Contracting Frictions in Global Sourcing: Implications for Welfare

Davin Chor
Dartmouth, NUS and NBER

Lin Ma
NUS

Dec 2019

Backdrop

Contracting frictions matter:

- for the pattern of trade (e.g., Levchenko 2007; Nunn 2007); and
- for the global sourcing of inputs (e.g., Antràs and Helpman 2004, 2008; Antràs and Chor 2013; Alfaro et al. 2019).

We now have:

- Frameworks that spotlight how decisions over organizational mode – i.e., integration vs outsourcing – can help firms to cope with contracting frictions and holdup problems encountered when they source from suppliers.
- Supporting empirical evidence, often based on the intrafirm trade share as a proxy for the propensity to integrate vs outsource.

Backdrop

Contracting frictions matter:

- for the pattern of trade (e.g., Levchenko 2007; Nunn 2007); and
- for the global sourcing of inputs (e.g., Antràs and Helpman 2004, 2008; Antràs and Chor 2013; Alfaro et al. 2019).

We now have:

- Frameworks that spotlight how decisions over organizational mode – i.e., integration vs outsourcing – can help firms to cope with contracting frictions and holdup problems encountered when they source from suppliers.
- Supporting empirical evidence, often based on the intrafirm trade share as a proxy for the propensity to integrate vs outsource.

However: Much less is known about *how much* such considerations related to contracting frictions matter for welfare.

(Notwithstanding: Boehm 2018; Fally and Hillberry 2015; Startz 2018.)

This project

Develop a quantitative trade model based on Eaton-Kortum where:

- Firms source a continuum of input varieties
  - . . . and decide both the source country and organizational mode under which to procure each input variety
- Source countries differ in terms of technology, factor costs, trade costs,
  - . . . and the severity of contracting frictions, specifically the extent to which firm-supplier bargaining constrains production outcomes (*a la* Grossman-Hart-Moore)
- Adopt a nested-Fréchet specification for the joint distribution of supplier productivities across sourcing modes,. . .
  - which facilitates aggregation

This project (cont.)

The model delivers:

- **Sourcing:** An EK type expression for sourcing shares by country-mode
- **Gravity:** A modified gravity equation for bilateral trade flows by source country and organizational mode

This project (cont.)

The model delivers:

- **Sourcing:** An EK type expression for sourcing shares by country-mode
- **Gravity:** A modified gravity equation for bilateral trade flows by source country and organizational mode
- **Welfare:** A closed-form expression for welfare change, in response to shifts in trade costs or contracting frictions
  - Nests ACR (2012) as a special case
  - ... while highlighting clearly how contracting frictions – as captured by the generalized Nash bargaining shares – modify the standard formula.

    One interpretation: Contracting frictions distort the effective state of technology accessible to input-sourcing firms.

This project (cont.)

Propose an estimation strategy.

- Based on:
  - (i) a structural estimating equation where the dependent variable is the intrafirm import share; and
  - (ii) a functional form for how country variables (such as the rule of law) or industry characteristics (such as contractibility) map into the bargaining parameters underlying the contracting frictions

This project (cont.)

Propose an estimation strategy.

- Based on:
  - (i) a structural estimating equation where the dependent variable is the intrafirm import share; and
  - (ii) a functional form for how country variables (such as the rule of law) or industry characteristics (such as contractibility) map into the bargaining parameters underlying the contracting frictions
- Relatively low data requirements for implementation: Intrafirm trade shares at the industry level (e.g., from the U.S. Related Party Database), with key parameters estimated via NLLS

$\Rightarrow$ Yields all the ingredients we need to evaluate welfare counterfactuals.

E.g.: How much does an improvement in country rule of law affect welfare via this input-sourcing channel?

Caveats for today's presentation:

- Model has a lot of building blocks

  At the expense of over-simplifying: Think Grossman and Hart (1986), Antràs (2003) in a quantitative trade model.

- Rich counterfactuals (in need of unpacking)

  Today's exercise: An improvement in rule of law in China.

- Empirical estimates are still *preliminary*.

  Work-in-progress: A richer model with partial contractibility, following Acemoglu et al. (2007), Antràs and Helpman (2008)

Roadmap for this talk

1. Motivation and Introduction
2. Model: Contracting Frictions and Global Sourcing meets Quantitative Trade
3. Taking the Model to the Data
4. Estimation and Counterfactuals (Preliminary)
5. Concluding remarks and next steps

Contracting Frictions and Global Sourcing in a Quantitative Trade Model

Utility

J countries (indexed by j).

Representative consumer derives utility from final-good varieties (indexed by ω):

$$U_j = \left(\int_{\omega \in \Omega} c_j(\omega)^\rho d\omega \right)^{\frac{1}{\rho}}, \ \rho \in (0,1). \tag{1}$$

Assume a fixed measure of firms. Associate each ω with a final-good producing firm whose productivity ϕ is an iid draw from $G_j(\phi)$.

We have:

$$q_j(\phi) = A_j p_j(\phi)^{-\frac{1}{1-\rho}},$$
$$R_j(\phi) = A_j^{1-\rho} q_j(\phi)^\rho.$$

where $A_j = I_j P_j^{\frac{\rho}{1-\rho}}$ is a function of total country-j income, I_j.

Final-good Production

- Each final-good variety is produced using inputs from K industries.
- Input varieties are sourced globally, and assembled with domestic labor. (Final-goods are not traded.)

$$y_j(\phi) = \phi \left(\prod_{k=1}^{K} \left(X_j^k(\phi) \right)^{\eta^k} \right)^{1-\alpha} L_j(\phi)^{\alpha}, \text{ where} \tag{2}$$

$$X_j^k(\phi) = \left(\int_{\ell=0}^{1} \tilde{x}_j^k(\phi;\ell)^{\rho^k} d\ell \right)^{\frac{1}{\rho^k}}.$$

- $X_j^k(\phi)$: Composite industry-k input, from a unit measure of input varieties, $\tilde{x}_j^k(\phi;\ell)$, indexed by ℓ. (c.f., Tintelnot 2017, Antràs et al. 2017)
- $L_j(\phi)$: Labor used in final assembly.
- Assume: $0 < \alpha < 1$; $0 < \eta^k < 1$; $\sum_k \eta^k = 1$; $0 < \rho < \rho^k < 1$.

Final-good Production

$$X_j^k(\phi) = \left(\int_{\ell=0}^{1} \tilde{x}_j^k(\phi;\ell)^{\rho^k} d\ell \right)^{\frac{1}{\rho^k}}$$

- Each input variety ℓ is produced by combining headquarter services from the firm, $h_j^k(\phi;\ell)$, and supplier inputs, $x_j^k(\phi;\ell)$:

$$\tilde{x}_j^k(\phi;\ell) = \left[h_j^k(\phi;\ell) \right]^{\alpha^k} \left[x_j^k(\phi;\ell) \right]^{1-\alpha^k}, \; 0 < \alpha^k < 1.$$

- Both $h_j^k(\phi;\ell)$ and $x_j^k(\phi;\ell)$ are relationship-specific.

Input Sourcing and Bargaining

For each input variety, ℓ:

- Let source country be i and organizational mode be $\chi \in \{V, O\}$ (V: integration; O: outsourcing)
- $2J$ possible "sourcing modes", (i, χ)

Input Sourcing and Bargaining

For each input variety, ℓ:

- Let source country be i and organizational mode be $\chi \in \{V, O\}$ (V: integration; O: outsourcing)
- $2J$ possible "sourcing modes", (i, χ)
- With an incomplete contracting environment, payoffs are determined ex-post in bilateral negotiations between the firm and each supplier.
- $\beta^k_{ij\chi}$: Generalized Nash bargaining share that accrues to the firm under sourcing mode (i, χ). Varies by:
  - Source country i. E.g.: Rule of law.
  - Industry k. E.g.: Contractibility.
- Natural assumption: $0 < \beta^k_{ijO} < \beta^k_{ijV} < 1$, reflecting the firm's greater residual rights of control when it has ownership over the supplier (Grossman and Hart 1986)

Input Sourcing and Bargaining: Timing

- Firm posts contracts for a supplier for each input variety ℓ, specifying: (i) an ex-ante participation fee; and (ii) the sourcing mode over ℓ
- Firm picks a supplier for each ℓ
- Supplier of ℓ chooses how much to invest in providing the input: $x_j^k(\phi;\ell)$
- Firm simultaneously chooses how much to invest in hq services: $h_j^k(\phi;\ell)$

Input Sourcing and Bargaining: Timing

- Firm posts contracts for a supplier for each input variety ℓ, specifying: (i) an ex-ante participation fee; and (ii) the sourcing mode over ℓ
- Firm picks a supplier for each ℓ
- Supplier of ℓ chooses how much to invest in providing the input: $x_j^k(\phi;\ell)$
- Firm simultaneously chooses how much to invest in hq services: $h_j^k(\phi;\ell)$
- Firm and each supplier bargain over the incremental revenue contributed by the input variety ℓ, taking the investment levels for other inputs as given
- Incremental revenue $r_j^k(\phi;\ell)$ computed following heuristic from Acemoglu et al. (2007): Details

$$r_j^k(\phi;\ell) = (1-\alpha)\frac{\rho\eta^k}{\rho^k} R_j(\phi) \left(\frac{\tilde{x}_j^k(\phi;\ell)}{X_j^k(\phi)}\right)^{\rho^k}. \tag{3}$$

Input Sourcing and Bargaining: Setup

Firm chooses $h_j^k(\phi;\ell)$ to maximize:

$$\beta_{ij\chi}^k r_j^k(\phi;\ell) - s_j h_j^k(\phi;\ell). \tag{4}$$

where the firm's costs are in units of skilled labor.

Input Sourcing and Bargaining: Setup

Firm chooses $h_j^k(\phi;\ell)$ to maximize:

$$\beta_{ij\chi}^k r_j^k(\phi;\ell) - s_j h_j^k(\phi;\ell). \tag{4}$$

where the firm's costs are in units of skilled labor.

Supplier ℓ chooses $x_j^k(\phi;\ell)$ to maximize:

$$F_{ij}^k(\phi;\ell) = (1-\beta_{ij\chi}^k) r_j^k(\phi;\ell) - c_{ij\chi}^k(\phi;\ell) x_j^k(\phi;\ell), \tag{5}$$

where the unit cost, $c_{ij\chi}^k$, is incurred in units of labor:

$$c_{ij\chi}^k(\phi;\ell) = \frac{d_{ij}^k w_i}{Z_{ij\chi}^k(\phi;\ell)}. \tag{6}$$

- $d_{ij}^k \geq 1$: iceberg trade costs
- $Z_{ij\chi}^k(\phi;\ell)$: labor productivity

Input Sourcing and Bargaining: Setup

Specify a nested Fréchet for the joint distribution of the $Z^k_{ij\chi}(\phi;\ell)$'s over the $2J$ possible sourcing modes.

$Pr\left(Z^k_{1jV} \leq z^k_{1jV}, Z^k_{1jO} \leq z^k_{1jO}, \ldots, Z^k_{JjO} \leq z^k_{JjO}\right)$ is given by:

$$\exp\left\{-\sum_{i=1}^{J} T_i^k \left(\left(z^k_{ijV}\right)^{-\frac{\theta^k}{1-\lambda_i}} + \left(z^k_{ijO}\right)^{-\frac{\theta^k}{1-\lambda_i}}\right)^{1-\lambda_i}\right\}, \quad (7)$$

where $\theta^k > 1$ and $0 < \lambda_i < 1$.

Input Sourcing and Bargaining: Setup

Specify a nested Fréchet for the joint distribution of the $Z^k_{ij\chi}(\phi;\ell)$'s over the $2J$ possible sourcing modes.

$Pr\left(Z^k_{1jV} \leq z^k_{1jV}, Z^k_{1jO} \leq z^k_{1jO}, \ldots, Z^k_{JjO} \leq z^k_{JjO}\right)$ is given by:

$$\exp\left\{-\sum_{i=1}^{J} T^k_i \left(\left(z^k_{ijV}\right)^{-\frac{\theta^k}{1-\lambda_i}} + \left(z^k_{ijO}\right)^{-\frac{\theta^k}{1-\lambda_i}}\right)^{1-\lambda_i}\right\}, \tag{7}$$

where $\theta^k > 1$ and $0 < \lambda_i < 1$.

Remarks:

- Analogue of the nested logit in discrete choice models.
- Relaxes the Independence of Irrelevant Alternatives (IIA) assumption inherent in Fréchet, ... by introducing a correlation parameter λ_i for "within-nest" draws.
- Timing: Full set of productivity draws for each ℓ are observed by the firm prior to contracting with any supplier.

Input sourcing decision

- Solve for $h_j^k(\phi;\ell)$ and $x_j^k(\phi;\ell)$ from FOCs of firm and supplier ℓ.
- Bearing in mind the ex-ante transfer, firm chooses sourcing mode (i,χ) over input variety ℓ to maximize:

$$r_j^k(\phi;\ell) - s_j h_j^k(\phi;\ell) - c_{ij\chi}^k(\phi;\ell)x_j^k(\phi;\ell).$$

s.t. $h_j^k(\phi;\ell)$ and $x_j^k(\phi;\ell)$ from the FOCs.

Input sourcing decision

- Solve for $h_j^k(\phi;\ell)$ and $x_j^k(\phi;\ell)$ from FOCs of firm and supplier ℓ.
- Bearing in mind the ex-ante transfer, firm chooses sourcing mode (i,χ) over input variety ℓ to maximize:

$$r_j^k(\phi;\ell) - s_j h_j^k(\phi;\ell) - c_{ij\chi}^k(\phi;\ell) x_j^k(\phi;\ell).$$

s.t. $h_j^k(\phi;\ell)$ and $x_j^k(\phi;\ell)$ from the FOCs.

- Or equivalently:

$$\arg\max_{(i,\chi)} \Xi_{ij\chi}^k Z_{ij\chi}^k,$$

where:

$$\Xi_{ij\chi}^k = \left(1-\beta_{ij\chi}^k\right)\left(\beta_{ij\chi}^k\right)^{\frac{\alpha^k}{1-\alpha^k}}\left[\frac{1}{\rho^k} - \alpha^k\beta_{ij\chi}^k - (1-\alpha^k)(1-\beta_{ij\chi}^k)\right]^{\frac{1-\rho^k}{\rho^k(1-\alpha^k)}}$$
$$\times\left[(1-\alpha)\rho\eta^k R_j(\phi)\left(X_j^k\right)^{-\rho^k}\right]^{\frac{1}{\rho^k(1-\alpha^k)}}\left(\frac{\alpha^k}{s_j}\right)^{\frac{\alpha^k}{1-\alpha^k}}\left(\frac{1-\alpha^k}{d_{ij}^k w_i}\right) \quad (8)$$

Sourcing Shares

Share of inputs sourced under mode (i, χ) is equal to $\pi_{ij}^{k} \pi_{\chi|ij}^{k}$.

Sourcing Shares

Share of inputs sourced under mode (i, χ) is equal to $\pi_{ij}^k \pi_{\chi|ij}^k$.

$$\pi_{ij}^k = \frac{T_i^k (d_{ij}^k w_i)^{-\theta^k} \left((B_{ijV}^k)^{\frac{\theta^k}{1-\lambda_i}} + (B_{ijO}^k)^{\frac{\theta^k}{1-\lambda_i}} \right)^{1-\lambda_i}}{\Phi_j^k},$$

where: $\Phi_j^k \equiv \sum_{i'=1}^J T_{i'}^k (d_{i'j}^k w_{i'})^{-\theta^k} \left((B_{i'jV}^k)^{\frac{\theta^k}{1-\lambda_{i'}}} + (B_{i'jO}^k)^{\frac{\theta^k}{1-\lambda_{i'}}} \right)^{1-\lambda_{i'}}.$

- π_{ij}^k: probability of sourcing from country i
- $B_{ij\chi}^k \equiv (1 - \beta_{ij\chi}^k) \left(\beta_{ij\chi}^k\right)^{\frac{\alpha^k}{1-\alpha^k}} \left[\frac{1}{\rho^k} - \alpha^k \beta_{ij\chi}^k - (1-\alpha^k)(1-\beta_{ij\chi}^k)\right]^{\frac{1-\rho^k}{\rho^k(1-\alpha^k)}}.$

  Reflects the non-monotonic effect of the firm's bargaining share $\beta_{ij\chi}^k$ on sourcing choices:

  A higher $\beta_{ij\chi}^k$ raises the firm's payoff, but dis-incentivizes the supplier.

Sourcing Shares

Share of inputs sourced under mode (i, χ) is equal to $\pi_{ij}^k \pi_{\chi|ij}^k$.

$$\pi_{ij}^k = \frac{T_i^k (d_{ij}^k w_i)^{-\theta^k} \left((B_{ijV}^k)^{\frac{\theta^k}{1-\lambda_i}} + (B_{ijO}^k)^{\frac{\theta^k}{1-\lambda_i}} \right)^{1-\lambda_i}}{\Phi_j^k},$$

where: $\Phi_j^k \equiv \sum_{i'=1}^J T_{i'}^k (d_{i'j}^k w_{i'})^{-\theta^k} \left((B_{i'jV}^k)^{\frac{\theta^k}{1-\lambda_{i'}}} + (B_{i'jO}^k)^{\frac{\theta^k}{1-\lambda_{i'}}} \right)^{1-\lambda_{i'}}$.

