Production Networks, Trade, and Misallocation

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Resource Misallocation and TFP

- A well-functioning economy will allocate resources in a way so that more productive firms are bigger and use more resources for production.
- Policy-distorted allocation of resources $\rightarrow$ substantial TFP and income losses.
- A huge literature quantifies the macro costs of distortions, using firm/ plant data.
- The "Misallocation" literature typically ignores input sourcing, and uses a value-added production function.
- Also ignores industry input-output (IO) linkages.
- Examples: State-dominated banks and other upstream sectors in China; Inefficient electricity grid in India.

Our Research Questions

1. Does incorporating firms' input sourcing change the estimate of industry-level TFP losses due to resource misallocation?
2. How much do input-output (IO) linkages amplify the macroeconomic cost of misallocation?
3. How does trade liberalization affect the domestic IO linkages, and thus the macroeconomic cost of misallocation?

Findings

- Build a model of heterogeneous firms' domestic and global sourcing, in the presence of policy distortions.

Using Indian and Chinese manufacturing establishment data:

1. With Cobb-Douglas production functions, agg TFP loss due to misallocation = geometric mean of sector TFP losses, w/ weights equal to sectors' (trade-adjusted) Domar weights (IO multiplier: 2.2 for India; 3.6 for China).

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3. Reason: Estimated sectoral TFP losses are on average half of that of the va approach.
4. Further reason: The MRP of material are much less dispersed across firms within industries, compared to those of labor and capital.
5. Trade liberalization, by raising the domestic IO multiplier, can increase the cost of misallocation (seems to be the case for India).

Literature Review

Resource Misallocation

- Banerjee and Duflo (2005), Guner, Ventura, and Xu (2006), Dollar and Wei (2007), Alfaro et al. (2009), Restuccia and Rogerson (2008), Hsieh and Klenow (2009), Buera et al. (2011), Bartelsman et al. (2013); Restuccia and Rogerson (2013); Hopenhayn (2014); Midrigan and Xu (2014), Chen and Irarrazabal (2015) ...

IO Linkages

- Classics: Hirschman (1958), Chenery and Watanabe (1958), Yotopoulos and Nugent (1973), Chenery et al. (1986), Jones (1976), Shultz (1982), and Long and Plosser (1983)...
- Recent: Ciccone (2002), Acemoglu, Antras, and Helpman (2007), Jones (2011, 2013), Acemoglu et al. (2012), Carvalho and Gabaix (2013), Caliendo and Parro (2015), Acemoglu, Ozdaglar and Tahbaz-Salehi (2017), Baqaee (2016), Baqaee and Fahri (2017), Caliendo, Parro, and Tsyvinski (2015) Grassi (2017), Kikkawa, et al. (2017), Lim (2017), Liu (2017) ...

Trade and Misallocation

- Khandelwal, Schott, and Wei (2013), Ding, Jiang and Sun (2016), Alfaro and Chen (2017), Berthou et al. (2017) ...

Structure of the Closed-Economy Model

- A closed economy with L workers and J sectors.
- Two kinds of firms—finished good producers and input variety producers (Feenstra, Luck, Obstfeld, and Russ, 2014).
- Fixed number of input variety producers in each sector, using labor and finished goods from J sectors to produce and sell differentiated goods under monopolistic competition back to finished-good producers, who produce finished goods: $Q_j = \left[\int_{\Omega_j} q_{j\omega}^{1-\sigma_k} d\omega\right]^{\frac{1}{1-\sigma_j}}$, with $\sigma_j > 1$.
- Each sector's representative finished-good producer sells output either as final goods for domestic consumption or materials to input variety firms under perfect competition.
- GDP is the numeraire: $Y = \prod_{j=1}^{J} \left(\frac{Y_j}{\beta_j}\right)^{\beta_j}$.

Firm's Revenue and the Logic of Domar weights

- Firm's production function:

$$q_{j\omega} = z_\omega \Lambda_j l_{j\omega}^{\lambda_{j\omega}} \prod_{k=1}^{K} m_{jk\omega}^{\gamma_{jk}}$$

- $l_{j\omega}$ is labor, $\lambda_{j\omega}$ = cost share of labor. γ_{jk} = cost share of sector-k inputs.

