Growth accounting in open economies with distortions*

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*The views expressed are those of the authors and do not necessarily represent the views of the Central Bank of Chile or its board members.

Motivation: Aggregation with distortions

- In the presence of distortions:

  $$\Delta \text{ Aggregate TFP} = \Delta \text{ Technology} + \Delta \text{ Allocative Efficiency}$$

- Trade is argued to be an important source of aggregate TFP growth
  - But, through technology? Through allocative efficiency?

- We study the role of trade in growth accounting
  - Need less assumptions than for full quantitative analysis
  - It is what policymakers typically analyze (e.g. central banks)

- Relevant for open economies with stagnant aggregate TFP

This paper: Theory

- TFP growth accounting in open economies with distortions
  - Baqaee & Farhi (2024) + SMO
  - Heterogenous wedges (markups) shape allocative efficiency

- Distorted trade influences aggregate TFP growth through three channels
  (a) Export Channel: Exporting goods markups affect domestic factor allocation
  (b) Import Channel: Marked-up production using imports $\Rightarrow$ Downstream distortions
  (c) Import Bias: National accounts adjustment of imports

This paper: Measurement and application

- Measurement for Chile: Firm-level markups + Firm-to-firm IO matrix
  - Markups: i) Accounting markups ; ii) DLW + input and output prices
  - Firm-to-firm flows: Captures direct and indirect role of distorted trade
- Application: Aggregate TFP growth decomposition of 15 years for Chile
  - Non-technolgical forces explain the bulk of aggregate TFP growth
  - International trade accounts for half of aggregate TFP growth
  - All three channels are quantitatively relevant

Literature

Growth accounting in the presence of distortions

Restuccia and Rogerson (2008), Hsieh and Klenow (2010), Hsieh and Klenow (2009), and Baqaee and Farhi (2020)

International trade and aggregate TFP growth

Baqaee and Farhi (2024), Burstein and Cravino (2015), Blaum et al. (2018), and Kehoe and Ruhl (2008)

Impact of trade in economies with distortions

Feenstra et al. (2013), Gopinath and Neiman (2014), Bai et al. (2023), and Baqaee and Farhi (2024)

Outline

(a) Theory

(b) Data

(c) Measurement and Estimation

(d) Results

(e) Conclusion

Theory: Technology

- $\mathcal{N}$ firms, produce domestic ($\mathcal{D} \in \mathcal{N}$) and export ($\mathcal{E} \in \mathcal{N}$) goods with CRS

$$q_i = A_i H_i \left(\{q_{ij}\}_{j \in \mathcal{D}}, L_{L,i}, L_{K,i}, L_{M,i} \right)$$

- Primary factors: Labor (L_L), capital (L_K), and imported inputs (L_M)
    - Assume SOE, can extend the theory to large economies, but...
    - Large economy: Not implementable in the data
- Firms minimize costs given input prices and sell their products charging a markup (μ_i) over marginal cost: $p_i = \mu_i mc_i$

Preferences   Market clearing

Theory: General equilibrium

- Given firm-level productivity A_i, markup μ_i, exogenous foreign demand, and exogenous import prices
- The general equilibrium is the set of prices p_i, intermediate input choices q_{ij}, factor input choices $(L_{L,i}, L_{K,i}, L_{M,i})$, output q_i, and consumption choices y_i, such that:
  - The price of each good is equal to its markup multiplied by its marginal cost
  - Households maximize utility given the budget constraints and given prices
  - Markets clear for all goods and factors

Theory: National accounts

- GDP definition

$$GDP = \sum_{i \in \mathcal{D}+\mathcal{E}} p_i y_i - w_M L_M$$

- Firm GDP shares

$$b_i = \begin{cases} \frac{p_i y_i}{GDP} & \text{if } i \in \mathcal{D} + \mathcal{E} \\ -\frac{w_M L_M}{GDP} & \text{if } i \in M \\ 0 & \text{otherwise} \end{cases}$$

- Factor GDP shares

$$\Lambda_L = \frac{w_L L_L}{GDP}, \quad \Lambda_K = \frac{w_K L_K}{GDP}, \quad \Lambda_M = \frac{w_M L_M}{GDP}$$

