

Production Network Formation, Trade, and Welfare¹

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

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 - ▶ Shipment and transaction cost
 - ▶ Matching frictions (Rauch-Trindade '02, Allen '14, Bernard-Moxnes-Saito '19, Miyauchi '24, Startz '24, Cai-Lin-Szeidl '24, Demir-Javorcik-Panigrahi '24...)

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- ▶ Current debate about how supply chain response might influence the impact of trade shocks
- ▶ How do endogenous firm network formation affect aggregate impact of trade shocks?

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 - ▶ Ex-post regional welfare: Deviate from ACR due to network formation cost amplification
 - ▶ Insights carry over to other network microfound., eg targeted search & fixed cost, random search

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 - ▶ Insights carry over to other network microfound., eg targeted search & fixed cost, random search
- ▶ Multi-sector quantification using Chilean domestic and international firm-to-firm trade data
 - ▶ Estimate model and rationalize \uparrow foreign and domestic links during trade liberalization
 - ▶ Endogenous network **increases** welfare effects of...
 - ▶ import cost increase from trade liberalization by 30% (fixing trade elasticity)
 - ▶ gains from trade relative to municipality autarky by 100% (fixing trade elasticity)

Literature

- ▶ **Production network formation and trade** Antràs-Fort-Tintelnot '17; Oberfield '18; Lim '18; Huneus '19; Antràs-de-Gortari '20; Bernard-Moxnes-Saito '20; Dhyne et al '23; Demir et al '24; Eaton-Kortum-Kramarz '24
⇒ **Aggregate implications of production network formation in multi-location GE environment**
- ▶ **Welfare sufficient statistics in trade** Atkeson-Burstein '10; Arkolakis-Costinot-Rodriguez-Clare '12; Melitz-Redding '15; Caliendo-Parro '15; Blaum-Lelarge-Peters '18; Baqaee-Fahri '24; Burstein et al '24
⇒ **Incorporate endogenous production network formation**
- ▶ **Inefficiency in production network formation** Boehm-Oberfield '20; Grossman-Helpman-Lhuillier '23; Grossman-Helpman-Sabal '24; Acemoglu-Tahbaz-Salehi '24
⇒ **Matching externality; relate to sufficient statistics in multi-location GE environment**
- ▶ **Matching frictions in trade** Rauch '01; Chaney '14; Allen '14; Brancaccio et al '20; Bernard-Moxnes-Saito '20; Lenoir-Martin-Mejean '20; Krolkowski-McCallum '21; Startz '24; Miyauchi '24; Eaton et al '24; Huang et al '24, Cai et al '24
⇒ **Characterize equilibrium inefficiency, optimal policy and aggregate welfare**

Outline

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Planning Problem and Equilibrium Inefficiency

Aggregate Effects of Trade Cost Shocks

Data and Reduced-Form Evidence

Quantitative Analysis

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Environment

- ▶ Locations $i, u, d \in \mathcal{N}$, measure L_i households
- ▶ Goods
 - ▶ Intermediate goods: iceberg trade cost $\tau_{ud} \geq 1$
 - ▶ Retail goods: nontraded, used for final consumption and firm's relationship-formation costs
- ▶ Firms (intermediate goods producers)
 - ▶ Measure N_i , productivity $z \sim g_i(z)$
 - ▶ Buy (supply) intermediate goods from (to) other connected firms
 - ▶ Connections are formed under firms' expenditure in forming linkages and matching
- ▶ Retailers
 - ▶ Produce retail goods with CRS aggregator from local intermediates under perfect competition

Production given Networks

- ▶ Unit cost of production by firm ω in location d

$$c_d(\omega) = \frac{1}{z(\omega)} w_d^\beta \left(\sum_{u \in \mathcal{N}} \int_{v \in \mathcal{S}_{ud}(\omega)} p_{ud}(v, \omega)^{1-\sigma} dv \right)^{\frac{1-\beta}{1-\sigma}}$$

- ▶ w_d : wage
 - ▶ $\mathcal{S}_{ud}(\omega)$: set of suppliers in location u that ω has access to: endogenize later
 - ▶ $p_{ud}(v, \omega)$: price charged by supplier v in location u to buyer ω in location d
- ▶ Each supplier is monopolistic to each buyer \Rightarrow constant markup

$$p_{ud}(v, \omega) = \tilde{\sigma} \tau_{ud} c_u(v), \quad \tilde{\sigma} = \frac{\sigma}{\sigma - 1}$$

- ▶ Retail goods prices (no markups charged by firms): $P_i = \tilde{g}_i \left(\{c_i(\omega)\}_{\omega \in \Omega_i} \right)$