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- $l_{j\omega}$ is labor, $\lambda_{j\omega}$ = cost share of labor. γ_{jk} = cost share of sector-k inputs.
- Firm revenue:

$$r_{j\omega} = \left(\frac{p_{j\omega}}{P_j}\right)^{1-\sigma_j} R_j,$$

- R_j is the aggregate spending of the economy on good j:

$$R_j = \underbrace{\beta_j Y}_{\text{final goods}} + \underbrace{\sum_{k=1}^{K} \gamma_{jk} R_k}_{\text{input demand}},$$

Firm's Distortions and Sector-level TFP

$$\max_{l_j, m_{jk}\ \forall k} (1-\tau_y)\, r_{j\omega} - (1+\tau_m) \sum_{k=1}^{K} P_k m_{jk\omega} - (1+\tau_l)\, w l_{j\omega},$$

- Aggregating firms' outcomes to the sector level: $TFP_j = \dfrac{Y_j}{\Lambda_j L_j^{\lambda_j} \prod_{k=1}^{K} M_{jk}^{\gamma_{jk}}}$
- Given that z, $(1-\tau)$, and all $(1+\tau)'s$ are jointly iid log-normal, the law of large number + the Central Limit Thm:

$$\log\left(\frac{TFP_j}{TFP_j^e}\right) = -\frac{\sigma_j}{2} v_y - \frac{\lambda_j + (\sigma_j - 1)\lambda_j^2}{2} v_l - \frac{(\sigma_j - 1)(1-\lambda_j)^2 + (1-\lambda_j)}{2} v_m$$

Macroeconomy with IO Linkages

- Express sector j's quantity supplied as a recursive equation of quantities supplied of other sectors:

$$Q_j = TFP_j \left(l_j L\right)^{\lambda_j} \prod_{k=1} \left[\gamma_{jk} \frac{\delta_j}{\delta_k} Q_k\right]^{\gamma_{jk}}$$

- Stacking $\log Q_j$ up as a vector:

$$\underset{\mathbf{J}\times\mathbf{1}}{\mathbf{q}} = (1-\mathbf{B})^{-1} \left(\mathbf{tfp} + \boldsymbol{\lambda} \log L + \omega_q\right)$$

- $\boldsymbol{B}$ is a $J \times J$ matrix of γ_{jk} and $(1-\mathbf{B}')^{-1} = \mathbf{I} + \mathbf{B}' + \mathbf{B}'^2 + \ldots$
- λ is a vector of λ_j; ω_q is a vector of sector-specific constants.
- Using the identity of an economy's GDP and consumers' optimal choices: $\log Y = \boldsymbol{\beta}' \log \mathbf{C}$:

$$\log Y = \boldsymbol{\beta}' (1-\mathbf{B})^{-1} \mathbf{tfp} + \boldsymbol{\beta}' (1-\mathbf{B})^{-1} \boldsymbol{\lambda} \log L + \log \varepsilon$$

where ε is a collection of sector-specific constants.

GDP

- A country's GDP can be expressed as

$$Y = \left(\prod_j TFP_j^{\delta_j}\right) L^{\upsilon} \varepsilon$$

- δ_j is the j-th element of the vector $\beta' \left(1 - \mathbf{B}'\right)^{-1}$, the Domar weight, $\frac{P_j Q_j}{Y}$,
- $\upsilon = \sum_{j=1}^{J} \delta_j \lambda_j$.
- Remark: as long as there is no more distortion on sector-level prices, Hulten (1978) formula implies (macroeconomic envelope theorem, Baqaee and Farhi, 2017):

$$\frac{d \log TFP}{d \log TFP_j} = \frac{d \log Y}{d \log TFP_j} = \delta_j$$

How global sourcing matters?

- Adding another nest:

$$Q_j^D = \left[\left(Q_{D,j}^D \right)^{\frac{\theta_j - 1}{\theta_j}} + \left(Q_{D,j}^F \right)^{\frac{\theta_j - 1}{\theta_j}} \right]^{\frac{\theta_j}{\theta_j - 1}},$$

- The price of finished goods j in the domestic economy:

$$P_j^D = \left[\left(P_{Dj}^D \right)^{1-\theta_j} + \left(P_{Dj}^F \right)^{1-\theta_j} \right]^{\frac{1}{1-\theta_j}}$$

-

$$P_{Dj}^D = \left[\int_{\Omega_{Dj}^D} \left(p_{j\omega}^D \right)^{1-\sigma_j} d\omega \right]^{\frac{1}{1-\sigma_j}} ; \quad P_{Dj}^F = (1+\tau_j) \left[\int_{\Omega_{Dj}^F} \left(p_{j\omega}^F \right)^{1-\sigma_j} d\omega \right]^{\frac{1}{1-\sigma_j}}$$

- Let ϕ_{Dkj}^D = domestic trade share of sector j inputs chosen by the finished goods firm in sector k.

$$\phi_{Dkj}^D = \phi_{Dj}^D = \left(\frac{P_{Dj}^D}{P_j^D} \right)^{1-\theta_j}.$$