Theory: Input-output Objects

- Cost-based input-output matrix ($\tilde{\Omega}$) of dimensions $(\mathcal{D}+\mathcal{E}+\mathcal{F}) \times (\mathcal{D}+\mathcal{E}+\mathcal{F})$ Details

$$\tilde{\Omega}_{ij} = \frac{\text{Value of input j used by firm i}}{\text{Firm i total cost}} = \frac{p_j q_{ij}}{\sum_{j \in \mathcal{D}+\mathcal{E}+\mathcal{F}} p_j q_{ij}}$$

- Cost-based Leontief inverse matrix ($\tilde{\Psi}$) accounts for firms' direct and indirect cost exposures through supply chains

$$\tilde{\Psi} \equiv (I - \tilde{\Omega})^{-1} = I + \tilde{\Omega} + \tilde{\Omega}^2 + \dots$$

- Cost-based Domar weights $\tilde{\lambda}$ ($\tilde{\Lambda}$ for factors)

$$\tilde{\lambda}' \equiv b' \tilde{\Psi}$$

Theory: Growth accounting

All feasible allocations are defined by an allocation matrix $\mathcal{X}$ ($\mathcal{X}_{ij} = q_{ij}/y_j$), a vector of productivities A, a vector of markups μ, and a vector of factor supplies, $\mathcal{F} = [L, K, M]$

The equilibrium allocation yields an allocation matrix $\mathcal{X}(A, \mathcal{F}, \mu)$, which in turn generates an output level of $\mathcal{Y}(A, \mathcal{X}(A, \mathcal{F}, \mu))$

Theory: Growth accounting

- Real GDP effects can be unpacked into:

$$\mathrm{d}\log\mathcal{Y} = \underbrace{\frac{\partial\log\mathcal{Y}}{\partial\log A}\mathrm{d}\log A}_{(a)\ \Delta\ \text{Technology}} + \underbrace{\frac{\partial\log\mathcal{Y}}{\partial\mathcal{X}}\mathrm{d}\log\mathcal{X}}_{(b)\ \Delta\text{Allocative Efficiency}}$$

(a) Change in technology ($\mathrm{d}\log A$), given allocation matrix $\mathcal{X}(A, F, \mu)$

(b) Change in allocation matrix ($\mathrm{d}\mathcal{X}$), given technology A

Theory: Growth accounting -Technology

- Aggregate TFP growth in response to firm-level productivity shocks can be summarized, to a first-order, as:

$$\Delta \text{ Technology} = \sum_{i \in \mathcal{D}+\mathcal{E}} \left(\tilde{\lambda}^{\mathcal{D}}_{i,t-1} + \tilde{\lambda}^{\mathcal{E}}_{i,t-1} \right) \; d \log A_i$$

- Every firm has two Domar weights:
  - $\tilde{\lambda}^{\mathcal{D}}_i$ accounts for firm i direct and indirect effects on domestic production
  - $\tilde{\lambda}^{\mathcal{E}}_i$ for direct and indirect effects on exporting goods

Theory: Growth accounting -Domestic allocative efficiency

- Aggregate TFP growth in response to factor supply shocks and shocks to wedges can be summarized, to a first-order, as:

$$\Delta \text{ Domestic allocative efficiency} = \underbrace{- \sum_{f \in \{L,K\}} \tilde{\Lambda}^{\mathcal{D}}_{f,t-1} \, d \log \Lambda_f}_{(a)} \underbrace{- \sum_{i \in \mathcal{D},\mathcal{E}} \tilde{\lambda}^{\mathcal{D}}_{i,t-1} \, d \log \mu_i}_{(b)}$$

(a) $(a) > 0$: Resource reallocation to underproduced parts of the economy $\Rightarrow \Delta^-$ Factor shares $\Rightarrow \Delta^+$ allocative efficiency $\Rightarrow \Delta^+$ TFP

