Technology with unequal gains: Steamship and globalization

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Summary

- What was the effect of steamships on development?
- Digitize shipping data using deep learning
- Unequal gains using the market access approach
- Extend trade with heterogeneous firms to understand this difference in gains

Outline

1. Why Steamships?
2. Data and Digitization
3. Empirical Evidence on Unequal Gains
4. Adoption of Steamships: Theory
5. Adoption of Steamships: Estimation

Technology and Integration

What if

- the world became more integrated?
- the technology to integrate was not available to all?

Why unequal gains from integration?

- Generally positive gains from trade
  (Donaldson, 2015) (Redding & Venables, 2004) (Donaldson & Hornbeck, 2016) (Bernhofen et al., 2016)
- Difference in gains due to transportation
  (Pascali, 2017) (Faber, 2014) (Campante & Yanagizawa-Drott, 2018) (Okoye et al., 2019)
- How does transportation technology relate to differences in gains?
- Relates to whether technology worsens inequality
  (Reichardt, 2023) (Goldin & Katz, 1998) (Acemoglu & Autor, 2011)

Steamships as an ideal case study

- Huge changes in the late 19th century (1880-1914)
  - The First Era of Globalization
  - The Great Divergence
  - Transition from sailing to steamships (natural experiment)
- Null average effect of trade (Pascali, 2017)
- Why?
  - Transportation technology is not adopted uniformly?
  - Possible to see who actually used steamships!

The paper

- Digitize historical documents using deep learning
  - Shipping data to see who used steamships
  - Provide precise measurement in changes in duration
- Evidence of gains from the transportation technology
  - Large gains due to access to large consumer markets
  - Smaller gains from access to large suppliers
  - Negative effects for colonized countries
- Provides a framework to think about trade and technology
  - (Melitz, 2003)
  - Incorporate sailing and steamships
  - Show differences in welfare

Data and Digitization

Overview

- Country-level (Pascali, 2017)
- Port-level (Lloyd's Shipping Index)

Country level

For 1880-1900 (Pascali, 2017)

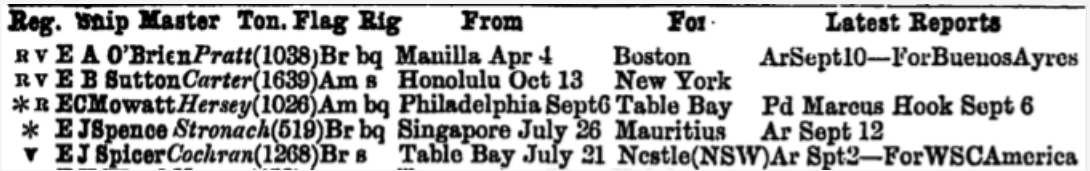
- Country-level trade volumes (in US pounds)
- Country-level GDP, population, institution

Port level

- Lloyd's Shipping Index

  Used in (Juhász & Steinwender, 2018) (Xu, 2022)

- Comprehensive data set on global shipping from 1880
  - Weekly reports compiled by the insurance company Lloyd's
  - Ships travelling from port to port

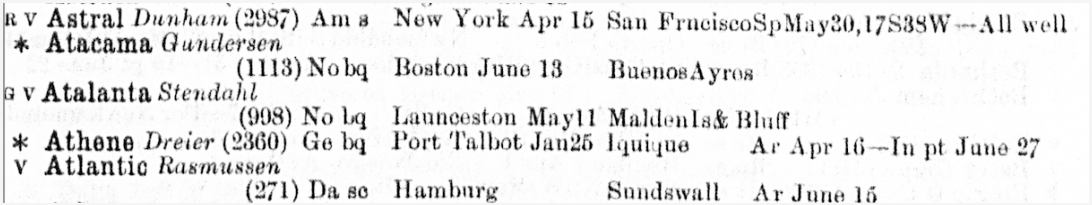


Reg.	Ship	Master	Ton.	Flag	Rig	From	For	Latest Reports
R V	E A O'Brien	*Pratt*	(1038)	Br	bq	Manilla Apr 4	Boston	ArSept10—ForBuenosAyres
R V	E B Sutton	*Carter*	(1639)	Am	s	Honolulu Oct 13	New York	
* R	E C Mowatt	*Hersey*	(1026)	Am	bq	Philadelphia Sept6	Table Bay	Pd Marcus Hook Sept 6
*	E J Spence	*Stronach*	(519)	Br	bq	Singapore July 26	Mauritius	Ar Sept 12
V	E J Spicer	*Cochran*	(1268)	Br	s	Table Bay July 21	Ncstle(NSW)	Ar Spt2—ForWSCAmerica