Endogenous trade shares and Domar weights

- Resource constraint for sector j

$$P_j^D Q_j^D = \beta_j Y^D + \sum_{c \in \{D,F\}} \sum_k \phi_{cj}^D \gamma_{kj} P_k^c Q_k^c,$$

- Now the vector of Domar weights across sector:

$$\underset{2J \times 1}{\boldsymbol{\delta}} = \left(1 - \overline{\boldsymbol{B}}'\right)^{-1} \underset{2J \times 1}{\boldsymbol{\beta}},$$

- The matrix $\overline{\mathbf{B}}$ depends on the cost share of domestic material within each sector and thus the relative prices of materials:

$$\underset{2J \times 2J}{\overline{\mathbf{B}}} = \begin{bmatrix} \mathbf{B_D} & \mathbf{B_D} \\ \mathbf{B_F} & \mathbf{B_F} \end{bmatrix} \circ \begin{bmatrix} \Phi_D^D & \Phi_D^F \\ \Phi_F^D & \Phi_F^F \end{bmatrix},$$

where $\mathbf{B_c}$ is the *exogenous* IO matrix and $\Phi_c^{c'}$ is a $J \times J$ matrix with jk-th element equal $\phi_{ck}^{c'}$

Aggregate effect of sectoral TFP shocks & tariff changes

- The aggregate effect of a small change in $\log TFP_k^D$ and $\log \tau_k$ on the domestic economy's TFP:

$$\frac{d \log TFP^D}{d \log TFP_k^D} \approx \delta_k^D \phi_{Dk}^D \left(\frac{\overline{\phi}_F^F}{\overline{\phi}_D^D + \overline{\phi}_F^F - 1} \right)$$

$$\frac{d \log TFP^D}{d \log \tau_k} \approx -\delta_k^D \left(1 - \phi_{Dk}^D\right) \left(\frac{\overline{\phi}_F^F}{\overline{\phi}_D^D + \overline{\phi}_F^F - 1} \right),$$

where $\overline{\phi}_c^{c'} = \sum_j \frac{w^c L_j^c}{Y^c} \phi_{cj}^{c'}$.

- Larger ϕ_{Dk}^D (+ for TFP shock; - for tariff shocks)
- Larger $\overline{\phi}_D^D$ or $\overline{\phi}_F^F$ $\rightarrow$ Weaker effects of both tariff hikes and positive sectoral productivity shocks on aggregate TFP.

Data - China (2000-2007)

- Manufacturing firm survey data from China's National Bureau of Statistics (NBS).
- Covers all state-owned firms and all private firms with sales > 5 million RMB (about 600,000 USD during the sample period).
- Balanced-sheet variables: firm ownership, output, value added, exports, employment, original value of fixed asset, and intermediate inputs.
- Sample: 200-300k plants per year.
- Complements with sectoral trade data from China Customs.

Data - India (2000-2008)

- Annual Survey of Industries (ASI) from Indian Ministry of Statistics
- Annual data on the plant-level balanced-sheet data.
- Registered plants employing 10+ workers using power, or 20+ workers without power.
- Plants with 100+ workers are surveyed every year, while all other plants with < 100 workers were randomly sampled.
- Sample: 40-50k plants per year.
- Information on firm-level domestic and foreign sourcing.

Identifying Wedges and Computing TFP

Firm Revenue TFP:

$$TFPR_\omega = \frac{\left[\left(1+\tau_{m\omega}\right)P_m\right]^{1-\lambda}\left[\left(1+\tau_{l\omega}\right)w\right]^{\lambda\beta}\left[\left(1+\tau_{k\omega}\right)r\right]^{\lambda(1-\beta)}}{\eta\left(1-\tau_{Y\omega}\right)},$$

Firm Distortions:

$$\frac{1+\tau_{k\omega}}{1+\tau_{l\omega}} = \frac{1-\beta}{\beta}\frac{wl_\omega}{rk_\omega};$$

$$\frac{1+\tau_{m\omega}}{1+\tau_{l\omega}} = \frac{1-\lambda}{\lambda\beta}\frac{wl_\omega}{P_m m_\omega} \quad \text{(overall)}$$

$$\frac{1-\tau_{Y\omega}}{1+\tau_{l\omega}} = \frac{1}{\eta}\frac{1}{\lambda\beta}\frac{wl_\omega}{R_\omega}$$

Firm TFP:

$$z_\omega = \kappa\frac{R_\omega}{\left(l_\omega^\alpha k_\omega^{1-\alpha}\right)^\lambda\left(m_\omega\right)^{1-\lambda}}$$

