across transport mode while treating transport cost exogenous allows us to compare distance elasticity across different measures of distance that goods travel in international trade. In contrast, Brancaccio, Kalouptsidi and Papageorgiou (2020) focus entirely on maritime transport and endogenize the maritime transport cost in studying the trade pattern.

Our work also relates to search models in trade and economic geography literature. Geographical barriers such as physical distance keep the competition low (see for e.g., Beckmann, 1976; Henderson, 1987; Krugman, 1991; Krugman, 1992). For this reason, reduction in transportation cost may lead to increase in contention, however, distance effect need not come entirely from transportation costs (Leamer, 2007). In our case, one such barrier that firms face is the search for trade partners as in Arkolakis (2010). We build a firm-level search model, where each firm builds trade ties with other firms in sequential search process. Every search identifies intervals of distances that have the same transportation costs and the fixed search cost. This fixed cost varies by search as it is drawn from a derived distribution of firms' distribution in space. As a result, we are able to do away with autarky equilibrium, recreate entry barrier as in Melitz (2003), and predict pockets of intense competition depending on firms' spatial distribution.

Our contribution to the broader literature stems also from our counterfactual exercise that hinges on trade data only for the recent wave of globalization in examining the cumulative effect globalization has produced on the distance effect of international trade since 1810. Hence our paper is also a part of the existing literature that studies globalization in the historical context by focusing on trade costs. For example, Estevadeordal, Frantz and Taylor (2003), Jacks (2009) and Jacks, Meissner and Novy (2011) focused respectively on transport costs from 18701-1939, distance from 1810-1913, and trade costs from 1870-2000. Our main point of departure from these studies is that they characterize the role of globalization on trade through instantaneous effects on trade costs for the periods considered. In contrast, our paper describes the cumulative effects globalization has produced on the distance effect and thus on trade volume since the 1810s. A part of the difference is related to the unavailability of reliable international trade data before the 1810s. We side-step this problem by making use of recently available historical ships

voyage record database.[2] We map information on port-to-port distance from voyages ships made during 1762 to 1810 to modern-day bilateral trade data in a theoretically consistent counterfactual analysis.

Standaert, Ronsse and Vandermarliere (2016) examine the distance effect on an index of trade integration across two waves of globalization. They find that the distance effect decreases in the first wave of globalization but tends to increase in the second half. The study discusses trade flow data in detail. However, it omits the discussion of the distance variable or its source. Perhaps, it reflects the long-standing practice in international trade literature where we accept crow-fly distance as the default and gold standard measuring tape of bilateral distance in international trade (see Disdier and Head, 2008 p47).

II. Theoretical Model

We model the trade relationship between firms and their evolution as a continuous parameter process $\xi(m)$ of a vector-valued distance function $D^m(.)$ on circular interfaces, which varies by transportation mode m. Imagine firms as minuscule points distributed over earth's topological space, which we formalize as consisting of several concentric rings. Let z_i describe the latent position of firm i in the topological space. A ring is immaterial unless a firm located on the ring builds a trade tie with another firm in its foci. First, a firm i attempts to buy or sell a product to firm j at a distance d_{ij} in a direction randomly chosen in the range $[0, 2\pi)$. This guarantees that the firm is indifferent to whom it sells along its loci at d_{ij}. The probability P that the two firms trade is defined as:

$$P[Y_{ij} = 1|\alpha, z_i, z_j] = \alpha - D^m(z_i, z_j) \tag{1}$$

where $D^m(z_i, z_j)$ is the vector-valued distance function. Suppose the vector space is partitioned into vector space of physical distance $\tilde{D}^m(z_i, z_j) : |z_i - z_j| \to d_{ij}^m$ in R^3 between z_i and z_j and other p covariates affecting firms' latent position. Thus, (1) can be rewritten as below:

$$P[Y_{ij} = 1|\alpha, z_i, z_j, X_{ij}, \beta] = \alpha + X_{ij}\beta - \tilde{D}^m(z_i, z_j) \tag{2}$$

where X_{ij} is the collection of p covariates and β is the corresponding coefficient vector of length p. The latent positions z_i's are assumed to have a multivariate normal distribution. Without further loss of generality assume that the true coefficients $\beta_0 = 0$ and $\sigma^2 = 1$. The vector parameter α determines the scale of the tie probabilities as it imposes the upper bound on the probability. Firms i and j will trade so long as, $\alpha \geq \tilde{D}^m(z_i, z_k|X_{ij})$. The bound is sensitive to the choice of parameterization of the conditional probability in (1) and (2). Regardless, the probability that the two firms trade increases the closer two firms are in the topological space.

At any given time, firms may want to expand their export destinations. By construct, firms follow sequential decision making process. That is, first they search for potential

[2] See Section III for details.

equal-cost destinations around their position at some distance. Based on the outcome of this search, firms decide whether to make more searches. Independent of the search cost and firm productivity, every period firms may exit because of a bad shock δ as in Melitz (2003). Given the firm survives the production, its search process results in rings of varying widths such that $d_{ij}^m < \infty$, as shown in Figure 1. Suppose the immediate cost of any search s is $c_i(s)$. If a firm i is able to create trade ties with other firms after its new search s', its value function v_i changes to v_i':

$$v_i' = \begin{cases} v_i \quad if \quad C_i(s') = 0 \quad or \quad P_{ij}(s') = 0 \quad \forall \text{s'} \\ \sum_{t=0}^{t=\infty} (1-\delta)^t \sum_j (P_{ij}(s')\pi_{ij}(s') - c_i(s')) \quad otherwise \end{cases} \tag{3}$$

where the dependence of P_{ij} on X_{ij} and $\tilde{D}^m(z_i, z_j)$ from (2) is understood. At any given time, firm is able to decide whether to keep its value v_i or to undertake new searches and transition to new v_i'. $\pi_{ij}(s')$ is firm's profit function, whose structure including firms production, consumer demand, and equilibrium, we discuss henceforth.

In the following production and consumption are as in Krugman (1980) and Dixit and Stiglitz (1977). We present the optimal and aggregate variables in the style of Melitz (2003). Search cost, transportation cost, and ensuing equilibrium is our innovation.

A. *Production*

Suppose there is a continuum of firms, and each produces a unique variety ω. Labor is the only factor of production, and firms bear identical cost functions. This cost function exhibits a fixed set-up cost and constant marginal cost. Thus, labor (l) used in producing any good is a linear function of output produced:

$$l = f + \frac{q(\omega)}{\varphi} \tag{4}$$

where $f > 0$ is the fixed set-up cost. Firms are heterogeneous in the sense that each produce a different good as in Krugman(1980).

B. *Consumption*

On the demand side, all individuals have the same utility function. They derive utility from consuming the continuum of the goods ω which enter the demand system symmetrically as below:

$$U = \left[\int_{\omega \in \Omega} X(\omega)_{ij}^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}} \tag{5}$$

where Ω represents the available mass of differentiated goods, and σ the constant

elasticity of substitution between the goods such that $\sigma > 1$. If Q is the set of varieties consumed, measure on this set is equivalent to U. This index of aggregated consumption will have an associated price index $P = \left[\int_{\omega\in\Omega} p(\omega)^{1-\sigma} d\omega\right]^{\frac{1}{1-\sigma}}$. As shown originally in Dixit and Stiglitz (1977), Q and P together characterize consumer behavior in the model such that optimal consumption $q(\omega)$ in the economy is:

$$q(\omega) = Q\left[\frac{p(\omega)}{P}\right]^{\frac{1}{\sigma}} \tag{6}$$

Let L denote the total population. Then, under full employment condition, the above can be rewritten as $q(\omega) = \frac{wL}{P}\left[\frac{p(\omega)}{P}\right]^{\frac{1}{\sigma}}$, where w is the common wage rate in the economy. Thus, the optimal expenditure on a variety is $r(\omega) = \left[\frac{p(\omega)}{P}\right]^{1-\sigma}$, where $R = PQ = \int_{\omega\in\Omega} r(\omega) d\omega$.

C. *Pricing Rule and Profit Function Without Search or Transportation Cost*

Firms face iso-elastic residual demand curve with constant elasticity of substitution σ, and thus choose the same profit maximizing mark up $\frac{\sigma}{\sigma-1}$, which yields the pricing rule $p(\omega) = \frac{\sigma}{\sigma-1}\frac{w}{\varphi}$. Because all firms have the same productivity level, $p(w) = p$. Then, the profit is:

$$\pi(\omega) = pq(\omega) - \frac{q(\omega)w}{\varphi} - f \tag{7}$$

There is no free entry because of the search cost, which is discussed below. Given that $P = \left[\int_{\omega\in\Omega} p(\omega)^{1-\sigma} d\omega\right]^{\frac{1}{1-\sigma}} = M^{\frac{1}{1-\sigma}} p$, entry of new firms drives down P and thus the $\pi(w)$.

D. *Search Cost*

Irrespective of whether firm j is an international or domestic buyer, firm i faces a probabilistic search cost and a deterministic transportation cost in delivering its product to firm j. Each search identifies potential destinations in the form of interval of distances with equal delivery cost. The search cost is in addition to the production cost discussed above. That is, a precondition to the search is production. Firms follow a spatial distribution is well established in the economic geography literature. For this reason, search cost is modeled as a derived distribution of firm distribution in space. Firms draw their immediate search cost from this common derived distribution $\psi(c_s(F))$, whose support takes a value $(0,\infty)$ in $\Re^+$ and $\Psi(c_s(F))$ is the corresponding continuous cumulative distribution. For ease of notation though, we reserve $\psi(c)$ and $\Psi(c)$ to denote the probability density function and cumulative distribution, respectively.

Upon draw of a very high search cost at t, an incumbent firm may abandon search process in $t+1$. Given that every period firm may also exit because of a bad shock δ, the ex-ante survival probabilities of firms is determined by δ and $\psi(c)$. Equilibrium mass of firms, the number of markets that a firm serves, and distance goods travels in international trade is endogenously determined. We consider only steady state equilibrium, therefore, aggregate variables such as optimal profit, optimal quantity and optimal factory gate prices remain unchanged period to period. Further, firms subsequent draws are independent of previous draws.

From (3), $c_i^*(s') = sup\{c_i(s') : v_i' > 0\}$ identifies the highest search cost beyond which the firm i won't undertake new searches holding the transportation cost constant. The dependence on firms' latent position is understood but not shown for simplicity in exposition. At first, a firm may not know it is drawing from a derived distribution. However, after the first successful search, the firm may realize that its search cost is related to other firms' spatial distribution. As a result, their search process may not be continuous in space. Nevertheless, the search will be sequential and order-preserving in the distance in the sense that the distance closer to it will be searched first. It is a reasonable assumption, given the transportation cost is related to distance. Assuming an additive search cost and an 'iceberg' transportation cost, that is delivering a unit of good from firm i to j requires producing τ_{ij} units in i, $c_i^*(s') = p * \tau_{ij} - {}^{w}/_{\varphi}$, then $\pi = -f$, defines the upper bound of the equilibrium distribution of the search cost.

Any firm drawing a search cost $c > p\tau_{ij} - {}^{w}/_{\varphi}$ will not be able to make new trade ties. Therefore, the search cost acts as an entry barrier as the productivity does in Melitz (2003), although here (and hereafter) entry refers to entering into a trade relationship. By assumption, the subsequent exit will not affect the equilibrium distribution of the search cost. Thus, the distribution of the search cost is determined by the initial draw, conditional on successful entry. The conditional equilibrium distribution of the search cost $\mu(c)$ over $(0, c^*]$ is:

$$\mu(c) = \begin{cases} \frac{\psi(c)}{\Psi(c^*)} & if \quad c^* \leq p\tau_{ij} - {}^{w}/_{\varphi} \\ 0 & otherwise \end{cases} \tag{8}$$

Thus, the ex-ante probability of successful entry is $p_{in} = \Psi(c^*)$. By law of large numbers, this also gives the fraction of producing firms that successfully sell their product. Firms can build new trade ties each period, but the overall equilibrium mass (M) of firms stays the same. This implies that the mass of firms that enter the trade relationship (M_e) for the first time exactly replaces the total amount of death by exogenous shock δ. That is, for any given period $p_{in}M_e = \delta M$.