Deep Learning in Digitization

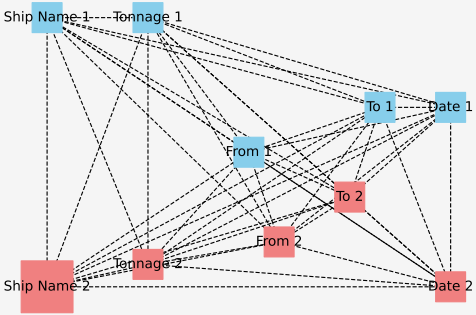
Recognize from images

- Texts (Optical Character Recognition)
  - LayoutParser (Shen et al., 2021)
- Tables (Table Structure Recognition)
  - Difficult even in contemporary documents
  - Bottleneck in other digitization efforts



Idea and Algorithm

Predict each connection of words



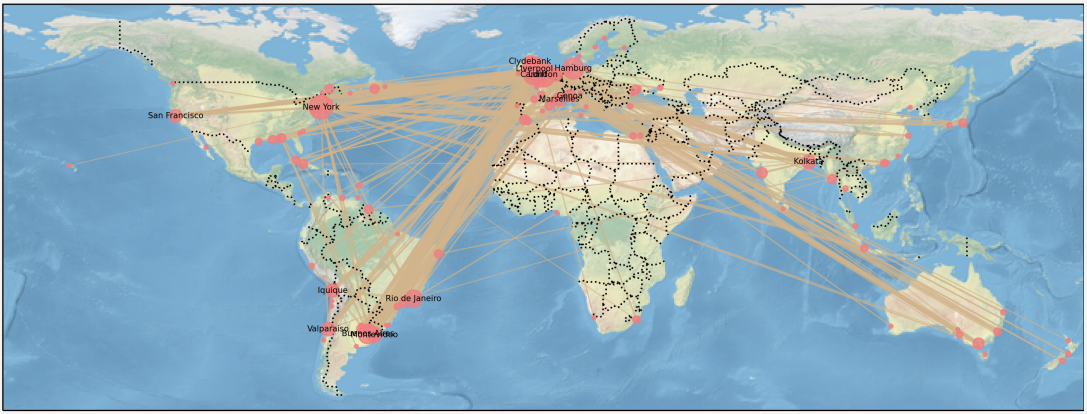
- Text information
  - Google OCR
  - BERT (Large Language Model)
- Connections
  - Graph Neural Network

Lloyd's Shipping Index 1.0

Extract 30,000 trips across the years 1880, 1890, and 1900

- Port to port by sailing and steamships
  - Total tonnage (tons)
  - Duration (days)
- Caveat
  - Reporting bias (skewed towards ships in Europe)
  - Digitization Error (skewed towards common ship trips)