Quantifying Aggregate TFP Losses

For each sector:

$$TFP_j = \left[\sum_{\omega=1}^{N_j} \left(z_{j\omega} \frac{\overline{TFPR_j}}{TFPR_{j\omega}} \right)^{\sigma_j - 1} \right]^{\frac{1}{\sigma_j - 1}},$$

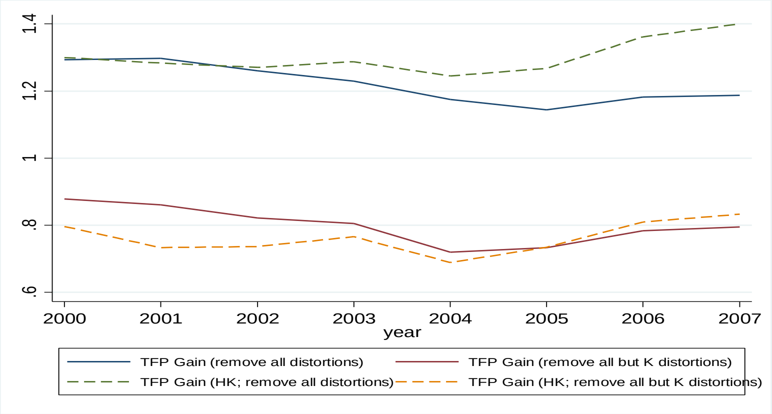
Aggregating across sectors:

$$\frac{TFP^e}{TFP} - 1 = \prod_{j=1}^{J} \left(\frac{TFP_j^e}{TFP_j} \right)^{\widehat{\delta}_j} - 1$$

Table 1: Parameter Values

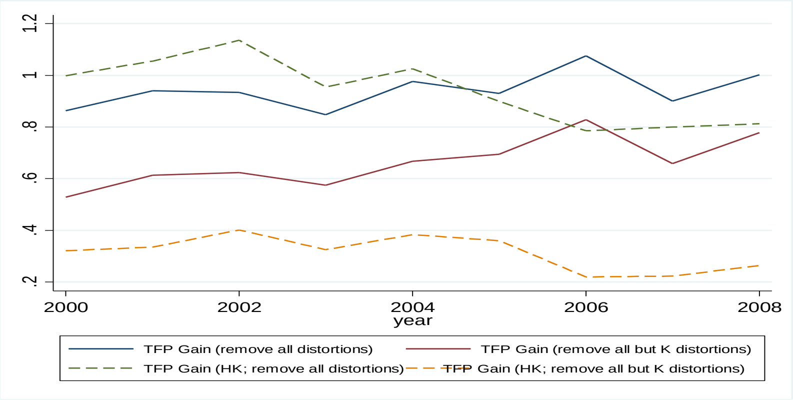
σ_j	3 (Hsieh and Klenow, 2009)
capital, labor, material shares	US 6-digit NAICS (average 1990-2005)
r	0.2 (China: Song and Wu, 2016)
	0.2 (India: Bils, Klenow, and Ruane, 2017)
w	1 (normalized)
Intermediate Input Deflators: P_{mj}	China: Brandt, Van Biesebroeck, and Zhang (2013)
	India: Allcott, Collard-Wexler, and O'Connell (2016)
Sectors' Domar weights: δ_j	Computed using each country's firm data
Domestic Trade Share in Intermediate Inputs (j)	Computed using WIOD for China; firm data for India

Aggregate TFP Gains by Removing All Distortions (China)



Source: Authors' calculation and China's NBS Data (2000-2007).

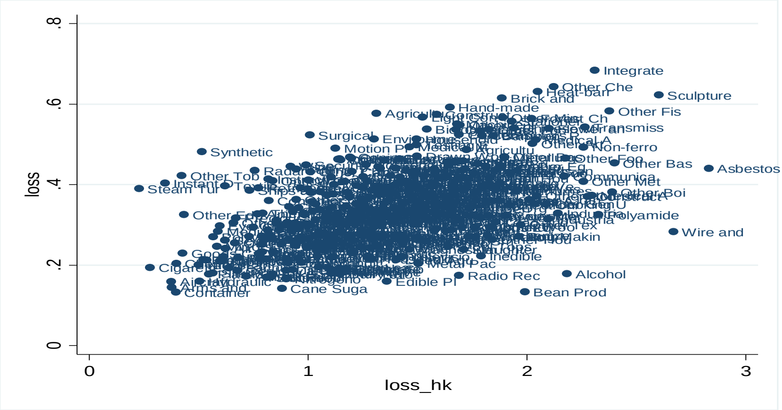
Aggregate TFP Gains by Removing All Distortions (India)



Source: Authors' calculation and India's ASI Data (2000-2008).

Why are aggregate TFP losses lower with IO linkages?