(b) Factor reallocation due to markup changes must be discounted

Theory: Growth accounting -Trade allocative efficiency

$$\Delta\text{Trade allocative efficiency} =$$

$$\underbrace{-\sum_{f\in\{L,K\}} \tilde{\Lambda}^{\mathcal{E}}_{f,t-1}\, d\log\Lambda_f - \sum_{i\in\mathcal{D},\mathcal{E}} \tilde{\lambda}^{\mathcal{E}}_{i,t-1}\, d\log\mu_i}_{(a)\ \ Export\ \ channel}$$

$$\underbrace{-\left(\tilde{\Lambda}^{\mathcal{D}}_{M,t-1} - \Lambda^{\mathcal{D}}_{M,t-1}\right) d\log\Lambda_{M,t} - \left(\tilde{\Lambda}^{\mathcal{E}}_{M,t-1} - \Lambda^{\mathcal{E}}_{M,t-1}\right) d\log\Lambda_{M,t}}_{(b)\ \ Import\ \ channel}$$

(a) Exports contribution to reallocation, similar to domestic reallocation

(b) Imports reallocation to high markups firms $\Rightarrow \Delta^{-}$ Intermediate import share
- Weight adjustment: Imports subtracted in GDP with revenue-based measure
- Distortions $\Rightarrow$ Revenue generated by imports exceeds their costs
- Imported markups allocated abroad $\Rightarrow$ No need to discount markup changes

Theory: Growth accounting - Import bias

National accounts adjustment of imports

$$\Delta \text{ Import bias} = \left(\tilde{\Lambda}_{M,t-1} - \Lambda^R_{M,t-1}\right) d \log L_M$$

- Imports are a factor in this economy but not subtracted for aggregate TFP
- Imports are subtracted in GDP with a revenue-based measure Λ^R_M
- With distortions, they should be subtracted using a cost-based measure $\tilde{\Lambda}_M$
- The larger $\tilde{\Lambda}_M - \Lambda^R_M > 0$ is, the greatest are imported goods driven distortions in aggregate TFP

Theory: Growth accounting with distorted trade

- Aggregate TFP growth in response to productivity shocks, factor supply shocks, and shocks to wedges can be summarized, to a first-order, as:

$$
\begin{aligned}
d\log Y_t - \sum_{f\in\{L,K\}} \tilde{\Lambda}_{f,t-1} d\log L_{f,t} &= \\
\Delta \text{ Agreggate TFP} &= \Delta \text{ Technology} \\
&\quad + \Delta \text{ Domestic allocative efficiency} \\
&\quad + \Delta \text{ Trade allocative efficiency} \\
&\quad + \Delta \text{ Import Bias}
\end{aligned}
$$

Connection to reallocation of standard models

- Decomposition highlights reallocation, ignoring within-between firm margin
  - Conditional on markup changes, aggregate factor changes is what matters
  - $\Rightarrow$ Allocative efficiency independent of within-between firm factor changes
- $\Rightarrow$ Within and between firm forces can contribute to allocative efficiency
  - Melitz (2003), which is between, is a subset of allocative efficiency gains
- Reallocation forces similar to standard firm models
  - Allocative efficiency improves if factors reallocate to high-markup firms
  - As in Hsieh, Klenow (2008), Edmond, Midrigan, Xu (2014)

Data Sources: Administrative tax data from Chilean IRS

(a) Firm accounting balance sheets: Sales, materials, investment, main industry

(b) Employer-employee: Wages, headcount employees

(c) Capital stock: Perpetual inventory using initial fixed assets and investment

(d) Firm-to-firm transactions: Prices, quantities, products, supplier, buyer

Data cleaning

- Firm: Tax ID with positive sales, materials, wage bill, and capital
- Firms with less than two employees or capital below US$20 are dropped
- Variables are winsorized at 1% and 99% levels to reduce measurement error
- Data is anonymized for the confidentiality of the firm's and workers' identities

Measurement and estimation: Markups

- To implement growth accounting, we need to measure three objects:
  - Markups, cost-based Domar weights and aggregate objects

- Markups
  - Accounting markups (observed sales to observed cost ratio)
  - DLW
    - Controlling for firm-level input and output prices
    - 3 factors Cobb-Douglas production function
    - 6-digit sector (626) different time invariant production functions
    - Materials elasticties to recover markups