- **Compare with EK2002:** Contracting frictions distort the effective state of technology available to sourcing firms

Sourcing Shares

Share of inputs sourced under mode (i, χ) is equal to $\pi_{ij}^{k} \pi_{\chi|ij}^{k}$.

$$\pi_{\chi|ij}^{k} = \frac{(B_{ij\chi}^{k})^{\frac{\theta^k}{1-\lambda_i}}}{(B_{ijV}^{k})^{\frac{\theta^k}{1-\lambda_i}} + (B_{ijO}^{k})^{\frac{\theta^k}{1-\lambda_i}}}.$$

- $\pi_{\chi|ij}^{k}$: probability of sourcing under organizational mode χ conditional on selecting country i
- Conditional probability is a function of the $\beta_{ij\chi}^{k}$'s and other deep model parameters

  (In particular: Does not depend on T_i^k, d_{ij}^k or w_i.)

Towards Aggregate Trade Flows and Welfare

Next step: From firm-level decisions to aggregate variables.

To get there, need to fully solve out the firm's problem.

Towards Aggregate Trade Flows and Welfare

Next step: From firm-level decisions to aggregate variables.

To get there, need to fully solve out the firm's problem.

(i) *Composite industry-k input*:

$$X_j^k(\phi)^{\rho^k} = \mathbb{E}_\ell\left[\tilde{x}_j^k(\phi; l)^{\rho^k}\right] \propto \mathbb{E}_\ell\left[Z_{ij\chi}^k(\phi;\ell)^{\frac{(1-\alpha^k)\rho^k}{1-\rho^k}}\right]. \tag{9}$$

Assuming $\theta^k > \frac{\rho^k}{1-\rho^k}$, can be evaluated explicitly using:

$$\mathbb{E}_\ell\left[Z_{ij\chi}^k(\phi;\ell)^{\frac{(1-\alpha^k)\rho^k}{1-\rho^k}}\right] = \bar{\Gamma}^k \times \pi_{ij}^k \pi_{\chi|ij}^k \left(\Phi_j^k\right)^{\frac{1}{\theta^k}\frac{(1-\alpha^k)\rho^k}{1-\rho^k}} \frac{\left(d_{ij}^k w_i\right)^{\frac{(1-\alpha^k)\rho^k}{1-\rho^k}}}{\left(\beta_{ij\chi}^k\right)^{\frac{1-\rho^k(1-\alpha^k)}{1-\rho^k}}\left(1-\beta_{ij\chi}^k\right)^{\frac{(1-\alpha^k)\rho^k}{1-\rho^k}}}.$$

where $\bar{\Gamma}^k \equiv \Gamma\left(1 - \frac{1}{\theta^k}\frac{(1-\alpha^k)\rho^k}{1-\rho^k}\right)$, and $\Gamma(\cdot)$ denotes the Gamma function.

Towards Aggregate Trade Flows and Welfare (cont.)

(ii) *Full solution to the firm's problem.*

Firm's overall payoff (with ex-ante transfers):

$$F_j(\phi) = R_j(\phi) - \sum_{k=1}^{K} \int_{\ell=0}^{1} s_j h_j^k(\phi, \ell) d\ell - \sum_{k=1}^{K} \int_{\ell=0}^{1} c_{ij\chi}^k(\phi, \ell) x_j^k(\phi, \ell) d\ell - w_j L_j(\phi), \tag{10}$$

- Use this to solve for $L_j(\phi)$ (labor used in home country for final-good assembly)
- After simplification: $X_j^k(\phi)$, $L_j(\phi)$ and hence $q_j(\phi)$ are all linear functions of $R_j(\phi)$.

Towards Aggregate Trade Flows and Welfare (cont.)

(ii) *Full solution to the firm's problem.*

In particular:

$$
\begin{aligned}
X_j^k(\phi) &= \left(1-\alpha^k\right)^{1-\alpha^k}\left(\frac{\alpha^k}{s_j}\right)^{\alpha^k}(1-\alpha)\rho\eta^k\left(\bar{\Gamma}^k\right)^{\frac{1-\rho^k}{\rho^k}}\left(\Phi_j^k\right)^{\frac{1-\alpha^k}{\theta^k}}\left(\Upsilon_j^k\right)^{-\frac{1-\rho^k}{\rho^k}}R_j(\phi), \\
L_j(\phi) &= \frac{\alpha\rho}{w_j}\bar{\Upsilon}_j R_j(\phi).
\end{aligned}
$$

- Υ_j^k and $\bar{\Upsilon}_j$ are functions of the underlying parameters, including the $\beta_{ij\chi}^k$ bargaining shares
- These capture how contracting frictions distort the aggregate composite input and decisions over assembly labor, relative to a frictionless benchmark. Details

Towards Aggregate Trade Flows and Welfare (cont.)

(iii) Moreover, can show that:

$$R_j(\phi) \quad = \quad I_j \left(\phi/\bar{\phi}\right)^{\frac{\rho}{1-\rho}} ,$$

where $\bar{\phi} = \left(\int \phi^{\frac{\rho}{1-\rho}} dG_j(\phi)\right)^{\frac{1-\rho}{\rho}}$ and $I_j = \frac{w_j \bar{L}_j + s_j \bar{H}_j}{1-(1-\alpha\rho)\bar{\Upsilon}_j}$.

Towards Aggregate Trade Flows and Welfare (cont.)

(iii) Moreover, can show that:

$$R_j(\phi) \quad = \quad I_j \left(\phi/\bar{\phi}\right)^{\frac{\rho}{1-\rho}},$$

where $\bar{\phi} = \left(\int \phi^{\frac{\rho}{1-\rho}} dG_j(\phi)\right)^{\frac{1-\rho}{\rho}}$ and $I_j = \frac{w_j \bar{L}_j + s_j \bar{H}_j}{1-(1-\alpha\rho)\bar{\Upsilon}_j}$.

Upshot: $q_j(\phi)$ – and hence utility – can be solved for explicitly as a function of:

- Deep model parameters; and
- the factor prices (w_j and s_j), the Υ_j^k's, $\bar{\Upsilon}_j$, and the Φ_j^k's.

One last useful substitution:

$$\Phi_j^k \quad = \quad \frac{T_j^k (w_j)^{-\theta^k}}{\pi_{jj}^k} \left((B_{jjV}^k)^{\frac{\theta^k}{1-\lambda_j}} + (B_{jjO}^k)^{\frac{\theta^k}{1-\lambda_j}} \right)^{1-\lambda_j}.$$

Welfare

$$U_j \propto \rho I_j \frac{\alpha^\alpha (1-\alpha)^{1-\alpha}}{w_j^\alpha} \bar{\phi} \times \left[\prod_{k=1}^{K} \left(\frac{1-\alpha^k}{w_j} \right)^{\eta^k (1-\alpha^k)} \left(\frac{\alpha^k}{s_j} \right)^{\eta^k \alpha^k} \right]^{1-\alpha} \times (\bar{\Upsilon}_j)^\alpha$$

$$\times \prod_{k=1}^{K} \left(\left(\frac{T_j^k}{\pi_{jj}^k} \right)^{\frac{1-\alpha^k}{\theta^k}} \left((B_{jjV}^k)^{\frac{\theta^k}{1-\lambda_j}} + (B_{jjO}^k)^{\frac{\theta^k}{1-\lambda_j}} \right)^{\frac{(1-\lambda_j)(1-\alpha^k)}{\theta^k}} \left(\Upsilon_j^k \right)^{-\frac{1-\rho^k}{\rho^k}} \right)^{\eta^k (1-\alpha)} .$$

Contracting frictions affect welfare directly through three channels:

(i) $\left((B_{jjV}^k)^{\frac{\theta^k}{1-\lambda_j}} + (B_{jjO}^k)^{\frac{\theta^k}{1-\lambda_j}} \right)^{\frac{(1-\lambda_j)(1-\alpha^k)}{\theta^k}}$: The effective state of technology

Welfare

$$U_j \quad \propto \quad \rho I_j \frac{\alpha^\alpha (1-\alpha)^{1-\alpha}}{w_j^\alpha} \bar{\phi} \times \left[\prod_{k=1}^{K} \left(\frac{1-\alpha^k}{w_j} \right)^{\eta^k (1-\alpha^k)} \left(\frac{\alpha^k}{s_j} \right)^{\eta^k \alpha^k} \right]^{1-\alpha} \times (\bar{\Upsilon}_j)^\alpha$$

$$\times \prod_{k=1}^{K} \left(\left(\frac{T_j^k}{\pi_{jj}^k} \right)^{\frac{1-\alpha^k}{\theta^k}} \left((B_{jjV}^k)^{\frac{\theta^k}{1-\lambda_j}} + (B_{jjO}^k)^{\frac{\theta^k}{1-\lambda_j}} \right)^{\frac{(1-\lambda_j)(1-\alpha^k)}{\theta^k}} \left(\Upsilon_j^k \right)^{-\frac{1-\rho^k}{\rho^k}} \right)^{\eta^k (1-\alpha)} .$$

Contracting frictions affect welfare directly through three channels:

(i) $\left((B_{jjV}^k)^{\frac{\theta^k}{1-\lambda_j}} + (B_{jjO}^k)^{\frac{\theta^k}{1-\lambda_j}} \right)^{\frac{(1-\lambda_j)(1-\alpha^k)}{\theta^k}}$: The effective state of technology

(ii) $\left(\Upsilon_j^k \right)^{-\frac{1-\rho^k}{\rho^k}}$: Distortion to investments in the relationship-specific inputs

(iii) $(\bar{\Upsilon}_j)^\alpha$: Firm can compensate for (ii) via its optimal choice of $L_j(\phi)$

Welfare (cont.)