China

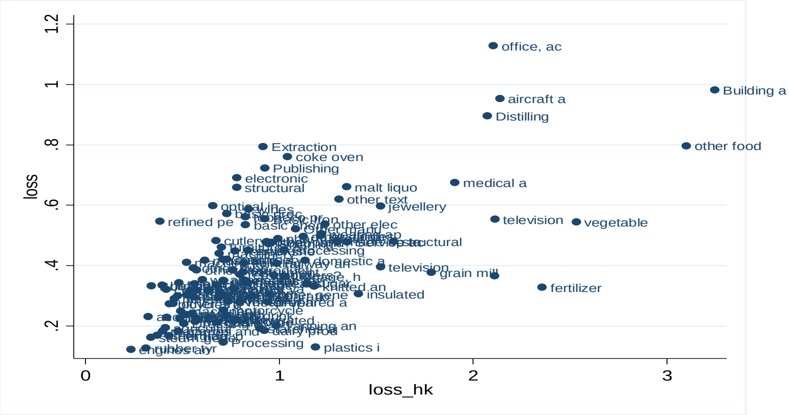


Source: Authors' calculation and China's NBS Data (2005).

- Mean = 0.63 (gross output approach) compared to Mean = 1.33 (value added approach)

Why are aggregate TFP losses lower with IO linkages?

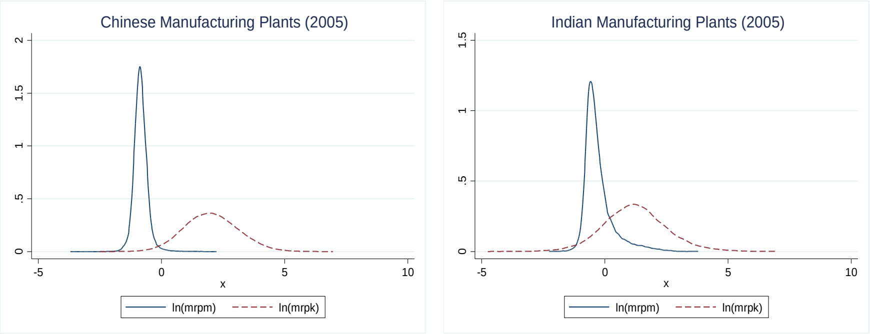
India



Source: Authors' calculation and India's ASI Data (2005).

- Mean = 0.39 (gross output approach) compared to Mean = 0.93 (value added approach)

How could TFP gains be lower after incorporating IO linkages?



Source: Authors' calculation and China's NBS and India's ASI Data (2005)

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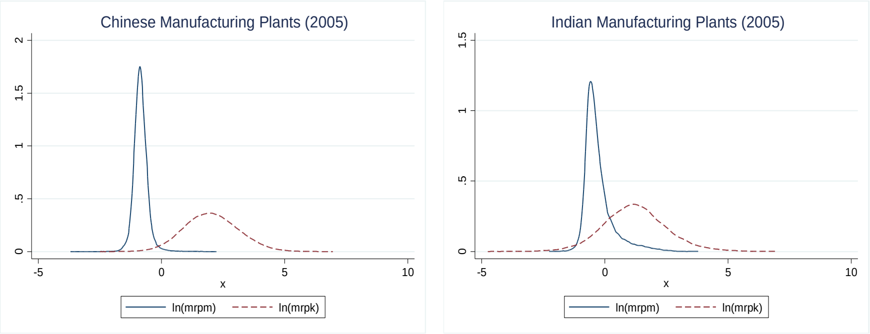


Source: Authors' calculation and China's NBS and India's ASI Data (2005)

Measurement error (e.g., Gandhi, Navarro, and Rivers, 2013)? For India, true MRP is about one-half as dispersed as the measured average products (Bils, Ruane, and Klenow, 2017).

Why are TFP gains lower after incorporating IO linkages?

Table 4: Dispersions of log marginal revenue products

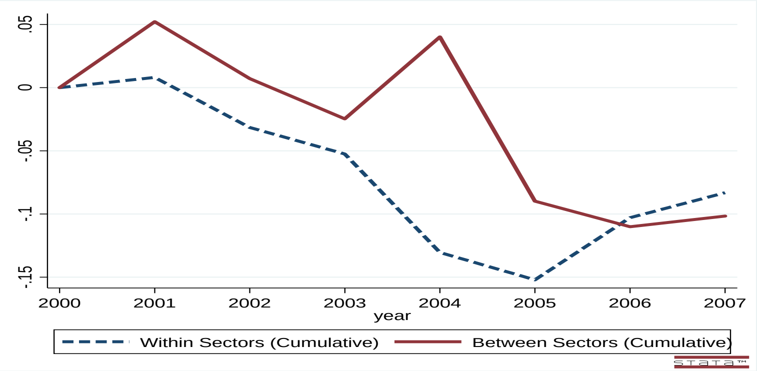
Year	India		China	
	sd(ln(mrpk))	sd(ln(mrpm))	sd(ln(mrpk))	sd(ln(mrpm))
2000	1.356	0.592	1.191	0.306
2001	1.325	0.592	1.187	0.288
2002	1.323	0.628	1.161	0.287
2003	1.298	0.612	1.133	0.278
2004	1.304	0.613	1.130	0.277
2005	1.292	0.603	1.091	0.275
2006	1.269	0.608	1.082	0.272
2007	1.270	0.641	1.079	0.273
Average	1.305	0.611	1.132	0.282

Source: Authors' calculation based on China's NBS and India's ASI data

Source: Authors' calculation and China's NBS and India's ASI Data (2005)

Decomposition - China

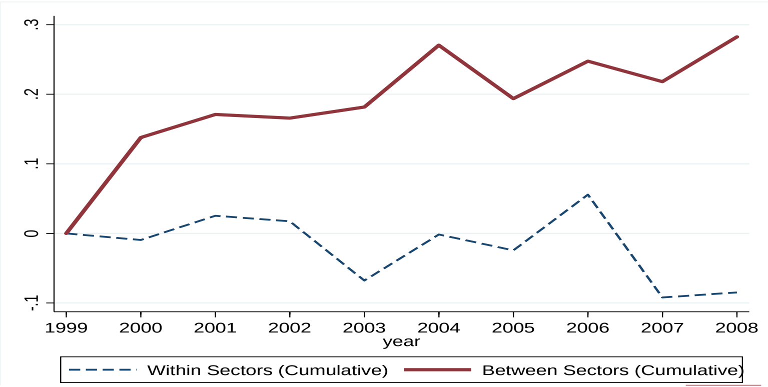
- $$\triangle TFP_t^{loss} = \underbrace{\sum_{j=1}^{J} \overline{\widehat{\delta_{jt}}} \triangle TFP_{jt}^{loss}}_{within} + \underbrace{\sum_{j=1}^{J} \triangle \widehat{\delta_{jt}} \overline{TFP_{jt}^{loss}}}_{between},$$



Source: Authors' calculation and China's NBS (2000-2007)

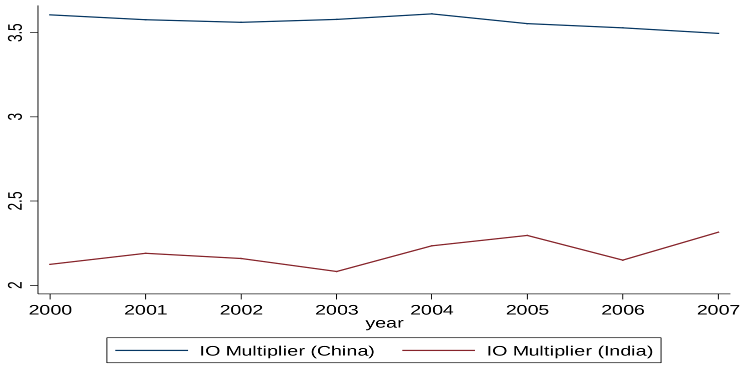
Decomposition - India

- $\triangle TFP_t^{loss} = \underbrace{\sum_{j=1}^{J} \overline{\widehat{\delta_{jt}}} \triangle TFP_{jt}^{loss}}_{within} + \underbrace{\sum_{j=1}^{J} \triangle \widehat{\delta_{jt}} \overline{TFP_{jt}^{loss}}}_{between},$

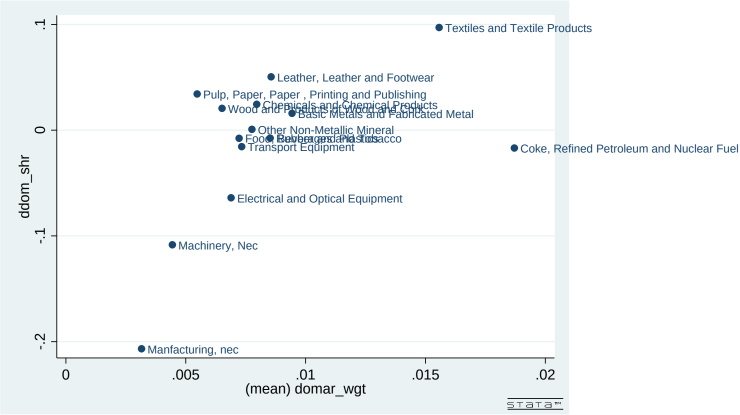


Source: Authors' calculation and India's ASI (1999-2008)

