Spatial Production Networks[1]

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[1] The views and opinions expressed are those of the authors alone and do not necessarily reflect those of the Central Bank of Chile.

Motivation

- Key feature of a modern economy is the geographic complexity of production networks
  - Fragmented across countries, regions, and firms
  - “Global Value Chains” crucial for economic success (World Bank ’19)

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  - **Microeconomics** of how firms form endogenous production networks
  - **Macroeconomic** conditions determined by production network across countries and regions

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- Two current approaches advancing in *parallel* (Johnson '18, Antràs & Chor '21)
  - **Microeconomics** of how firms form endogenous production networks
  - **Macroeconomic** conditions determined by production network across countries and regions
- Limited theoretical and empirical understanding of how endogenous network affects aggregate trade flows and welfare across countries and regions

This Paper

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    - Firms form supplier and buyer relationships across space under trade costs and matching frictions

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  - Gravity equations of trade flows in extensive (number of relationships) and intensive margins
  - Existence/uniqueness, minimal data requirement for counterfactuals, welfare sufficient statistics
  - Characterize first- and second-order effects of shocks on aggregate welfare

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- Characterize aggregate production networks and spatial distribution of economic activity
  - Gravity equations of trade flows in extensive (number of relationships) and intensive margins
  - Existence/uniqueness, minimal data requirement for counterfactuals, welfare sufficient statistics
  - Characterize first- and second-order effects of shocks on aggregate welfare
- Using calibrated model using firm-to-firm transaction data from Chile, show that:
  - Search and matching frictions are as important as iceberg cost for aggregate trade flows
  - Endogenous network $\Rightarrow$ larger & more dispersed effects of inter- and intra-national trade shocks

Literature

- Production networks and global value chains
  - "Macro" approaches: Yi '03, '09; Johnson-Noguera '12; Caliendo-Parro '15; Johnson-Moxnes '19; Antràs-Chor '19; Huo-Levchenko-Pandalai-Nayar '20
  - "Micro" approaches / endogenous networks: Bernard-Moxnes '18; Oberfield '18; Lim '18; Huneeus '18; Bernard-Moxnes-Saito '19; Furusawa-Inui-Ito-Tang '19; Boehm-Oberfield '20; Bernard-Dhyne-Magerman-Manova-Moxnes '20; Zou '20; Dhyne-Kikkawa-Kong-Mogstad-Tintelnot '22; Demir-Fieler-Xu-Yang '21
  - Endogenous networks in space: Eaton-Kortum-Kramarz '22; Miyauchi '21; Panigraphi '21; Antràs-de-Gortari '20
- Microfounded gravity trade models and sufficient statistics for welfare: Anderson '79; Eaton-Kortum '02; Melitz '03; Chaney '08; Eaton-Kortum-Kramarz '11; Arkolakis-Costinot-Rodriguez-Clare '12; Caliendo-Parro '15; Allen-Arkolakis-Takahashi '19
- Propagation of shocks in production networks:
  - Hulten '78; Atkeson-Burstein '10; Baqaee-Fahri '19, '20
  - Acemoglu-Carvalho-Ozdaglar-Tahbaz-Salehi '12; Di-Giovanni-Levchenko-Mejean '14, 18; Acemoglu-Akcigit-Kerr '16; Carvalho-Nirei-Saito-Tahbaz-Salehi '21; Caliendo-Parro-Rossi-Hansberg-Sarte '18

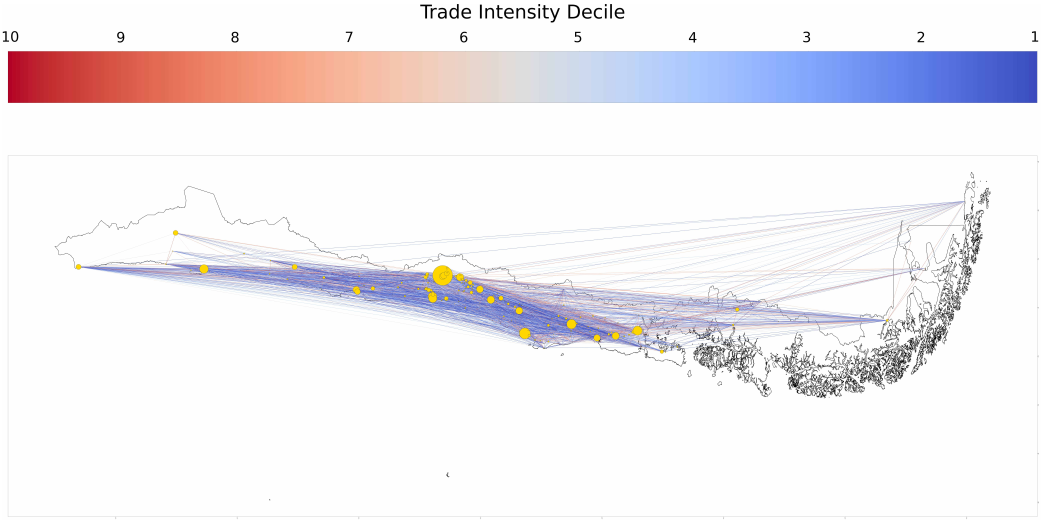
Outline

Outline

Data

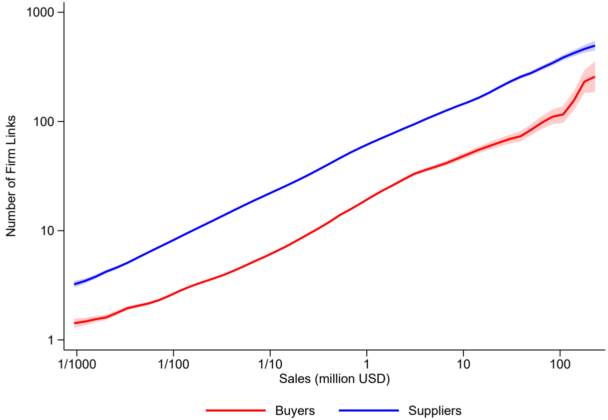
- Domestic firm-to-firm transaction-level dataset in Chile
  - Collected for value-added tax collection purpose
  - Covers the universe of domestic trade between all firms in Chile in 2018 and 2019
  - Seller and buyer tax ID, dates, total amounts, origin and destination municipalities of establishments (345 municipalities in Chile)
- Combined with various firm-level data sets:
  - Customs data $\Rightarrow$ Imports and exports
  - Firm balance sheet characteristics $\Rightarrow$ Total sales, labor share, sector

Chilean Domestic Network



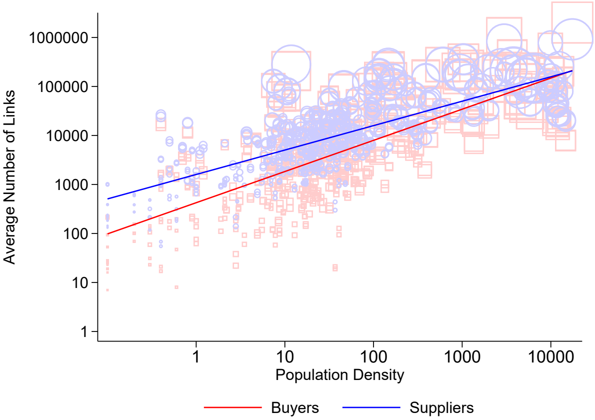
Size of the dot represents aggregate revenue