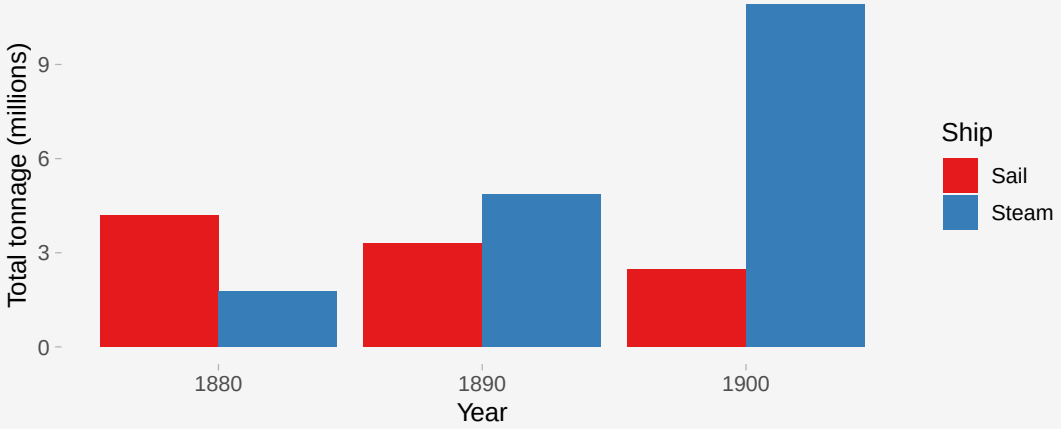
Shipping Network



Empirical Evidence

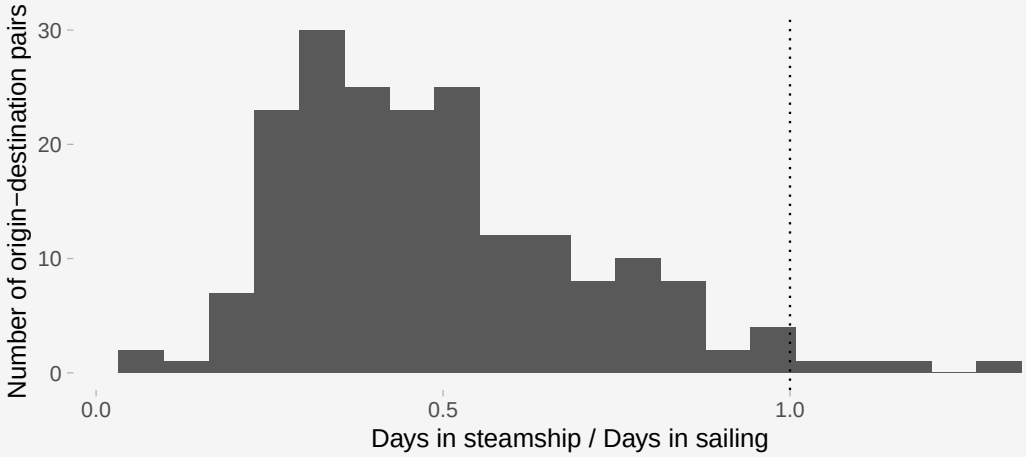
Steamships vs Sailing

The adoption of steamships in the late 19th century



Faster

Change in duration by origin-destination pair $\frac{duration_{ij}^{steam}}{duration_{ij}^{sail}}$



Empirical framework

$$\Delta GDP\ Per\ Capita_c = \beta_0 + \beta_1 \Delta Market\ Access_c + \beta_2 \Delta Supplier\ Access_c + \nu_c \quad (1)$$

$$Market\ Access_{i,t} = \sum_j duration_{ij,t}^{-1}\ population_{j,t} \quad (2)$$

$$Supplier\ Access_{i,t} = \sum_j duration_{ji,t}^{-1}\ population_{j,t} \quad (3)$$

- 1880 ... Duration of sailing ships
- 1890 ... Weighted duration of sailing and steamships
- 1900 ... Duration of steamships

Average positive effect of steamships

Dependent Variable:	$\Delta GDPpercapita$		
Model:	(1)	(2)	(3)
Variables			
$\Delta MarketAccess$	0.061***		0.103***
	(0.012)		(0.024)
$\Delta SupplierAccess$		0.064***	-0.066*
		(0.023)	(0.035)
Fixed-effects			
Year	Yes	Yes	Yes
Fit statistics			
R^2	0.465	0.236	0.448
Observations	59	59	58

Clustered (Country) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

- Export market increases wage
- Import market increases real wage
- Import market increases competition

Negative effect on colonized countries

Dependent Variable:	$\Delta GDPpercapita$	
Model:	(1)	(2)
Variables		
$\Delta MarketAccess$	0.062***	
	(0.015)	
Colony	-0.122***	-0.097***
	(0.037)	(0.028)
$\Delta MarketAccess \times$ Colony	-0.087***	
	(0.030)	
$\Delta SupplierAccess$		0.091***
		(0.028)
$\Delta SupplierAccess \times$ Colony		-0.123***
		(0.036)
Fixed-effects		
Year	Yes	Yes
Fit statistics		
R^2	0.528	0.404
Observations	59	59

Low steamships adoption at the port level

Dependent Variables: Model:	Only sailing (1)	Only steam (2)	Share steam (3)
Variables			
Constant	0.649***	0.067***	0.177***
	(0.025)	(0.021)	(0.021)
Year 1900	-0.379***	0.279***	0.424***
	(0.032)	(0.028)	(0.027)
Year 1880 × Colony	0.050	0.010	-0.030
	(0.052)	(0.045)	(0.043)
Year 1900 × Colony	0.173***	-0.082**	-0.133***
	(0.044)	(0.038)	(0.037)
Fit statistics			
R^2	0.135	0.097	0.217
Observations	1,096	1,096	1,096

IID standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Steamships increasing inequality

- Steamships provided faster transportation
- This increased integration did not benefit colonized countries
- The low adoption of steamships as a possible explanation

Adoption of Steamships: Theory

Motivation

Can standard trade theory explain this?