IO Multiplier



Changes in domestic trade shares and Domar weights (India)



Source: Authors' calculation and WIOD (2000-2007)

Conclusions

- Using the gross output approach, estimated industry-level TFP losses due to misallocation are on average about half of the previous estimates (e.g., Hsieh and Klenow, 2009).
- Main reason: substantially smaller dispersion in the MRP of intermediate inputs, compared to capital and labor.
- Incorporating IO linkages pushes aggregate TFP loss up, but not necessarily higher than the existing estimates based on the value-added approach.
- Trade liberalization may raise the size of the IO multiplier (seems to be the case of India), amplifying the costs of resource allocation for India.
- Room for sequential trade policy in the second-best world?

How global sourcing matters?

A simple short-cut proposed by Jones(2011)

- Production function:

$$q_j^D(z) = z\Lambda_j l_j^D(z)^{\lambda_j} \prod_{k=1}^{K} m_{jk}^D(z)^{\gamma_{jk}^D} m_{jk}^F(z)^{\gamma_{jk}^F}$$

- Trade is balanced with exports of final goods, but imports of input varieties.

$$\log Y^D = \boldsymbol{\beta}'\left(1-\mathbf{B}'\right)^{-1}\mathbf{tfp} + \boldsymbol{\beta}'\left(1-\mathbf{B}'\right)^{-1}\left(\boldsymbol{\lambda}\log L + \boldsymbol{\gamma}^F \log Y\right) + \log\varepsilon$$

- GDP:

$$Y^D = \left(\prod_j TFP_j^{\phi_j^D}\right)(L_D)^{\widehat{\upsilon}}\,\widehat{\varepsilon}$$

- where ϕ_j^D is the j-th element of the vector $\frac{\beta'(1-\mathbf{B})^{-1}}{1-\beta'(1-\mathbf{B})^{-1}\boldsymbol{\gamma}^F}$

$$\phi_j^D = \frac{\delta_j^D}{1-\sum_j^J \delta_j^D \gamma_j^F}$$

Sector-level Outcomes

Plugging the solution back to the revenue function, aggregating revenue up to the sector level:

$$
\begin{aligned}
TFP_j &= \frac{Y_j}{\Lambda_j L_j^{\lambda_j} \prod_{k=1}^{K} M_{jk}^{\gamma_{jk}}} \\
&= \left[\left[\left[\frac{(1-\tau_y)\, z}{(1+\tau_l)^{\lambda_j} (1+\tau_m)^{1-\lambda_j}} \right]^{\frac{\eta_j}{1-\eta_j}} \right]^{\frac{1}{\eta_j}} \right. \\
&\times \left[\left[\left[\frac{(1-\tau_y)\, z^{\eta_j}}{(1+\tau_l)^{\eta_j\lambda_j} (1+\tau_m)^{\eta_j(1-\lambda_j)}} \right]^{\frac{1}{1-\eta_j}} \right]^{-(1-\lambda_j)} T_j^{-\lambda_j}
\end{aligned}
$$

Given that both z, $(1-\tau)$, and all $(1+\tau)'s$ are jointly log-normal, evoking the law of large number and the Central Limit Thm:

$$
\log\left(\frac{TFP_j}{TFP_j^e}\right)_{gross} = -\frac{\sigma_j}{2} v_y - \frac{\lambda_j + (\sigma_j - 1)\lambda_j^2}{2} v_l - \frac{(\sigma_j-1)(1-\lambda_j)^2 + (1-\lambda_j)}{2} v_m
$$

Which are the influential sectors in China?

▶

Table 7: Domar Weights and Doma/ Consumption Share by Industry - China (2005)

Top 10 industries: Domar weights		Top 10 industries: Domar/ Beta	
	Domar Weight		Domar/Beta
Cotton Spinning	0.132	Acrylic Fibres	7.699
Apparel	0.118	Containers	5.441
Steel Rolling	0.096	Synthetic Fibres	5.415
Automobile Parts	0.091	Mining Vehicles	5.413
Cement	0.074	Tin Smelting	5.350
Bottom 10 industries: Domar weights		**Bottom 10 industries: Domar/ Beta**	
Artificial Crude Oil Production	0.000	Biological Products	2.236
Nuclear and Nuclear Radiation Instrs	0.000	Chinese Medicines and Phama	2.171
Other Production-Use Goods	0.000	Other Production-Use Goods	2.117
Diving and underwater rescue equip	0.000	Other Aircraft and Spacecraft	1.908
Other Aquatic Products	0.000	Cigarettes	1.754

Source: Authors' calculation and China's National Bureau of Statistics Data.

Which are the influential sectors in India?