1. Domestic Suppliers & Buyers and Firm Size



- Number of domestic suppliers and buyers per firm correlated with firm size, consistent with findings in other contexts (e.g. Bernard-Saito-Moxnes '18, Lim '18)

2. Domestic Suppliers & Buyers and Geographic Location



- Number of domestic suppliers and buyers per firm correlated with market size
- Robust to controlling for firm size details

3. Intensive and Extensive Margin of Trade Flows

$$\log TradeFlow_{ijt} = \beta \log Dist_{ij} + \xi_{it} + \zeta_{jt} + \epsilon_{ijt}$$

where i, j are municipalities in Chile and t is year

	Total		Intensive		Extensive	
	(1)	(2)	(3)	(4)	(5)	(6)
Log Distance	-1.334***		-0.404***		-0.929***	
	(0.006)		(0.005)		(0.003)	
Log Time Travel		-1.571***		-0.482***		-1.089***
		(0.008)		(0.006)		(0.003)
R^2	0.639	0.639	0.312	0.313	0.818	0.816
Origin Municipality-Year FE	✓	✓	✓	✓	✓	✓
Destination Municipality- Year FE	✓	✓	✓	✓	✓	✓
Same Municipality- Year FE	✓	✓	✓	✓	✓	✓
N	134898	134898	134898	134898	134898	134898

- Extensive and intensive margin decay at different rates

Outline

Data and Motivating Facts

Model and Theoretical Analysis

Quantitative Analysis

Conclusion

Set-Up

- Space: $i, u, d \in N$, workers: L_i
- Goods:
  - Intermediate goods: traded across locations subject to iceberg trade cost $\tau_{ud} \geq 1$
  - Final goods: locally traded
- Firms:
  - Reach final consumers and buy/supply intermediate goods to other firms
  - Firm productivity $z \sim g_i(z)$
  - Cobb-Douglas production with labor (β) and intermediates from connected suppliers, CES within intermediates (σ)
- Single sector for model presentation, multiple sector for quantification

Production given Networks

- Unit cost of production by firm ω in location d

$$c_d(\omega) = \frac{1}{z(\omega)} w_d^{\beta} \left(\int_{\upsilon \in \mathcal{S}(\omega)} p_{id}(\upsilon, \omega)^{1-\sigma} d\upsilon \right)^{\frac{1-\beta}{1-\sigma}}$$

  - $z(\omega)$: productivity of firm ω
  - w_d: local wage
  - $p_{id}(\upsilon, \omega)$: the price charged by supplier υ in location i to ω
  - $\mathcal{S}(\omega)$ is the set of suppliers that ω has access to (endogenized later)

- Each supplier is monopolistic to each buyer $\Rightarrow$ constant markup

$$p_{id}(\upsilon, \omega) = \tilde{\sigma} \tau_{id} c_i(\upsilon), \quad \tilde{\sigma} = \frac{\sigma}{\sigma - 1}$$

- Final consumers: CES utility with same substitution σ

Production Network Formation

- Firms with productivity z in location i choose optimal level of advertisement to:
  - final consumers: post n_i^F, no matching frictions, no cross-region trade (Arkolakis '10)
  - firm buyers and suppliers: post n_{ui}^S, n_{id}^B, random matching with probability m_{ui}^S, m_{id}^B determined through matching functions (DMP; Demir-Fieler-Xu-Yang '21)
- Search costs:

$$e_i \left\{ f_i^F \frac{\left(n_i^F\right)^{\gamma^F}}{\gamma^F} + \sum_{d \in N} f_{id}^B \frac{\left(n_{id}^B\right)^{\gamma^B}}{\gamma^B} + \sum_{u \in N} f_{ui}^S \frac{\left(n_{ui}^S\right)^{\gamma^S}}{\gamma^S} \right\}$$

Search and Matching between Firms

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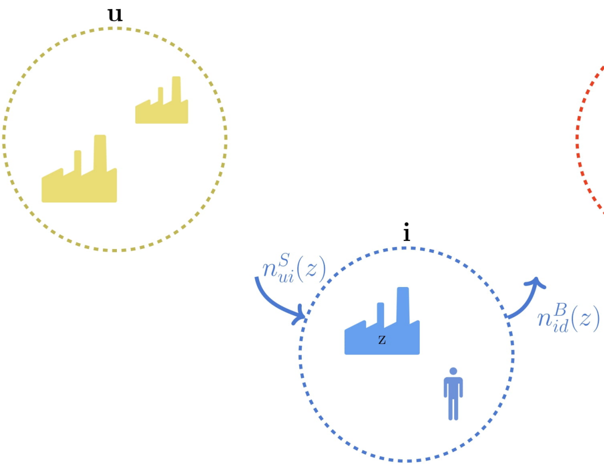

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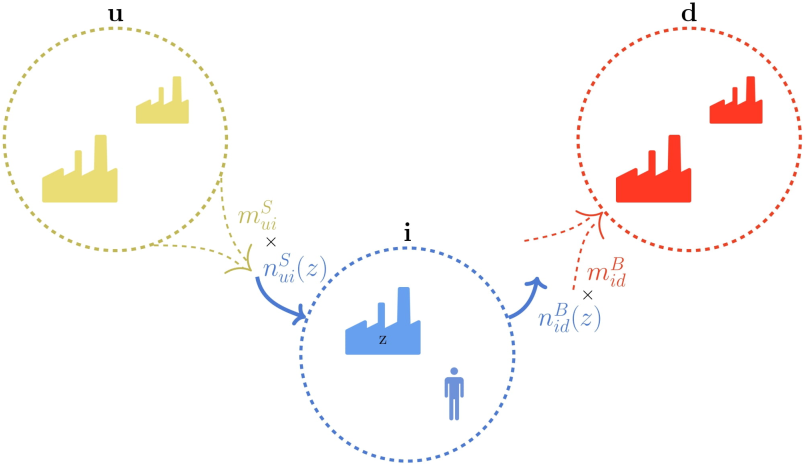
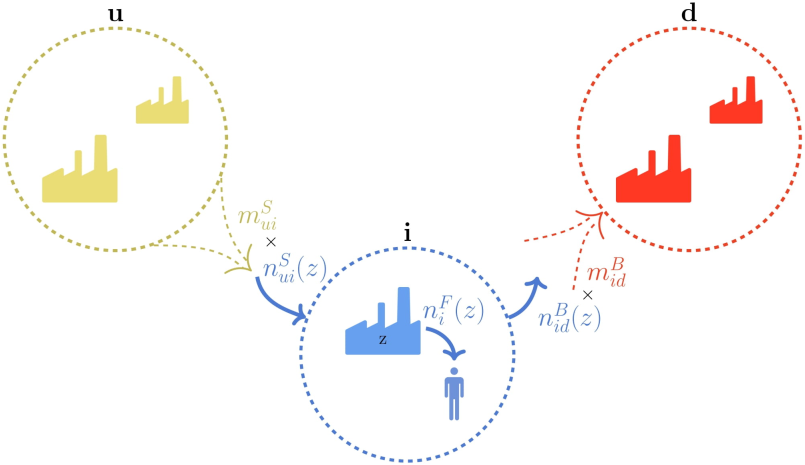


