# Key sectors for economic development: A perspective from inter-sectoral linkages and cross-sector misallocation

Julio Leal[1]

[1]Banco de México

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# Disclaimer

The views I will express next do not necessarily represent the views of Banco de México.

# Outline

# Motivation

- Which are the key sectors for economic development?
  - agriculture, manufacturing, or services?
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- The productivity of highly *interconnected* sectors is an important determinant for aggregate productivity.
  - Example: Productivity of refined petroleum affects gasoline production, which in turn affects transportation, which affects trade, which affects refined petroleum products, and so on.

- It matters:
  - The productivity gap of a single sector with respect to the leader.
  - The degree of interconnections of this sector with the rest of the economy.

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- Sector-specific distortions affect aggregate productivity.
  - Create cross-sector misallocation.
  - Reduce the resources available for consumption.
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  - Distortions in highly interconnected sectors have a larger impact on aggregate productivity, than distortions in other sectors.

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- Set-up a multi-sector model.
  - Output of a given sector can be used as an intermediate input for production in other sectors.
    - Introduces a link between the performance of a single sector, and the performance of the rest.
- Use the model to study three types of distortions per sector:
  - Productivity wedge.
  - Wedge between marginal revenue and marginal cost (a markup).
  - Wedge between the marginal productivity of labor and the marginal cost of labor (MC of labor wedge).
- Calibrate the model for both, the US and Mexico:
  - Make use of input-output tables.
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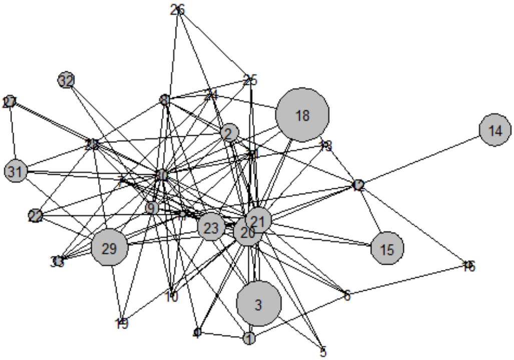
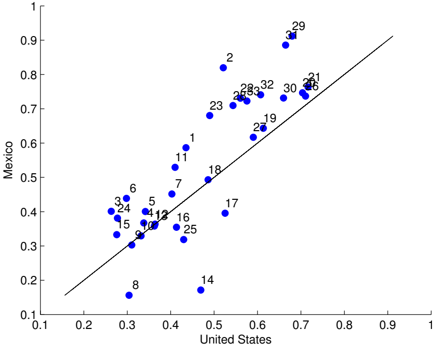
# Network map

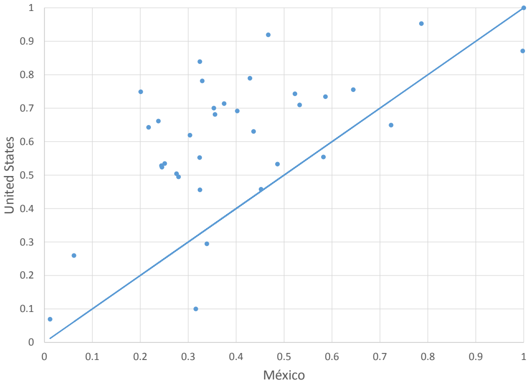


# Share of value added in gross output



# Labor income share in GDP, by sector.

Figure: Labor income share in value-added



# Model

- Multi-sector model with $N$ sectors (Long and Plosser, 1983, Jones, 2011; Acemoglu et al, 2012, and others).
- Supply of labor $H$ is exogenous.
- Each sector uses labor, and commodities from all sectors (including its own) to produce.
- There exist three wedges per sector in the economy:
  - Productivity wedge.
  - Markup wedge.
  - MC of labor wedge.

# Technology

Production function of a representative firm in sector $i$ :

$$Q_i = A_i (H_i)^{\alpha_i (1-\sigma_i)} \prod_{j=1}^{N} x_{ij}^{\sigma_{ij}}, \tag{1}$$

where $\sigma_i = \sum_{j=1}^{N} \sigma_{ij}$; and $\sigma_i + (1-\sigma_i)\alpha_i < 1$.
Resource constraint of each sector $j$:

$$Q_j = c_j + \sum_{i=1}^{N} x_{ij}, \forall j = 1, ..., N.$$

Final good:

$$Y = c_1^{\beta_1} c_2^{\beta_2} \dots c_N^{\beta_N}.$$

# Problem of the final good producer

The problem consists on choosing $\{c_i\}$, taking $\{p_i\}$ as given, to solve:

$$\max_{\{c_i\}} \left\{ c_1^{\beta_1} c_{2\dots}^{\beta_2} c_N^{\beta_N} - \sum_{i=1}^{N} p_i c_i \right\}.$$

The first order conditions are given by:

$$\beta_i(Y/c_i) - p_i = 0 \Leftrightarrow \beta_i Y = p_i c_i, \; \forall i. \tag{2}$$

$$\beta_i = \frac{p_i c_i}{Y}$$

# Problem of the representative firm in sector $i$

The problem of the representative firm in industry $i$ is given by

$$\max_{H_i,\{x_{ij}\}} \quad \left\{ \frac{1}{\psi_i} p_i A_i (H_i)^{\alpha_i(1-\sigma_i)} \prod_{j=1}^{N} x_{ij}^{\sigma_{ij}} - \phi_i w H_i \ldots \right.$$

$$\left. - \textstyle\sum_{j=1}^{N} p_j x_{ij} \right\}$$

# FOCs

$$\frac{1}{\psi_i}\alpha_i(1-\sigma_i)\frac{p_i Q_i}{H_i} = \phi_i w, \ \forall i \tag{3}$$

$$\frac{1}{\psi_i}\sigma_{ij}\frac{p_i Q_i}{x_{ij}} = p_j, \ \forall i,j \tag{4}$$

# FOCs

$$\frac{1}{\psi_i}\alpha_i(1-\sigma_i)\frac{p_iQ_i}{H_i} = \phi_i w,\ \forall i \tag{5}$$

$$\frac{1}{\psi_i}\sigma_{ij}\frac{p_iQ_i}{x_{ij}} = p_j,\ \forall i,j \tag{6}$$

# Equilibrium aggregate output

- Equilibrium aggregate output is given by:

$$Y = \mathscr{A} H^{\tilde{\alpha}}$$

where $\tilde{\alpha}$ and $\mathscr{A}$ are constants. Additionally,

$$ln(\mathscr{A}) = m'a + const$$

where:

$$m'a = [m_1\, m_2\, m_3 \ldots m_N] \begin{bmatrix} lnA_1 \\ lnA_2 \\ lnA_3 \\ \vdots \\ lnA_N \end{bmatrix}$$

# Vector of influence (or multipliers)

Vector of influence:

$$m' = \beta'(I - B)^{-1}$$

- Two terms:
  - Weights: $\beta$
  - Inter-sectoral linkages: $(I - B)^{-1}$.
    - where typical element of $B$ is $\sigma_{ij}$.
- Interpretation: a 1% increase in $A_i$ rises aggregate GDP in $m_i$%.

$$dln(Y) = m_i da_i$$

# Allocation of labor

Economy without distortions:

$$\frac{\hat{H}_i}{H} = \hat{\theta}_i = \frac{\alpha_i(1-\sigma_i)m_i}{\sum_{s=1}^{N}\alpha_s(1-\sigma_s)m_s}$$

- Does not depends on relative productivity ($A_i$).

Economy with distortions.

$$\frac{H_i}{H} = \theta_i = \frac{\alpha_i(1-\sigma_i)\left(\frac{1}{\psi_i}\right)\left(\frac{1}{\phi_i}\right)\tilde{m}_i}{\sum_{s=1}^{N}\alpha_s(1-\sigma_s)\left(\frac{1}{\psi_s}\right)\left(\frac{1}{\phi_s}\right)\tilde{m}_s}$$

- where, $\tilde{m} = \beta'(I-\tilde{B})^{-1}$, and a typical element of NxN matrix $\tilde{B}$ is $\sigma_{ij}/\psi_i$.
- If distortions are homogeneous, the allocation of labor is not affected (dispersion is key).

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# Rents of distortions are lost $T = 0$

- In this case distortions are isomorphic to productivity.

$$\frac{1}{\psi_i} Q_i = \frac{1}{\psi_i} A_i f(H_i, \{x_{ij}\}) = c_j + \sum_{i=1}^{N} x_{ij}, \forall i \quad (7)$$

- Effect on aggregate output and productivity could be sizable if resources are not given back.

# Removal of a single distortion: Total effect

Change in one of the distortions: $\psi_i^1 < \psi_i^0$:

$$ln\left(\frac{Y^1}{Y^0}\right) = \sum_{j=1}^{N} m_j \alpha_i (1-\sigma_i) ln\left(\frac{\theta_j^1}{\theta_j^0}\right) + m_i \sigma_i ln\left(\frac{\psi_i^0}{\psi_i^1}\right) + \sum_{j=1}^{N} m_j (1-\sigma_j) ln\left(\frac{\tilde{m}_i^0}{\tilde{m}_i^1}\right) \tag{8}$$

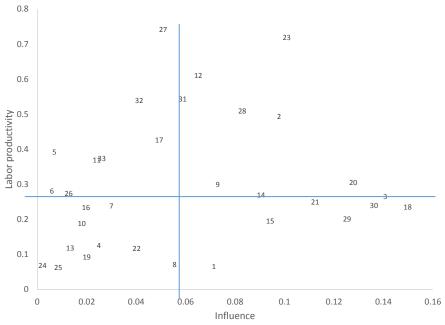
1. Effect on the allocation of labor.
   - It could be positive or negative depending on whether the change in $\psi_i$ reduces the dispersion of wedges.
   - It depends on the degree of influence of each sector $m_i$.
2. Effect on aggregate output through the supply of sector $i$ (positive).
3. Effect on the allocation of gross output into final and intermediate uses (negative).

# Calibration

- Calibrate the model to Mexico and the US.
- Use the FOC in each country and data from input-output tables to pin-down the value of the parameters.
- Assume that the US is a relatively undistorted economy.
  - Common parameters across countries:
    - $(1-\sigma_i)$ =VA share in the US.
    - $\alpha_i =$ Labor share in the US.
  - Use deviations from the 45 degree lines to pin-down $\psi_i$ and $\phi_i$.

# Key sectors

Figure: Productivity vs. degree of influence




- 18 Construction; 30 Business Services; 29 Real Estate; 21 Retail Trade;

# Closing productivity gaps

Figure: Effect in Y of closing the productivity gap

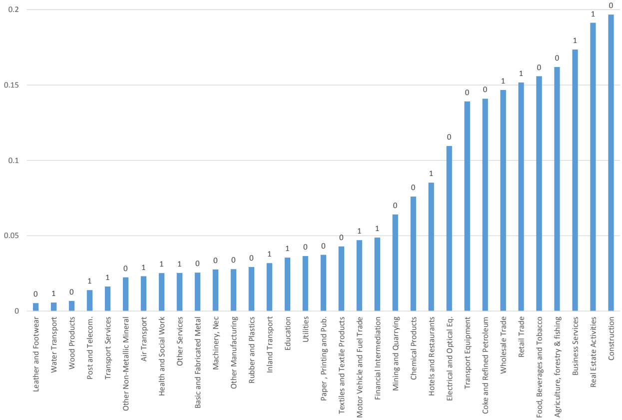
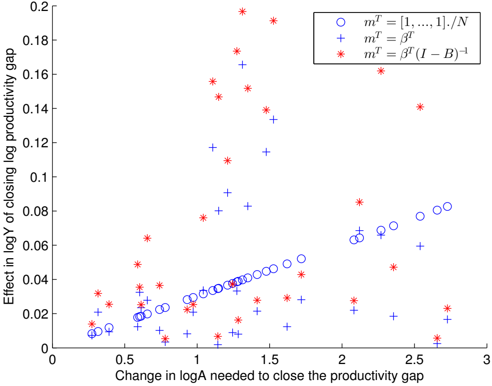
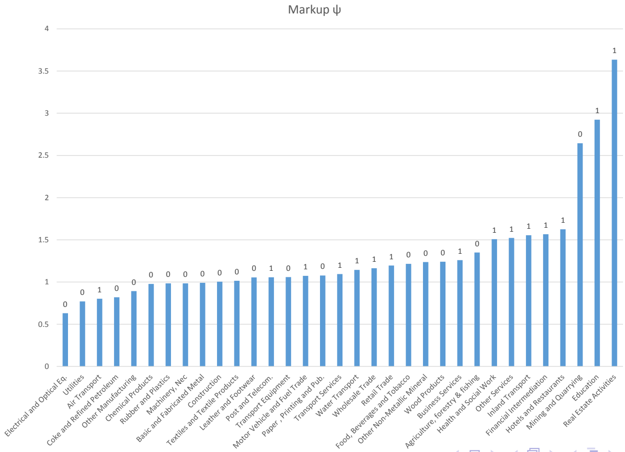


Figure: Decomposing the effect in Y of closing the productivity gap



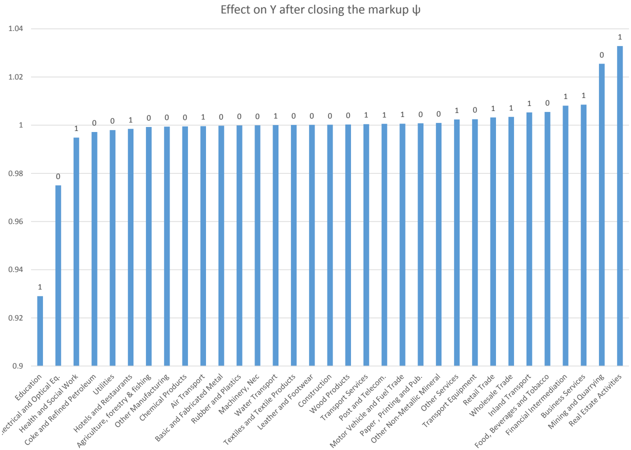
# Markup wedge

Figure: Calibrated markup values



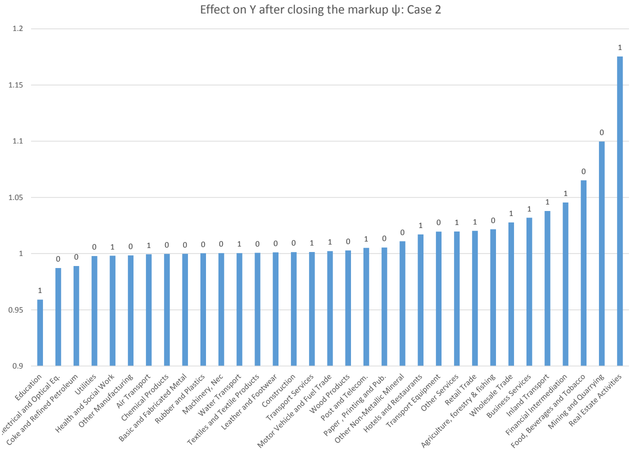
# Reducing distortions: $T > 0$

Figure: Effect in Y of reducing markups in Case 1



# Reducing distortions: $T = 0$

Figure: Effect in Y of reducing markups in Case 2

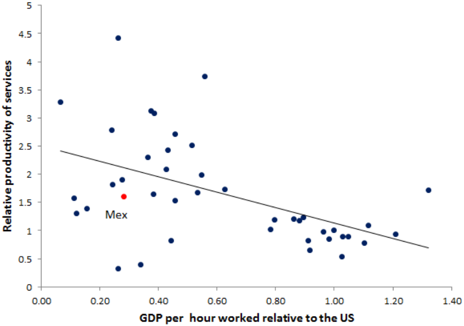


# Conclusion

- I studied a model with inter-sectoral linkages with wedges and calibrated it to match relevant features of the US and México.
- I found that the effect of inter-sectoral linkages is important to determine the gains of closing sectoral productivity gaps.
    - Closing the gap in services gives the biggest gains.
- I also studied the effect of sector-level distortions and found that its effect could be big depending on whether the rents from distortions stay in the economy or not.

# Productivity gap is larger in manufacturing

Data from Inklaar and Timmer (2012)



# Productivity gap is larger in manufactures

Data from Herrendorf and Valentinyi (2012)

| Category | Ratio | Value |
|---|---|---|
| Aggregate | $TFP^{US}/TFP^{LA}$ | 2.30 |
| Services | $TFP_s^{US}/TFP_s^{LA}$ | 1.86 |
| Goods | $TFP_g^{US}/TFP_g^{LA}$ | 3.58 |

Table: Labor share in Mexico

| Method | Description | Value |
|---|---|---|
| Naive | Compensation of employees / GDP | 0.28 |
| Corrected (Gollin, 2001) | Compensation of employees/ (GDP-Net Mixed Income-Net indirect taxes) | 0.42 |

# Related Literature

- Development literature.
  - