As the Door Closes: Non-Tariff Measures, Export Fixed Costs and Cascading Effects in the Global Production Network

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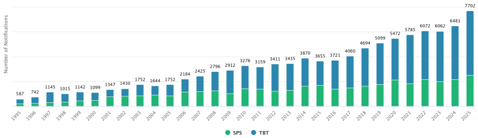
Background

- Non-tariff measures (NTMs) refer to policy instruments that restrict imports and exports through channels other than tariffs.
  - Import/Export Quotas
  - Sanitary and Phytosanitary (SPS) measures
  - Technical Barriers to Trade (TBT)



- Compliance with these regulations requires firms to incur additional costs before entering export markets.
  - If these compliance costs exceed expected profits, fewer firms enter export markets.
- The mass of firms is also a major source of welfare gains and losses (Melitz, 2003).

Background

- Due to supplier-customer links, changes in the mass of firms generate cascading effects through input-output linkages and affect aggregate outcomes (Baqaee, 2018).
  - Baqaee (2018) only focuses on a single-country setting, and does not consider international trade.
- Existing trade studies mainly examine tariff shocks in global production networks (Caliendo and Parro, 2015; Baqaee and Farhi, 2024).
- Little is known about how **NTM shocks** propagate through **global production networks**.
- It also remains unclear how input-output linkages change the welfare effects of **NTM shocks**.

Background

- Arkolakis, Costinot and Rodríguez-Clare (2012) provides the benchmark welfare formula,

$$d\ln\left(C_i\right) = -\sum_{j=1}^{N} \pi_{ji}\left(d\ln\left(w_i\right) + d\ln\left(\tau_{ji}\right)\right) = \frac{1}{1-\sigma} d\ln\left(\pi_{ii}\right)$$

- The formula relies on many assumptions, including
  - Labor is the only factor of production.
  - Variable costs take a separable form in labor and trade costs is $VC(\omega) = wG(\tau, T(\omega))$.
- Production networks with CES technology break the above two assumptions.

Preview of Results

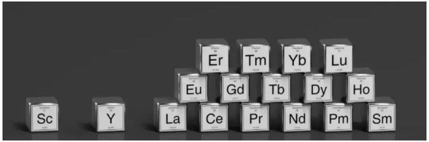
We develop a multi-country Melitz model with production networks and derive

$$d\ln(C_i) = -\sum_{j=1}^{N}\sum_{s=1}^{S}\Omega_s^{ji}\left[\underbrace{\frac{1}{1-\epsilon}d\ln(\widetilde{\alpha}_{js})}_{\text{Centrality}} + \underbrace{d\ln(\tau_s^{ji})}_{\text{Trade Cost}} + \underbrace{\frac{1}{1-\sigma_s}d\ln(\varsigma_s^{ji})}_{\text{Selection}}\right]$$

- τ_s^{ji}: trade cost
- $\widetilde{\alpha}_{js}$: consumer centrality
- ς_s^{ji}: cumulative market share of exporters.

Preview of Results

- We quantify the welfare effects of China's rare-earth export restrictions **(CREER)**.
- Welfare declines by
  - **0.37%** in China;
  - **1.25%** in the United States.



- Welfare losses arise from three channels: **direct trade exposure**, **direct production linkages**, and **production-network feedback loops**.
  - For China, welfare losses arise **almost** entirely from **production-network feedback loops**.
  - For the United States, **31%** of welfare losses come from **production-network feedback loops**, while **64%** are explained by its **direct trade exposure**.