Search for Final Consumers



Firm's Search Problem

$$\max_{\{n^S_{ui}\}_u,\{n^B_{id}\}_d,n^F_i} \underbrace{\frac{1}{\sigma} n^F_i \left(\tilde{\sigma} c_i(z)\right)^{1-\sigma} D^F_i}_{\text{profit from consumers}} + \underbrace{\frac{1}{\sigma} \sum_{d\in N} m^B_{id} n^B_{id} \left(\tilde{\sigma} c_i(z) \times \tau_{id}\right)^{1-\sigma} D_d}_{\text{profit from firm buyers}}$$

$$\underbrace{- e_i \left\{ f^F_i \frac{\left(n^F_i\right)^{\gamma^F}}{\gamma^F} + \sum_{d\in N} f^B_{id} \frac{\left(n^B_{id}\right)^{\gamma^B}}{\gamma^B} + \sum_{u\in N} f^S_{ui} \frac{\left(n^S_{ui}\right)^{\gamma^S}}{\gamma^S} \right\}}_{\text{search cost}}$$

$$\text{subject to} \quad c_i(z) = \frac{w_i^{\beta} \left(\sum_{u\in N} n^S_{ui} m^S_{ui} \left(C_{ui}\right)^{1-\sigma} \right)^{\frac{1-\beta}{1-\sigma}}}{z}$$

- D^F_i, D_d: demand shifters (isoelastic demand from CES demand + random matching)
- e_i: unit cost for advertisement
- $f^F_i, f^B_{id}, f^S_{ui}, \gamma^F, \gamma^B, \gamma^S$: exogenous parameters for search cost; Assume $\gamma^F = \gamma^B$
- C_{ui}: average intermediate goods cost from u to i

Solution to Firm's Search Problem

- Solution gives:

$$n_i^F(z) = a_i^F z^{\frac{\delta_1}{\gamma^B}}, \quad n_{id}^B(z) = a_{id}^B z^{\frac{\delta_1}{\gamma^B}}, \quad n_{ui}^S(z) = a_{ui}^S z^{\frac{\delta_1}{\gamma^S}}$$

where $\delta_1 \equiv \frac{\sigma-1}{1-\frac{1}{\gamma^B}-\frac{1-\beta}{\gamma^S}}$

  - a_{ui}^S, a_{id}^B depend on bilateral search/iceberg cost, demand shifters (***geography***)
  - Number of linkages relates to geography and firm size, Cf Fact 1 and 2

- Unit cost of firm with productivity z:

$$c_i(z) = (C_i^*) \times z^{-\frac{\delta_1}{\gamma^S}\frac{1-\beta}{\sigma-1}-1}, \quad (C_i^*)^{1-\sigma} \equiv w_i^{\beta(1-\sigma)}\left(\sum_{u\in\mathcal{N}} a_{ui}^S m_{ui}^S \left(\tilde{\sigma} C_u^* \tau_{ui}\right)^{1-\sigma}\right)^{1-\beta}.$$

  - C_i^* summarizes "supplier market access" in region i

Matching between Suppliers and Buyers

- Measure of supplier-to-buyer relationships determined by Cobb-Douglas matching function:

$$M_{ud} = \kappa_{ud} \Bigg(\underbrace{N_d \int n^S_{ud}(z) dG_d(z)}_{\tilde{M}^S_{ud} \equiv} \Bigg)^{\lambda^S} \Bigg(\underbrace{N_u \int n^B_{ud}(z) dG_u(z)}_{\tilde{M}^B_{ud} \equiv} \Bigg)^{\lambda^B}$$

- Matching probability (intensity):

$$m^S_{ud} = \frac{M_{ud}}{\tilde{M}^S_{ud}} \quad m^B_{ud} = \frac{M_{ud}}{\tilde{M}^B_{ud}}$$

Gravity Equations of Aggregate Trade Flows

- Total number of successful relationships ("extensive margin"), from u to d

$$M_{ud} = \varrho^E \chi^E_{ud} \zeta^E_u \xi^E_d, \qquad \chi^E_{ud} \equiv \left[\kappa_{ud} \left(f^B_{ud}\right)^{-\tilde{\lambda}^B} \left(f^S_{ud}\right)^{-\tilde{\lambda}^S} \left(\tau^{1-\sigma}_{ud}\right)^{\tilde{\lambda}^S + \tilde{\lambda}^B}\right]^{\delta_2}$$

$$\tilde{\lambda}^S \equiv \lambda^S / \gamma^S, \tilde{\lambda}^B \equiv \lambda^B / \gamma^B, \delta_2 \equiv \left[1 - \tilde{\lambda}^S - \tilde{\lambda}^B\right]^{-1}$$

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- Transaction volume per relationship ("intensive margin")

$$\bar{r}_{ud} = \varrho^I \chi^I_{ud} \zeta^I_u \xi^I_d, \qquad \chi^I_{ud} \equiv \left(\tau_{ud} \right)^{1-\sigma}$$

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- Different response of "extensive" and "intensive" to trade frictions (Cf Fact 3)

General Equilibrium

- Embed the production network formation model into general equilibrium framework:
  - Free firm entry (N_i)
  - Trade balance (w_i)
  - Cost shifter ($C_u^* \propto C_{ui}/\tau_{ui}$) and demand shifter ($D_d$, D_d^F) from accounting relationships
- Advertisement cost (e_i):

$$e_i = A_i \left(w_i\right)^{\mu} \left(C_i^*\right)^{1-\mu}$$

  - μ: labor share in search cost

Theoretical Results

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3. Show that a special case with exogenous production networks ($\lambda^B = \lambda^S = 0$) is isomorphic to gravity trade models with roundabout production
   - Eaton-Kortum '02, Alvarez-Lucas '07, Caliendo and Parro '14 (single-sector); Eaton-Kortum-Kramarz '11; Arkolakis-Costinot-Rodriguez-Clare (ACR) '12; Costinot-Rodriguez-Clare '14

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4. Import penetration & domestic linkages sufficient stat for welfare, extending ACR '12
5. First- and second- order effects on aggregate welfare amplified by endogenous network formation, extending Baqaee-Farhi '20