Let $\hat{X} \equiv X'/X$. Consider shocks to either trade costs (the d_{ij}^k's) or to contracting conditions (the $\beta_{ij\chi}^k$'s). Then:

$$\widehat{U_j} = \widehat{\frac{I_j}{w_j^\alpha}} \left[\widehat{\prod_{k=1}^K (w_j)^{-\eta^k(1-\alpha^k)} (s_j)^{-\eta^k \alpha^k}} \right]^{1-\alpha} \times \widehat{(\bar{\Upsilon}_j)^\alpha}$$

$$\times \prod_{k=1}^K \left(\left(\widehat{\pi_{jj}^k}\right)^{-\frac{1-\alpha^k}{\theta^k}} \left(\widehat{(B_{jjV}^k)^{\frac{\theta^k}{1-\lambda_j}} + (B_{jjO}^k)^{\frac{\theta^k}{1-\lambda_j}}} \right)^{\frac{(1-\lambda_j)(1-\alpha^k)}{\theta^k}} \left(\widehat{\Upsilon_j^k}\right)^{-\frac{1-\rho^k}{\rho^k}} \right)^{\eta^k(1-\alpha)}$$

Neat decomposition of sources of welfare change:

(i) $\left(\widehat{\pi_{jj}^k}\right)^{-\frac{1}{\theta^k}}$: As in e.g., ACR (2012) and Costinot and Rodriguez-Clare (2014)

(ii) Three terms that capture distortions induced by contracting frictions

(iii) General equilibrium effects through factor prices

Trade flows by sourcing mode

Assume trade flows observed are equal to payments to suppliers, i.e., the share $(1-\beta^k_{ij\chi})$ of incremental revenues, summed over all suppliers under mode (i,χ)

$$t^k_{ij\chi} = (1-\alpha)\rho\eta^k \frac{\Upsilon^k_j}{\Phi^k_j}\gamma I_j \times T^k_i (w_i)^{-\theta^k} \left[\left(B^k_{ijV}\right)^{\frac{\theta^k}{1-\lambda_i}} + \left(B^k_{ijO}\right)^{\frac{\theta^k}{1-\lambda_i}} \right]^{-\lambda_i}$$
$$\times \left(d^k_{ij}\right)^{-\theta^k} \times \left(1-\beta^k_{ij\chi}\right) \frac{1+\alpha^k\beta^k_{ij\chi} + (1-\alpha^k)(1-\beta^k_{ij\chi})}{\frac{1}{\rho^k} - \alpha^k\beta^k_{ij\chi} - (1-\alpha^k)(1-\beta^k_{ij\chi})} \left(B^k_{ij\chi}\right)^{\frac{\theta^k}{1-\lambda_i}} \tag{11}$$

A gravity-like decomposition of terms into:

- a destination-country by industry component
- a source-country by industry component
- bilateral trade costs
- a component specific to sourcing mode (i,χ)

Taking the Model to the Data

Estimation: Framework

Empirical setting: U.S. Related Party Trade Database

- $\tilde{t}^k_{ij\chi}$: Observed value of industry-k imports from country i, under mode $\chi \in \{V, O\}$. ($j = US$ throughout.)
- Map k to NAICS 6-digit industries

Posit that trade flows from (11) are observed with error:

$$\tilde{t}^k_{ij\chi} = t^k_{ij\chi} \cdot \epsilon^k_{ij\chi} \;=\; a^k_{ij\chi} \cdot a^k_{ij} \cdot \epsilon^k_{ij\chi}, \tag{12}$$

where:

- a^k_{ij} collects terms that are specific to the country-pair-by-industry; Details
- $a^k_{ij\chi}$ collects terms that vary further by organizational mode; and
- $\epsilon^k_{ij\chi}$ is an iid Poisson noise term with unit mean.

Estimation: Framework (cont.)

Treat a_{ij}^k as a source-by-industry fixed effect. Writing down the quasi-maximum likelihood function, the FOC with respect to a_{ij}^k implies:

$$a_{ij}^k \sum_{\chi \in \{V,O\}} a_{ij\chi}^k = \sum_{\chi \in \{V,O\}} \tilde{t}_{ij\chi}^k$$

$$\Rightarrow \qquad a_{ij}^k = \frac{\sum_{\chi = V,O} \tilde{t}_{ij\chi}^k}{\sum_{\chi = V,O} a_{ij\chi}^k}$$

Estimation: Framework (cont.)

Treat a_{ij}^k as a source-by-industry fixed effect. Writing down the quasi-maximum likelihood function, the FOC with respect to a_{ij}^k implies:

$$a_{ij}^k \sum_{\chi \in \{V,O\}} a_{ij\chi}^k = \sum_{\chi \in \{V,O\}} \tilde{t}_{ij\chi}^k$$

$$\Rightarrow \qquad a_{ij}^k = \frac{\sum_{\chi=V,O} \tilde{t}_{ij\chi}^k}{\sum_{\chi=V,O} a_{ij\chi}^k}$$

Substituting this back into the expression for $\tilde{t}_{ij\chi}^k$ from (12), we have:

$$\frac{\tilde{t}_{ijV}^k}{\sum_{\chi \in \{V,O\}} \tilde{t}_{ij\chi}^k} = \frac{a_{ijV}^k}{\sum_{\chi \in \{V,O\}} a_{ij\chi}^k} \varepsilon_{ijV}^k. \qquad (13)$$

This yields a structural estimating equation in which: Alt. Foundation

- the observed intrafirm import share is the dependent variable; and
- $a_{ij\chi}^k$ is a parsimonious function of $\beta_{ij\chi}^k$, α^k, θ^k, λ_i and ρ^k.

Estimation: Mapping to observables (preliminary)

Take a stand on how to map the $\beta^k_{ij\chi}$'s to observables:

- Since $\beta^k_{ijO} \in [0,1]$, adopt a logistic function specification for the firm's bargaining share under outsourcing:

$$\beta^k_{ijO} = \frac{e^{\mathbf{b}(i,k)}}{1+e^{\mathbf{b}(i,k)}}, \text{ where:}$$

and $\mathbf{b}(i,k)$ is a full second-order polynomial in Contractibility^k and ROL$_i$.

Estimation: Mapping to observables (preliminary)

Take a stand on how to map the $\beta^k_{ij\chi}$'s to observables:

- Since $\beta^k_{ijO} \in [0, 1]$, adopt a logistic function specification for the firm's bargaining share under outsourcing:

$$\beta^k_{ijO} = \frac{e^{\mathbf{b}(i,k)}}{1 + e^{\mathbf{b}(i,k)}}, \text{ where:}$$

  and $\mathbf{b}(i, k)$ is a full second-order polynomial in Contractibility^k and ROL$_i$.

- Set: $\beta^k_{ijV} = (1 - \delta^k_{ij})\beta^k_{ijO} + \delta^k_{ij}$, where $\delta^k_{ij} \in [0, 1]$ is the share of bilateral surplus over which the firm has residual rights of control, *a la* Grossman and Hart (1986). Specify:

$$\delta^k_{ij} = \frac{e^{\mathbf{d}(i,k)}}{1 + e^{\mathbf{d}(i,k)}}, \text{ where:}$$

  and $\mathbf{d}(i, k)$ is a full second-order polynomial in Specificity^k and ROL$_i$.

Estimation: Mapping to observables (preliminary)

- Contractibility^k: Industry contractibility based on Nunn (2007)
- Specificity^k: Industry specificity based on Rauch (1999)
- ROL_i: country rule-of-law index from the World Governance Indicators.

Estimation: Mapping to observables (preliminary)

- Contractibility^k: Industry contractibility based on Nunn (2007)
- Specificity^k: Industry specificity based on Rauch (1999)
- ROL_i: country rule-of-law index from the World Governance Indicators.

- For the α^k's:

$$\alpha^k = \frac{e^{\mathbf{a}(i,k)}}{1 + e^{\mathbf{a}(i,k)}}, \text{ where:}$$

$\mathbf{a}(i,k)$ is a quadratic in $\log(K/L)^k$.

$\log(K/L)^k$: Industry capital-labor ratio based on NBER CES Dataset

Estimation: Framework (cont.)

Weighted non-linear least squares (NLLS), with moment condition:

$$\mathbb{E}\left[\tilde{t}_{ij\chi}^{k}\left(\frac{\tilde{t}_{ij\chi}^{k}}{\sum_{\chi\in\{V,O\}}\tilde{t}_{ij\chi}^{k}}-\frac{a_{ij\chi}^{k}}{\sum_{\chi\in\{V,O\}}a_{ij\chi}^{k}}\right)\middle|\mathbf{X}_{ij}^{k}\right]=0, \tag{14}$$

where $\mathbf{X}_{ij}^{k}$ denotes the country and industry observables that enter into the $\mathbf{a}(i,k)$, $\mathbf{b}(i,k)$, and $\mathbf{d}(i,k)$ functions.

- Intrafirm trade share: Use average over 2001-2005.

  Top 50 U.S. import partners (less HKG and IRQ).
- Pin down externally:
  - ρ^k: From Soderbery (2015). At the NAICS 3-digit level.

Estimation: Framework (cont.)

Weighted non-linear least squares (NLLS), with moment condition:

$$\mathbb{E}\left[\tilde{t}^k_{ij\chi}\left(\frac{\tilde{t}^k_{ij\chi}}{\sum_{\chi\in\{V,O\}}\tilde{t}^k_{ij\chi}} - \frac{a^k_{ij\chi}}{\sum_{\chi\in\{V,O\}}a^k_{ij\chi}}\right)\Big|\mathbf{X}^k_{ij}\right] = 0, \tag{14}$$

where $\mathbf{X}^k_{ij}$ denotes the country and industry observables that enter into the $\mathbf{a}(i,k)$, $\mathbf{b}(i,k)$, and $\mathbf{d}(i,k)$ functions.

- Also pin down:
  - Constant in the $\mathbf{d}(i,k)$ function for δ^k_{ij}: To match the aggregate intra-firm trade share.
  - Constant in the $\mathbf{a}(i,k)$ function for α^k: To match the average value-added to output ratio in the manufacturing industries (0.44) in 2005.

Estimation: Framework (cont.)

Weighted non-linear least squares (NLLS), with moment condition:

$$\mathbb{E}\left[\tilde{t}_{ij\chi}^{k}\left(\frac{\tilde{t}_{ij\chi}^{k}}{\sum_{\chi\in\{V,O\}}\tilde{t}_{ij\chi}^{k}}-\frac{a_{ij\chi}^{k}}{\sum_{\chi\in\{V,O\}}a_{ij\chi}^{k}}\right)\middle|\mathbf{X}_{ij}^{k}\right]=0, \qquad (14)$$

where $\mathbf{X}_{ij}^{k}$ denotes the country and industry observables that enter into the $\mathbf{a}(i,k)$, $\mathbf{b}(i,k)$, and $\mathbf{d}(i,k)$ functions.

- Remaining parameters to be estimated: $\Theta = \{\theta^k, \lambda, \gamma_1, \ldots\}$.
- Note: A θ^k for each NAICS 3-digit industry. A single nested-Fréchet correlation parameter λ for all countries.
- Algorithm: Levenberg-Marquardt (with theoretical restrictions)

  Standard errors: Computed using information on the Jacobian matrix (Davidson and MacKinnon 2004).

Point estimates (preliminary)

name	est.	se	95 CI,LB	95 CI, UB
$\gamma_1 : \beta^k_{ijO}$ constant	-0.495	0.022	-0.538	-0.451
$\gamma_2 : \beta^k_{ijO}$ $Cont^k$	2.115	0.169	1.785	2.446
$\gamma_3 : \beta^k_{ijO}$ ROL_i	-0.551	0.058	-0.664	-0.438
$\gamma_4 : \beta^k_{ijO}$ $Cont^k \times ROL_i$	-3.269	0.368	-3.989	-2.548
$\gamma_5 : \beta^k_{ijO}$ $\left(Cont^k\right)^2$	-0.407	0.246	-0.888	0.075
$\gamma_6 : \beta^k_{ijO}$ $(ROL_i)^2$	2.002	0.328	1.359	2.646
$\gamma_7 : \delta^k_{ij}$ constant	-2.800	-	-	-
$\gamma_8 : \delta^k_{ij}$ $Speci^k$	-0.682	0.152	-0.979	-0.385
$\gamma_9 : \delta^k_{ij}$ ROL_i	0.433	0.101	0.236	0.630
$\gamma_{10} : \delta^k_{ij}$ $Speci^k \times ROL_i$	-2.986	0.206	-3.390	-2.582
$\gamma_{11} : \delta^k_{ij}$ $\left(Speci^k\right)^2$	-0.044	0.216	-0.468	0.381
$\gamma_{12} : \delta^k_{ij}$ $(ROL_i)^2$	-0.709	0.519	-1.725	0.308
$\gamma_{13} : \alpha^k$ constant	-0.238	-	-	-
$\gamma_{14} : \alpha^k$ $Ln(K/L)$	0.674	0.056	0.564	0.785
$\gamma_{15} : \alpha^k$ $(Ln(K/L))^2$	-0.238	0.021	-0.280	-0.196
λ	0.673	0.084	0.509	0.837

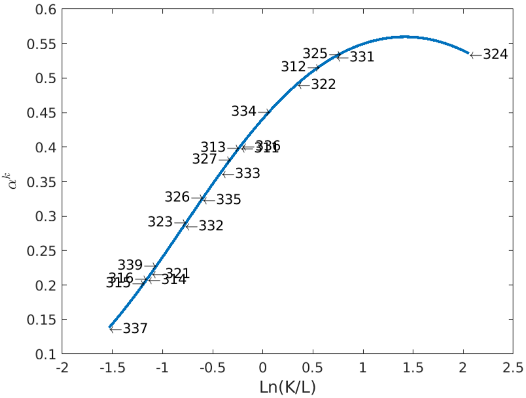
▸ θ^k's, α^k's, ρ^k's

Predicted vs actual: Intrafirm import shares

(b) Model v.s. Data

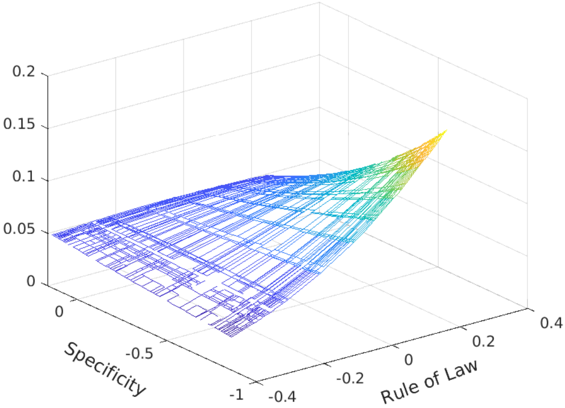
Illustrating the estimation results

- α^k: Increasing in capital-intensity.



Illustrating the estimation results

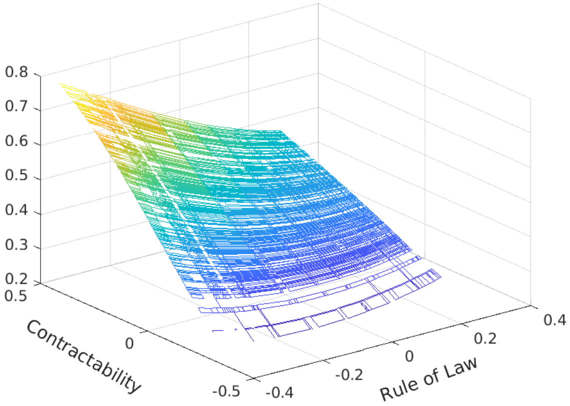
- δ^k: Rule of law raises the firm's residual rights-of-control, for industries where specificity is low.



(a) δ_i^k

Illustrating the estimation results

- β^k: Contractibility raises the firm's bilateral bargaining share.



(a) β^k_{ijO}

Counterfactuals (cont.)

Factor-market clearing conditions in each country to close the model:

- Labor endowment $\bar{L}_j$ equals the sum of factor demand from: (i) final-good producers for assembly; and (ii) country-j input suppliers.
- Skill endowment $\bar{H}_j$ equals the sum of factor demand from firms headquartered in country j

Counterfactual changes can then be computed via a "hat algebra" system, following Dekle et al. (2008) ▸ Details

- To operationalize: need only the initial π's across countries (which we take from the ICIO), and calibrated/estimated values for the model parameters
  - η^k: Value-added share of each industry k
  - $\alpha = 0.18$: Average total employee compensation over output in mfg.
  - $\rho = 0.75$: Implied final-good demand elasticity of 4.

Counterfactuals (cont.)

Factor-market clearing conditions in each country to close the model:

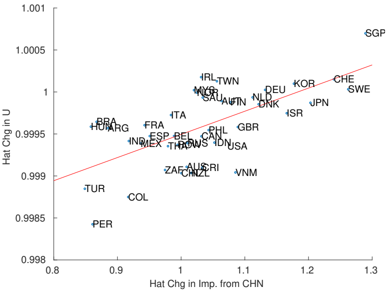
- Labor endowment $\bar{L}_j$ equals the sum of factor demand from: (i) final-good producers for assembly; and (ii) country-j input suppliers.
- Skill endowment $\bar{H}_j$ equals the sum of factor demand from firms headquartered in country j

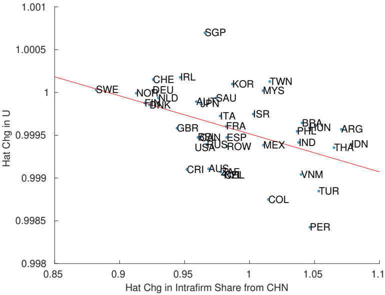
Counterfactual changes can then be computed via a "hat algebra" system, following Dekle et al. (2008) Details

- Today: Consider an improvement in ROL in China that halves the gap between itself and the world frontier (NOR).

Implications for Welfare

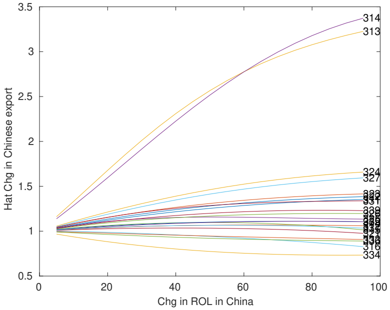
- Countries who see their imports from China rise more under the counterfactual also experience a larger welfare increase
- The above shift is accompanied by an increase in arm's length relative to intrafirm imports from China.

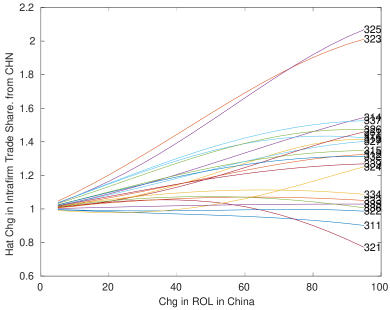




Implications for Welfare

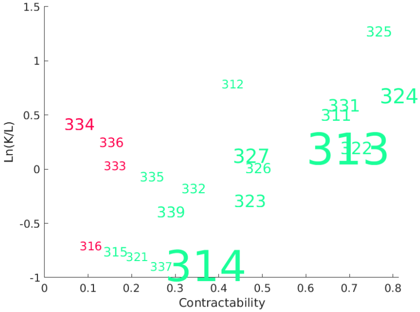
- Large increase in CHN exports in high contractibility, low capital-intensity industries (NAICS 313, 314; related to textiles)
- Followed by high contractibility, high capital-intensity industries, though this is accompanied by a switch away from outsourcing towards intrafirm trade (NAICS 324, 325; petroleum products, chemicals) ▸ More





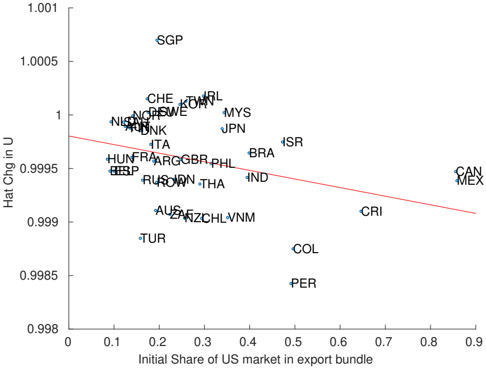
Implications for Welfare

- Large increase in CHN exports in high contractibility, low capital-intensity industries (NAICS 313, 314; related to textiles)
- Followed by high contractibility, high capital-intensity industries, though this is accompanied by a switch away from outsourcing towards intrafirm trade (NAICS 324, 325; petroleum products, chemicals) More

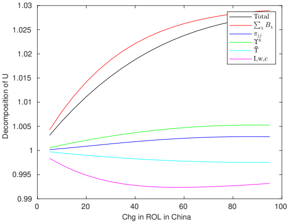


Implications for Welfare

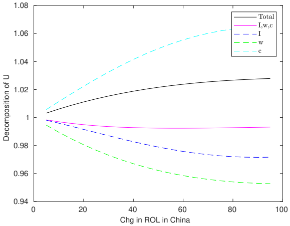
- Welfare change is negatively correlated with the importance of developed-country export markets (in this case, the US) in the country's initial export bundle.



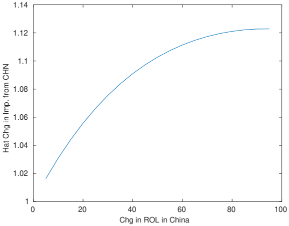
Implications for Welfare: Country Examples



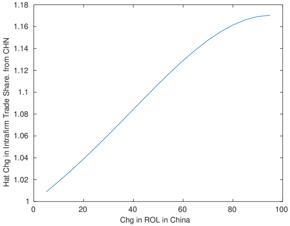
(a) CHN, Welfare Decomposition



(b) CHN, Welfare Decomposition, I,w,c

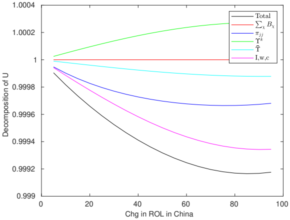


(c) CHN, Imports from China

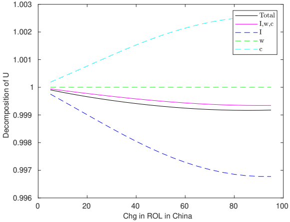


(d) CHN, Intra-firm trade share from China

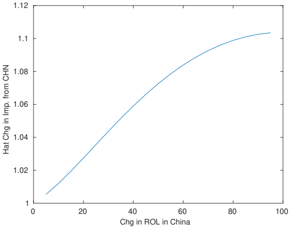
Implications for Welfare: Country Examples



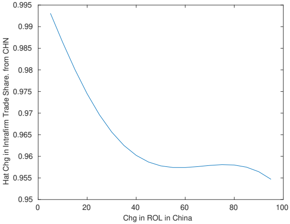
(a) USA, Welfare Decomposition



(b) USA, Welfare Decomposition, I,w,c

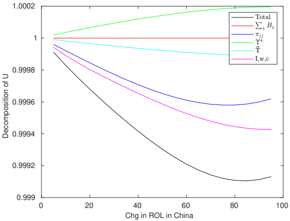


(c) USA, Imports from China

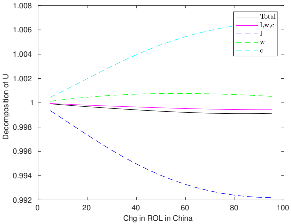


(d) USA, Intra-firm trade share from China

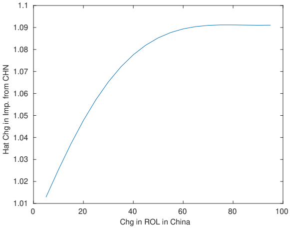
Implications for Welfare: Country Examples



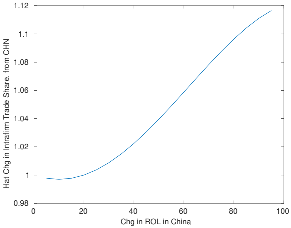
(a) VNM, Welfare Decomposition



(b) VNM, Welfare Decomposition, I,w,c

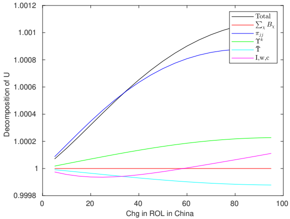


(c) VNM, Imports from China

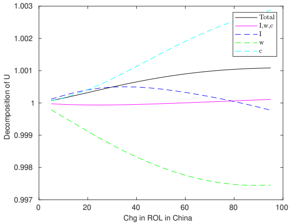


(d) VNM, Intra-firm trade share from China

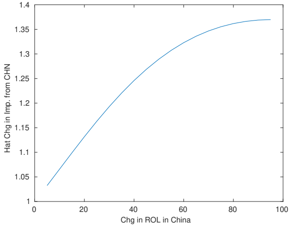
Implications for Welfare: Country Examples



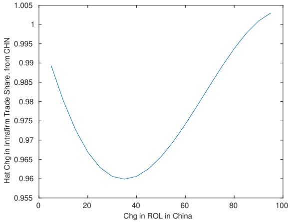
(a) SGP, Welfare Decomposition



(b) SGP, Welfare Decomposition, I,w,c



(c) SGP, Imports from China



(d) SGP, Intra-firm trade share from China

Concluding Remarks

Next steps

- Developed a quantitative trade model that incorporates contracting frictions in global sourcing decisions
  - Delivers a modified gains-from-trade formula, that reflects the effects of contracting frictions
  - Quantification via a structural estimating equation for the intrafirm import share
  - Has the potential to shed light on how much improving country institutions related to contract enforcement would affect welfare in a world with global sourcing

Ongoing:

- Partial contractibility of inputs
- Converging on a functional form for contracting frictions
- Unpacking the counterfactuals

Supplementary Slides

Incremental revenue: Derivation ▸ Details

Compute for discrete number of suppliers, L, each in charge of $\epsilon = 1/L$ inputs.

$$\widetilde{r}(\ell;\epsilon) = A_j^{1-\rho}\phi^{\rho}L_j(\phi)^{\alpha\rho}\left[\prod_{k'\neq k}\left(X_j^{k'}(\phi)\right)^{\eta^{k'}(1-\alpha)\rho}\right]\times$$

$$\left\{\left[\left(\sum_{\ell'\neq\ell}x_j^k(\phi;\ell')^{\rho^k}\epsilon'\right)+x_j^k(\phi;\ell)^{\rho^k}\epsilon\right]^{\frac{\eta^k(1-\alpha)\rho}{\rho^k}}-\left[\left(\sum_{\ell'\neq\ell}x_j^k(\phi;\ell')^{\rho^k}\epsilon'\right)\right]^{\frac{\eta^k(1-\alpha)\rho}{\rho^k}}\right\}.$$

Approximate the term in the curly braces via a first-order Taylor expansion about $\epsilon = 0$. Then, evaluate the limit as $L \to \infty$.

$$\frac{\widetilde{r}(\ell;\epsilon)}{\epsilon} \approx A_j^{1-\rho}\phi^{\rho}L_j(\phi)^{\alpha\rho}\left[\prod_{k'\neq k}\left(X_j^{k'}(\phi)\right)^{\eta^{k'}(1-\alpha)\rho}\right]\times$$

$$\left[\left(\sum_{\ell'\neq\ell}x_j^k(\phi;\ell')^{\rho^k}\epsilon'\right)+x_j^k(\phi;\ell)^{\rho^k}\epsilon\right]^{\frac{\eta^k(1-\alpha)\rho}{\rho^k}-1}\left(\frac{\eta^k(1-\alpha)\rho}{\rho^k}\right)x_j^k(\phi;\ell)^{\rho^k}$$

$$\Rightarrow\quad r_j^k(\phi;\ell) = \lim_{L\to\infty}\frac{\widetilde{r}(\epsilon)}{\epsilon} = (1-\alpha)\frac{\rho\eta^k}{\rho^k}R_j(\phi)\left(\frac{x_j^k(\phi;\ell)}{X_j^k(\phi)}\right)^{\rho^k}.$$

Υ_j^k and $\bar{\Upsilon}_j$: Details

▸ Return

- $\bar{\Upsilon}_j$: Share of revenues that accrue to the firm (after accounting for the ex-ante transfer and payments to factors)

$$\Upsilon_j^k = \left\{ \sum_{i=1}^{J} \sum_{\chi \in \{V,O\}} \frac{\pi_{ij}^k \pi_{\chi|ij}^k}{\frac{1}{\rho^k} - \alpha^k \beta_{ij\chi}^k - (1-\alpha^k)(1-\beta_{ij\chi}^k)} \right\}^{-1}, \text{ and}$$

$$\bar{\Upsilon}_j = \left\{ 1 - (1-\alpha)\,\rho \sum_{k=1}^{K} \left(\eta^k\right) \left(\Upsilon_j^k\right) \sum_{i=1}^{J} \sum_{\chi \in V,O} \frac{\left[\alpha^k \beta_{ij\chi}^k + \left(1-\alpha^k\right)\left(1-\beta_{ij\chi}^k\right)\right] \pi_{ij}^k \pi_{\chi|ij}^k}{\frac{1}{\rho^k} - \alpha^k \beta_{ij\chi}^k - (1-\alpha^k)(1-\beta_{ij\chi}^k)} \right\}$$

From Model to Data: Details

▸ Return

$$\tilde{t}^k_{ij\chi} = t^k_{ij\chi} \cdot \epsilon^k_{ij\chi} \;=\; a^k_{ij\chi} \cdot a^k_{ij} \cdot \epsilon^k_{ij\chi},$$

$$\begin{aligned}
a^k_{ij} &= \left[(1-\alpha)\rho\eta^k\right] \frac{\Upsilon^k_j}{\Phi^k_j}\gamma I_j T^k_i (w_i)^{-\theta^k} \left[\left(B^k_{ijV}\right)^{\frac{\theta^k}{1-\lambda_i}} + \left(B^k_{ijO}\right)^{\frac{\theta^k}{1-\lambda_i}}\right]^{-\lambda_i} \left(d^k_{ij}\right)^{-\theta^k}, \text{ and} \\
a^k_{ij\chi} &= \left(1-\beta^k_{ij\chi}\right)^{\frac{\theta^k}{1-\lambda_i}+1} \left(\beta^k_{ij\chi}\right)^{\frac{\alpha^k}{1-\alpha^k}\frac{\theta^k}{1-\lambda_i}} \times \left[1+\alpha^k\beta^k_{ij\chi} + (1-\alpha^k)(1-\beta^k_{ij\chi})\right] \\
&\quad \times \left[\frac{1}{\rho^k} - \alpha^k\beta^k_{ij\chi} - (1-\alpha^k)(1-\beta^k_{ij\chi})\right]^{\frac{\theta^k}{1-\lambda_i}\frac{1-\rho^k}{\rho^k(1-\alpha^k)}-1}.
\end{aligned}$$

Alternative foundation

Return

- $\tilde{t}_{ij}^k$ is the sum of two independent Poisson random variables, $\tilde{t}_{ijV}^k + \tilde{t}_{ijO}^k = \tilde{t}_{ij}^k$.
- Property: Conditional on the realized value of $\tilde{t}_{ij}^k$, the distribution of $\tilde{t}_{ijV}^k$ is a binomial distribution where:
  - $\tilde{t}_{ij}^k$ is the number of the trials; and
  - $a_{ijV}^k a_{ij}^k / \left(\sum_{\chi=\{V,O\}} a_{ij\chi}^k a_{ij}^k \right)$ is the success probability.
- It follows that the distribution of $\tilde{t}_{ijV}^k / \tilde{t}_{ij}^k$ conditional on $\tilde{t}_{ij}^k$, is Bernoulli with the same success probability.
- This yields the following moment condition for estimation; compare to (14):

$$E\left[\frac{\tilde{t}_{ijV}^k}{\tilde{t}_{ij}^k} \middle| \tilde{t}_{ij}^k \right] = \frac{a_{ijV}^k a_{ij}^k}{\sum_{\chi=\{V,O\}} a_{ij\chi}^k a_{ij}^k} = \frac{a_{ijV}^k}{\sum_{\chi=\{V,O\}} a_{ij\chi}^k}$$

Industry Parameters

▸ Return

ID	Desc	Est. α^k	Est. θ^k	ρ^k (Soderbery)
1	Food Manufactur ...	0.411	5.000	0.886
2	Beverage and To ...	0.450	6.058	0.788
3	Textile Mills ...	0.113	22.946	0.821
4	Textile Product ...	0.128	18.077	0.768
5	Apparel Manufac ...	0.154	19.683	0.852
6	Leather and All ...	0.142	25.000	0.781
7	Wood Product Ma ...	0.116	25.000	0.777
8	Paper Manufactu ...	0.387	4.263	0.580
9	Printing and Re ...	0.187	22.729	0.688
10	Petroleum and C ...	0.355	7.387	0.881
11	Chemical Manufa ...	0.401	14.883	0.771
12	Plastics and Ru ...	0.246	17.768	0.879
13	Nonmetallic Min ...	0.318	12.910	0.738
14	Primary Metal M ...	0.349	8.138	0.891
15	Fabricated Meta ...	0.335	13.824	0.708
16	Machinery Manuf ...	0.470	5.272	0.841
17	Computer and El ...	0.534	6.549	0.728
18	Electrical Equi ...	0.473	1.714	0.632
19	Transportation ...	0.540	7.978	0.749
20	Furniture and R ...	0.177	24.959	0.297
21	Miscellaneous M ...	0.261	12.818	0.714

Industry Parameters (cont.)

name	est.	se	95 CI,LB	95 CI, UB
θ_{01}	5.000	-	-	-
θ_{02}	6.058	0.905	4.285	7.832
θ_{03}	22.946	2.719	17.616	28.275
θ_{04}	18.077	2.100	13.961	22.193
θ_{05}	19.683	2.097	15.572	23.794
θ_{06}	25.000	2.848	19.418	30.582
θ_{07}	25.000	2.838	19.438	30.562
θ_{08}	4.263	0.530	3.225	5.301
θ_{09}	22.729	2.947	16.952	28.506
θ_{10}	7.387	1.975	3.516	11.259
θ_{11}	14.883	1.448	12.045	17.722
θ_{12}	17.768	1.981	13.886	21.650
θ_{13}	12.910	1.340	10.284	15.536
θ_{14}	8.138	0.919	6.337	9.938
θ_{15}	13.824	1.443	10.997	16.651
θ_{16}	5.272	0.661	3.975	6.568
θ_{17}	6.549	0.784	5.012	8.087
θ_{18}	1.714	0.752	0.241	3.188
θ_{19}	7.978	0.961	6.095	9.861
θ_{20}	24.959	2.871	19.331	30.587
θ_{21}	12.818	1.328	10.215	15.420

Hat algebra: Details

Details

$$\left(B_{ij\chi}^k\right)' = \left[1 - \left(\beta_{ij\chi}^k\right)'\right] \left[\left(\beta_{ij\chi}^k\right)'\right]^{\frac{\alpha^k}{1-\alpha^k}} \left[\frac{1}{\rho^k} - \alpha^k \left(\beta_{ij\chi}^k\right)' - \left(1 - \alpha^k\right) \left[1 - \left(\beta_{ij\chi}^k\right)'\right]\right]^{\frac{1-\rho^k}{\rho^k(1-\alpha^k)}} \tag{15}$$

$$\left(\pi_{\chi|ij}^k\right)' = \frac{\left((B_{ij\chi}^k)'\right)^{\frac{\theta^k}{1-\lambda_i}}}{\left((B_{ijV}^k)'\right)^{\frac{\theta^k}{1-\lambda_i}} + \left((B_{ijO}^k)'\right)^{\frac{\theta^k}{1-\lambda_i}}} \tag{16}$$

$$\widehat{\pi_{ij}^k} = \frac{(\widehat{d_{ij}^k}\widehat{w}_i)^{-\theta^k}}{\widehat{\Phi_j^k}} \left(\widehat{(B_{ijV}^k)^{\frac{\theta^k}{1-\lambda_i}} + (B_{ijO}^k)^{\frac{\theta^k}{1-\lambda_i}}}\right)^{1-\lambda_i} \tag{17}$$

$$\widehat{\Phi_j^k} \equiv \sum_{i=1}^{J} \pi_{ij}^k (\widehat{d_{ij}^k}\widehat{w}_i)^{-\theta^k} \left(\widehat{(B_{ijV}^k)^{\frac{\theta^k}{1-\lambda_i}} + (B_{ijO}^k)^{\frac{\theta^k}{1-\lambda_i}}}\right)^{1-\lambda_i} \tag{18}$$

Hat algebra: Details (cont.)

$$\text{Define:} \qquad \left(\upsilon_{ij\chi}^{k}\right)' = \frac{\left(\pi_{ij}^{k}\right)' \left(\pi_{\chi|ij}^{k}\right)'}{\frac{1}{\rho^k} - \alpha^k \left(\beta_{ij\chi}^{k}\right)' - \left(1-\alpha^k\right)\left[1 - \left(\beta_{ij\chi}^{k}\right)'\right]} \tag{19}$$

$$\left(\Upsilon_j^k\right)' = \left\{\sum_{i=1}^{J} \sum_{\chi=\{V,O\}} \left(\upsilon_{ij\chi}^{k}\right)'\right\}^{-1} \tag{20}$$

$$\left(\bar{\Upsilon}_j\right)' = 1 - (1-\alpha)\,\rho \sum_{k=1}^{K} \left(\eta^k\right)\left(\Upsilon_j^k\right)' \sum_{i=1}^{J} \sum_{\chi \in V,O} \left[\alpha^k \left(\beta_{ij\chi}^{k}\right)' + \left(1-\alpha^k\right)\left(1 - \left(\beta_{ij\chi}^{k}\right)'\right)\right]\left(\upsilon_{ij\chi}^{k}\right)' \tag{21}$$

$$I_j' = \frac{\widehat{w_j} w_j \bar{L}_j + \widehat{s_j} s_j \bar{H}_j}{1 - (1-\alpha\rho)\left(\bar{\Upsilon}_j\right)'} \tag{22}$$

Hat algebra: Details (cont.)

Factor market-clearing:

$$\widehat{w}_j w_j \bar{L}_j = \rho \left\{ \alpha \left(\bar{\Upsilon}_j\right)' (I_j)' + (1-\alpha) \sum_{k=1}^{K} \sum_{m=1}^{J} \sum_{\chi \in \{V,O\}} \eta^k (I_m)' \left(\Upsilon_m^k\right)' (1-\alpha^k) \left[1 - \left(\beta_{jm\chi}^k\right)'\right] \left(\upsilon_{jm\chi}^k\right)' \right\} \tag{23}$$

$$\widehat{s}_j s_j \bar{H}_j = (1-\alpha)\gamma (I_j)' \sum_{k=1}^{K} \left(\rho \eta^k\right) \left(\Upsilon_j^k\right)' \sum_{i=1}^{J} \sum_{\chi = V,O} \alpha^k \left(\beta_{ij\chi}^k\right)' \left(\upsilon_{ij\chi}^k\right)' \tag{24}$$

Note: Data for $w_j \bar{L}_j$ are from the Penn World Tables. Value of $s_j \bar{H}_j$ is inferred from the Cobb-Douglas condition in the initial equilibrium.

Hat algebra: Details (cont.)

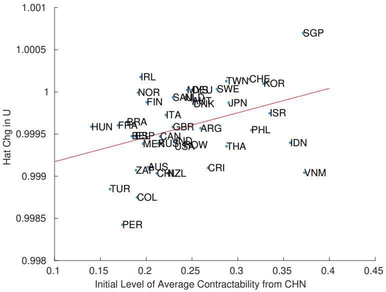
The algorithm:

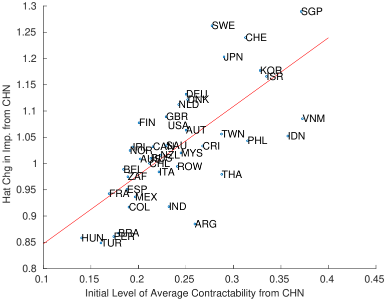
1. Given $(\beta^k_{ij\chi})'$, use equation (15) to solve for $(B^k_{ij\chi})'$.
2. Use equation (16) and $(B^k_{ij\chi})'$ to get $\left(\pi^k_{\chi|ij}\right)'$ and $\widehat{\pi^k_{\chi|ij}}$.
3. Guess a vector of $\widehat{w}_j$ and $\widehat{s}_j$.
4. Conditional on the guessed $\widehat{w}_m$ and $\widehat{s}_j$, use equation (18) to solve for $\widehat{\Phi^k_j}$ and equation (22) to solve for $\left(I_j\right)'$.
5. Use $\widehat{\Phi^k_j}$ and equation (17) to solve for $\widehat{\pi^k_{ij}}$ and $\left(\pi^k_{ij}\right)'$.
6. With $\left(\pi^k_{ij}\right)'$, we can use equation (20) and (21) to get $\left(\Upsilon^k_m\right)'$ and $\left(\bar{\Upsilon}_m\right)'$.
7. With all the above information, invert equation (23) to get a new $\widetilde{w_j}$. Similarly, we can update the price of capital, $\widetilde{s_j}$ by inverting equation (24).
8. Update $\left(\widehat{w_j}, \widehat{s_j}\right)$ with $\left(\widetilde{w_j}, \widetilde{s_j}\right)$, and iterate from step 3 until convergence.

Implications for Welfare (more)

Return

- Import and hence welfare increases are larger the greater the contractibility of the country's initial profile of imports from China

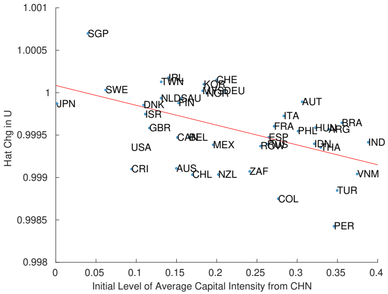


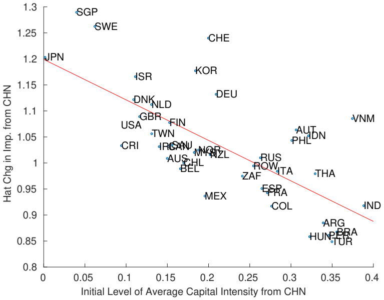


Implications for Welfare (more)

Return

- Import and hence welfare increases are larger the lower the capital-intensity of the country's initial profile of imports from China





Implications for Welfare (more)

▸ Return

- Import and hence welfare increases are smaller the greater the specificity of the country's initial profile of imports from China