Related Literature

- Production Networks
  - Leontief (1936); Acemoglu et al. (2012); Acemoglu, Akcigit and Kerr (2016); Baqaee and Farhi (2019, 2021, 2024)
  - Baqaee (2018)
- Quantitative Trade
  - Eaton and Kortum (2002); Melitz (2003)
  - Caliendo and Parro (2015)
- Empirical Evaluation of NTMs
  - NTMs: Calì et al. (2026)
  - CREER: Müller, Schweizer and Seiler (2016); Chen, Hu and Li (2021)

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Set-up

- The world economy of N countries (indexed by i, j).
- Each country has S sectors (indexed by t, s), and is endowed with L_i units of labor and a representative household.
- There are M_{is} firms and M_{is}^E potential entrants in sector s.
- $\epsilon > 1$ is the elasticity of substitution among production factors. σ_s is the elasticity of substitution across firms within industry s, with $\sigma_s > \epsilon$.
- **We model NTMs as export fixed costs.**

Demand

- Representative households consume differentiated varieties from multiple countries.
- Preferences are CES across sectors and across varieties within sectors.
- Labor income finances consumption expenditure. $\prod_s L_{is}^{\gamma_{is}}$ denotes the disutility of labor.

$$\max_{c_s^{ji}(\varphi)} \quad U_i = \left(\sum_s \beta_{is}^{\frac{1}{\epsilon}} c_{is}^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}} - \prod_s L_{is}^{\gamma_{is}} \quad \text{s.t.} \quad \sum_s \tilde{p}_{is} c_{is} = w_i L_i,$$

$$c_{is} = \left(\sum_j \int_{\varphi_s^{ji*}}^{\infty} \frac{M_s^{ji}}{1 - G\left(\varphi_s^{ji*}\right)} c_s^{ji}(\varphi)^{\frac{\sigma_s - 1}{\sigma_s}} \, dG(\varphi) \right)^{\frac{\sigma_s}{\sigma_s - 1}}.$$

Production

- Firms combine labor $L_{is}(\varphi_{is})$ and intermediate inputs $x^i_{ts}(\varphi_{is})$.
- Intermediate inputs can be sourced from multiple countries $x^{ji}_{ts}(\varphi_{is})$.
- Production networks are captured by the input-output coefficients α^i_{ts}.

$$q_{is}(\varphi_{is}) = \left[(\alpha^L_{is})^{\frac{1}{\epsilon}} L_{is}(\varphi_{is})^{\frac{\epsilon-1}{\epsilon}} + \sum_{t\in S} (\alpha^i_{ts})^{\frac{1}{\epsilon}} x^i_{ts}(\varphi_{is})^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}$$

$$x^i_{ts}(\varphi_{is}) = \left(\sum_{j=1}^{N} \int_{\varphi^{ji*}_t}^{+\infty} \frac{M^{ji}_s}{1 - G\left(\varphi^{ji*}_s\right)} x^{ji}_{ts}(\varphi_{is})^{\frac{\sigma_t-1}{\sigma_t}} \, dG(\varphi_{jt}) \right)^{\frac{\sigma_t}{\sigma_t-1}}$$

Marginal costs and prices setting

- Firms in industry s face monopolistic competition and constant markup rate μ_s.
- Marginal costs depend on wages and intermediate-input prices.
- Intermediate-input prices aggregate suppliers from different countries.

$$mc_{is} = \left[\alpha_{is}^{L} w_{is}^{1-\epsilon} + \sum_{t \in S} \alpha_{ts}^{i} \tilde{p}_{it}^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}} \qquad \tilde{p}_{is} = \left(\sum_{j=1}^{N} (\tau_s^{ji} p_s^{ji})^{1-\sigma_s} \right)^{\frac{1}{1-\sigma_s}}$$

where p_s^{ji} denotes the price index of sector s varieties supplied from country j.

- Therefore, marginal cost equation shows how upstream shocks propagate to downstream industries through intermediate-input linkages.

Market clearing

- The flow of product of firm φ_{is} in country i and industry s is given by

$$y_{is}(\varphi_{is}) = \sum_{j=1}^{N} c_s^{ij}(\varphi_{is}) + \sum_{i=1}^{N}\sum_{t=1}^{S} x_{st}^{ij}(\varphi_{is})$$

- According to the optimal consumption and input,

$$c_s^{ij}(\varphi_{is}) = \left(\frac{P_j}{\tilde{p}_{js}}\right)^{\epsilon}\left(\frac{\tilde{p}_{js}}{\tau_s^{ij} p_{is}(\varphi_{is})}\right)^{\sigma_s}\beta_{js}C_j \quad x_{st}^{ij}(\varphi_{is}) = \left(\frac{mc_{jt}}{\tilde{p}_{js}}\right)^{\epsilon}\left(\frac{\tilde{p}_{js}}{\tau_s^{ij} p_{is}(\varphi_{is})}\right)^{\sigma_s}\alpha_{st}^{j} y_{jt}$$

- Market clearing conditions determine how downstream demand feedback to upstream industries.