Not all successful firms sell their product to all firms as each search has associated distance and the interval where the search cost is fixed and the transportation cost is the same. Because of the search cost, firms have an incentive to sell their products while minimizing their search. This is also the reason the firms follow sequential searches in concentric rings. For example, the radius of the circle is unity, and there are N firms on the ring. This would imply a firm located on the ring would have access to ${}^{N}/_{2\Pi}$

firms on unit arc length in one direction. However, if the same firm is at the center, it will have access to all N firms in the unit distance around $[0, 2\pi)$. Therefore, this type of search results in more competition between firms. Compared to the monopolistic models without search cost, for example, in Krugman (1980), in this case, monopolistic incentives are stronger – "no firm will ever want to produce the exact same product as the other firm" even though the equilibrium mass of firms will be lower here.

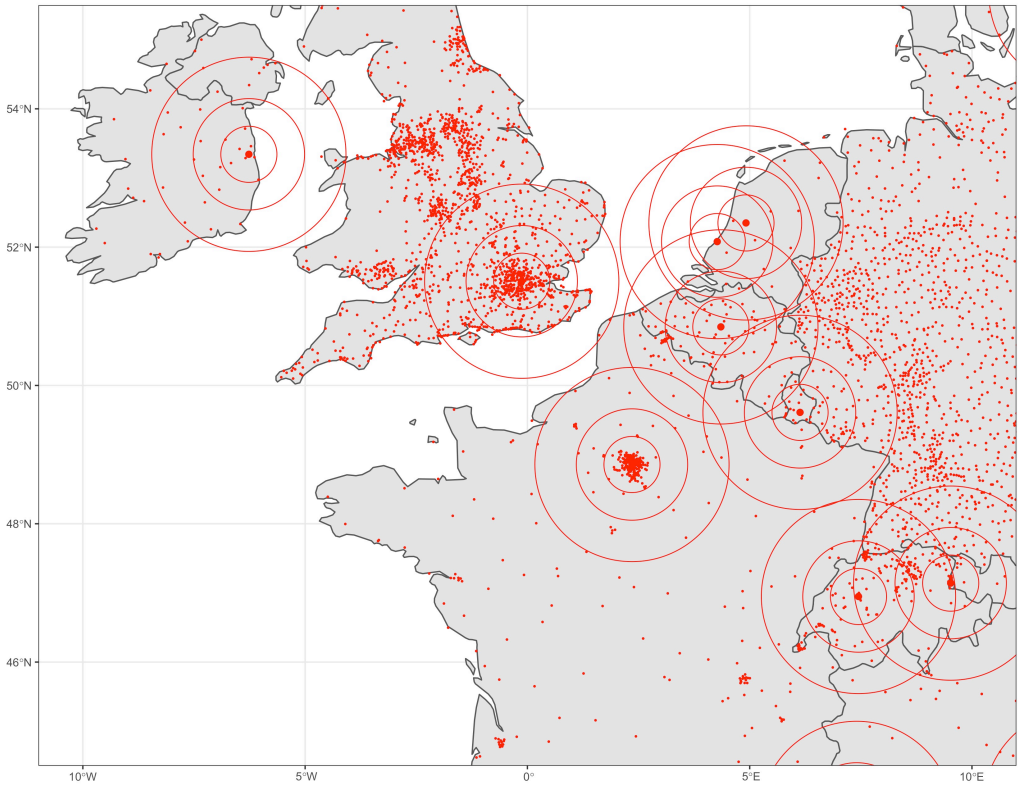


FIGURE 1. FIRMS' ANNULAR SEARCH PROCESS.

Note: Firms are depicted as minuscule points distributed over the earth's surface following a non-uniform distribution. Annular rings represent the firms' sequential search process around their loci in building trade ties with other firms. The map shows a portion of Europe. Only one firm located centrally per city is revealed. The concentric rings illustrate the sequential search process of firms in the capital cities.

E. Firm-level Exports and Aggregate Exports at Some Distance **x**

Let's begin with a simplifying assumption that firm i conducts only one search and identifies the interval $[a,b]$ such that its delivery cost to all firms in the interval is fixed. Suppose the firm builds trade ties with all other firms in the interval $[a,b]$ with the outmost distance x from its latent position. Let $f_i(x)$ be the fraction of its good supplied to

any firm in the interval. Then the following holds:

$$\int_a^b f_i(x)dx \leq q(w) \tag{9}$$

With multiple continuous searches, the number of firms i serves may increase. Regardless, the following holds:

$$\int_{a_{min}}^{b_{max}} g_i(x')dx' \leq q(w) \tag{10}$$

Transforming coordinates to polar coordinates, normalizing firm i's position to the origin and measuring all other firms' position with respect to i, the sum of all firm-level exports at x gives an aggregate exports at a distance x from i:

$$\int_0^{c^*} \int_0^1 g_x(\omega)M\Psi(c^*|\tau_{ij} = x)d\omega dc \tag{11}$$

Proposition 1: The probability that a firm j trades with firm k is affected by firm i under certain conditions.

Suppose a triangle $(\alpha_0, \beta_0, \gamma_0)$ shown in Figure 2 is formed by any intersection of concentric rings in the annular search process shown in Figure 1. Let γ_0 and β_0 be the minimizing geodesics from j to i and k to i respectively, and α_0 is a geo-desic from j to k. Then, as in the euclidean geometry, triangle inequality applies, such that $|\alpha_0| \leq |\gamma_0| + |\beta_0|$. That is, if two firms j and k are close to firm i in this spherical topological space, j and k must also be closer to each other. Thus, any sequence of $\{d_{jk}\}$ satisfying the triangle inequality can substitute for $|z_i - z_j|'s$ in $\tilde{D}^m(z_i, z_j)$.

A lateral result is that depending upon the firms' distribution on earth's surface, the search process may create pocket of intense competition.

Proposition 2: The width of each loop in the search process will be upper bounded in firm's cost function.

The proof follows directly from (3) and (8). In the present context, we don't need to know the exact distribution of firms on the rings. The idea here is to interpret the trade relationship as the maximal outcome of such a process $\xi(m)$, where $\tilde{d_{ij}}$ is the minimum of the values of the sequence to reach from i to j. Mathematically, $\tilde{D}_{ij}^m = inf\tilde{D}^m(z_i, z_j)$: $\tilde{d_{ij}} \leq d_{ij}^{m'}$ $\forall m$.

F. Analysis of the Equilibrium and Closing the Model

We pause for a brief discussion of our model implications. By introducing variable fixed costs of the sequential search for trade partners into the trade model, we do away

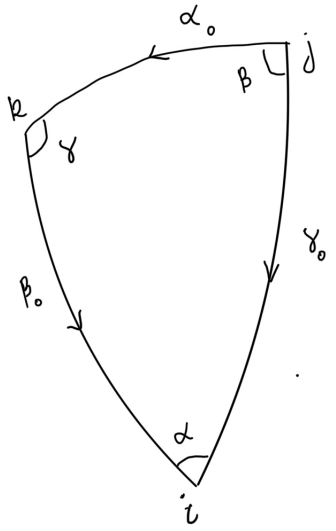


FIGURE 2. TRIANGLE INEQUALITY

with reliance on natural[3] autarky equilibrium and leapfrog to open trade equilibrium. Even when firms are homogeneous in productivity, in a sequential search, firms endogenously sort into sellers and non-sellers based on their draw of search cost. Suppose a firm's sequential search identifies the equal-cost destinations. Further, its sequence of searches is such that in the limit, no search is compatible with trade ties with firms across the border. In that case, this firm sorts into non-exporters. We do not further explore the consequence of skipping the autarky equilibrium, a transition phase in most trade models which facilitate drawing out the predictions for trade liberalization/ globalization. However, compared to isomorphic models with autarky equilibrium, consumers would have access to higher number of goods in this model. Sequential search in annular rings also implies pockets of intense competition depending upon firms' spatial distribution. This competition only strengthens the monopolistic incentive for product differentiation, even beyond the monopolistic competition with heterogeneous firms *à* la Melitz (2003). If firms survive the intense competition, in the extreme case, there may emerge a local monopsony in the product market. In this sense, we anticipate our model would predict a different[4] welfare gain on the consumption side than its isomorphic models with autarky equilibrium. This model also predicts wasteful production unless firms that draw low search cost are able to arbitrage from non-sellers. Given that production, consumption, and transportation costs are isomorphic to Krugman (1980) and Melitz (2003), and the outcomes of our search cost are equivalent to entry barriers in Melitz (2003), it is not hard

[3]In the absence of policy induced autarky equilibrium

[4]Lower if welfare loss from loss in varieties because of intense competition outweighs gain in varieties from firms across the border. Full implications of monopsony on welfare gains would be better studied with non-homothetic preferences.

to see that our model leads to gravity equation of international trade. With this, equation (2) needs an update to allow bilateral trade Y_{ij} to take any value ≥ 0. Further, the full employment condition and inelastic labor supply at the aggregate level are sufficient to generate country-level differences in aggregate variables of the model even if there is no natural autarky equilibrium in the model.

G. Back to Transportation Costs

Next, we model the idea that the actual distance traveled between firm i and j is different based on mode of transportation (m). Assume the continuum of goods $\omega \in [0,1]$ can be traded between firms i and j via maritime and air transportation. Further, the goods are arranged in the continuum with diminishing relative transportation cost for air transportation. While the goods intrinsic characters may have led to the differences in their transport costs across modes, it is sufficient for modeler to be able to know the sorting.

$$\frac{\tau_1^*}{\tau_1} \geq ... \geq \frac{\tau_n^*}{\tau_n}, \quad F(\omega) = {}^{\tau^*(\omega)}/_{\tau(\omega)}, \quad F'(\omega) < 0 \tag{12}$$

where $\frac{\tau_z^*}{\tau_z}$ represents the trade cost for air transportation relative to maritime transportation and $F'(.)$ represents the decreasing per unit transportation cost for air transportation and is shown as downward sloping curve in Figure 3. Assuming firms want to minimize cost, the range of commodities whose maritime transportation cost is lower will be shipped using maritime transportation. If there is at least one borderline commodity for which the relative costs are equivalent, relative trade costs can be characterized using this borderline commodity (l). The use of l will provide a strong reminiscent to Dornbusch, Fischer and Samuelson (1977). Assume there are no fixed cost for individual firms. This assumption does not preclude the fixed cost of transportation at the industry level. Moreover, they can vary by industry. Then, the relative trade cost is:

$$\frac{\tau^*(l,z_i,z_j)}{\tau(l,z_i,z_j)} = g * \frac{d_{ij}}{d_{ij}^*} \tag{13}$$

where g is a proportionality constant that may stem from industry level differences in efficiency across transportation industries. While d_{ij} and d_{ij}^* are minimal of respective sequences, with the inclusion of g, we relax the assumption that they are also equal. Assume the transport expenditures on goods traded via air and maritime transport are distributed as below:

$$\frac{\tau_{ij}^*(l,z_i,z_j)}{\tau_{ij}(l,z_i,z_j)} = k * \frac{\varphi_{ij}(l)}{1-\varphi_{ij}(l)} \tag{14}$$

where $\{\varphi_{ij}(l), 1-\varphi_{ij}(l)\}$ stand for the share of total trade expenditure on goods traded via maritime and air transportation between i and j, and k is a proportionality constant.