Measurement and estimation: Cost-based Domar weights

Details: $\tilde{\lambda}_i$ | Details: $\tilde{\Omega}$ | Aggregate Objects

$$\tilde{\lambda}_i \equiv b'\tilde{\Psi} = b'(I - \tilde{\Omega})^{-1}$$

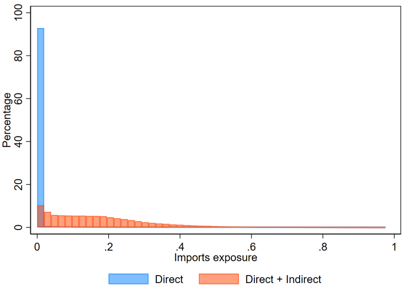
- Decompose Leontief inverse, e.g., factors' role on domestic production

$$\tilde{\Psi}_{\mathcal{DF}} = \begin{bmatrix} \tilde{\Psi}_{\mathcal{D}L} & \tilde{\Psi}_{\mathcal{D}K} & \tilde{\Psi}_{\mathcal{D}M} \end{bmatrix}$$

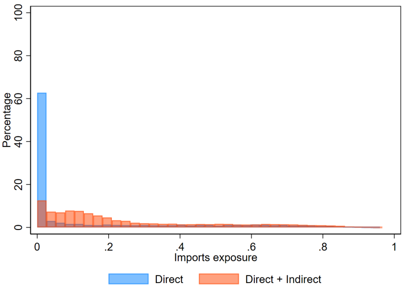
- $\tilde{\Psi}_{\mathcal{D}M}$: Relevance of imports in domestic production, directly and indirectly
- Homologous for $\tilde{\Psi}_{\mathcal{E}M}$ on exports production

Direct and indirect exposure to imported inputs

(a) Domestic: $\tilde{\Omega}_{\mathcal{D}M}$ vs $\tilde{\Psi}_{\mathcal{D}M}$



(b) Exports: $\tilde{\Omega}_{\mathcal{E}M}$ vs $\tilde{\Psi}_{\mathcal{E}M}$



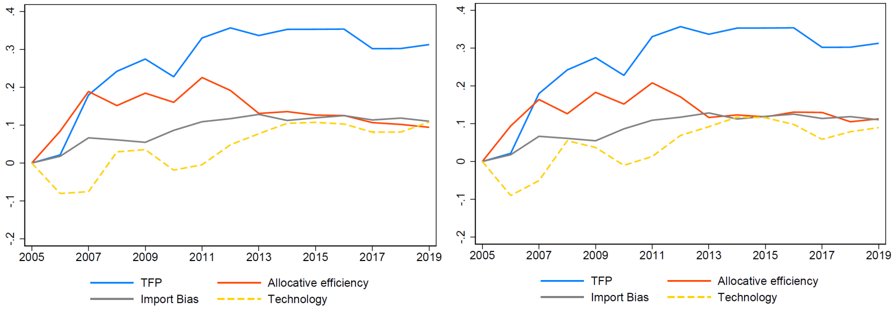
- 11% (99%) of firms are directly (indirectly) exposed to imports
- 38% of exporters use imports directly $\Rightarrow$ More engaged in international trade
- Still, the majority of exporters (62%) use imports only indirectly

Growth accounting with distorted trade

$$\Delta\text{Aggregate TFP} = \Delta\text{Technology} + \Delta\text{Allocative efficiency} + \Delta\text{Import Bias}$$

(a) DLW markups

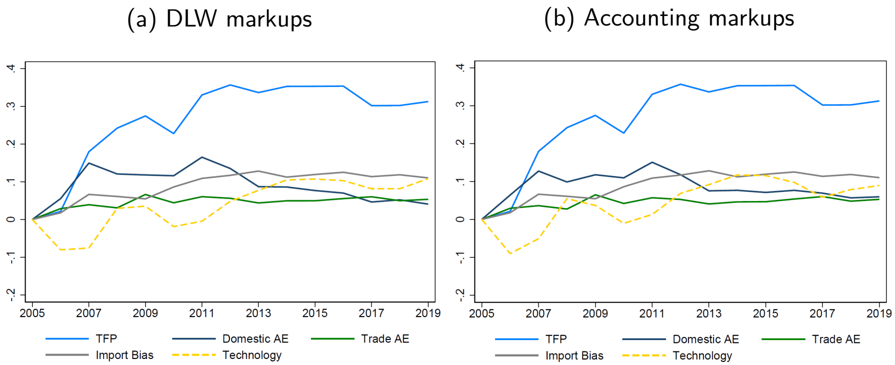
(b) Accounting markups



- Allocative efficiency + Import bias accounts for around 70% of cumulative TFP growth

Growth accounting domestic vs. trade allocative efficiency

$$\Delta \text{Aggregate TFP} = \Delta \text{Technology} + \Delta \text{Domestic AE} + \Delta \text{Trade AE} + \Delta \text{Import Bias}$$

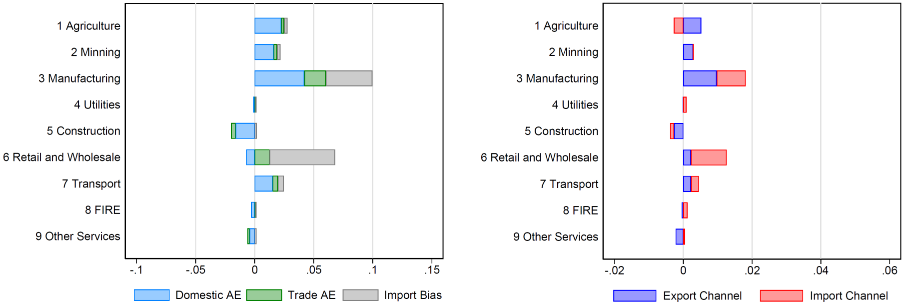


- Domestic and trade allocative efficiency are quantitatively equivalent
- Trade forces (import bias+trade AE) account for around half of TFP growth

Growth accounting across sectors (using accounting markups)

(a) Three Channels

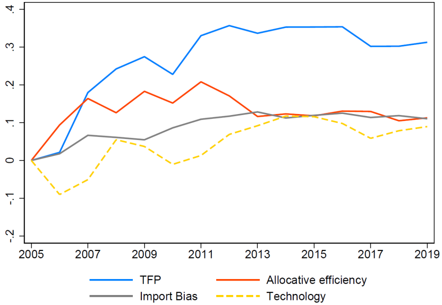
(b) Export and Import Channel



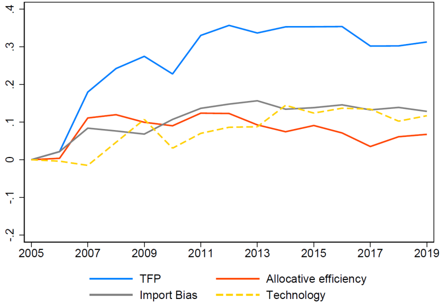
- Allocative efficiency matters in trade-intensive sectors (1-3)
- Import bias matters for manufacturing and retail & wholesale
- Export channel dominates across sectors except for retail & wholesale
- Import channel is relevant for manufacturing and retail & wholesale

Benchmark vs sector level objects (using accounting markups)

(a) Firm level objects



(b) Sector level objects (2 digit)



- Sector level I-O matrices and markups
- Allocative efficiency declines when missing granular objects
- Resource reallocation is happening within sector rather than between

Conclusion

- We present a framework to understand how trade drives aggregate TFP
  - Trough allocative efficiency (both imports and exports) and import bias
- We show that all channels are quantitatively relevant
- Measurement is relevant, especially by using firm-level input-output matrices
- Policymakers can asses trade forces of allocative efficiency for aggregate TFP measurement
  - The necessary data are becoming increasingly available across the world (ie. Ecuador, Belgium, Turkey and Costa Rica)

Appendix

Theory: Preferences Return

- Domestic representative household with homothetic preferences

$$\mathcal{W} = \mathcal{W}\left(\{y_i\}_{i\in\mathcal{D}}\right)$$

- Budget constraint

$$\underbrace{\sum_{i\in\mathcal{D}} p_i y_i}_{Final\ \ Goods\ \ Expenditure} = \underbrace{\sum_{f\in\{L,K\}} w_f L_f}_{Factor\ \ Income} + \underbrace{\sum_{i\in\mathcal{D}+\mathcal{E}} \left(1 - 1/\mu_i\right) p_i q_i}_{Non-Factor\ \ Income:\ \ Profits}$$

- All imports are channeled through intermediaries

Theory: Market Clearing Return

- Goods

$$i \in \mathcal{D}: \quad q_i = y_i + \sum_{j \in \mathcal{D}} q_{ji}; \quad i \in \mathcal{E}: \quad q_i = y_i$$

- Factors

$$\sum_{i \in \mathcal{D}+\mathcal{E}} L_{L,i} = L_L, \quad \sum_{i \in \mathcal{D}+\mathcal{E}} L_{K,i} = L_K, \quad \sum_{i \in \mathcal{D}+\mathcal{E}} L_{M,i} = L_M$$

- GDP deflator

$$d \log P = \sum_{i \in \mathcal{D}+\mathcal{E}} \frac{p_i y_i}{GDP} d \log p_i - \frac{w_M L_M}{GDP} d \log w_M$$

Cost-Based Input-Output Matrix $\tilde{\Omega}$ Return Theory Return Measurement

$$\tilde{\Omega} = \begin{bmatrix} \tilde{\Omega}_{\mathcal{DD}} & \tilde{\Omega}_{\mathcal{DE}} & \tilde{\Omega}_{\mathcal{DF}} \\ \tilde{\Omega}_{\mathcal{ED}} & \tilde{\Omega}_{\mathcal{EE}} & \tilde{\Omega}_{\mathcal{EF}} \\ \tilde{\Omega}_{\mathcal{FD}} & \tilde{\Omega}_{\mathcal{FE}} & \tilde{\Omega}_{\mathcal{FF}} \end{bmatrix} = \begin{bmatrix} \tilde{\Omega}_{\mathcal{DD}} & 0 & \tilde{\Omega}_{\mathcal{DF}} \\ \tilde{\Omega}_{\mathcal{ED}} & 0 & \tilde{\Omega}_{\mathcal{EF}} \\ 0 & 0 & 0 \end{bmatrix}$$

- Row i is buying from column j
- Factors do not require inputs $\Rightarrow \tilde{\Omega}_{\mathcal{F}j} = 0$ for all $j = \{\mathcal{D}, \mathcal{E}, \mathcal{F}\}$
- Exports sold only internationally $\Rightarrow \tilde{\Omega}_{\mathcal{DE}} = 0$ and $\tilde{\Omega}_{\mathcal{EE}} = 0$
- Numerator of $\tilde{\Omega}_{\mathcal{DD}}$ and $\tilde{\Omega}_{\mathcal{ED}}$: Firm-to-firm trade flows
- Numerator of $\tilde{\Omega}_{\mathcal{DF}}$ and $\tilde{\Omega}_{\mathcal{EF}}$: Factor expenditures

Cost-based Domar Weights components Return

$$\tilde{\lambda}_i \equiv b'\tilde{\Psi} = b'(I - \tilde{\Omega})^{-1}$$

Expenditure shares b:
A vector of dimension $(D + X + F) \times 1$, where D is the number of firms that sell domestically, X is the number of firms that export, F is the number of factors, is measured relative to GDP.

The first D entries are measured by taking the residual between firms' total sales (excluding exports) and firms' intermediate sales to other firms (which we measure from the firm-to-firm data). For the next X entries, we measure them directly using firms' exports. The final F entries are zero because the household does not buy factors directly.

Aggregated objects

Return

We measure the following aggregate objects directly from the data:

- Aggregate value added: Y
- Aggregate employment: L_L
- Aggregate capital: L_K
- Aggregate imports: L_{IM}
- Import Share: Λ_{IM}