Sufficient Statistics for Welfare

Proposition

Consider an iceberg cost shock $\{\hat{\tau}_{ij}\}$. The proportional change of welfare is given by:

$$\widehat{\frac{w_i}{P_i^F}} = \left(\underbrace{\hat{\Lambda}_{ii}}_{\text{aggregate own import share}} \Big/ \underbrace{\hat{M}_{ii}}_{\text{number of linkages within location}} \right)^{-\frac{1}{\sigma-1}\frac{1-\beta}{\beta}\left(1+\frac{\gamma^B-1}{\gamma^B}\frac{1-\mu}{\sigma-1}\right)}$$

- $\lambda^B = \lambda^S = 0 \Rightarrow \hat{M}_{ii} = 1 \Rightarrow$ Gravity trade models (Arkolakis '10; ACR '12)
- $\hat{M}_{ii}$ captures "variety" effect of suppliers (cf Golderg et al '10, Gopinath-Neiman '14)

First-Order Effect of Trade Shocks on Aggregate Welfare

Proposition

The first-order effect of $\{d \log \tau_{ij}\}$ *on world welfare is given by:*

$$d \log \mathcal{W} = \underbrace{-\sum_{i,j} \varsigma X_{ij} d \log \tau_{ij}}_{\textit{technological effect}} + \underbrace{\frac{1}{\sigma - 1} \sum_{i,j} \varsigma X_{ij} d \log M_{ij}}_{\textit{endogenous network effect}}$$

where $\varsigma \equiv \frac{1-\beta}{1-\tilde{\beta}} \frac{\tilde{\beta}}{\beta} \left(1 + \frac{1}{\gamma^B} \frac{1-\mu}{\sigma-1}\right) \geq 1$

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- Extend Baqaee-Fahri '20 with endogenous production networks
- Second term: "variety" effect of suppliers (cf Golderg et al '10, Gopinath-Neiman '14)

First-Order Effect on World Welfare: Amplification

Proposition

"Endogenous network effect" is proportional to "technological effect," i.e.,

$$\underbrace{\frac{1}{\sigma-1}\sum_{i,j}\varsigma X_{ij}\, d\log M_{ij}}_{\textit{endogenous network effect}} = \frac{\left(\tilde{\lambda}^S+\tilde{\lambda}^B\right)\frac{1-\beta}{\beta}\frac{1-\mu}{\sigma-1}}{1-\left(\tilde{\lambda}^S+\tilde{\lambda}^B\right)\frac{1-\beta}{\beta}\frac{1-\mu}{\sigma-1}}\underbrace{\left(-\sum_{i,j}\varsigma X_{ij}\, d\log\tau_{ij}\right)}_{\textit{technological effect}}.$$

- Amplification from endogenous network if
  - $\tilde{\lambda}^S+\tilde{\lambda}^B=\lambda^S/\gamma^S+\lambda^B/\gamma^B>0$ and $\beta<1$
  - $\mu<1$ (search cost is partly paid by intermediate goods) second-order effect

Outline

Calibration

- Multiple sector (9) extension as in Caliendo-Parro '15: Cobb-douglas in tech/pref detail
- Calibrate the model with 345 municipalities in Chile + US, China, ROW
- Exactly match bilateral sectoral domestic & international trade flows ($X_{ud,kl}$)

Parameters	Value	Description	Source
α_k	Figure 1	Final consumption share	Observed Final Consumption Share in Each Sector
$\{\beta_{k,L}, \beta_{kl}\}$	Figure 2	Sectoral input share in production	Observed Input Share in Each Sector
μ	0.58	Labor share in advertisement service sector	Observed Labor Share in Advertisement Sector
λ^S	0.5	Matching function elasticity w.r.t. suppliers	Krolikowski and McCallum (2021)
λ^B	0.5	Matching function elasticity w.r.t. buyers	Krolikowski and McCallum (2021)
γ_k^S	Figure 3	Search cost curvature w.r.t. suppliers	Elasticity of Sales to Number of Suppliers (Cond. on Location FE)
γ_k^B	Figure 3	Search cost curvature w.r.t. buyers	Elasticity of Sales to Number of Buyers (Cond. on Location FE)
σ_k	Figure 4	Elasticity of substitution	Fontagne et al (2022) and Gervais and Jensen (2019)

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- Show that both iceberg trade costs and search-and-matching frictions are important determinant for aggregate trade flows and production networks detail

Aggregate Effects of Tariff Changes from/to US and China

- Reverse tariff changes from/to US and China as observed in the last two decades detail

	Imports (p.p.)		Exports (p.p.)	
	China	US	China	US
a) Agriculture and Fishing	-6.54	-6.54	-12.84	-1.86
b) Mining	-6.45	-6.45	-2.63	-0.20
c) Manufacturing	-6.45	-6.45	-13.06	-3.85

- Compare results with exogenous production networks

Aggregate Effects of Tariff Changes from/to US and China

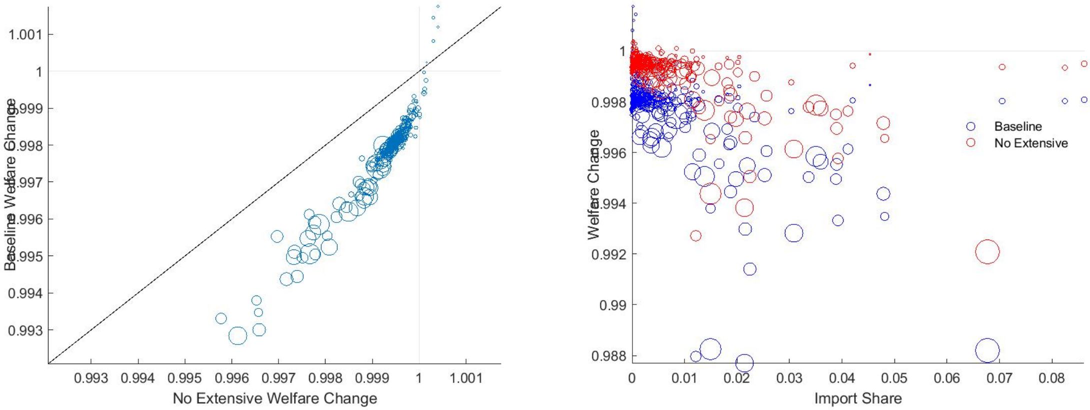
	1) $\widehat{\text{Welfare}}$ (%)	2) Rel. to Baseline	3) $\hat{X}_{ui,u\in\{\text{US,China}\}}$	4) $\hat{X}_{ui,u\in\text{Chile}}$	5) $\hat{M}_{ui,u\in\{\text{US,China}\}}$	6) $\hat{M}_{ui,u\in\text{Chile}}$
a) Baseline	-0.67	100	-5.95	0.23	-2.69	-0.25
b) Exogenous Network: Low Sigma	-0.40	60	-2.35	0.10	0	0
c) Exogenous Network: Baseline Sigma	-0.32	48	-4.22	0.16	0	0
d) Exogenous Network: High Sigma	-0.32	47	-5.98	0.21	0	0