$$\frac{d_{ij}}{d_{ij}^{*}} = \frac{k}{g} * \frac{\varphi_{ij}(l)}{1-\varphi_{ij}(l)} \equiv G^{1}\left(.\right) \tag{15}$$

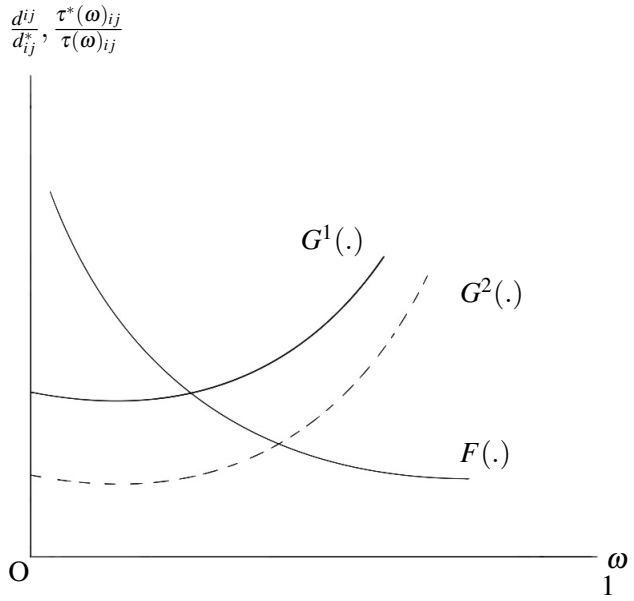


FIGURE 3. TRADE EXPENDITURE ON GOODS TRANSPORT

$G^{1}\left(.\right)$ is shown as an upward sloping curve in Figure 3. The fall in the effective maritime transport barrier at a fixed relative distance raises the demand for maritime and lowers the demand for air transportation. Similarly, if technology improves maritime transport, the upward sloping curve shifts right, as shown by $G^{2}\left(.\right)$. It implies that the range of commodities exported using maritime transport increases while decreasing the goods transported with air transport. A broader implication to our model is that the distance or the associated cost variable for air and maritime transport simultaneously enter the gravity system, and in additive terms in equation (2).

III. Data

This article aims to study if bilateral distance has become less relevant in international trade across the three waves of globalization. Thus, this work requires layers of data; the first layer consists of the actual distance the sailor ships covered during voyages in the later and early half of the 18th and 19th century, which is retrieved from the

CLIWOC database.[5] For a given ship, this database contains information on voyage start and end date, voyage origin and voyage destination port, date of observation, distance covered each day, and the coordinates (latitude and longitude) taken 24 hours apart. Thus, we can locate a ship's daily en route position, recreate its actual route of a given trip when needed, and retrieve the total distance the ship navigated between ports during the voyage. This distance is the horizontal summation of daily distances covered from the voyage start date to the voyage end date. Ships have multiple journeys and take different routes in the data. Given the information in the coordinate system and using non-missing information on voyage start and end date, and ordering the available coordinates by date of travel for a given ship, we identify a total of 173744 unique voyages. Using these observations, we reconstruct a century's worth of data on bilateral time-varying navigable distance between 3780 port pairs for 1750 to 1853. Note that this is a highly unbalanced panel with 796 and 832 unique origin and destination ports.

This CLIWOC database primarily contains ancient port names and ancient country names in several cases, allowing us to identify modern country names. Country mapping was trivial when the old names matched the current country names. To fill in country names for the rest of the observations, we create crosswalks using GEO2XY and GEOINPOLY in Stata, which jointly map latitude and longitude data to country names. Country identification was not complete for all ports at this stage. We suspect voyage records were made several hours before arrival at the destination port. In such cases, coordinates for voyage end date would fall on the ocean. We use Google Maps and assign the port to the nearest landmass/country if identification is straightforward. We then use trip identifiers (year-ship name-captain-voyage origin and destination) to retrieve recorded information in voyage record books[6] and thus validate our country assignment. We adopt a (panel) subset of this data combined with our sample for 1965 to 2010 to conduct our counterfactual analysis. This panel subset contains 56 exporters and 60 importers, 210 bilateral pairs, 602 importer-exporter-year tuples, and 699 importer-exporter-distance tuples. Note that this subset is not equivalent to random sampling from the voyage database, as the panel subset is constructed to match the country pairs in the latter sample.

The second layer of data in our sample spans 1850 to 1900 and is also the oldest time frame for which bilateral trade flows are available to us. To construct this data, we combine shortest port to port distance taken from CERDI-sea distance database[7] by Bertoli, Goujon and Santoni (2016) with historical bilateral trade data from Pascali (2017). Unlike the voyage data, to harmonize the port names across these two datasets, we use stata module GEO2XY and map the latitude and longitude data in Pascali (2017) to modern names. The latter also contains information on shipping time across sail and steamships for 1850-1900. As the introduction of the steam engines had profound changes on time traveled by ships, we also used the shipping time to recover the distance elasticity across

[5]Data Source: https://webs.ucm.es/info/cliwoc/cliwoc15.htm

[6]For example, we validate the location of Fermouse Harbor in Newfound land using https://digitalarchive.tpl.ca/objects/341248/sailing-directions-for-the-island-of-newfoundland-and-adjac?ctx=ea03c08f06d8f13a038735c09bc4f5b7eccc8db9idx=0

[7]Data Source: https://ferdi.fr/en/indicators/the-cerdi-seadistance-database

two different shipping technologies for the sample span. In the CERDI database, the shortest bilateral port distance is constructed from the actual trips modern ships follow in international trade. In contrast, the time data in Pascali (2017) is a time function of sea distance the steamships and sailboats travel under optimized routes (see Pascali, 2017 for details).

The third layer of data covers 1962 to 2010 and consists of Standard International Trade Classification revision one bilateral trade flows for 185 countries from the UN Comtrade database (UNCTAD 2019). Unique to this time frame, we also construct country-level intranational trade flows as the difference between GDP and total international exports. The use of intranational trade data permits us to analyze the distance effect on international trade relative to the internal distance traveled in within-country trade. A table summarizing all measures of distance is available in Table A1 of the appendix. We take data on bilateral air or crow-fly distance, contiguity, and common language from the Centre deEtudes Prospectives et d'Informations Internationales (CEPII) database (Mayer and Zignago, 2011). Data on Gross Domestic Product are from the World Bank's database on World Development Indicators.[8] Policy variables on membership in regional trade agreements[9], preferential trade agreements [10]and World Trade Organization (WTO)[11] are retrieved from WTO website.

IV. Econometric specification

We use the Poisson pseudo-maximum likelihood (PPML) estimator to obtain and compare distance estimates using maritime and Crow-fly distance. First, we estimate the following structural gravity equation.

$$Y_{ijt} = exp[\phi_{it} + \phi_{jt} + \beta_1 lnDistij + \tag{16}$$

$$\beta_3 Cntg_{ij} + \beta_4 Lang_{ij} + \beta_5 Clny_{ij}] + \varepsilon_{ijt} \tag{17}$$

where, Y_{ijt} is the value of exports from country i to country j and includes both internal $(i = j)$ and international trade flows $(i \neq j)$. Intranational trade, Y_{ii} is the discrepancy between country i's GDP and the total international exports. $Cntg_{ij}$, $Lang_{ij}$, and $Clny_{ij}$ control for contiguous border, common official language, and colonial relationship between i and j, respectively. $lnDist_{ij}$ is the logarithm of (maritime or crow-fly) distance between trading pairs. For internal trade, distance variable is replaced with $lnDist_{ii}$, the internal distance. We follow methods in Mayer and Zignago (2011) to construct internal geo-distance for each ii pair. For maritime distance though, we use the distance between the capital city and the bilateral port as an internal distance. We construct this variable by matching bilateral ports to bilateral trade partners. For international distance, we either use the actual shortest bilateral port to port sea-route distance or the optimized sea distance between trading pairs. Finally, $\{\phi_{it}, \phi_{jt}\}$ control for theoretically relevant outward

[8]Data Source: https://databank.worldbank.org/source/world-development-indicators
[9]Data Source: http://rtais.wto.org/UI/PublicMaintainRTAHome.aspx
[10]Data Source: http://ptadb.wto.org/
[11]Data Source: https://www.wto.org/english/thewto$_e$/$whatis_e$/tif_e/$org6_e$.htm

and inward multilateral resistances, and ε_{ijt} is the stochastic error term.

There was a tremendous increase in world trade to world GDP ratio during the 1970s to the late 2010s. As noted in Antràs (2020), this ratio increased from 3.7% in 1970 to 29.7% in 2018 with 80% of the increase accrued to the period 1986-2008. Moreover, this increase in the world trade to GDP ratio is mostly attributed to trade liberalization efforts led by developing countries since the early 1970s. For this reason, in our second specification, we also include trade policy variables to capture membership in common regional trade agreements ($Common_RTA_{ijt}$), membership in WTO ($Both_in_WTO_{ijt}$), membership in preferential trade agreements and whether the preferential treatment recipients' export ($PTA_Recipient_Exports_{ijt}$). This permits us to examine the distance effect vis-à-vis the trade policy impact on trade. Where we include per capita GDP for exporters (GDP_{it}) and importers (GDP_{jt}), we are not able to incorporate exporter-time $\{\phi_{it}\}$ and importer-time fixed effect panel dummies $\{\phi_{jt}\}$, as they would absorb all variations in the former variables. Instead, we add three sets of exporter $\{\phi_i\}$, importer $\{\phi_j\}$, and time $\{\phi_t\}$ fixed effects to this third specification.

Moving closer to our theoretical framework, we incorporate crow-fly and sea distance into a single specification to examine the relative changes in distance elasticity across these two measures of distance. In a separate specification, we also allow distance variables to take different coefficients across time to examine the temporal pattern in distance elasticity when using sea and crow-fly distances in gravity estimation. Different from the above description, our most preferred specification to explore temporal pattern is the one with exporter-time and importer-time fixed effects $\{\phi_{it}, \phi_{jt}\}$, where we omit the GDP variables. For one reason, these allow us to capture the average effect of much broader sets of unobserved time-changing country-specific variables than the use of GDP would allow. In the historical context, when most economies would be Malthusian, we believe GDP or per capita GDP would be less adequate measures even to proxy the relative economic size across nations. Finally, the distance puzzle would be present in the estimates so long as the absolute value of the estimates of the distance effect increases or remains constant across both modes of transportation over time.

V. Regression results

Table 1 presents the results from estimating the structural gravity equation using data for 1962-2010. The dependent variable is nominal exports and includes intranational trade. Thus, the distance elasticity is measured relative to the internal distance corresponding to intranational trade. All results are obtained using PPML estimator with robust standard errors shown in parenthesis.

In columns 1-6 of Table 1, we provide pairwise comparisons of distance coefficients recovered from crow-fly and sea distances in three separate specifications. We preserve the order and present the results with crow-fly distance first in each of the three specifications. In columns 1-2 of Table 1, we control for multilateral resistances using importer-time and exporter-time fixed effects. The results indicate that having a contiguous border or sharing a common official language increases trade. The coefficient on colonial ties is close to zero and not significant in column 2, but is positive and statistically significant

with crow-fly distance in column 1. Focusing on our primary variable of interest - bilateral distance, the coefficients are statistically significant, negative with both distance measures, and the decline is greater with crow-fly distance. In particular, a one percent increase in crow-fly distance decreases trade flows by about 0.68% and by 0.26% in the case of sea distance.