- **Difference in fixed cost of adoption**
  - Port investment
- Shipping sector in the trade cost
- Outside trade (e.g. institutions)

Overview

- Trade with heterogeneous firms (Melitz, 2003)
- Include differences in shipping technology
  - duration
  - adoption cost
- Welfare difference between countries differing in adoption rate

Set up

- Set of countries S
- Exogenous measure L_i of workers in $i \in S$ supply unit labour at wage w_i
- Representative consumer has CES preferences over varieties from all firms

$$U_j = \left(\sum_{i \in S} \int_{\Omega_{ij}} (q_{ij}(\omega))^{\frac{\sigma}{\sigma-1}} d\omega \right)^{\frac{\sigma-1}{\sigma}}$$

- Demand of good $\omega \in \Omega$

$$q_{ij}(\omega) = p_{ij}(\omega)^{-\sigma} Y_j P_j^{\sigma-1}$$

$$P_j = \left(\sum_{i \in S} \int_{\Omega_i} p_{ij}(\omega)^{1-\sigma} d\omega \right)^{\frac{1}{1-\sigma}}$$

Y_j ... income of country j

Firm's decision

- Every firm in the world produces a distinct variety $\omega \in \Omega$
- A firm uses $\frac{1}{\varphi}$ unit of labour to produce a unit of its variety, drawn from $G_i(\varphi)$.
- Conditional on selling to j, subject to iceberg trade cost $\{\tau_{ij}\}_{i,j \in S}$

$$p_{ij}(\varphi) = \frac{\sigma}{\sigma - 1} \frac{w_i}{\varphi} \tau_{ij}$$

$$x_{ij}(\varphi) = \left(\frac{\sigma}{\sigma - 1} \frac{w_i}{\varphi} \tau_{ij} \right)^{1-\sigma} Y_j P_j^{\sigma - 1}$$

Which firm uses steamships?

- A ship type $s \in \{sail, steam\}$ has different τ_{ij}^s and f_{ij}^s, fixed cost to export to j
- The profit of a firm with productivity φ using ship s is

$$\pi_{ij}^s(\varphi) = \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\frac{w_i}{\varphi}\tau_{ij}^s\right)^{1-\sigma} Y_j P_j^{\sigma-1} - f_{ij}^s$$

- Cutoff productivity for exporting using sailing or steamships

$$\varphi_{ij,sail}^* = \left(\frac{\sigma f_{ij}^{sail}\left(\frac{\sigma}{\sigma-1}w_i\tau_{ij}^{sail}\right)^{\sigma-1}}{Y_j P_j^{\sigma-1}}\right)^{\frac{1}{\sigma-1}}$$

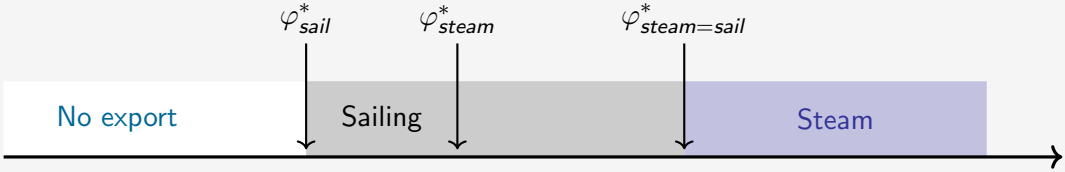
$$\varphi_{ij,steam}^* = \varphi_{ij,sail}^*\left((f_{ij}^{steam}/f_{ij}^{sail})(\tau_{ij}^{steam}/\tau_{ij}^{sail})^{\sigma-1}\right)^{\frac{1}{\sigma-1}}$$

$$\varphi_{ij,steam=sail}^* = \varphi_{ij,sail}^*\left(\frac{(f_{ij}^{steam}/f_{ij}^{sail})-1}{(\tau_{ij}^{steam}/\tau_{ij}^{sail})^{1-\sigma}-1}\right)^{\frac{1}{\sigma-1}}$$

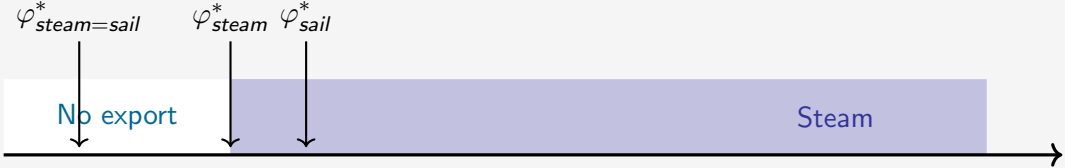
Difference in adoption

When using steamship is harder to export: $\varphi^*_{sail} \leq \varphi^*_{steam}$

Figure: Export and ship used when cost of using steamship is high



When using steamship is easier to export: $\varphi^*_{sail} > \varphi^*_{steam}$



Welfare

- Entry cost to the domestic market (Cutoff productivity φ^* for producing)
- Expected profits must be equal to the fixed cost of entry
- Set wage as the numeraire
- Welfare is described by the price index

Fixed cost and Welfare

Under the assumptions of (1) symmetric countries and (2) productivity is Pareto distributed with shape parameter $\theta > \sigma - 1$, welfare monotonically increases as the fixed cost of using steamships decreases

Adoption of Steamships: Estimation

Are facts consistent with theory?

- The relative fixed cost of using steamships crucial for differences in gains
- Do colonized countries have a higher fixed cost of adoption ($f_{ij}^{steam}/f_{ij}^{sail}$)?

Estimating adoption costs by port-pairs

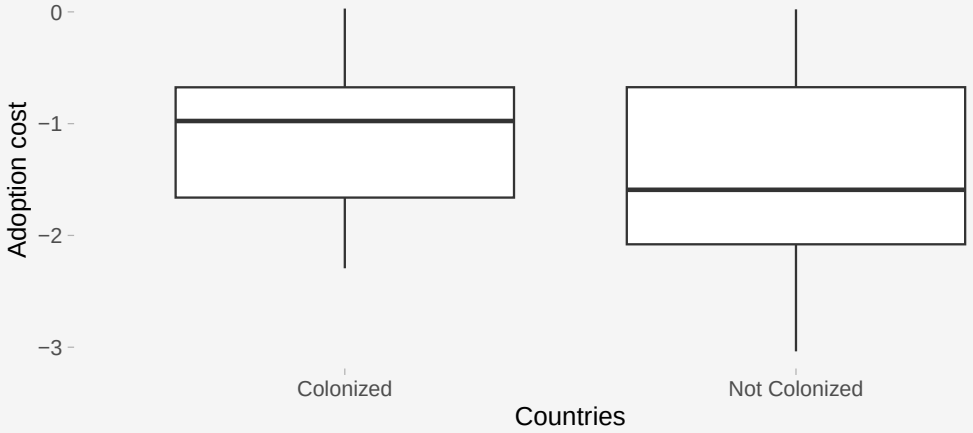
Fixed cost using ports with both sailing and steamships

$$\mu_{ij} = \frac{\int_{\varphi^*_{steam=sail}}^{\infty} q_{ij}(\varphi) dG(\varphi)}{\int_{\varphi^*_{sail}}^{\infty} q_{ij}(\varphi) dG(\varphi)} = \frac{\tau_{ij}^{steam}/\tau_{ij}^{sail}}{1 - \left(\frac{f_{ij}^{steam}/f_{ij}^{sail} - 1}{(\tau_{ij}^{steam}/\tau_{ij}^{sail})^{1-\sigma} - 1} \right)^{\frac{1}{1-\sigma}}}$$

Fixed cost using ports that transitioned to full steamships

$$\log x_{ij,t+1} - \log x_{ij,t} = \alpha_i + \alpha_j - \theta_i \log \left(\tau_{ij}^{steam}/\tau_{ij}^{sail} \right) + \frac{\sigma - \theta_i}{\sigma - 1} \log \left(f_{ij}^{steam}/f_{ij}^{sail} \right)$$

Difference between colonized or not



More questions (Preliminary)

Close the model

- Port investment
- Institution

Introducing Port Investment

Decompose fix cost into rents for both ports: $f_{ij}^s = r_i^s r_j^s$

- Competitive market of landlords
  - firms pay the "marginal cost" of using the port
  - Port productivity depends on fundamental and past sailing ship usage $A_i^s = \bar{A}_i^s X_{i,t-1}^{\lambda}$
- Dynamic problem
  - invest in ports if the expected sum of profits is higher than not
  - endogenous rent seems difficult

Conclusion

Summary of work so far

- Digitized valuable historical shipping data
- Provided preliminary evidence on unequal benefits from steamships
- Incorporated shipping technology into a canonical trade model to illustrate biased technology upgrade

Take away

- Digitization of historical documents is an active field
- Evidence of transportation technology and its distributive effect is relatively unknown
- Standard trade model may provide insights into inequality and the effect of integration

comments, questions, advice, critiques etc.

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