Endogenous production networks lead to

- a larger aggregate effect
- larger reorganization of trade flows and production networks

sensitivity | sign and magnitudes | import vs export shocks

Endogenous Networks Leads to More Dispersed Effects



Transportation Infrastructure: Effects of Chiloe Island Mega-Bridge

- Planned to open in 2025 as the largest suspension bridge in South America
  - Shorten travel time between the island and mainland from 35 (by ferry) $\rightarrow$ 0 minutes
- Simulate the reduction of bilateral trade costs and matching frictions using travel time elasticities for these spatial frictions estimated from cross-section data

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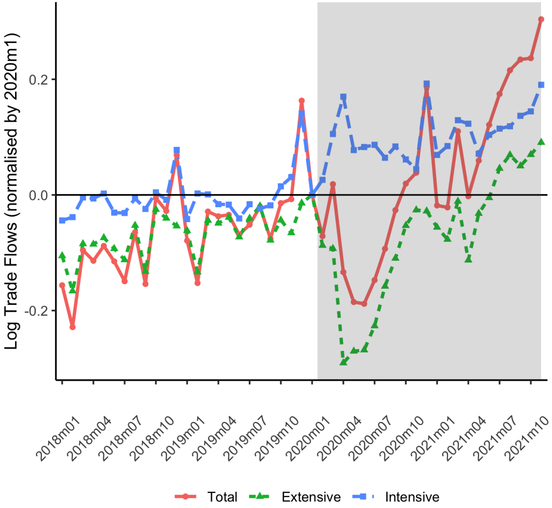
	1) $\widehat{\text{Welfare}}$	2) Rel. to Baseline	3) $\hat{X}_{ui,u\in\text{Chiloe}}$	4) $\hat{X}_{ui,u\notin\text{Chiloe}}$	5) $\hat{M}_{ui,u\in\text{Chiloe}}$	6) $\hat{M}_{ui,u\notin\text{Chiloe}}$
a) Baseline	0.25	100	1.13	-0.01	2.29	-0.08
b) Exogenous Network: Low Sigma	0.17	68	0.37	-0.00	0	0
c) Exogenous Network: Baseline Sigma	0.16	62	0.61	-0.00	0	0
d) Exogenous Network: High Sigma	0.14	58	0.77	-0.00	0	0

- Highly localized welfare gains, with large contribution from endogenous networks detail

Conclusion

- Analyze endogenous production network formation in space
- Characterize aggregate production networks and spatial distribution of economic activity
- Apply our model to firms' domestic and foreign transaction data from Chile
  - Endogenous networks $\Rightarrow$ larger and more dispersed effects of inter- & intra-national trade shocks
- Two ongoing work:
  - Dynamics of Supply Chain Disruptions
  - RCT of Network Formation: Evidence from Trade Fairs

Ongoing Work: Dynamics of Supply Chain Disruption



Appendix

Domestic Suppliers & Buyers and Market Size Return

	Log Number of Buyers				Log Number of Suppliers			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log Density	0.039***		0.027***	0.018***	0.121***		0.109***	0.051***
	(0.001)		(0.001)	(0.001)	(0.002)		(0.002)	(0.002)
Log Sales		0.422***	0.421***	0.421***		0.449***	0.447***	0.412***
		(0.001)	(0.001)	(0.001)		(0.002)	(0.002)	(0.001)
R^2	0.012	0.461	0.462	0.541	0.019	0.198	0.207	0.419
Year FE	✓	✓	✓	✓	✓	✓	✓	✓
State FE	✓	✓	✓	✓	✓	✓	✓	✓
Industry FE				✓				✓
Other Controls				✓				✓
N	361142	361142	361142	361142	361886	361886	361886	361886

Characterizing Equilibrium: Buyer and Supplier Access

go back

- We show that equilibrium is characterized by two fixed points of wages w_i and cost shifter C_i^*
- Buyer access:

$$w_i = \frac{\vartheta}{L_i} \sum_d X_{id}$$

where $X_{id}\left(\{w\}, \{C^*\}; \left\{\chi^E\right\}, \left\{\chi^I\right\}\right) = M_{id}\bar{r}_{id}$

- Supplier access:

$$(C_i^*)^{1-\sigma} = w_i^{\beta(1-\sigma)} \left[(\tilde{\sigma})^{\sigma} \mathbb{M}_i \left(\frac{\delta}{\gamma^S}\right) N_i\right]^{\beta-1} \left(\frac{\sum_u X_{ui}}{D_i}\right)^{1-\beta}$$

- Similar to previous literature (Anderson-van-Wincoop '03, Reddding-Venables '04, Donaldson-Hornbeck '16) while incorporating the endogenous search and matching

Characterizing Equilibrium go back

- After manipulations, "typical" mathematical structure in gravity trade and spatial models

Theorem

Equilibrium can be written in terms of wages w_i and cost shifter C_i^*

$$
\begin{aligned}
(w_i)^{1+\tilde{\lambda}^B\delta_2\mu}\left(C_i^*\right)^{(\sigma-1)\delta_2+\tilde{\lambda}^B\delta_2(1-\mu)} &= \frac{1}{L_i}\sum_d K_{id}\left(w_d\right)^{\delta_G}\left(C_d^*\right)^{\frac{(\sigma-1)\delta_2}{1-\beta}-\tilde{\lambda}^S\delta_2(1-\mu)}, \\
(w_i)^{1-\delta_G}\left(C_i^*\right)^{-\frac{(\sigma-1)\delta_2}{1-\beta}+\tilde{\lambda}^S\delta_2(1-\mu)} &= \frac{1}{L_i}\sum_u K_{ui}\left(w_u\right)^{-\tilde{\lambda}^B\delta_2\mu}\left(C_u^*\right)^{-(\sigma-1)\delta_2-\tilde{\lambda}^B\delta_2(1-\mu)},
\end{aligned}
$$

where $\delta_G = \left[-\tilde{\lambda}^S\mu + \frac{1-\beta\sigma}{1-\beta}\right]\delta_2$ *and* K_{id} *are combination of exogenous parameters*

Characterizing Equilibrium: Uniqueness go back

- From buyer access equation:

$$\left(w_i\right)^{1+\tilde{\lambda}^B\delta_2\mu}\left(C_i^*\right)^{(\sigma-1)\delta_2+\tilde{\lambda}^B\delta_2(1-\mu)}=\sum_d K_{id}\left(w_d\right)^{\delta_G}\left(C_d^*\right)^{\frac{(\sigma-1)\delta_2}{1-\beta}-\tilde{\lambda}^S\delta_2(1-\mu)}$$

  - Demand effects dissipates as infinitely going to upstream when $\delta_G \leq 1$

- From supplier access equation:

$$\left(w_i\right)^{1-\delta_G}\left(C_i^*\right)^{-\frac{(\sigma-1)\delta_2}{1-\beta}+\tilde{\lambda}^S\delta_2(1-\mu)}=\sum_u K_{ui}\left(w_u\right)^{-\tilde{\lambda}^B\delta_2\mu}\left(C_u^*\right)^{-(\sigma-1)\delta_2-\tilde{\lambda}^B\delta_2(1-\mu)}$$