The results are only minimally affected with the inclusion of trade policy variables in columns 3-4 of Table 1. Importantly, the coefficients on crow-fly distance and sea distance are unaffected with the inclusion of trade policy variables. All geographic trade cost variables that were positive and statistically significant in columns 1-2 of Table 1 remain such. The same holds for the coefficient on colonial ties, which continues to be close to zero and non-significant in specification with sea distance. There are only slight changes in the magnitude of coefficients on contiguity and colony. Language is the only variable for which the χ^2 test cannot reject the null of pairwise equality of the estimates (in columns 2 and 4). The estimates on $Both_in_WTO_{ijt}$ and $Common_RTA_{ijt}$ are positive, large, and statistically significant, suggesting that the WTO membership and participation in a common RTA increase trade. GSP does not have a relevant impact on trade with sea distance in column 2, while it has a positive and significant effect on trade with crow-fly distance. These results seem fairly consistent with the theoretical predictions that reciprocal trade agreements increase bilateral trade, and non-reciprocal trade agreements increase preference recipient's exports within the bounds of supply-side constraints.

Columns 5-6 of Table 1 include GDP per capita for exporter and importer in addition to all other explanatory variables discussed above and are estimated with exporter, importer and time fixed effects. Again, the coefficients on crow-fly and sea distances are stable. The other results are less affected. The difference is that in this new specification, the magnitude of the coefficients on WTO membership in columns 5-6 are larger, the coefficient of RTA membership in column 6 is slightly smaller, and these coefficients are estimated at similar level of precision. The coefficients on GDP per capita for exporter and importer are large, positive, and statistically significant and virtually same in columns 5 and 6. That is, our results are generally consistent across specifications. Two points are worth noting in this respect. First, the unobserved trade cost variables missing from our specifications are likely to be country-specific rather than country-pair-specific. Consequently, importer-time, exporter-time fixed effects, or importer, exporter, time fixed effects included in our specifications accounted for the unobserved variables. This observation will prove relevant for our counterfactual exercise where we choose to combine importer, exporter and year fixed effects for our baseline estimates in Section VI.

Next, we discuss empirical results that connect our data to the theoretical underpinnings derived in Section II. We combine crow-fly and sea distance variables into a single specification to obtain these results. The results are presented in columns 7-9 of Table 1. Columns 7-8 show estimates with importer-time and exporter-time fixed effects, and column 9 with the exporter, importer, and time fixed effects. There are only minor changes to the results across columns 7-9, but also more generally when compared to our previous

TABLE 1—USING DIFFERENT MEASURES OF DISTANCE TO ASSESS ITS IMPACT ON INTERNATIONAL TRADE.

$Nominal_Exports_{ijt}$	Crow-fly	Sea	Crow-fly	Sea	Crow-fly	Sea	Both	Both	Both
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$DIST_{ij}$	-0.68	-0.26	-0.68	-0.25	-0.68	-0.25			
	(0.005)	(0.006)	(0.005)	(0.006)	(0.006)	(0.006)			
$SEADIST_{ij}$							-0.05	-0.05	-0.05
							(0.004)	(0.004)	(0.005))
$CROW-FLY DIST_{ij}$							-0.63	-0.63	-0.64
							(0.006)	(0.007)	(0.007)
$Cntg_{ij}$	0.55	1.18	0.55	1.10	0.55	1.14	0.55	0.54	0.54
	(0.019)	(0.218)	(0.020)	(0.023)	(0.020)	(0.025)	(0.019)	(0.020)	(0.020)
$Clny_{ij}$	0.15	-0.02	0.15	0.01	0.12	0.06	0.14	0.15	0.11
	(0.020)	(0.020)	(0.020)	(0.02)	(0.022)	(0.020)	(0.020)	(0.020)	(0.021)
$Lang_{ij}$	0.23	0.24	0.22	0.36	0.24	0.36	0.24	0.23	0.25
	(0.016)	(0.018)	(0.016)	(0.019)	(0.017)	(0.019)	(0.016)	(0.016)	(0.017)
GDP_{it}					0.65	0.64			0.65
					(0.021)	(0.022)			(0.021)
GDP_{jt}					0.65	0.65			0.64
					(0.021)	(0.022)			(0.024)
$Both_in_WTO_{ijt}$			0.40	0.28	0.54	0.54		0.39	0.55
			(0.050)	(0.053)	(0.027)	(0.026)		(0.050)	(0.027)
$Common_RTA_{ijt}$			0.03	0.35	0.04	0.25		0.04	0.01
			(0.016)	(0.020)	(0.037)	(0.021)		(0.016)	(0.018)
$GSP_Recipient_Exports_{ijt}$			0.13	-0.01	0.10	-0.04		0.12	0.09
			(0.027)	(0.022)	(0.030)	(0.024)		(0.027)	(0.029)
No. of observations	1,076,442	1,067,695	1,076,442	1,067,695	857,300	856,353	1,067695	1,067,695	856,353
Pseudo log-likelihood	-3.605e+13	-4.793+12	-3.58820e+13	-4.70656e+13	-3.77981e+13	-4.87895e+13	-3.54532e+12	-3.52832e+13	-3.73861e+13
Pseudo R^2	0.88	0.85	0.95	0.94	0.95	0.93	0.95	0.95	0.95

*Notes:*Robust standard errors (S.E.) in parentheses. The dependent variable is nominal exports and includes intranational trade. Bilateral distance is replaced with internal distance for intranational trade. All estimates are obtained with PPML estimator. Columns 1-4 and 7-8 include importer-time and exporter-time fixed effects, and Columns 5-6 and 9 include importer, exporter, and time fixed effects. Coefficient for fixed effects are omitted for brevity. See text for further details.

findings in columns 1-6. The results imply that sharing a contiguous border, speaking a common official language, having colonial ties, membership in WTO, or receiving GSP preferences increases trade. The coefficient estimates on GDP variables are also large, positive, and statistically significant.

In only difference, with the inclusion of GDP variable and in the presence of GSP variable, the coefficient on regional trade agreement turns statistically non-significant in column 9. Given the perpetual increase in PTAs from 1990 to 2008, there might have been some preference erosion across PTAs (Fugazza and Nicita, 2013). Reciprocal preferences offered through RTAs are generally uniform across member countries, while non-reciprocal preferences offered through GSP have some discrimination and are typically offered to less developed countries. For this reason, we view the results as aligned with the findings that relative preferences (for example, tariff reductions) compared to competing suppliers are more important than the absolute value of preferences countries receive in international trade. With this exception, both magnitudes and significance levels are consistent across specifications in Table 1 for all other variables.

With the above validation of our approach, we now describe our primary variable of interest, distance. Our estimation sample includes intranational trade and concurrent internal distance goods travel in domestic sales. For this reason, our distance elasticities have a natural distance function interpretation. Under the assumption that globalization integrated international markets more than the domestic markets, we expect the elasticities to assume low values compared to the literature, where typically the elasticities are measured exclusively with data on international trade. If the two different distance proxy transportation modes in international trade adequately, our estimates would show even lower values in light of globalization that already unfolded. In this sense, this sample for 1962-2010 covering the period of innovation in air-cargo freights and where advances in maritime technology have already been internalized serves as a good sample to study the mean value (over time and bilateral pairs) impact of globalization on international trade.

The coefficient estimates on crow-fly and sea distances are statistically significant, negative, and large for crow-fly distance. Specifically, the estimated elasticities are -0.63 and -0.05 for crow-fly and sea distances, respectively. When distance is viewed analogous to transportation costs, this lower estimate for sea distance suggests a smaller role for maritime transportation in determining trade patterns conditional on the simultaneous use of air transport in the international trade of goods. Caution should be applied in interpreting these results. A smaller role in determining trade patterns is not akin to its lack of importance in trade. It merely says maritime transport offers less resistance in international trade of goods compared to air transport. From a methodological standpoint, the estimates presented are novel as they identify distance elasticity with crow-fly and sea distances within a single specification. However, it is unclear to what extent globalization affected the temporal patterns in the elasticities, which we explore below.

Table 2 shows the results obtained from allowing distance estimates to vary every ten years from 1850 to 2010. Results from given regressions are presented along rows in the table. The dependent variable is nominal exports, and coefficient estimates are obtained with robust standard errors shown in parentheses. All specifications include geographic

TABLE 2—DISTANCE EFFECT ACROSS THE TWO WAVES OF GLOBALIZATION

Panel A		1850-59 (1)	1860-69 (2)	1870-79 (3)	1880-89 (4)	1890-99 (5)	1900-1910 (6)	*Obs* (7)	*Pseudo LL* (8)	*Pseudo* R^2 (9)
Row 1.	Crow-fly Distance	-0.21	-0.08	-0.32	-0.26	-0.28	-0.26			
	S.E.	(0.128)	(0.107)	(0.073)	(0.066)	(0.064)	(0.055)	21,388	-39289	0.60
Row 2.	Sea Distance	0.10	-0.13	-0.31	-0.31	-0.30	-0.25			
	S.E.	(0.208)	(0.113)	(0.077)	(0.076)	(0.072)	(0.066)	21,316	-38661	0.60
Row 3.	Optimized Time Distance		-0.22	-0.30	-0.40	-0.38	-0.36			
	S.E.		(0.026)	(0.021)	(0.015)	(0.016)	(0.017)	23,926	-36880	0.70
Row 4.	Optimized Time Distance		-0.43, 0.23	-0.16, -0.21	-0.47	-0.40	-0.38			
	S.E.		(0.100, 0.106)	(0.139, 0.143)	(0.017)	(0.018)	(0.017)	21,279	-33174	0.62
Panel B		1970-79 (1)	1980-89 (2)	1990-99 (3)	2000-09 (4)	2010 (5)	*Obs* (6)	*Pseudo LL* (7)	*Pseudo* R^2 (8)	
Row 5.	Crow-fly Distance	-0.31	-0.36	-0.38	-0.43	-0.41				
	S.E.	(0.028)	(0.023)	(0.022)	(0.022)	(0.024)	1,076,442	-5.441e+13	0.80	
Row 6.	Sea Distance	-0.14	-0.16	-0.17	-0.22	-0.18				
	S.E.	(0.028)	(0.030)	(0.028)	(0.022)	(0.021)	1,067,695	-5.580e+13	0.80	
Row 7.		-0.25, -0.026	-0.31, -0.025	-0.34, -0.015	-0.37, -0.03	-0.37, -0.019				
	S.E.	(0.038, 0.030)	(0.038, 0.033)	(0.036, 0.030)	(0.036, 0.026)	(0.034, 0.022)	1,067,695	-5.510e+13	0.83	

Notes: Robust standard errors (S.E.) in parentheses. The dependent variable is nominal exports. All estimates in Panel A and B include importer-time and exporter-time fixed effects whose estimates are omitted for brevity. In Panel B, sample includes intranational trade and bilateral distance is replaced with internal distance for intranational trade. Obs stands for number of observations, and Pseudo LL for Pseudo Log-likelihood in PPML estimation. In Row 4, the estimates for optimized time distance with sail (underlined) and steam engines are separated with a comma. The sail ship distance estimates are shown up to 1870-79 when the sail and steamships were believed to have co-existed. In Row 7, the estimates for sea and crow-fly (underlined) distances are separated by a comma. See text for further details.

trade cost variables- colonial ties, language, and contiguity, whose coefficients are not reported to focus our discussion on distance variable.[12]

We report temporal patterns in distance elasticity from 1850 to 1900 in Panel A of Table 2. We use importer-time and exporter-time fixed effects to control unobserved multilateral resistances, whose estimates are omitted for brevity. We report estimates for crow-fly, sea, and optimized sea distances in separate rows. In Rows 1-2 of Table 2, the crow-fly and sea distance coefficients are small in magnitude and not statistically significant until 1869. They turned statistically significant and remained negative from 1870 to 1900. Specifically, the crow-fly and sea distance coefficients take a value of -0.32 and -0.31 in the period from 1870-1879, -0.26 and -0.31 in the period from 1880-1889, stay at similar levels for 1890-1899, and -0.26 and -0.25 in 1900. These results mimic the transition period 1860-1870 when steam engines replaced sailor ships in the maritime industry. The sea distance elasticity turns economically relevant for the first time in our estimation during the same period. The reason is apparent. Bilateral maritime trade did not have to be at the mercy of wind, marking the onset of the golden age in trade globalization. It gradually declines by 19.4% over the next forty years, with the bulk (97%) of the decline occurring in 1900.