Firm entry

- Firms hire F^e_{is} units of labor as sunk cost to draw their productivity φ_{is} from a Pareto distribution $G(\varphi_{is})$.
- Firms also need to pay fixed costs to decide whether production for domestic market F_{is} and foreign market F^{ij}_s or not.
- The mass of active firms in industry s and country i is $M_{is} = M^e_{is}\,(1 - G(\varphi^*_{is}))$.
- The number of potential entrants is

$$M^E_{is} = \frac{\gamma_{is} L_i}{\left[1 + \frac{s^L_{is}}{\mu_s} \frac{\sigma_s \theta_s}{\theta_s - \sigma_s + 1}\right] \sum_j F^{ij}_s \left(\frac{\varphi^{ij*}_s}{\varphi^*_{is}}\right)^{-\theta_s} + F^e_{is}}.$$

- **Ceteris paribus**, an **increase** in export fixed costs **reduces** the mass of **potential entrants** and **active firms**.

Define Supplier Centrality $\widetilde{\beta}$

- It summarizes how shocks propagate to downstream sectors through the **market-clearing system**.

$$\widetilde{\beta} = \left[I - \left[\hat{\pi} \circ \tau^{-\epsilon} \circ \hat{\chi}\right] A \Phi^{\epsilon} \tilde{M}^{\epsilon} \mathcal{C}^{\epsilon} \mu^{-\epsilon}\right]^{-1} \left[\hat{\pi} \circ \tau^{-\epsilon} \circ \hat{\chi}\right] \beta$$

- Without trade, productivity, mass of firms as well as markup, the supplier centrality degenerates into

$$\widetilde{\beta} = [I - A]^{-1} \beta$$

- the standard Leontief inverse, measuring the total production required to satisfy final demand.

Define Consumer Centrality $\widetilde{\alpha}$

- It summarizes how upstream shocks affect each sector through the **marginal-cost system**.

$$\widetilde{\alpha} = \left[\mu^{\epsilon-1}\Phi^{1-\epsilon}\tilde{M}^{1-\epsilon}\mathcal{C}^{1-\epsilon} - \frac{1}{N}A'\left[\tilde{\pi}^{1-\epsilon} \circ \tau^{1-\epsilon} \circ \tilde{\chi}^{1-\epsilon}\right]'\right]^{-1} \alpha^{L}$$

- Without trade, productivity, mass of firms as well as markup, the consumer centrality degenerates into

$$\widetilde{\alpha} = \left[I - A'\right]^{-1} \alpha^{L}$$

- captures the total labor required, both directly and indirectly, through the production network.

Welfare Decomposition

In equilibrium, real consumption and the aggregate price index are given by $C_i = \frac{w_i L_i}{P_i}$ and $P_i = \left[\sum_{s=1}^{K} \beta_{is} \widetilde{p}_{is}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}$.

The welfare decomposition is

$$d\ln(C_i) = -\sum_{j=1}^{N}\sum_{s=1}^{S}\Omega_s^{ji}\left[\underbrace{\frac{1}{1-\epsilon}d\ln(\widetilde{\alpha}_{js})}_{\text{Centrality}} + \underbrace{d\ln(\tau_s^{ji})}_{\text{Trade Cost}} + \underbrace{\frac{1}{1-\sigma_s}d\ln(\varsigma_s^{ji})}_{\text{Selection}}\right]$$

$\Omega_s^{ji} = \frac{\beta_{is}\tilde{p}_{is}^{1-\epsilon}}{\sum_{h=1}^{K}\beta_{ih}\tilde{p}_{ih}^{1-\epsilon}}\pi_s^{ji}$ denotes the adjusted preference weight under CES utility function.

Quantify shocks and Welfare Changes

- In our framework, once we know the parameter values, we can calculate equilibrium objects, i.e. weighted productivity, mass of firms as well as trade shares.
- We measure CREER shocks by changes in export fixed costs.
- Similar to Caliendo and Parro (2015), we recover the change in export fixed costs as

$$\pi_s^{HF} = \frac{M_{Hs}^E \left(\tau_s^{HF} mc_{Hs}\right)^{-\theta_s} \left(F_s^{HF}\right)^{1-\frac{\theta_s}{\sigma_s - 1}}}{\sum_{h \in \{H,F\}} M_{hs}^E \left(\tau_s^{hF} mc_{hs}\right)^{-\theta_s} \left(F_s^{hF}\right)^{1-\frac{\theta_s}{\sigma_s-1}}} \Rightarrow \Delta \ln \left(F_s^{HF}\right) = \frac{\Delta \ln \left(\frac{\pi_s^{HF} \pi_s^{FH}}{\pi_s^{HH} \pi_s^{FF}}\right) + \theta_s \Delta \ln \left(\tau_s^{HF} \tau_s^{FH}\right)}{1 - \frac{\theta_s}{\sigma_s - 1}}$$

Quantify shocks and Welfare Changes

- Once we recover the change in export fixed costs, we can solve for two equilibria under two parameter sets. Let $*$ and $**$ denote the pre- and post-shock equilibria.

$$\widetilde{\alpha}^{*} = \left[\mu^{\epsilon-1}\left(\Phi^{*}\right)^{1-\epsilon}\left(\tilde{M}^{*}\right)^{1-\epsilon}\mathcal{C}^{1-\epsilon} - \frac{1}{N}A'\left[\left(\tilde{\pi}^{*}\right)^{1-\epsilon}\circ\tau^{1-\epsilon}\circ\left(\tilde{\chi}^{*}\right)^{1-\epsilon}\right]'\right]^{-1}\alpha^{L}$$

$$\widetilde{\alpha}^{**} = \left[\mu^{\epsilon-1}\left(\Phi^{**}\right)^{1-\epsilon}\left(\tilde{M}^{**}\right)^{1-\epsilon}\mathcal{C}^{1-\epsilon} - \frac{1}{N}A'\left[\left(\tilde{\pi}^{**}\right)^{1-\epsilon}\circ\tau^{1-\epsilon}\circ\left(\tilde{\chi}^{**}\right)^{1-\epsilon}\right]'\right]^{-1}\alpha^{L}$$

- Changes in consumer centrality are expressed by $d\ln(\widetilde{\alpha}) = \ln\left(\widetilde{\alpha}^{**}\right) - \ln\left(\widetilde{\alpha}^{*}\right)$
- The same procedure is used to compute changes in exporter selection and other equilibrium objects.

Specific Economic Structures

- Cobb-Douglas economic structure, $\epsilon \to 1$,

$$\tilde{\beta} \to \left[I - \left(\pi \circ \tau^{-1} \circ \hat{\chi}\right) A \Phi \tilde{M} C \mu^{-1}\right]^{-1} \left[\pi \circ \tau^{-1} \circ \hat{\chi}\right] \beta$$

$$\tilde{\alpha}' \to \left[I - \frac{1}{N} A'\right]^{-1} \alpha^{L} = \mathbf{1}$$

- Welfare decomposition degenerates into

$$d \ln \left(C_i\right) = - \sum_{j=1}^{N} \sum_{s=1}^{S} \beta_{is} \pi_s^{ji} \left[d \ln \left(\tau_s^{ji}\right) + \frac{1}{1-\sigma_s} d \ln \left(\varsigma_s^{ji}\right) \right]$$

Specific Economic Structures

- Closed Economy

$$\tilde{\beta} = \left[I - A\Phi^{\epsilon}\tilde{M}^{\epsilon}\mathcal{C}^{\epsilon}\mu^{-\epsilon}\right]^{-1}\beta$$

$$\tilde{\alpha}^{L} = \left[\mu^{\epsilon-1}\Phi^{1-\epsilon}\tilde{M}^{1-\epsilon}\mathcal{C}^{1-\epsilon} - A'\right]^{-1}\alpha^{L}$$

- Welfare decomposition degenerates into

$$d\ln\left(C_i\right) = -\sum_{s=1}^{S}\beta_{is}\left[\frac{1}{1-\epsilon}d\ln\left(\widetilde{\alpha}_{is}\right)\right]$$

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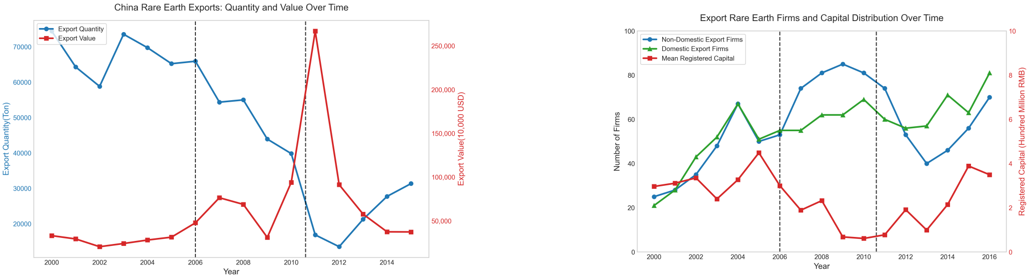
Background of CREER

- Since the early 2000s, China has been the dominant supplier in the global REE industry.
- Beginning in 2006, the Chinese government tightened the regulatory framework governing rare-earth production and exports.
  - Rare-earth exporters had to satisfy a broad set of qualification and compliance requirements to obtain export licenses and quota allocations.
- These regulations raised export fixed costs, leading to endogenous export selection.

Background of CREER

- NTMs substantially reduce China's rare-earth export volume.
- NTMs reshape the composition of exporting firms.

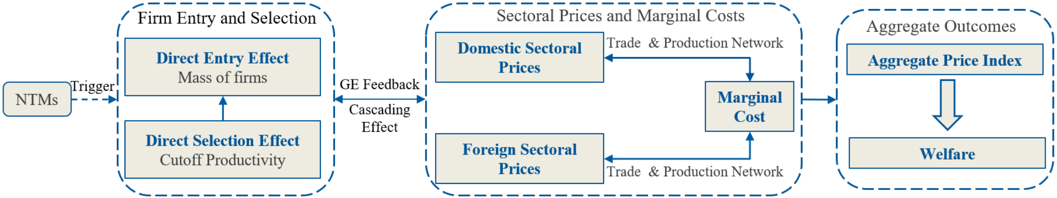


(a) China's Rare Earth Export Quantity and Value

(b) Rare Earth Export Firms and Capital Distribution

Figure 1: Export quantity, value and the number of firms

- CREER **triggers** firm exit and raises export cutoff productivity.
- Changes in firm mass and cutoff productivity reshape sectoral prices and costs by changing the **effective supply of varieties**.
- Through **trade** and **production networks**, changes in marginal costs and prices feed back into firm entry and selection, propagating the effects across **industries and countries**.
- Aggregate prices and welfare are then determined in the new equilibrium.



Calibration

- Parameter set

$$\{\sigma_s, \theta_s, b_i, F_s^{ij}\}_{s=1}^{K}$$

- σ_s are taken from Su et al. (2026), and θ_s are estimated from the firm-level sales distribution.
- Following Bai, Jin and Lu (2024), we normalize the sunk entry cost and calibrate common parameters.
- Export fixed costs F_s^{ij} and Pareto location parameters b_i are estimated by SMM.

Data

- Production Network: WIOD (2006, 2007, and 2010) $\Rightarrow$ Technology matrix A, Labor share vector α^L, trade matrix π and Preference vector β.
- Trade Data: Chinese customs transaction data (2000–2014) $\Rightarrow$ Elasticity of substitution σ and Tariffs τ.
- Firm Registration Data: National Industrial and Commercial Enterprise Registration Database (2000–2014) $\Rightarrow$ Domestic fixed cost F^D.
- Firm Data: Annual Survey of Industrial Firms (ASIF, 2005) $\Rightarrow$ Labor allocation vector γ, Export fixed cost F^X and Pareto shape parameter θ.

Empirical Results

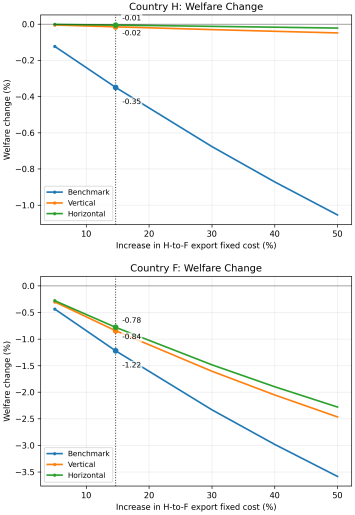
- The network channel accounts for the dominant share of welfare changes in both countries.
- Country F is more vulnerable because upstream supply disruptions are amplified through the production network.

Table 1: Welfare Decomposition under CREER

Country	Total GE	Centrality Effect	Selection Effect	Total Decomposed
China (H)	-0.3726	-0.3628	-0.0104	-0.3731
U.S. (F)	-1.2500	-1.2200	-0.0307	-1.2503

Empirical Results

- Horizontal economy → No production network.
- Vertical economy → Direct production linkages, no feedback loops.
  - ▷ Benchmark welfare losses are substantially larger.
  - ▷ **Network feedback loops** generate additional welfare losses beyond direct production-linkage effects.



Marginal Contribution

- We derive a welfare decomposition formula under production networks.
- Similar to Baqaee (2018), we use the consumer and supplier centrality to characterize shock propagation.
- The framework can be applied to a broad class of trade policy shocks, including both NTMs and tariffs.

Thank you!

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Define Centrality

Table 2: Matrices and Their Elements

Economic Object	Matrix	Element	Matrix Structure
Mass of Firms	$\tilde{M}$	$(M_{jt}^{E})^{\frac{1}{\sigma_t - 1}}$	$NK \times NK$ diagonal matrix
Trade Share	$\tilde{\pi}$	$(\pi_s^{ij})^{\frac{1}{1-\sigma_s}}$	$NK \times NK$ matrix, block-diagonal structure
	$\hat{\pi}$	$(\pi_s^{ij})^{\frac{\epsilon-\sigma_s}{1-\sigma_s}}$	$NK \times NK$ matrix, block-diagonal structure
Export Selection Intensity	$\tilde{\chi}$	$(\chi_s^{ij})^{\frac{\sigma_s - 1 - \theta_s}{\sigma_s - 1}}$	$NK \times NK$ matrix, same structure as π
	$\hat{\chi}$	$(\chi_s^{ij})^{(\sigma_s - \epsilon)\frac{\sigma_s - \theta_s - 1}{\sigma_s - 1}}$	$NK \times NK$ matrix, same structure as π
Productivity	Φ	$\tilde{\varphi}_{jt}^{\frac{\sigma_t - \theta_t - 1}{\sigma_t - 1}}$	$NK \times NK$ diagonal matrix
Scaler term	$\mathcal{C}$	$\left[\dfrac{\theta_t}{1 - \sigma_t + \theta_t}\right]^{\frac{\theta_t}{(\sigma_t - 1)^2}}$	$NK \times NK$ diagonal matrix

Specific Economic Structures: Vertical Economy

$$A = \begin{bmatrix} 0 & a_{12} \\ 0 & 0 \end{bmatrix} \text{ and } A^{(n)} = 0, n \geq 2$$

$$\tilde{\beta} = \begin{bmatrix} h_1^{11} d_{12} \left(h_2^{11} \beta_{12} + h_2^{12} \beta_{22} \right) + h_1^{12} d_{22} \left(h_2^{21} \beta_{12} + h_2^{12} \beta_{22} \right) \\ 0 \\ h_1^{21} d_{12} \left(h_2^{11} \beta_{12} + h_2^{12} \beta_{22} \right) + h_1^{22} d_{22} \left(h_2^{21} \beta_{12} + h_2^{22} \beta_{22} \right) \\ 0 \end{bmatrix}$$

$$\tilde{\alpha}' = \left[\frac{1}{e_{11}}, \frac{g_2^{11}}{2e_{11}e_{12}}, \frac{1}{e_{21}}, \frac{g_1^{12}}{2e_{11}e_{22}} + \frac{g_1^{22}}{2e_{21}e_{22}} \right]$$

A significant feature is that the feedback diminishes in finite rounds.

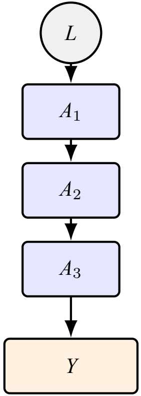

Figure 2: Vertical Economy

Specific Economic Structures: Horizontal Economy

$$A = \begin{bmatrix} 0 \end{bmatrix}$$

$$\tilde{\beta} = \begin{bmatrix} h_1^{11}\beta_{11} + h_1^{12}\beta_{21} \\ h_2^{11}\beta_{12} + h_2^{12}\beta_{22} \\ h_1^{21}\beta_{11} + h_1^{22}\beta_{21} \\ h_2^{21}\beta_{12} + h_2^{22}\beta_{22} \end{bmatrix} \tilde{\alpha} = \begin{bmatrix} \mu_{11}^{1-\epsilon}\Phi_{11}^{\epsilon-1}\tilde{M}_{11}^{\epsilon-1}\alpha_{11}^{L} \\ \mu_{12}^{1-\epsilon}\Phi_{12}^{\epsilon-1}\tilde{M}_{12}^{\epsilon-1}\alpha_{12}^{L} \\ \mu_{21}^{1-\epsilon}\Phi_{21}^{\epsilon-1}\tilde{M}_{21}^{\epsilon-1}\alpha_{21}^{L} \\ \mu_{22}^{1-\epsilon}\Phi_{22}^{\epsilon-1}\tilde{M}_{22}^{\epsilon-1}\alpha_{22}^{L} \end{bmatrix}$$

A significant feature is that there is no feedback which is close to tradition single-factor economy.

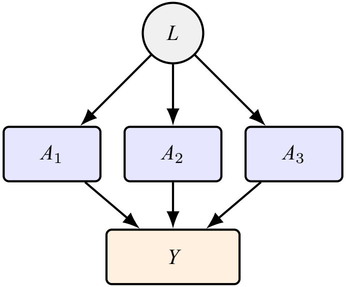

Figure 3: Horizontal Economy

Externally Calibrated Parameters

Table 3: Externally Calibrated Parameters

Sector-specific Parameters			Common Parameters		
	Sector 4	Sector 5		Sector 4	Sector 5
Elasticity, σ_s	5.515	3.353	Entry cost, F_s^E	1.000	1.000
Pareto shape, θ_s	6.161	3.291	Home wage, w_H	1.000	1.000
China labor share, γ_{Hs}	0.595	0.023	Foreign wage, w_F	1.500	1.500
Foreign labor share, γ_{Fs}	0.745	0.040	Home labor, L_H	1.000	1.000
China demand share, β_{Hs}	0.013	0.987	Foreign labor, L_F	1.000	1.000
Foreign demand share, β_{Fs}	0.021	0.979			

Estimated Parameters and Model Fit

Table 4: Estimated Parameters and Model Fit

Estimated Parameters			Model Fit		
	Sector 4	Sector 5		Sector 4	Sector 5
Domestic fixed cost, F_s^D	0.067	0.064	Survival rate (Data)	0.339	0.381
Export fixed cost, F_s^X	0.415	0.184	Survival rate (Model)	0.364	0.396
Foreign productivity shifter, z_F	1.736		Export share (Data)	0.193	0.242
$\Delta \ln(F_s^{HF})$	14.681		Export share (Model)	0.193	0.242
			Target output ratio	0.384	
			Model output ratio	0.384	