  - Cost effect dissipates as infinitely going to downstream when

$$-\frac{(\sigma-1)\,\delta_2}{1-\beta}+\tilde{\lambda}^S\delta_2\,(1-\mu)\leq-(\sigma-1)\,\delta_2-\tilde{\lambda}^B\delta_2\,(1-\mu)\,(<0)$$

$$\iff\frac{\beta\,(\sigma-1)}{1-\beta}\geq(1-\mu)\left(\tilde{\lambda}^B+\tilde{\lambda}^S\right)$$

Responses to Shocks go back

- Denote observed import share by, $\Lambda_{ui} \equiv \frac{X_{ui}}{\sum_\ell X_{\ell i}}$, and export share by $\Psi_{id} \equiv \frac{X_{id}}{\sum_\ell X_{i\ell}}$
- Consider a change in exogenous variables (e.g., trade costs), which feeds into the proportional changes in $\hat{K}_{id}$ (where $\hat{x} = x'/x$ and x' is the counterfactual value)

Proposition

The counterfactual changes of wages $\hat{w}_i$ and intermediate cost shifter $\hat{C}_i^*$ are solved by

$$(\hat{w}_i)^{1+\tilde{\lambda}^B\delta_2\mu}\left(\hat{C}_i^*\right)^{(\sigma-1)\delta_2+\tilde{\lambda}^B\delta_2(1-\mu)} = \sum_d \hat{K}_{id}\left(\hat{w}_d\right)^{\delta_G}\left(\hat{C}_d^*\right)^{\frac{(\sigma-1)\delta_2}{1-\beta}-\tilde{\lambda}^S\delta_2(1-\mu)}\Psi_{id}$$

$$(\hat{w}_i)^{1-\delta_G}\left(\hat{C}_i^*\right)^{-\frac{(\sigma-1)\delta_2}{1-\beta}+\tilde{\lambda}^S\delta_2(1-\mu)} = \sum_u \hat{K}_{ui}\left(\hat{w}_u\right)^{-\tilde{\lambda}^B\delta_2\mu}\left(\hat{C}_u^*\right)^{-(\sigma-1)\delta_2-\tilde{\lambda}^B\delta_2(1-\mu)}\Lambda_{ui}$$

- **Aggregate** bilateral trade flows (X_{ui}) and a set of structural parameters $(\tilde{\lambda}^B, \tilde{\lambda}^S, \beta, \sigma, \mu)$ are sufficient for characterizing counterfactual equilibrium

Second-Order Effect on World GDP go back

Proposition

Second-order effect from iceberg cost shock in a particular region-pair $d \log \tau_{ij}$ is given by

$$\frac{d^2 \log \mathcal{W}}{d \log \tau_{ij}^2} = - \underbrace{\frac{\varsigma}{1 - \left(\tilde{\lambda}^S + \tilde{\lambda}^B\right) \frac{1-\beta}{\beta} \frac{1-\mu}{\sigma-1}}}_{\geq 1} \underbrace{\frac{d \log X_{ij}}{d \log \tau_{ij}}}_{\textit{tend to be} <0 \textit{ from substitution}}$$

- Positive shock ($d \log \tau_{ij} < 0$) $\rightarrow$ amplification
- Negative shock ($d \log \tau_{ij} > 0$) $\rightarrow$ dampening
- Amplification and dampening tend to be stronger with endogenous production networks because of additional substitution margin

Model Extension: Multiple Sectors go back

- Unit cost of a firm in sector $k \in K$

$$c_{i,k}(\omega) = \frac{1}{z_{i,k}(\omega)} w_i^{\beta_{k,L}} \prod_{h \in K} \left(\int_{\upsilon \in \Omega_h(\omega)} p(\upsilon, \omega)^{1-\sigma_k} d\upsilon \right)^{\frac{\beta_{hk}}{1-\sigma_k}}$$

- Firms' search problem:

$$\max_{\{n^S_{ui,hk}\}_{u \in N, h \in K}, \{n^B_{id,kl}\}_{d \in N, l \in K}, n^F_{ik}} \frac{1}{\sigma_k} n^F_{i,k} \frac{c^{1-\sigma_k}}{\sigma_k} D^F_{ik} + \frac{1}{\sigma_k} \sum_{l \in K} \sum_{d \in N} m^B_{id,kl} n^B_{id,kl} D_{i,kl} \left(c\tau_{id,k} \right)^{1-\sigma_k}$$

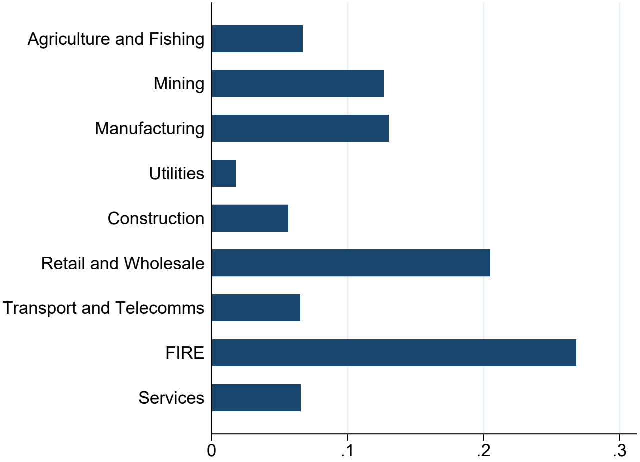
$$- e_{i,k} \left\{ \sum_{l \in K} \sum_{d \in N} f^B_{id,kl} \frac{\left(n^B_{id,kl}\right)^{\gamma^B_k}}{\gamma^B_k} + \sum_{h \in K} \sum_{u \in N} f^S_{ui,hk} \frac{\left(n^S_{ui,hk}\right)^{\gamma^S_k}}{\gamma^S_k} \right\}$$

$$\text{subject to} \quad c = \frac{w_i^{\beta_{k,L}} \prod_h \left(\sum_{u \in N} n^S_{ui,hk} m^S_{ui,hk} \left(C_{ui,h} \right)^{1-\sigma_h} \right)^{\frac{\beta_{hk}}{1-\sigma_h}}}{z}$$

- Solution: $n^S_{ui,hk}(z) = a^S_{ui,hk} z^{\frac{\delta_{1,k}}{\gamma^S_k}}$; $n^B_{id,kl}(z) = a^B_{id,kl} z^{\frac{\delta_{1,k}}{\gamma^B_k}}$; $n^F_{i,k}(z) = a^F_{i,k} z^{\frac{\delta_{1,k}}{\gamma^B_k}}$
- Hat-algebra for general equilibrium similarly as Caliendo and Parro (2015)