The coefficient estimates with crow-fly distance are identical to sea distance estimates when the steam engines began appearing in the maritime industry in 1870-79. After that, the coefficient drops sharply, by about 18.6% within a decade as opposed to the more gradual decline in estimates that we find with sea distance. As discussed above, it took forty years since 1870s to achieve almost identical level of decline with sea transport. Air-crafts were invented in 1903, but their effective usage in commercial air freight was delayed until more advanced jet engines were introduced in the late 1950s. Therefore, we view the crow-fly distance as just a construct to represent sea transport rather than air transport in international trade for the given period.

We also examine the temporal pattern in distance elasticity using optimized time for sea travel. While comparable to results in Pascali (2017), the results imply that the distance impeded trade by 136% - (0.30/0.22) and 182% -(0.40/0.22) more during 1870-79 and 1880-89 than it did from 1860-69. The coefficient does gradually decline after 1889 for the rest of the sample periods. However, a potential concern with using steam engines alone for optimized time is that the sail ships would have coexisted with steam engines during the early transition period. For this reason, we also include optimized time for sail ships for 1860-1880. The results are shown in Row 4 of Table 2. Where we include optimized time for both sail ships and steam engines, we separate the estimates with a comma and underline the ones for sail ships. The coefficient on shipping time by sail is negative and significant only for 1860-69. In contrast, the coefficient on shipping time by steam engine turns negative starting 1880. It is high in 1880 but gradually declines by 14.9% and 5% during 1890-99 and 1900.

We present the results for 1970 to 2010 in Panel B of Table 2.[13] The difference in

[12]The coefficient estimates match our previous results in Table 1 and are available upon request.

[13]We estimate coefficients at five-year intervals starting at 1970. That is, we have mid-point and end-point estimates for the time interval shown in Panel B of Table 2. We present estimates only for ten-year gaps in the table for brevity.

distance coefficient across the crow-fly and sea distance is much pronounced in this third wave of globalization. Rows 5-6 of Table 2 show results obtained from crow-fly and sea distance variables in separate specifications. The coefficients are negative, statistically significant, and smaller for sea distance throughout this period. The values are -0.31 and -0.14 in 1970, -0.36 and -0.16 for 1980, -0.38 and -0.17 in 1990, -0.43 and -0.22 for 2000 and -0.41 and -0.18 in 2010 for crow-fly and sea distances, respectively. Two more results stand out. First, these estimates for sea distance are consistently smaller than their corresponding sea distance estimates for 1850-1910 in Row 2. Second, these new estimates are also smaller when compared to any other distance estimates in Rows 1, 3, and 4 of Table 2. From 1957 to 1972 marks the period when jet engine usage became widespread in air cargo-freights (Hummels, 2007). Simultaneously, container shipping also spawned in the maritime industry. A given bilateral partners would have choice to use both modes of transport in international trade. For this reason, in Row 7 of Table 2, we combine crow-fly and sea distances into a single specification. The coefficients for crow-fly distances are underlined for clarity in Row 7. The coefficient estimates for crow-fly distance are statistically significant, negative, increasing over time between 1970-2010, and comparable in magnitude to estimates from regression without sea distance in Row 5 of Table 2.

In contrast, sea distance estimates are negative, close to zero, and have lost statistical significance at conventional levels. Per our theory, when both modes of transport in international trade are accounted for and when distance is viewed analogous to transport costs, we find that maritime transport cost has no relevant role in determining trade patterns between 1970-2010. The same is not valid for air transport, wherein it achieved an increasing role in determining trade patterns between countries as it offers a significant and increasing impediment to bilateral trade during the period.

A potential concern with this specification in Rows 1-7 of Table 2 is related to a remarkable increase in the number of preferential trade agreements (PTAs) during this period. PTAs increased from 37 to over 230 between 1995-2010 alone (Fugazza and Nicita, 2013). If these trade agreements affect multilateral resistances and thus the choice with whom countries trade simultaneously, the coefficient estimates may be biased. For this reason, we first add WTO, PTA, and RTA memberships to the specification. The results are presented in Row 1 of Table A2 of the appendix. There is no qualitative change in results with this modification. Second, we use exporter-importer and time-fixed effects instead of importer-time and exporter-time fixed effect panel dummies to soften the potential bias. This specification cannot capture the constant/fixed point estimates that we show in Table 1. It is feasible only to capture their relative changes over time. The results are shown in Row 2 of Table A2. Again, there is no substantive changes in the results.

For a perspective on our overall results so far, the coefficients are small compared to the estimates in Disdier and Head (2008), who report an estimate of 0.68 for 1870 to 1969 in a metanalysis study with 467 distance estimates from 103 papers. These estimates are also smaller relative to the estimates in Yotov (2012; 2017), where the bilateral distance effect is measured relative to internal distance for 1965-2005. Contrast to what Disdier and Head (2008) remark, it is not reassuring to use just the great-circle distances in

gravity estimation without time discrimination.

By now, we have established that the declining effect of distance is revealed with sea distance pertaining to maritime transport, a means by which more than 85% of the goods cross borders annually. These partial equilibrium results provide excellent evidence of an increasingly smaller role for maritime transport over time in bilateral trade. However, they fall short of providing an aggregate measure of the effect of globalization that unfolded since the early 1850s on international trade through its impact on the distance the goods travel in international trade. In the following, we use our theoretical framework to conduct a counterfactual analysis to answer this exact question of the aggregate effect on economies.

VI. Counterfactual Analysis

In the counterfactual scenario, we examine what would be the effect on trade, output, and expenditure assuming port to port distance countries would have to travel in international trade stayed constant as they were during 1762 to 1810 for each of the next corresponding two hundred years. This would imply globalization never happened, steam engines were never invented, and containers were not adopted in shipping. The data availability surrounding the exact onset of globalization is fuzzy. However, available evidence suggests that trade integration increased markedly from 1820 on wards before its interruption during the inter war period (see for example, O'rourke, 2002; Estevadeordal, Frantz and Taylor, 2003; O'rourke and Williamson, 2004) Therefore, we pick an end date of 1810 to allow for potential early onset. The start date is determined by the length of our sample from 1962 to 2010 to which these distances are mapped. As originally shown in Jones (1965) and later implemented in Dekle, Eaton and Kortum (2008) and Costinot and Rodríguez-Clare (2014), we combine exact 'hat algebra' on our theoretical model with its reduced form estimation to conduct the counterfactual exercise.

Step 1. Partial Equilibrium Effect

First, we estimate the baseline gravity model to obtain the point estimates of the effect of air distance, contiguity of borders, common official language of bilateral pairs, and colonial relationship on bilateral trade flows using ppml estimators including the exporter (ϕ_i) and importer (ϕ_{j-1}) fixed effects. We normalize the importer fixed effect with the country of reference, Canada and thus always replace its fixed effect estimate to 1. Thus, we have $j-1$ importer fixed effect estimates. These estimates are then combined to construct baseline bilateral trade costs $(\hat{\tau}_{ijt}^{1-\sigma})$. We use country level aggregate outputs (Y_{it}) and expenditures (E_{jt}), and importer and exporter fixed effects to create multilateral resistances. The additive separability of the ppml estimator allows us to link the estimated exporter $(\hat{\phi}_i)$ and importer $(\hat{\phi}_j)$ fixed effects to the theoretical outward (Π_{it}) and inward multilateral resistances (P_{jt}), respectively. Limiting to any single year for baseline analysis would result in loss of significant amount of country-pairs for the counterfactual analysis. Therefore, atypical to the literature, we choose to use the whole

panel for our baseline estimates.[14]

$$X_{ijt} = exp[\phi_i + \phi_{j-1} + \phi_t + \beta_1 lnDistij + \beta_3 Cntg_{ij} + \beta_4 Lang_{ij} + \beta_5 Clny_{ij}] + \varepsilon_{ijt} \tag{18}$$

$$\hat{\tau}_{ijt}^{1-\sigma} = exp[\hat{\phi}_i + \hat{\phi}_j + \hat{\beta}_1 lnDistij + \hat{\beta}_3 Cntg_{ij} + \hat{\beta}_4 Lang_{ij} + \hat{\beta}_5 Clny_{ij}] \tag{19}$$

$$[\hat{\Pi}_{it}^{1-\sigma}]^{bln} = Y_{it} \frac{E_{rt}}{exp(\hat{\pi}_t^{bln})} \tag{20}$$

where $exp(\hat{\pi}_t^{bln}) = \sum_i^n \hat{\phi}_{it}$

$$[\hat{P}_{jt}^{1-\sigma}]^{bln} = E_{jt} \frac{E_{rt}}{exp(\hat{\chi}_t^{bln})} \tag{21}$$

where $exp(\hat{\chi}_t^{bln}) = \sum_i^n \hat{\phi}_{jt}$

Step 2. Setting the Counterfactual Scenario

Second, we define the counterfactual scenario to simulate the hypothetical removal of the globalization effect especially considering the maritime transportation. For the purpose, we construct the bilateral trade cost variable shown in (22), wherein we replaced the crow-fly distance between two countries present in (19) with port to port distance ships traveled during their actual voyages exactly 200 years ago. For example, the bilateral crow-fly distance between importer Cuba and exporter Portugal for 1965 and 1979 is replaced with the distance navigated by ships during their voyages from La Coruãa of Portugal to La Habana of Cuba in 1765 and 1779, respectively. The counterfactual distances for the years 1965 and 1979 are 3888.5 and 2787 nauticle miles, respectively. Where more than one bilateral port pairs are available, we retain all.

$$[\hat{\tau}_{ijt}^{1-\sigma}]^{cfl} = exp[\bar{\hat{\beta}}_1^{airdist} lnDist_{ij,t-200}^{Maritime} + \bar{\hat{\beta}}_3 Cntg_{ij} + \bar{\hat{\beta}}_4 Lang_{ij} + \bar{\hat{\beta}}_5 Clny_{ij}] \tag{22}$$

With slight abuse of notation, we use ij also to indicate distance between bilateral maritime ports. All other coefficient estimates[15] and the variables are as in (19).

Step 3. Conditional General Equilibrium Effect

Third, we use *logarithmic* form of $\hat{\tau}_{ijt}^{1-\sigma}$ as a constraint in gravity estimation to obtain the conditional general equilibrium values of the multilateral resistances at a given level

[14]The coefficient estimates and standard erors (s.e) from (18) are: $\hat{\beta}_1(s.e) = -1.09(0.132)$, $\hat{\beta}_3(s.e) = -0.72(0.239), \hat{\beta}_4 = -1.17(0.388)$, $\hat{\beta}_5(s.e) = 1.89(0.414)$. In line with the literature, we choose $\sigma = 7$ (see Costinot and Rodríguez-Clare, 2014 for a detailed discussion on the current practices in the literature on the choice of values for elasticity of substitution between goods).

[15]Bars in the coefficient estimates are used to emphasize that the point estimates are taken from (18) as in (19).

of output and expenditure. The re-specified gravity equation with the constraint is shown in (23).

(23)
$$X_{ijt} = exp[\theta_i^{cfl} + \theta_{j-1}^{cfl} + \theta_t^{cfl} + \bar{\hat{\beta}}_1^{airdist} lnDist_{ij,t-200}^{Maritime} + \bar{\hat{\beta}}_3 Cntg_{ij} + \bar{\hat{\beta}}_4 Lang_{ij} + \bar{\hat{\beta}}_5 Clny_{ij}]\varepsilon_{ijt}^{cfl}$$

where $\{\theta_i, \theta_{j-1}, \theta_t\}$ indicate new sets of exporter, importer (less the country of reference, see step 1 for details) and time fixed effects, respectively, estimated under the counterfactual (cfl) scenario in (23). The estimated exporter and importer fixed effects are used to construct the new conditional general equilibrium (CD) multilateral resistances shown in (24) and (25).

$$[\hat{\Pi}_{it}^{1-\sigma}]^{CD} = Y_{it} \frac{E_{rt}}{exp(\hat{\pi}_t^{CD})} \tag{24}$$

where $exp(\hat{\pi}_t^{CD}) = \sum_i^n \hat{\theta}_{it}^{cfl}$

$$[\hat{P}_{jt}^{1-\sigma}]^{CD} = E_{jt} \frac{E_{rt}}{exp(\hat{\chi}_t^{CD})} \tag{25}$$

where $exp(\hat{\chi}_t^{CD}) = \sum_i^n \hat{\theta}_{jt}^{cfl}$

The changes to the trade costs τ_{ijt}, because of the change in distance variable, produces first order general equilibrium effect on X_{ijt} through direct changes in i and j's multilateral resistances. Notice the denominators in (24) and (25), they aggregate over all countries. For this reason, changes in multilateral resistances for i and j will also trigger changes in multilateral resistances for all other countries. In turn, these changes in multilateral resistances for all other countries channel to trade for all other countries, also through these newly affected multilateral resistances. The output and expenditure are still held constant at this stage.

Step 4. General Equilibrium (GE) Effect: Cumulative Impact of Globalization through the Distance Effect of International Trade

In this step, we endogenize the value of output (Y_{it}) and expenditure (E_{it}) in a four stage iterative procedure. We start by endogenizing the factory-gate prices. The change in factory-gate price would lead to changes in the value of domestic production (Y_{it}) and aggregate expenditure (E_{it}), which in turn would trigger additional changes to the multilateral resistance terms, and so forth. Thus, necessitating an iterative procedure. We conduct the iteration as follows:

i. First, we allow factory-gate prices (p_{it}) to respond to counterfactual trade costs $[\hat{\tau}_{ijt}^{1-\sigma}]^{cfl}$ and the associated ripple effects in multilateral resistances $(\hat{\Pi}_{it}^{CD}, \hat{P}_{jt}^{CD})$. For each of the country in our sample, the new factory-gate price is computed relative to its

original/baseline factory gate price as shown in (26).

$$\frac{p_{it}^{cfl}}{p_{it}} = \left(\frac{exp(\hat{\pi}_t^{CD})/E_{rt}^{CD}}{exp(\hat{\pi}_t)/E_{rt}} \right)^{\sigma-1} \tag{26}$$

ii. Second, we capture the first-order changes to the bilateral trade X_{ijt}^{cfl} of changes in factory gate prices as shown in (27).

$$X_{ijt}^{cfl} = \frac{[\tau_{ijt}^{1-\sigma}]^{cfl}}{\tau_{ijt}^{1-\sigma}} * \frac{Y_{it}^{cfl} E_{jt}^{cfl}}{Y_{it} E_{jt}} * \frac{\hat{\Pi}_{it}^{1-\sigma}}{[\hat{\Pi}_{it}^{1-\sigma}]^{cfl}} * \frac{\hat{P}_{jt}^{1-\sigma}}{[\hat{P}_{jt}^{1-\sigma}]^{cfl}} * X_{ijt} \tag{27}$$

iii. Third, we re-estimate the gravity specification using this new bilateral trade value as the dependent variable in (28):

$$X_{ijt}^{cfl} = exp[\gamma_i^{cfl} + \gamma_{j-1}^{cfl} + \theta_t^{cfl} + \bar{\hat{\beta}}_1^{airdist} lnDist_{ij,t-200}^{Maritime} + \bar{\hat{\beta}}_3 Cntg_{ij} + \bar{\hat{\beta}}_4 Lang_{ij} + \bar{\hat{\beta}}_5 Clny_{ij}] \varepsilon_{ijt}^{cfl} \tag{28}$$

where γs represent newer sets of importer and exporter fixed effects. Note its similarity with specification (23). Finally, we iterate the first through third stage described above to obtain newer sets of factory-gate prices, outputs, expenditures, and bilateral trade. We repeat these three stages in a loop[16] until the mean change in the factory-gate prices approaches zero, that is when the structural gravity model would have reached its new general equilibrium.[17] Thus, we retrieve the general equilibrium values for $\hat{\Pi}_{it}^{1-\sigma}$, $\hat{P}_{jt}^{1-\sigma}$, $\hat{p}_{it}^{1-\sigma}$, $\hat{X}_{ijt}$, and $\hat{Y}_{it}$. We compute their changes with respect to their baseline values. Detailed GE results are shown in Table A3, a short summary of the key results are shown in Table 3. We discuss these general equilibrium results below.

When we hypothetically remove the world from globalization in the counterfactual analysis discussed above, we find that outward multilateral resistances increase markedly, up to 14 times their baseline values in the sample (Row 1. Table 3). This change is uneven across countries. At the thresholds, top 25%, 10%, 5% and 1% of the countries in the distribution experience 2.5, 5.1, 5.6, and 14.7 folds increase in their multilateral resistances, respectively. The new outward multilateral resistance is more than double its baseline value for an average country in the distribution.

Given the above change in outward multilateral resistance, the natural question arises, what changes in the inward multilateral resistances compared to their baseline values would keep the factory gate prices unchanged at the new GE level. As shown in Row 2 Table 3, for countries below the 50th percentile, the inward multilateral resistances would have to decrease by about 99% ($[\hat{P}_{jt}^{1-\sigma}]^{ge}$). This result holds across the empirical

[16] Our algorithm could not estimate importer and exporter fixed effects for all cases when implementing the loop. For those missing estimates, we filled in using the time average of importer and exporter fixed effects in the sample.

[17] It brings to the natural question of what constitutes an appropriate convergence to zero, especially for data with high variance. As a rule, we sought convergence from below and above zero and stopped the loop when standard deviation stabilized.

distribution. For example, top 25%, 10%, and 5% of the countries in our sample would need a decline of 97%, 94%, and 87% to their inward multilateral resistances compared to their baseline values. For the top 1% of the countries, our model predicts an increase of 56% in their inward multilateral resistances.

Factory gate prices have generally decreased but fluctuate across countries. In Row 3 Table 3, the top 25%, 10%, and 5% of the countries experience a decline in factory gate price by 26%, 12%, and 6% compared to their baseline values. For the top 1%, the factory gate prices nearly doubled. For an average country in our sample, factory gate prices for producers have declined by approximately 50%.

The changes in multilateral resistances and factory gate prices have resulted in an average decline of 75% in the country's GDP in our sample (Row 4 Table 3). Across the distribution, we find a 99.4% drop at the 1% threshold, 98.4% at 5%, 96% at 10%, and 90.5% at 25% thresholds.

TABLE 3—CUMULATIVE IMPACT OF GLOBALIZATION ON DISTANCE EFFECT OF INTERNATIONAL TRADE

		Percentiles of Countries								
		1	5	10	25	50	75	90	95	99
Row 1.	$\frac{\hat{\Pi}_{ge}^{1/1-\sigma} - \hat{\Pi}_{bln}^{1/1-\sigma}}{\hat{\Pi}_{bln}^{1/1-\sigma}} * 100\%$	-67	-20	15	37	117	254	506	561	1475
Row 2.	$\frac{\hat{P}_{ge}^{1/1-\sigma} - \hat{P}_{bln}^{1/1-\sigma}}{\hat{P}_{bln}^{1/1-\sigma}} * 100\%$	-100	-99	-99	-99	-99	-98	-94	-87	57
Row 3.	$(P_i - 1) * 100\%$	-100	- 99	-89	- 66	-50	-27	- 13	-6	155
Row 4.	$\frac{GDP_{ge} - GDP_{bln}}{GDP_{bln}} * 100\%$	-99	-98	-97	-91	-74	-44	-20	5	662

*Notes:*This table summarizes the results from the counterfactual analysis described in Section VI. Full results for individual countries are presented in Tabale A3. Values represent changes in outward multilateral resistances (Row 1), inward multilateral resistances (Row 2), factory-gate prices (Row 3) and real GDP (Row 4) at given threshold percentiles. Holding outward multilateral resistances constant, Row 2 shows changes in inward multilateral resistance that would keep the price at the GE level. All changes are computed relative to their respective baseline (bln) values. $GDP = \frac{Y}{\hat{P}_i^{1/1-\sigma}}$, where Y is country-level output. GDP_{ge} and GDP_{bln} use respective ge and bln values for P_i and Y for computations. See text for further details.

We plot the relationship between percentage change in factory gate prices and percentage change in GDP in Figure 4A. The change in price is shown in y-axis and the change in GDP on the x-axis. The changes are measured relative to their respective baseline values. Given the panel nature of our data, for each country in our sample, the changes reflect the mean of changes in GDP and in factory gate prices over 48 years. As

shown, the GDP is monotone in positive ranges of the price, but as the prices fall there is a faster and non-monotone fall in the GDP. In the same graph, we also show the link between change in producer price and the change in outward multilateral resistances. There is a sharp rise in prices when multilateral resistances are approaching zero, and a non-monotone fall in prices in the positive domain of the multilateral resistances.

Figure 4B depicts relationship between proportionate changes in outward multilateral resistances and proportionate changes in real GDP. As in Figure 4A, we use the mean (over time) values of their changes.[18] There is a gradual decline in the GDP as the change in multilateral resistance approaches zero. Anywhere else in the multilateral resistances, fall in GDP is sharp. Importantly, change in GDP never turns positive with positive changes in outward multilateral resistances. That is, GDP never increases as the outward multilateral resistances increase compared to their baseline values. We plot the empirical densities for change in output and change in aggregate trade in Figure 4C and 4D, respectively. Consistent with our discussion above, bulk of these density is located left of zero.

[18]This same graph can also be obtained by correspondence mapping of changes in multilateral resistances onto y-axis and in GDP onto the x-axis.

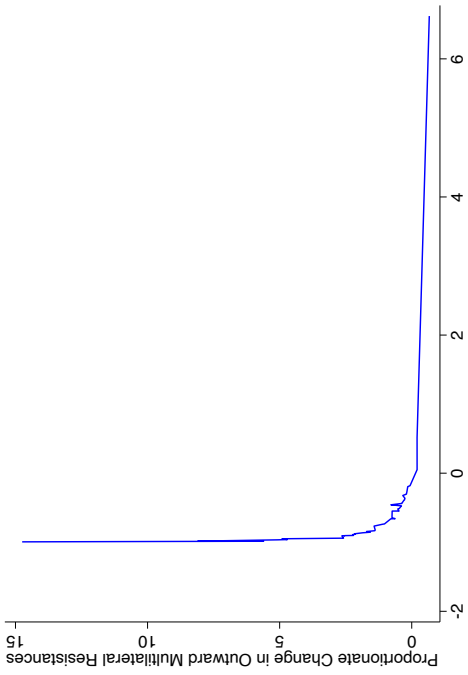


Figure B. Multilateral Resistance vs GDP

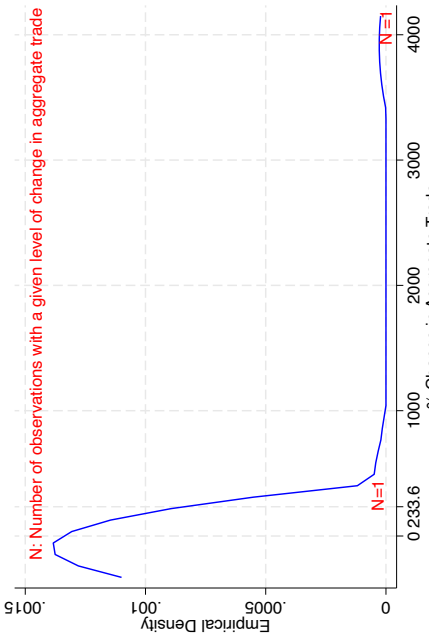


Figure D. Empirical Density Change in Aggregate Trade

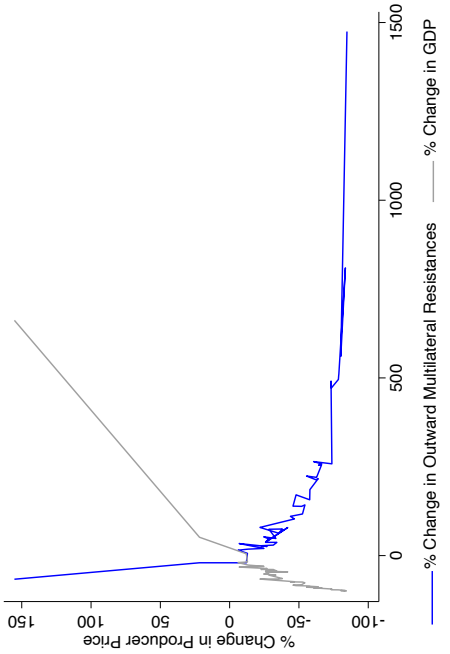


Figure A. Producer Price vs Multilateral Resistance, GDP

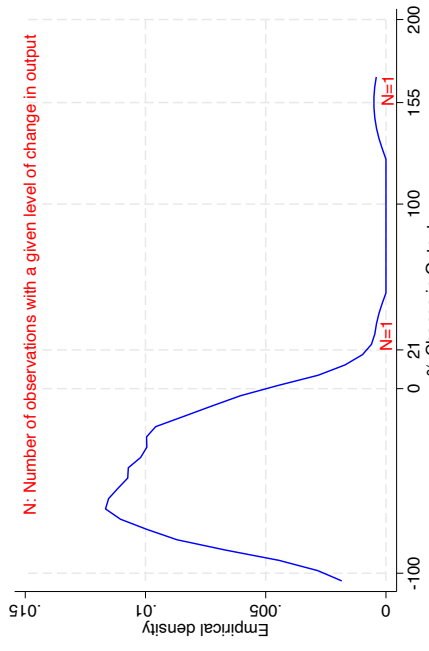


Figure C. Empirical Density Change in Output

FIGURE 4. CUMULATIVE IMPACT OF GLOBALIZATION ON DISTANCE EFFECT OF INTERNATIONAL TRADE

Given the extent of increase in multilateral resistances, decrease in factory gate price, and changes to the output, it is not surprising that our counterfactual exercise has enacted autarky equilibrium for economies. What is surprising is, we started with a reasonably optimistic scenario by bounding the distance elasticity to present day values, yet our counterfactual exercise ends with recreating hypothetical scenario where 49 out of 52 countries in the sample show zero international trade at equilibrium, which in most counterfactual analysis would be an extreme start point. Thus, we conclude globalization is very much present in estimates of the distance effect of trade and is not shy to reveal its true nature in the grand scale of time it has come unfolded.

VII. Conclusion

Disdier and Head(2008) note that "the distance coefficient is hardly affected by the use of distances by road or by sea...Perhaps it is reassuring to all who have relied on the great-circle distances because they wanted to avoid the task of collecting actual distances traveled". We make use of the recently available large collection of data on historical distances navigated by ships during their voyages in the mid-eighteenth to the early nineteenth century, and combine with shortest sea distances ships travel in modern-day international trade, and crow-fly distance to examine how globalization has affected the distance effect of international trade. To address this question, we build a sequential search model into a trade model such that transportation cost takes the role of marginal cost and the search cost the role of variable fixed cost. This model allows us to test the distance effect by considering both sea and air distance goods travel in international trade. The regression results reveal that the distance effect of international trade has indeed been declining over time and that the results are clear with sea distance. The estimates of distance elasticity are negative, statistically significant, and close to zero from 1962 to 2010 with sea distance. Temporal estimates show a monotonic decline between 1850 and 1910 and a non-monotonic between 1962 and 2010. Our general equilibrium results from the counterfactual analysis, which combines historical sea distance with modern-day bilateral trade data, corroborate our partial equilibrium result. If the distance effect remained constant despite globalization, it would generate autarky equilibrium for most economies in our sample.

An interesting feature of our integrated trade model is that it leads to no natural autarky equilibrium. Typically, the autarky equilibrium is a theoretical transition, allowing one to extract general implications for an open economy as the assumptions are gradually relaxed. It is well recognized that the autarky equilibrium has little empirical relevance. In this sense, we hope future works will develop general equilibrium frameworks along this line to study the full implications and relevance of leapfrogging this step for predictions about trade globalization.

REFERENCES

Acciaro, Michele, and Patrizia Serra. 2013. "Maritime supply chain security: A critical review." 636–651.

Anderson, James E, and Eric van Wincoop. 2003. "Gravity with gravitas: A solution to the border puzzle." *American Economic Review*, 93(1): 170–192.

Antràs, Pol. 2020. "Deglobalisation? Global value chains in the post-COVID-19 age." *NBER 28115*.

Antràs, Pol, Alonso De Gortari, and Oleg Itskhoki. 2017. "Globalization, inequality and welfare." *Journal of International Economics*, 108: 387–412.

Arkolakis, Costas. 2010. "Market penetration costs and the new consumers margin in international trade." *Journal of Political Economy*, 118(6): 1151–1199.

Arribas, Iván, Francisco Pérez, and Emili Tortosa-Ausina. 2011. "A new interpretation of the distance puzzle based on geographic neutrality." *Economic Geography*, 87(3): 335–362.

Beckmann, Martin J. 1976. "Spatial equilibrium in the dispersed city." In *Environment, Regional Science and Interregional Modeling*. 132–141. Springer.

Bernhofen, Daniel M, Zouheir El-Sahli, and Richard Kneller. 2016. "Estimating the effects of the container revolution on world trade." *Journal of International Economics*, 98: 36–50.

Berthelon, M, and C Freund. 2004. "On the Conservation of Distance in International Trade, World Bank Policy Research Working Paper, no. 3293." *Washington, DC: World Bank*.

Bertoli, Simone, Michaël Goujon, and Olivier Santoni. 2016. "The CERDI-seadistance database."

Blum, Bernardo S, and Avi Goldfarb. 2006. "Does the internet defy the law of gravity?" *Journal of International Economics*, 70(2): 384–405.

Borchert, Ingo, and Yoto V Yotov. 2017. "Distance, globalization, and international trade." *Economics Letters*, 153: 32–38.

Boulhol, Hervé, and Alain De Serres. 2010. "Have developed countries escaped the curse of distance?" *Journal of Economic Geography*, 10(1): 113–139.

Brancaccio, Giulia, Myrto Kalouptsidi, and Theodore Papageorgiou. 2020. "Geography, transportation, and endogenous trade costs." *Econometrica*, 88(2): 657–691.

Brooks, Mary R, and Peter Faust. 2018. *Fifty years of review of maritime transport, 1968-2018: Reflecting on the past, exploring the future.* Technical Report, UNCTAD.

Brun, Jean-Francois, Céline Carrère, Patrick Guillaumont, and Jaime De Melo. 2005. "Has distance died? Evidence from a panel gravity model." *World Bank Economic Review*, 19(1): 99–120.

Buch, Claudia M, Jörn Kleinert, and Farid Toubal. 2004. "The distance puzzle: On the interpretation of the distance coefficient in gravity equations." *Economics Letters*, 83(3): 293–298.

Buehler, David, and Roger White. 2015. "A simple solution to the distance puzzle: Balanced data and Poisson estimation." *Applied Economics Letters*, 22(7): 587–592.

Carrère, Céline, Jaime De Melo, and John Wilson. 2013. "The distance puzzle and low-income countries: An update." *Journal of Economic Surveys*, 27(4): 717–742.

Chaney, Thomas. 2018. "The gravity equation in international trade: An explanation." *Journal of Political Economy*, 126(1): 150–177.

Chaudhari, Bhargav N, and Timothy T Takahashi. 2022. "Reassessing the B2707-100 Supersonic Transport Aircraft." 0776.

Coe, David T, Arvind Subramanian, Natalia T Tamirisa, and Rikhil R Bhavnani. 2002. "The missing globalization puzzle." *IMF Working Paper*.

Costinot, Arnaud, and Andrés Rodríguez-Clare. 2014. "Trade theory with numbers: Quantifying the consequences of globalization." In *Handbook of International Economics*. Vol. 4, 197–261. Elsevier.

Deardorff, Alan V. 2003. "Time and trade: The role of time in determining the structure and effects of international trade, with an application to Japan." *Japan's Economic Recovery*, 63–76.

Dekle, Robert, Jonathan Eaton, and Samuel Kortum. 2008. "Global rebalancing with gravity: Measuring the burden of adjustment." *IMF Staff Papers*, 55(3): 511–540.

Disdier, Anne-Célia, and Keith Head. 2008. "The puzzling persistence of the distance effect on bilateral trade." *Review of Economics and statistics*, 90(1): 37–48.

Dixit, Avinash K, and Joseph E Stiglitz. 1977. "Monopolistic competition and optimum product diversity." *American Economic Review*, 67(3): 297–308.

Dornbusch, Rudiger, Stanley Fischer, and Paul Anthony Samuelson. 1977. "Comparative advantage, trade, and payments in a Ricardian model with a continuum of goods." *American Economic Review*, 67(5): 823–839.

Estevadeordal, Antoni, Brian Frantz, and Alan M Taylor. 2003. "The rise and fall of world trade, 1870–1939." *Quarterly Journal of Economics*, 118(2): 359–407.

Federico, Giovanni, and Antonio Tena-Junguito. 2017. "A tale of two globalizations: gains from trade and openness 1800–2010." *Review of World Economics*, 153(3): 601–626.

Frankel, Jeffrey A, Ernesto Stein, and Shang-Jin Wei. 1997. *Regional trading blocs in the world economic system.* Peterson Institute.

Fugazza, Marco, and Alessandro Nicita. 2013. "The direct and relative effects of preferential market access." *Journal of International Economics*, 89(2): 357–368.

Goldberg, Pinelopi K, and Nina Pavcnik. 2004. "Trade, inequality, and poverty: What do we know? Evidence from recent trade liberalization episodes in developing countries." *NBER 10593*.

Goldberg, Pinelopi Koujianou, and Nina Pavcnik. 2007. "Distributional effects of globalization in developing countries." *Journal of Economic Literature*, 45(1): 39–82.

Grossman, Gene M, and Elhanan Helpman. 2015. "Globalization and growth." *American Economic Review*, 105(5): 100–104.

Head, Keith, and Thierry Mayer. 2014. "Gravity equations: Workhorse, toolkit, and cookbook." In *Handbook of International Economics*. Vol. 4, 131–195. Elsevier.

Henderson, J Vernon. 1987. "General equilibrium modeling of systems of cities." In *Handbook of Regional and Urban Economics*. Vol. 2, 927–956. Elsevier.

Hummels, David. 2007. "Transportation costs and international trade in the second era of globalization." *Journal of Economic Perspectives*, 21(3): 131–154.

Jacks, David S. 2009. "On the death of distance and borders: Evidence from the nineteenth century." *Economics Letters*, 105(3): 230–233.

Jacks, David S, Christopher M Meissner, and Dennis Novy. 2011. "Trade booms, trade busts, and trade costs." *Journal of International Economics*, 83(2): 185–201.

Jones, Ronald W. 1965. "The structure of simple general equilibrium models." *Journal of Political Economy*, 73(6): 557–572.

Karpiarz, Mariusz, Piotr Fronczak, and Agata Fronczak. 2014. "International trade network: Fractal properties and globalization puzzle." *Physical Review Letters*, 113(24): 248701.

Krugman, Paul. 1980. "Scale economies, product differentiation, and the pattern of trade." *American Economic Review*, 70(5): 950–959.

Krugman, Paul. 1991. "Increasing returns and economic geography." *Journal of Political Economy*, 99(3): 483–499.

Krugman, Paul. 1992. *Geography and Trade.* MIT press.

Larch, Mario, Pehr-Johan Norbäck, Steffen Sirries, and Dieter M Urban. 2016. "Heterogeneous firms, globalisation and the distance puzzle." *The World Economy*, 39(9): 1307–1338.

Leamer, Edward E. 2007. "A flat world, a level playing field, a small world after all, or none of the above? A review of Thomas L Friedman's The World is Flat." *Journal of Economic Literature*, 45(1): 83–126.

Levison, Marc. 2006. *The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger.* Princeton, NJ:Princeton University Press.

Lin, Faqin. 2013. "Are distance effects really a puzzle?" *Economic Modelling*, 31: 684–689.

Lin, Faqin, and Nicholas CS Sim. 2012. "Death of distance and the distance puzzle." *Economics Letters*, 116(2): 225–228.

Li, Qing, Chao Xue, Jian-Ping Liu, Jun-Fei Wu, Shan-Qing Yang, Cheng-Gang Shao, Li-Di Quan, Wen-Hai Tan, Liang-Cheng Tu, Qi Liu, et al. 2018. "Measurements of the gravitational constant using two independent methods." *Nature*, 560(7720): 582–588.

López-Córdova, J Ernesto, and Christopher M Meissner. 2005. "The globalization of trade and democracy, 1870-2000." *NBER 11117*.

Mayer, Thierry, and Soledad Zignago. 2011. "Notes on CEPII's distances measures." *CEPII Working Paper 2011-25*.

Melitz, Marc J. 2003. "The impact of trade on intra-industry reallocations and aggregate industry productivity." *Econometrica*, 71(6): 1695–1725.

Notteboom, Theo, and Jean-Paul Rodrigue. 2008. "Containerisation, box logistics and global supply chains: The integration of ports and liner shipping networks." *Maritime Economics & Logistics*, 10(1): 152–174.

Notteboom, Theo E. 2006. "The time factor in liner shipping services." *Maritime Economics & Logistics*, 8(1): 19–39.

O'rourke, Kevin H, and Jeffrey G Williamson. 2004. "Once more: When did globalisation begin?" *European Review of Economic History*, 8(1): 109–117.

O'rourke, Kevin H. 2002. "Europe and the causes of globalization, 1790 to 2000." In *Europe and Globalization*. 64–86. Springer.

Pascali, Luigi. 2017. "The wind of change: Maritime technology, trade, and economic development." *American Economic Review*, 107(9): 2821–54.

Rauch, Ferdinand. 2016. "The geometry of the distance coefficient in gravity equations in international trade." *Review of International Economics*, 24(5): 1167–1177.

Soloaga, Isidro, and L Alan Wintersb. 2001. "Regionalism in the nineties: What effect on trade?" *North American Journal of Economics and Finance*, 12(1): 1–29.

Standaert, Samuel, Stijn Ronsse, and Benjamin Vandermarliere. 2016. "Historical trade integration: globalization and the distance puzzle in the long twentieth century." *Cliometrica*, 10(2): 225–250.

Sun, Yicheng, and Howard Smith. 2022. "Design and operational assessment of a low-boom low-drag supersonic business jet." *Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering*, 236(1): 82–95.

UNCTAD. 2011. "Review of Maritime Transport, 2011."

UNCTAD. 2021. "Review of Maritime Transport, 2021."

Yilmazkuday, Hakan. 2017. "A Solution to the Missing Globalization Puzzle by Non-CES Preferences." *Review of International Economics*, 25(3): 649–676.

Yotov, Yoto V. 2012. "A simple solution to the distance puzzle in international trade." *Economics Letters*, 117(3): 794–798.

APPENDIX

TABLE A1—SUMMARY STATISTICS ON DIFFERENT MEASURES OF DISTANCE

Log of Distance	Obs	Mean	Std. Dev.	Min	Max
Crow-fly with internal distance	1,137,448	8.64	0.90	0	9.90
Sea with internal distance	1,136,948	8.93	1.10	0	10.21
Crow-fly distance	1,128,246	8.67	0.81	4.09	9.90
Sea distance	1,127,746	8.97	0.97	0	10.22
Historical distance	700	7.39	1.24	1.25	10.76

Notes: All distances are in logarithmic scales. Crow-Fly distance is from CEPII database. Sea distance is from the CERDI-sea distance database. The historical distance corresponds to distances navigated by ships during their voyages from 1762 to 1810 and are constructed from the Cliwoc database (see text for further details). Internal distance is as in Mayer and Zignago, (2011).

TABLE A2—DISTANCE EFFECT WHILE CONSIDERING TRADE POLICY IMPACT

	Year							
	1970	1980	1990	2000	2010	*Obs*	*Pseudo LL*	*Pseudo* R^2
Row 1.	-0.67, -0.06	-0.69, 0.48	-0.73, -0.43	-0.78, -0.31	-0.98, -0.23	832,811	-3.51297e+14	0.81
	(0.047, 0.039)	(0.16, 0.15)	(0.15, 0.14)	(0.13, 0.08)	(0.08, 0.06)			
Row 2.	-0.13, 0.08	-0.05, -0.01	-0.08, 0.02	0.07, -0.004	0.11, -0.05	1119,584	-2.13747e+13	0.99
	(0.041, 0.036)	(0.025, 0.022)	(0.025, 0.020)	(0.022, 0.017)	(0.029, 0.020)			

Notes: Estimates shown are for crow-fly and sea distance and are separated by commas. The estimates for crow-fly distance are underlined. Robust standard errors (S.E.) in parentheses. The dependent variable is nominal exports. Row 1 includes importer-time and exporter-time fixed effects, and Row 2 includes exporter-importer and time fixed effects whose estimates are omitted for brevity. Estimates in Row 2 are relative changes, standardized for 1965 values. Both rows include PTA (PTA recipient exports), WTO (both in WTO) and RTA (importer and exporter in a common RTA) membership variables. The sample includes intranational trade, and bilateral distance is replaced with internal distance for intranational trade. See text for further details. Obs stands for the number of observations, and Pseudo LL for Pseudo Log-likelihood in PPML estimation.

TABLE A3—GENERAL EQUILIBRIUM (GE) RESULTS

Country	$\frac{\hat{\Pi}_{ge}^{1/1-\sigma} - \hat{\Pi}_{bln}^{1/1-\sigma}}{\hat{\Pi}_{bln}^{1/1-\sigma}}$	$(-1) * \frac{\hat{P}_{ge}^{1/1-\sigma} - \hat{P}_{bln}^{1/1-\sigma}}{\hat{P}_{bln}^{1/1-\sigma}}$	$\frac{GDP_{ge} - GDP_{bln}}{GDP_{bln}}$	$(P_i - 1)$	$\frac{\hat{X}_{i,ge} - \hat{X}_{i,bln}}{\hat{X}_{i,bln}}$
	(1)	(2)	(3)	(4)	(5)
Algeria	74.81535	56.67327	64.55989	-38.04525	-100
Antigua and Barbuda	142.5471	76.59148	-54.3009	-43.22333	-100
Argentina	25.66585	36.33747	-26.95238	-19.99794	-100
Australia	6.359511	98.20786	-18.06293	-12.85213	-100
Bahamas	33.85105	96.55814	-32.30584	-6.87474	-100
Barbados	-20.25129	98.68739	5.082698	-12.03084	-100
Bermuda	258.2027	99.51312	-94.08781	-73.76662	-99.99
Brazil	117.067	99.38163	-74.46317	-52.55703	-100
Cabo Verde	139.2059	98.78899	-83.2441	-45.69242	-100
Canada	110.4613		-73.90836	-43.8507	-99.99
Chile	20.19238	99.5007	-30.30883	-24.72674	-100
China, Hong Kong	74.09773	95.61536	-54.84209	-28.36479	-100
China, Macao	-66.49432	83.39191	661.9435	155.2944	-100
Comoros		98.00882		-99.51559	-100
Cuba	29.46592	98.97474	-39.11865	-31.51942	235.57
Dominica		-96.24493		-99.42982	-100
Equatorial Guinea	1474.693		-99.40209	-84.64605	-100
France	15.14351	98.95058	-19.50875	-6.081557	-100
Gambia	506.4127	91.23127	-96.48207	-78.66681	-100
Ghana	37.26057	99.1244	-43.54636	-34.05566	-100
Guadeloupe	257.7351	95.85204	-90.62531	-66.46343	-100
Guinea	18.17596	97.43545	-26.6664	-13.33731	-100
Guyana	255.1888		-90.50011	-66.25746	-100
India	38.94899	99.125	-47.2643	-26.13955	-100
Indonesia	48.07764	99.34461	-54.78477	-33.36982	-100
Ireland	37.20573	98.54411	-43.81329	-25.89316	-100
Italy	78.90194	99.03174	-45.78412	-41.8884	-100
Jamaica	62.97342	98.1649	-65.84017	-35.34803	-100
Madagascar	264.5304	99.06497	-90.76466	-60.60184	-100
Malaysia	27.72611	98.91455	-38.94477	-22.63185	-100
Mali	47.05836	98.52024	-51.14065	-28.14825	-100
Martinique	79.25465	94.19501	-66.09019	-21.88122	-100
Mauritius	185.6569	98.33336	-86.2878	-57.90336	-100
Mexico	52.87909	97.93948	-51.81094	-24.60615	-100
Mozambique	253.376	98.91031	-90.40941	-66.10915	-100
Netherlands	138.5186	99.13419	-81.92342	-51.87697	511.29
Norway	103.1577	99.36777	-73.47945	-46.74064	-100
Oman	809.5446		-98.39346	-83.49901	-99.99
Peru	216.5648	98.98239	-87.76418	-63.89518	-100
Philippines	495.6274		-96.38474	-78.46655	-99.99
Portugal	220.1274	98.72034	-90.12963	-62.72578	3919.70
Saint Kitts and Nevis	491.0379		-94.97373	-73.14358	-99.99
Senegal	560.7826	94.33149	-98.5211	-80.19775	-100
Sierra Leone	471.282	97.56344	-96.13882	-73.31108	-100
Spain	223.8351	99.23837	-88.98698	-55.51391	-100
Sri Lanka	213.5301	96.92258	-88.17369	-62.16873	-99.99
Suriname	157.0962	98.98555	-85.4675	-57.75994	-99.99
Switzerland	510.5959		-96.5267	-78.79215	-99.99
United Kingdom	170.9333		-84.48243	-47.92643	-100
Uruguay	254.3385		-90.57649	-64.15382	-100
Yemen	-20.18007	97.13777	51.6108	21.75922	-100

Notes: The results are based on the counterfactual analysis described in Section VI. All estimates are computed relative to their baseline and are in % values, % symbol suppressed for brevity. Column 1 shows the change in outward multilateral resistances (OMR). Holding OMR constant, column 2 shows changes in inward multilateral resistance that would keep the price at the GE level. Changes in GDP and factory gate prices are shown in columns 3 and 4, respectively. Each aggregate variable is our sample's time average (see text for more details). When aggregated averages at baseline are zero, we do not report values in columns 1-2.