Firm's Relationship Formation Decisions with Suppliers and Buyers

- ▶ Firms decide resources to spend on forming relationships with each location $\{n_{ui}^S\}_u, \{n_{id}^B\}_d$
- ▶ Random matching with endogenous rate $\{m_{ui}^S\}_u, \{m_{id}^B\}_d$
 - ▶ \Rightarrow realized connections $\{n_{ui}^S m_{ui}^S\}_u, \{n_{id}^B m_{id}^B\}_d$
 - ▶ Firms take matching rates as given; determined endogenously through matching technology
- ▶ Relationship-formation costs

$$e_i \left\{ \sum_{d \in \mathcal{N}} f_{id}^B \frac{(n_{id}^B)^{\gamma^B}}{\gamma^B} + \sum_{u \in \mathcal{N}} f_{ui}^S \frac{(n_{ui}^S)^{\gamma^S}}{\gamma^S} \right\}, \quad e_i = (w_i)^\mu (P_i)^{1-\mu}$$

- ▶ Use labor and retail goods for forming relationships with labor share μ
- ▶ E.g., advertisement cost, product customization, quality assurance

Firm's Relationship-Formation Problem

$$\max_{\{n_{id}^B\}_d, \{n_{ui}^S\}_u} \sum_{d \in \mathcal{N}} \underbrace{n_{id}^B m_{id}^B}_{\text{buyer links to } d} \underbrace{\frac{1}{\sigma} r_{id}(z, \{n_{ui}^S\}_u)}_{\text{average profit per link}} - e_i \underbrace{\left\{ \sum_{d \in \mathcal{N}} f_{id}^B \frac{(n_{id}^B)^{\gamma^B}}{\gamma^B} + \sum_{u \in \mathcal{N}} f_{ui}^S \frac{(n_{ui}^S)^{\gamma^S}}{\gamma^S} \right\}}_{\text{relationship formation cost}}$$

$$\text{subject to } \underbrace{c_i(z, \{n_{ui}^S\}_u)}_{\text{unit production cost}} = \frac{1}{z} w_i^\beta \left(\sum_{u \in \mathcal{N}} \underbrace{n_{ui}^S m_{ui}^S}_{\text{supplier links from } u} (C_{ui})^{1-\sigma} \right)^{\frac{1-\beta}{1-\sigma}}$$

- Solution: $n_{id}^B(z) = a_{id}^B z^{\frac{\delta}{\gamma^B}}$, $n_{ui}^S(z) = a_{ui}^S z^{\frac{\delta}{\gamma^S}}$, with $\delta \equiv (\sigma - 1) / (1 - \frac{1}{\gamma^B} - \frac{1-\beta}{\gamma^S})$

Matching Technology

- ▶ Equilibrium measure of supplier-to-buyer relationships

$$M_{ud} = \kappa_{ud} \left(\underbrace{N_u \int n_{ud}^B(z) dG_u(z)}_{\text{effort on buyers } \bar{M}_{ud}^B} \right)^{\lambda^B} \left(\underbrace{N_d \int n_{ud}^S(z) dG_d(z)}_{\text{effort on suppliers } \bar{M}_{ud}^S} \right)^{\lambda^S}$$

- ▶ Note! Elasticity wrt effort to form relationship with buyer (by suppliers): λ^B ; wrt effort on suppliers (by buyers): λ^S
- ▶ Allow for $\lambda^B + \lambda^S \neq 1$ (Miyachi '24; Eaton-Kortum-Kramarz '24)
- ▶ Matching probability (intensity)

$$m_{ud}^S = \frac{M_{ud}}{\bar{M}_{ud}^S} \quad m_{ud}^B = \frac{M_{ud}}{\bar{M}_{ud}^B}$$

Gravity Equations of Trade Flows

- ▶ **Intensive Margin:** Transaction volume per relationship

$$\bar{r}_{ud} = \frac{X_{ud}}{M_{ud}} = \varrho^I \chi_{ud}^I \zeta_u^I \xi_d^I, \quad \chi_{ud}^I \equiv (\tau_{ud})^{1-\sigma}$$

- ▶ **Extensive Margin:** Total number of successful relationships

$$M_{ud} = \varrho^E \chi_{ud}^E \zeta_u^E \xi_d^E, \quad \chi_{ud}^E \equiv \left[\kappa_{ud} \left(f_{ud}^B\right)^{-\tilde{\lambda}^B} \left(f_{ud}^S\right)^{-\tilde{\lambda}^S} \left(\tau_{ud}^{1-\sigma}\right)^{\tilde{\lambda}^S + \tilde{\lambda}^B} \right]^{\frac{1}{1 - (\tilde{\lambda}^S + \tilde{\lambda}^B)}}$$
$$\tilde{\lambda}^S \equiv \frac{\lambda^S}{\gamma^S}, \quad \tilde{\lambda}^B \equiv \frac{\lambda^B}{\gamma^B}$$

- ▶ Intensive + extensive margin \Rightarrow Aggregate trade elasticity

$$\varepsilon \equiv \frac{\partial \ln X_{ud}}{\partial \ln \tau_{ud}} = \frac{\sigma - 1}{1 - (\tilde{\lambda}^S + \tilde{\lambda}^B)}$$

General Equilibrium

- ▶ Intermediate goods, retail goods, and labor markets clear
- ▶ Gravity equations \Rightarrow
 - ▶ constant aggregate trade elasticity
 - ▶ conditions for equilibrium uniqueness
 - ▶ exact-hat algebra for counterfactuals
- ▶ $\lambda^B = \lambda^S = 0$ and $\gamma^B, \gamma^S \rightarrow \infty$ ($\tilde{\lambda}^B = \tilde{\lambda}^S = 0$): “fixed networks”

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Equilibrium Inefficiency

- ▶ Equilibrium is inefficient due to
 1. Double marginalization (present with both fixed and endogenous networks)
 2. Relationship-formation inefficiency (present only with endogenous networks)
- ▶ Impacts aggregate effects of shocks; deviation from Hulten

Equilibrium Inefficiency

- ▶ Equilibrium is inefficient due to
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- ▶ Impacts aggregate effects of shocks; deviation from Hulten
- ▶ Consider (constrained) planning problem with 3 types of instruments [detail](#)
 - ▶ sales subsidy $s_{id}^I \Rightarrow$ offset markups and double marginalization $\Rightarrow s_{id}^I = \frac{1}{\sigma}$
 - ▶ relationship formation taxes t_{id}^S and $t_{id}^B \Rightarrow$ equate social vs private returns for forming links
 - ▶ balances two classic inefficiencies: non-appropriability and business stealing (matching frictions and input substitution)
 - ▶ lump-sum transfers $T_i^F \Rightarrow$ redistribution

Constrained Efficiency: Hosios-Type Result

- ▶ Suppose $s_{id}^I = \frac{1}{\sigma}$. Then, $t_{id}^B = t_{id}^S = 0$ if and only if

$$\lambda^B = 1, \quad \lambda^S = 1 - \beta$$

- ▶ $\lambda^B = 1$: buyer relationship formation does not crowd-out each other
 - ▶ Similar to efficient entry with monopolistic competition & CES demand (Dixit-Stiglitz '77)
 - ▶ $\lambda^B < 1 \Rightarrow$ Too much equilibrium buyer relationship formation
- ▶ $\lambda^S = 1 - \beta \Rightarrow$ Lower private incentive for forming relationships with suppliers than buyers
- ▶ Efficiency requires IRS matching technology, unlike Hosios '90
 - ▶ non-appropriability effects vis-a-vis hold-up
 - ▶ business stealing vis-a-vis congestion

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Ex-Ante Sufficient Statistics: $\{d \ln \tau_{ud}\}$ on Global Welfare

$$d \ln \mathcal{W} \equiv \sum_i P_i^F Q_i^F d \ln Q_i^F = - \frac{\varsigma}{\frac{\beta}{1-\beta} - \frac{1-\mu}{\sigma-1} \left(\frac{\lambda^B}{\gamma^B} + \frac{\lambda^S}{\gamma^S} \right)} \underbrace{\sum_{u,d} X_{ud} d \ln \tau_{ud}}_{\text{Hulten}}$$

- ▶ ς : GDP to intermediate goods revenue ratio (inverse of Domar weights)

$$\varsigma = \underbrace{\frac{\beta}{1-\beta}}_{\text{IO multiplier}} + \underbrace{\frac{1}{\sigma}}_{\text{double marginalization}} - \underbrace{\frac{1-\mu}{\sigma} \left(\frac{1}{\gamma^B} + \frac{1-\beta}{\gamma^S} \right)}_{\text{relationship formation inefficiencies}}$$

- ▶ Deviation from Hulten occurs due to **inefficiencies**: double marginalization and search inefficiency

Special Case: Fixed Networks

$$d \ln \mathcal{W}^{\text{Fixed}} = - \underbrace{\frac{\zeta^{\text{Fixed}}}{1 - \beta}}_{\text{IO multiplier}} \underbrace{\sum_{u,d} X_{ud} d \ln \tau_{ud}}_{\text{Hulten}}$$

$$\zeta^{\text{Fixed}} = \frac{\beta}{1 - \beta} + \frac{1}{\sigma}$$

- ▶ Double marginalization \Rightarrow Hulten underpredicts welfare changes (e.g., Baqaee-Farhi '23)
- ▶ Optimal sales subsidy $s_{id}^I = \frac{1}{\sigma} \Rightarrow$ Hulten

Fixed vs Endogenous Networks

$$d \ln \mathcal{W} = -\frac{\underbrace{\varsigma}_{\text{red}}}{\frac{\beta}{1-\beta}} \sum_{u,d} X_{ud} \left(d \ln \tau_{ud} - \frac{1}{\sigma-1} d \ln M_{ud} \right)$$

- Endogenous networks \Rightarrow (1) $d \ln M_{ud} \neq 0$ and (2) $\varsigma < \varsigma^{\text{Fixed}}$

$$\sum_{u,d} X_{ud} \frac{1}{\sigma-1} d \ln M_{ud} = -\frac{\frac{1-\mu}{\sigma-1} \left(\frac{\lambda^B}{\gamma^B} + \frac{\lambda^S}{\gamma^S} \right)}{\frac{\beta}{1-\beta} - \frac{1-\mu}{\sigma-1} \left(\frac{\lambda^B}{\gamma^B} + \frac{\lambda^S}{\gamma^S} \right)} \sum_{u,d} X_{ud} d \ln \tau_{ud}$$

- \Rightarrow Larger first-order aggregate effect in endogenous vs fixed network (conditional on X_{ud}) iff

$$\underbrace{\frac{\varsigma^{\text{Fixed}}}{\underbrace{\varsigma}_{\text{red}}}}_{\text{Private cost of forming links}} < \underbrace{\frac{\frac{\beta}{1-\beta}}{\frac{\beta}{1-\beta} - \frac{1-\mu}{\sigma-1} \left(\frac{\lambda^B}{\gamma^B} + \frac{\lambda^S}{\gamma^S} \right)}}_{\text{Social value of multiplier effects}}$$

Ex-Post Sufficient Statistics for Each Region's Welfare

$$d \ln Q_i^F = - \frac{1}{\underbrace{\varepsilon}_{\text{trade elasticity}}} \frac{\beta}{\underbrace{1 - \beta}_{\text{IO multiplier}}} - \frac{1}{\underbrace{\frac{1 - \mu}{\sigma - 1} \left(\frac{\lambda^B}{\gamma^B} + \frac{\lambda^S}{\gamma^S} \right)}_{\text{amplification effect through search cost}}} \underbrace{d \ln \Lambda_{ij}}_{\text{intra-region exp share}}$$

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► Deviation from fixed networks:

1. Larger trade elasticity: $\varepsilon > \varepsilon^{\text{Fixed}}$ (ACR '12) \Rightarrow smaller effects
2. Multiplier effect through search costs \Rightarrow larger effects

► Trade elasticity matters for distributional effects or large shocks, i.e., Le Chatelier's principle

► Efficiency does not play a role: Aggregate trade shocks \Rightarrow no labor reallocation between production and relationship formation

Extension to Alternative Production Network Formation Models

- ▶ Key insights so far: Impact of **equilibrium inefficiencies**, **trade elasticities**, and **amplification through relationship-formation costs**
 - ▶ We show these new insights generalize to other endogenous network formation setups

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 - ▶ We show these new insights generalize to other endogenous network formation setups
- ▶ Assume ACR's three macro restrictions, and

$$d \ln M_{ud} = (\delta_{L,U} + \delta_{Q,U} + \delta_{L,D} + \delta_{Q,D}) d \ln X_{ud} \\ - \delta_{L,U} d \ln w_u - \delta_{Q,U} d \ln P_u - \delta_{L,D} d \ln w_d - \delta_{Q,D} d \ln P_d$$

$$d \ln P_i = \beta d \ln w_i + (1 - \beta) \sum_u \Lambda_{ui} (\nu d \ln M_{ui} - d \ln P_u - d \ln \tau_{ui})$$

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$$d \ln P_i = \beta d \ln w_i + (1 - \beta) \sum_u \Lambda_{ui} (\nu d \ln M_{ui} - d \ln P_u - d \ln \tau_{ui})$$

- ▶ Two propositions generalize

$$dW = \frac{\overset{S}{\beta}}{\frac{\beta}{1-\beta} - \nu (\delta_{Q,U} + \delta_{Q,D})} \sum_{u,d} X_{ud} d \ln \tau_{ud}, \quad d \ln Q_i^F = - \frac{1}{\varepsilon} \frac{1}{\frac{\beta}{1-\beta} - \nu (\delta_{Q,U} + \delta_{Q,D})} d \ln \Lambda_{ii}$$

- ▶ Cover models with relationship-fixed costs (**Bernard-Moxnes-Saito '20**) and discrete supplier choice with Pareto (**Oberfield '18, Eaton et al '24**)

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Data

- ▶ Domestic firm-to-firm transaction data from Chile
 - ▶ Collected for value-added tax collection purpose
 - ▶ Seller and buyer tax ID, dates, total amounts
 - ▶ Origin and destination municipalities of establishments since 2018 (345 municipalities in Chile)
- ▶ Customs firm-to-firm data ⇒ Imports and exports
- ▶ Firm balance sheet characteristics ⇒ Total sales, labor expenditure, sector
- ▶ Country-sector international trade data: Input-output database from OECD (ICIO)

Reduced-Form Evidence for Endogenous Network Formation

- Firm-level impacts of **tariff reduction** (US '04 and China '06 FTA) using **shift-share** design

$$\Delta \log y_{it} = \alpha \sum_{c,k} \underbrace{w_{ickt_0=2003}^D}_{\text{import by firm } i} \times \underbrace{\Delta_{2007-2003} \log(1 + \tau_{ckt})}_{\text{Chile's import tariffs with country } c \text{ of product } k} + \gamma X_{it} + \varepsilon_{it}$$

	Total Imports (1)	Number Int. Suppliers (2)	Number Dom. Buyers (3)	Number Dom. Suppliers (4)
Import Tariff Shock	-3.20 (1.26)	-1.88 (0.61)	-1.30 (1.10)	-1.52 (0.71)
Number Observations			33260	
Sector FE (6 digit)			Yes	
Prior Import Share			Yes	
Export Shock Residualized			Yes	
Period			2003-2007	

- Domestic links **decrease** in response to tariff **increase** \Rightarrow import complementarity

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Calibration

- ▶ Multi-sector (2) extension as in Caliendo-Parro '15: Cobb-Douglas in tech/pref [detail](#)
- ▶ Calibrate the model with 345 municipalities in Chile + US, China, ROW
 - ▶ Match observed $\{X_{ud,kl}\}$
 - ▶ Calibrate $\{\alpha_k, \beta_{km}, \varepsilon_k, \gamma_k^S, \gamma_k^B\}$ from data / literature
 - ▶ Calibrate $\mu = 0.35$ to labor coefficient in relationship-formation costs
 - ▶ Calibrate $\lambda^S = \lambda^B = 0.56$ to match domestic supplier response

	Untargeted		Targeted	
	Total Imports (1)	Number Int. Suppliers (2)	Number Dom. Buyers (3)	Number Dom. Suppliers (4)
Data	-3.20 (1.26)	-1.86 (0.71)	-1.23 (0.97)	-1.48 (0.39)
Model	-4.15	-1.66	-1.87	-1.48

- ▶ $\mu < 1$ rationalize the domestic supplier link **decrease** in response to tariff increase

↑ Iceberg import cost by the amount of the US & CN tariff reduction

	1) $\widehat{\text{Welfare}}$ (%)	2) Relative to Fixed Network	3) $\hat{X}_{ui,u \in \text{US,CN}}$	4) $\hat{M}_{ui,u \in \text{US,CN}}$	5) $\hat{M}_{ui,u \in \text{CL}}$
Panel 1: Baseline Calibration					
a) Endogenous Network	-0.88	1.6	-21.4	-8.3	-0.07
b) Fixed Network, fix ε	-0.56	1	-21.0	0	0
Panel 2: Sensitivity to Parameters					
c) Endogenous Network, $\gamma * 2$	-0.65	1.2	-20.9	-4.1	0.01
d) Endogenous Network, $\lambda/2$	-0.65	1.2	-21.0	-4.2	0.01
e) Endogenous Network, $\mu * 2$	-0.63	1.2	-21.3	-8.3	0.08
f) Endogenous Network, $\mu = 1$	-0.50	0.9	-21.2	-8.2	0.14

► Endogenous networks increases welfare loss by $\approx 60\%$

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- ▶ Endogenous networks increases welfare loss by $\approx 60\%$
 - ▶ Consistent with inefficiently low search (given double marginalization) column 5)

nonlinear effects

Gains From Trade

(b) Relative to International Autarky (Allow for Trade within Chile)

	1) $\widehat{\text{Welfare}}$ (%)	2) Relative to Fixed Network
Panel 1: Baseline Calibration		
a) Endogenous Network	15.1	1.36
b) Fixed Network, fix ε	11.1	1
Panel 2: Sensitivity to Parameters		
c) Endogenous Network, $\gamma * 2$	12.6	1.14
d) Endogenous Network, $\lambda/2$	12.6	1.14
e) Endogenous Network, $\mu * 2$	11.3	1.02
f) Endogenous Network, $\mu = 1$	9.2	0.82

- ▶ More “attenuation” effects from endogenous networks when we allow for domestic trade

Gains From Trade

(a) Relative to Municipality Autarky

	1) $\widehat{\text{Welfare}}$ (%)	2) Relative to Fixed Network
Panel 1: Baseline Calibration		
a) Endogenous Network	401	2.01
b) Fixed Network, fix ε	191	1
Panel 2: Sensitivity to Parameters		
c) Endogenous Network, $\gamma * 2$	241	1.26
d) Endogenous Network, $\lambda/2$	246	1.29
e) Endogenous Network, $\mu * 2$	205	1.07
f) Endogenous Network, $\mu = 1$	194	1.02

Gains From Trade

(a) Relative to Municipality Autarky

	1) $\widehat{\text{Welfare}}$ (%)	2) Relative to Fixed Network
Panel 1: Baseline Calibration		
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Panel 2: Sensitivity to Parameters		
c) Endogenous Network, $\gamma * 2$	241	1.26
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e) Endogenous Network, $\mu * 2$	205	1.07
f) Endogenous Network, $\mu = 1$	194	1.02

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Conclusion

- ▶ Build a multi-location GE model of production network formation under matching frictions
 - ▶ Tractably incorporate production network formation into the workhorse quantitative trade toolkit
- ▶ Provide ex-ante and ex-post sufficient statistics for aggregate effects of trade cost shocks
 - ▶ Network formation matters due to inefficiency, reallocation and amplification
- ▶ Estimated model with Chilean data shows that endogenous network tend to increase welfare effects of various trade shocks (40-60%)
 - ▶ Depends on the nature of experiment (sign, magnitudes, scope of shocks)

Appendix

(Constrained) Planning Problem

- ▶ Ad-valorem sales subsidy s_{id}^I
- ▶ Ad-valorem supplier and buyer search taxes t_{id}^S and t_{id}^B
- ▶ Lump-sum transfers to household T_i^F
- ▶ Planning problem with welfare weight ψ_i :

$$\max_{\{\{s_{id}^I, t_{id}^B, t_{id}^S\}, T_i^F\}} \sum_i \psi_i L_i Q_i^F$$

subject to equilibrium constraints and global planner balanced budget

- ▶ Focus on welfare weight $\psi_i = P_i$; see paper for general case

Optimal Policy Formula

- ▶ Optimal taxes/subsidies must satisfy

$$s_{id}^I = \frac{1}{\sigma}, \quad t_{id}^B = \frac{1}{\lambda^B} - 1, \quad t_{id}^S = \frac{1}{\lambda^S} (1 - \beta) \frac{E_d}{R_d} - 1$$

- ▶ s_{id}^I offset double marginalization
- ▶ t_{id}^B and t_{id}^S offset search and matching externalities, balancing two inefficiencies
 - ▶ non-appropriability: capture only a fraction of social surplus as revenue
 - ▶ business stealing: through congestion in matching and substitution among connected suppliers

Constrained Efficiency: Hosios-Type Result

Suppose $s_{id}^I = \frac{1}{\sigma}$. Then, $t_{id}^B = t_{id}^S = 0$ if and only if

$$\lambda^B = 1, \quad \lambda^S = 1 - \beta$$

► Intuition of buyer search:

$$\underbrace{\frac{1}{\sigma - 1} \frac{\lambda^B}{\gamma^B}}_{\text{social return of buyer search}} = \underbrace{\frac{1}{1 - s_{id}^I} \frac{1}{\sigma} \frac{1}{\gamma^B}}_{\text{firms' expenditure share for buyer search}}$$

- $\lambda^B = 1 \Rightarrow$ No congestion externality \Rightarrow Two inefficiencies cancel out
 - Similar to entry models with monopolistic competition & CES demand (Dixit-Stiglitz '77)
 - Efficiency requires IRS matching technology, unlike Hosios '90
 - Due to business stealing among connected suppliers

Ex-Ante Sufficient Statistics: $\{d \ln \tau_{ud}\}$ on Global Welfare

For welfare weights $\psi_i = P_i$,

$$d \ln \mathcal{W} = - \frac{\varsigma}{\frac{\beta}{1-\beta} - \frac{1-\mu}{\sigma-1} \left(\frac{\lambda^B}{\gamma^B} + \frac{\lambda^S}{\gamma^S} \right)} \underbrace{\sum_{u,d} X_{ud} d \ln \tau_{ud}}_{\text{Hulten}}$$

► ς : GDP to intermediate goods revenue ratio

$$\varsigma = \frac{\beta}{1-\beta} + \frac{1}{\sigma} - \frac{1-\mu}{\sigma} \left(\frac{1}{\gamma^B} + \frac{1-\beta}{\gamma^S} \right)$$

► Will proceed with special cases to build intuition

Special Case 1: Fixed Networks

$$d \ln \mathcal{W}^{\text{Fixed}} = - \underbrace{\frac{\zeta^{\text{Fixed}}}{1 - \beta}}_{\text{IO multiplier}} \underbrace{\sum_{u,d} X_{ud} d \ln \tau_{ud}}_{\text{Hulten}}$$

$$\zeta^{\text{Fixed}} = \frac{\beta}{1 - \beta} + \frac{1}{\sigma}$$

- ▶ Double marginalization \Rightarrow Hulten underpredicts welfare changes (e.g., Baqaee-Farhi '23)
- ▶ Optimal sales subsidy $s_{id}^I = \frac{1}{\sigma} \Rightarrow$ Hulten

Special Case 2: Endogenous Networks with Sales Subsidy $s_{id}^I = \frac{1}{\sigma}$

$$d \ln \mathcal{W}^{\text{SalesSubsidy}} = - \frac{\zeta}{\frac{\beta}{1-\beta} - \underbrace{\frac{1-\mu}{\sigma-1} \left(\frac{\lambda^B}{\gamma^B} + \frac{\lambda^S}{\gamma^S} \right)}_{\text{multiplier effect through search cost}}} \underbrace{\sum_{u,d} X_{ud} d \ln \tau_{ud}}_{\text{Hulten}}$$

$$\zeta = \frac{\beta}{1-\beta} - \underbrace{\frac{1-\mu}{\sigma-1} \left(\frac{1}{\gamma^B} + \frac{1-\beta}{\gamma^S} \right)}_{\text{spending of retail goods for search activity}}$$

- ▶ $\lambda^B = 1, \lambda^S = 1 - \beta \Rightarrow$ Search is constrained efficient \Rightarrow Hulten

Special Case 2: Endogenous Networks with Sales Subsidy $s_{id}^! = \frac{1}{\sigma}$

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- ▶ $\lambda^B = 1, \lambda^S = 1 - \beta \Rightarrow$ Search is constrained efficient \Rightarrow Hulten
- ▶ ... but not vice versa if $\mu = 1$ (no intermediates in search costs) or $\frac{\lambda^B}{\gamma^B} + \frac{\lambda^S}{\gamma^S} = \frac{1}{\gamma^B} + \frac{1-\beta}{\gamma^S}$
 - ▶ While labor may be misallocated, trade flows are not distorted
 - ▶ Misallocation between buyer and supplier search also does not matter if total search is not

Endogenous Networks with Laissez-Faire Equilibrium $s_{id}^l = 0$

$$d \ln \mathcal{W} = - \frac{\varsigma}{\frac{\beta}{1-\beta} - \underbrace{\frac{1-\mu}{\sigma-1} \left(\frac{\lambda^B}{\gamma^B} + \frac{\lambda^S}{\gamma^S} \right)}_{\text{multiplier effect through search cost}}} \underbrace{\sum_{u,d} X_{ud} d \ln \tau_{ud}}_{\text{Hulten}}$$

$$\varsigma = \frac{\beta}{1-\beta} + \frac{1}{\sigma} - \underbrace{\frac{1-\mu}{\sigma} \left(\frac{1}{\gamma^B} + \frac{1-\beta}{\gamma^S} \right)}_{\text{spending of retail goods for search activity}}$$

- ▶ Fixed networks: double marginalization
- ▶ Endogenous networks: double marginalization + search inefficiency

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- ▶ Fixed networks: double marginalization
- ▶ Endogenous networks: double marginalization + search inefficiency
- ▶ Two inefficiencies interact
 - ▶ Double marginalization lowers firm revenue, decreasing private incentive for search
 - ▶ Even if $\lambda^B = 1$, $\lambda^S = 1 - \beta$, endogenous networks implies a larger coefficient

Calibration

- ▶ Multi-sector (2) extension as in Caliendo-Parro '15: Cobb-Douglas in tech/pref [detail](#)
- ▶ Calibrate the model with 345 municipalities in Chile + US, China, ROW
- ▶ Match bilateral sectoral domestic & international trade flows ($X_{ud,kl}$)
- ▶ Calibrated parameters [detail](#)
 - ▶ Input coefficients and final consumption $\{\alpha_k, \beta_{km}\}$ from aggregate IO table
 - ▶ $\{\gamma_k^S, \gamma_k^B\}$ from firm-level relationship between sales and number of linkages
 - ▶ Trade elasticities $\{\varepsilon_k\}$ from literature (Fontagné et al., 2022; Gervais and Jensen, 2019)
 - ▶ $\{\lambda^S = \lambda^B, \mu\}$ by targeting reduced-form effects of import tariff reduction \Rightarrow Indirect inference

Impacts of Import Tariff Changes: Data vs Model

- ▶ Simulate the import tariff reduction from US and China
- ▶ Choose $\{\lambda^S = \lambda^B, \mu\}$ that minimize squared distance to targeted regression coefficients

Parameters	Value
$\lambda^S = \lambda^B$	0.64
μ	0.05

	Untargeted		Targeted	
	Total Imports (1)	Number Foreign Suppliers (2)	Number Domestic Suppliers (3)	Number Domestic Buyers (4)
Data	-3.20 (1.11)	-1.86 (0.61)	-1.48 (0.72)	-1.23 (1.10)
Model	-3.93	-1.44	-1.40	-1.54

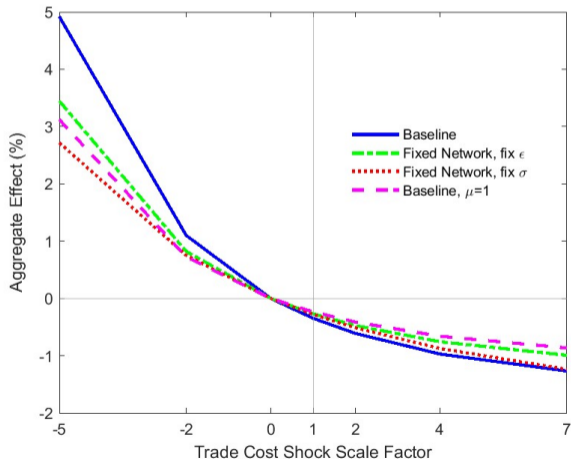
- ▶ $\mu \ll 1$ rationalize the domestic supplier link **decrease** in response to tariff increase intuition

Calibration Results

Parameters	Goods	Services	Description
α_k	0.25	0.75	Final consumption share
$\{\beta_{k,L}\}$	0.14	0.33	Labor coefficient in production
$\{\beta_{lk}\}$			Intermediate input coefficient in production
<i>l</i> : Goods Sector	0.45	0.10	
<i>l</i> : Services Sector	0.41	0.57	
γ_k^S	2.6	2.7	Search cost curvature w.r.t. suppliers
γ_k^B	4.5	2.8	Search cost curvature w.r.t. buyers
ε_k	5.0	4.6	Trade elasticity
μ_k	0.05	0.05	Labor coefficient in search
$\lambda_{kl}^S = \lambda_{kl}^B (\forall k, l)$	0.64	0.64	Matching function elasticity
σ_k	4.1	3.5	Elasticity of substitution

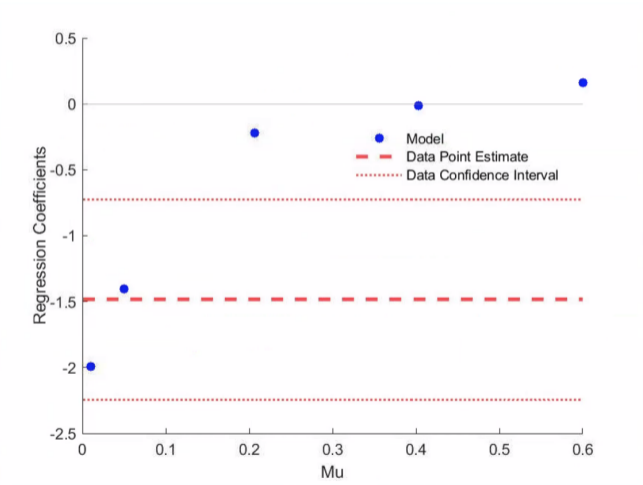
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Nonlinear Effects



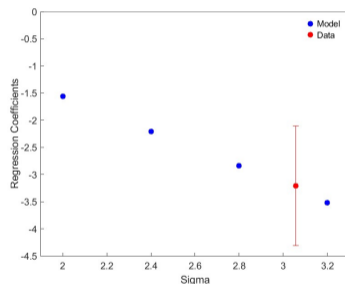
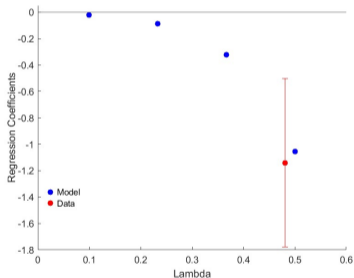
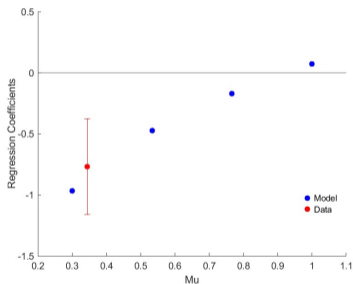
- ▶ Fixing trade elasticity ϵ , shutting down endogenous networks always \downarrow effects
 - ▶ From search cost amplification ($\mu < 1$)
- ▶ Fixing elasticity of substitution σ , shutting down endogenous networks can \uparrow welfare effects for large increase in trade costs
 - ▶ Larger $\epsilon \Rightarrow$ reallocation of trade flows

Intuition Behind Identification of μ



(a) μ : Number of Domestic Suppliers

Identification of $\lambda^S = \lambda^B$, σ , μ from Indirect Inference



(b) μ : Number of Domestic Suppliers

(c) λ : Number of Domestic Buyers

(d) σ : Total Imports