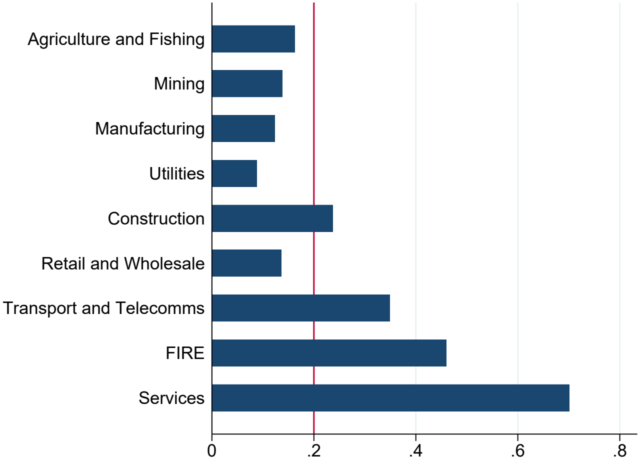
Final Consumption Shares: By Sector (α_k) Return

Figure: Final Consumption Shares: By Sector (α_k)



Labor Shares of Cost: By Sector ($\beta_{k,L}$) Return

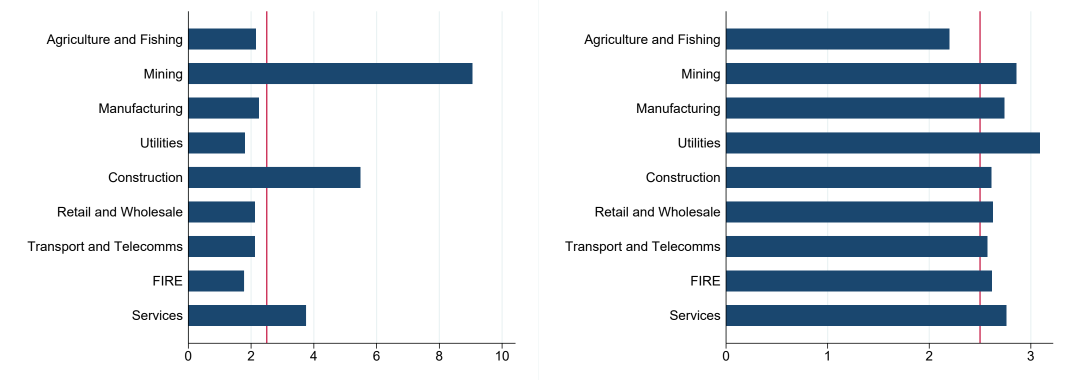
Figure: Labor Shares of Cost: By Sector ($\beta_{k,L}$)



Curvature of Advertisement Cost: By Sector

Return

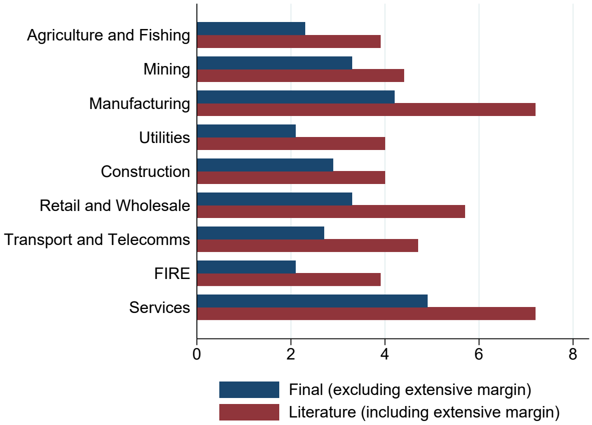
Figure: Curvature of Advertisement Cost: By Sector



(a) Suppliers (γ_k^S) (b) Buyers (γ_k^B)

Consumption and Labor Shares Return

Figure: Elasticity of Substitution: By Sector



Estimating Spatial Frictions Return

- Decompose bilateral trade frictions in "search frictions" and "iceberg cost"

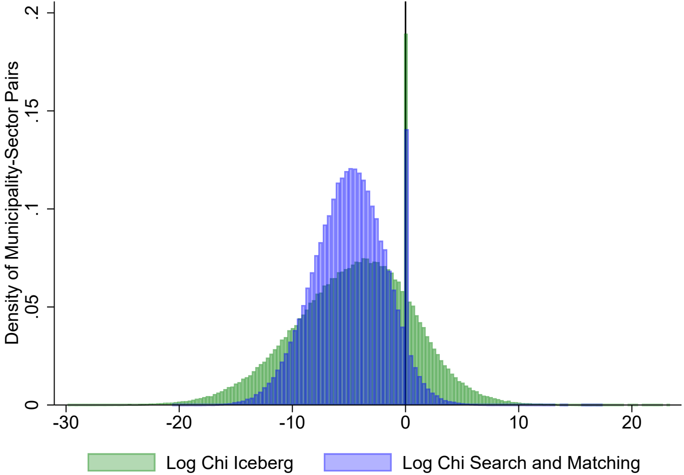
$$\chi_{ud,kl} \equiv \chi^{E}_{ud,kl}\chi^{I}_{ud,kl} = \underbrace{\left[\kappa_{ud,kl}\left(f^{B}_{ud,kl}\right)^{-\tilde{\lambda}^{B}_{kl}}\left(f^{S}_{ud,kl}\right)^{-\tilde{\lambda}^{S}_{kl}}\right]^{\delta_{2,k}}}_{\chi^{\text{matching}}_{ud,kl}} \underbrace{\left(\tau_{ud,kl}\right)^{\frac{1-\sigma_k}{1-\tilde{\lambda}^{B}_{kl}-\tilde{\lambda}^{S}_{kl}}}}_{\chi^{\text{iceberg}}_{ud,kl}}$$

- Use intensive and extensive margin of bilateral flows to estimate two spatial frictions relative to within-location-sector trade (Head Ries '01)

$$\frac{\chi^{\text{iceberg}}_{ud,kl}}{\chi^{\text{iceberg}}_{uu,kk}}\frac{\chi^{\text{iceberg}}_{du,lk}}{\chi^{\text{iceberg}}_{dd,ll}} = \left(\frac{\bar{r}_{ud,kl}}{\bar{r}_{uu,kk}}\frac{\bar{r}_{du,lk}}{\bar{r}_{dd,ll}}\right)^{\frac{1}{1-\tilde{\lambda}^{B}_{kl}-\tilde{\lambda}^{S}_{kl}}}$$

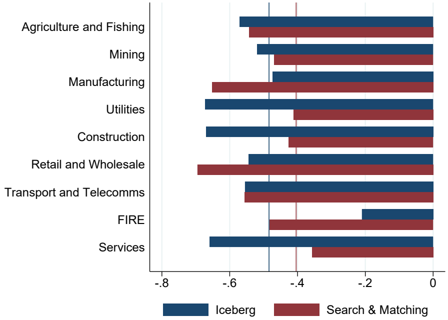
$$\frac{\chi^{\text{matching}}_{ud,kl}}{\chi^{\text{matching}}_{uu,kk}}\frac{\chi^{\text{matching}}_{du,lk}}{\chi^{\text{matching}}_{dd,ll}} = \frac{M_{ud,kl}}{M_{uu,kk}}\frac{M_{du,lk}}{M_{dd,ll}}\left(\frac{\bar{r}_{ud,kl}}{\bar{r}_{uu,kk}}\frac{\bar{r}_{du,lk}}{\bar{r}_{dd,ll}}\right)^{\frac{-\left(\tilde{\lambda}^{B}_{kl}+\tilde{\lambda}^{S}_{kl}\right)}{1-\tilde{\lambda}^{B}_{kl}-\tilde{\lambda}^{S}_{kl}}}$$

Estimates of Iceberg Costs and Matching Frictions Return



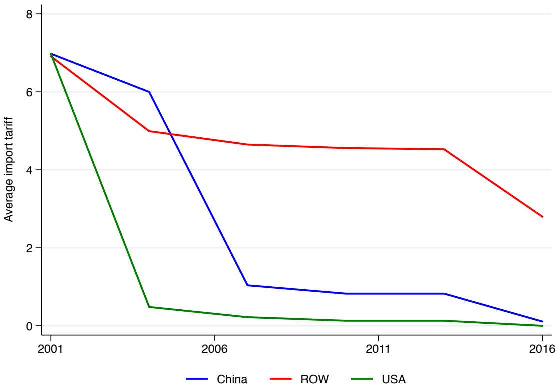
Spatial Frictions and Geographic Distance Return

- Elasticity of frictions with travel distance, by sector

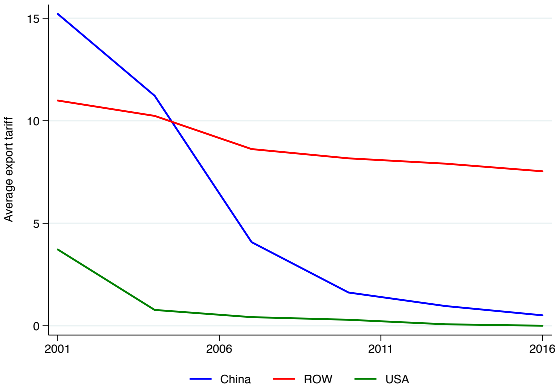


- Both search & matching costs and iceberg costs increase in geographic distance
- Consistent with recent literature on search and matching frictions in trade (Chaney 2014, Allen 2014, Eaton-Kortum-Kramarz 2016, Brancaccio-Kalouptsidi-Papageorgiou 2020, Lenoir-Martin-Mejean 2020, Krolikowski-McCallum 2021, Startz 2021, Miyauchi 2021)

International Trade Shocks: Tariff Changes Faced by Chile Return



(a) Import



(b) Export

International Trade Shocks: Sensitivity

go back

	1) $\widehat{\text{Welfare}}$	2) Exog. Network / Baseline (%)	3) $\hat{X}_{ui,u\in\{\text{US,China}\}}$	4) $\hat{X}_{ui,u\in\text{Chile}}$	5) $\hat{M}_{ui,u\in\{\text{US,China}\}}$	6) $\hat{M}_{ui,u\in\text{Chile}}$
a) Baseline	0.99	40	7.55	-0.29	3.02	0.31
b) $\beta_{k,L} + 0.2$	0.56	43	8.03	-0.30	3.06	0.17
c) $\mu = 0$	1.92	23	6.41	-0.26	3.04	0.96
d) $\mu = 1$	0.69	53	7.91	-0.31	3.00	0.08
e) $\lambda^S = 1, \lambda^B = 0$	0.94	42	8.00	-0.29	3.31	0.20
f) $\lambda^S = 0, \lambda^B = 1$	1.07	37	7.72	-0.31	3.16	0.45
g) $\lambda^S = \lambda^B = 0.6$	1.49	27	8.37	-0.33	4.27	0.63
h) $\lambda^S = \lambda^B = 0.3$	0.61	65	6.25	-0.24	1.43	0.11
i) $\lambda^S/\lambda^B = \sigma/(\sigma-1), \lambda^S + \lambda^B = 1$	0.99	40	7.58	-0.29	3.03	0.30

International Trade Shocks: Sign and Magnitudes go back

	1) $\widehat{\text{Welfare}}$	2) Exog. Network / Baseline (%)	3) $\hat{X}_{ui,u\in\{\text{US,China}\}}$	4) $\hat{X}_{ui,u\in\text{Chile}}$	5) $\hat{M}_{ui,u\in\{\text{US,China}\}}$	6) $\hat{M}_{ui,u\in\text{Chile}}$
a) Large Increase of Tariffs (Baseline Counterfactual)	-0.67	48	-5.95	0.23	-2.69	-0.25
b) Small Increase of Tariffs (10% of Row (a))	-0.07	40	-0.69	0.03	-0.31	-0.04
c) Large Decrease of Tariffs (Inverse of Row (a))	0.99	40	7.55	-0.29	3.02	0.31
d) Small Decrease of Tariffs (10% of Row (c))	0.06	41	0.66	-0.03	0.29	0.04

- Large positive shocks are more amplified, large negative shocks are less amplified

International Trade Shocks: Sign and Magnitudes

go back

Table: Only Import Tariff Changes

	1) $\widehat{\text{Welfare}}$	2) Rel. to Baseline	3) $\hat{X}_{ui,u\in\{\text{US,China}\}}$	4) $\hat{X}_{ui,u\in\text{Chile}}$	5) $\hat{M}_{ui,u\in\{\text{US,China}\}}$	6) $\hat{M}_{ui,u\in\text{Chile}}$
a) Baseline	-0.59	100	-5.57	0.23	-2.52	-0.20
b) Exogenous Network: Low Sigma	-0.38	65	-2.14	0.10	0	0
c) Exogenous Network: Baseline Sigma	-0.32	55	-3.88	0.15	0	0
d) Exogenous Network: High Sigma	-0.32	54	-5.54	0.20	0	0

Table: Only Export Tariff Changes

	1) $\widehat{\text{Welfare}}$	2) Rel. to Baseline	3) $\hat{X}_{ui,u\in\{\text{US,China}\}}$	4) $\hat{X}_{ui,u\in\text{Chile}}$	5) $\hat{M}_{ui,u\in\{\text{US,China}\}}$	6) $\hat{M}_{ui,u\in\text{Chile}}$
a) Baseline	-0.08	100	-0.36	0.00	-0.13	-0.02
b) Exogenous Network: Low Sigma	-0.02	19	-0.22	0.00	0	0
c) Exogenous Network: Baseline Sigma	-0.00	1	-0.36	0.01	0	0
d) Exogenous Network: High Sigma	-0.00	2	-0.46	0.01	0	0

Transportation Infrastructure: Heterogeneity

go back

	1) All Municipalities	2) High Exposure Municipalities	3) Low Exposure Municipalities
(A) $\widehat{\text{Welfare}(\%)}$			
a) Baseline	0.25	2.15	0.22
b) Exogenous Network: Baseline Sigma	0.16	1.19	0.14
(B) $\hat{M}_{ui,u \in \text{Chiloe}}$			
c) Baseline	2.29	8.48	2.19
d) Exogenous Network: Baseline Sigma	0	0	0