▶

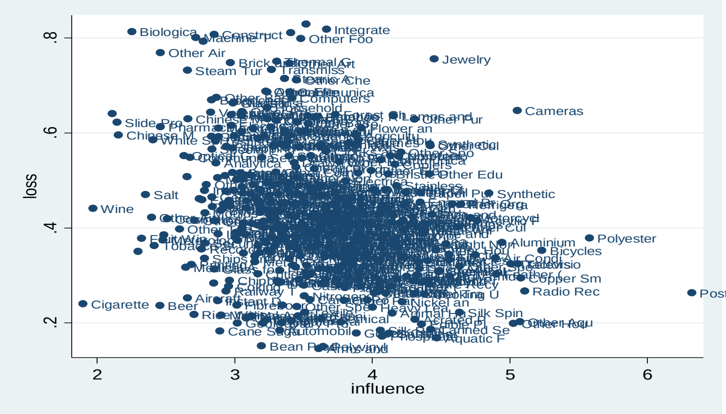
Table 6: Domar Weights and Doma/ Consumption Share by Industry - India (2005)

Top 10 industries: Domar weights	Domar Weight	Top 10 industries: Domar/ Beta	Domar/Beta
Refined petroleum products	0.256	Grain mill products	5.866
Motor vehicles	0.135	Saw milling and planing of wood	5.487
Basic Iron & Steel	0.111	Processing and preserving of fish and fish products	5.172
Preparation and spinning of textile fiber	0.100	Dairy product	4.520
Sugar	0.059	Bicycles and invalid carriages	3.575
Bottom 10 industries: Domar weights		**Bottom 10 industries: Domar/ Beta**	
Service activities related to printing	0.000	malt liquors and malt	1.242
Macaroni, noodles, conscious, etc.	0.000	tobacco products	1.235
Aircraft and spacecraft	0.000	glass and glass products	1.234
Musical instruments	0.000	musical instruments	1.183
Building and repairing of pleasure & sporting boats	0.000	cement, lime and plaster	1.159

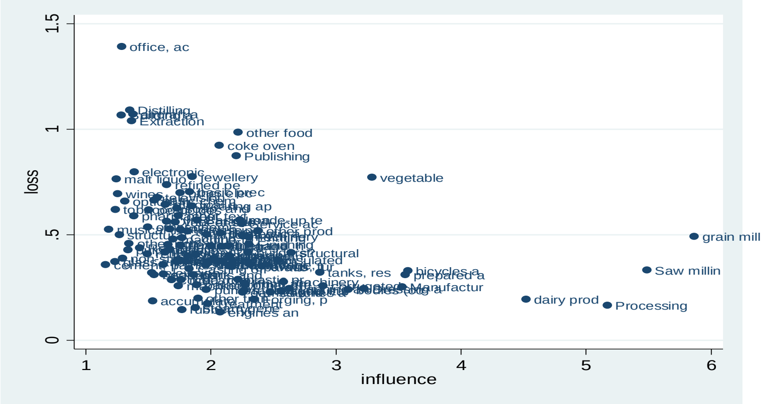
Source: Authors' calculation and India's Annual Survey of Industries (ASI) Data.

Distortions and Influential (Upstream) Sectors

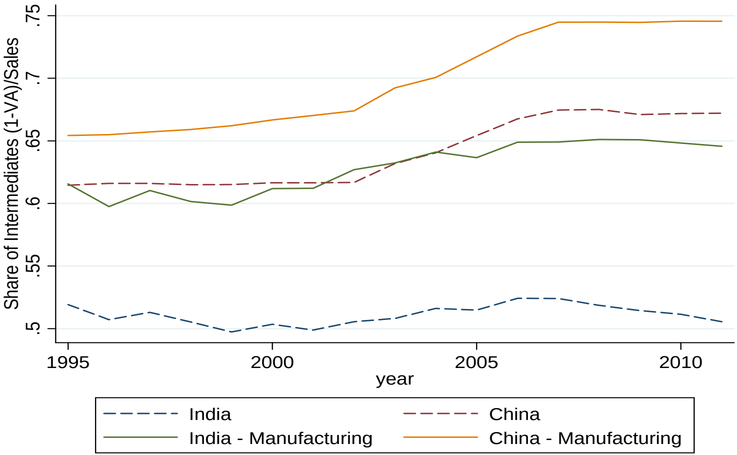
- The more upstream a sector is, the larger the macroeconomic impact of distortions as there are more firms and sectors (links) through which the costs travel downstream (Liu, 2017).



Distortions and Influential (Upstream) Sectors (India)



Increasing Shares of Intermediate Inputs



Source: Authors' calculation using World Input-Output Database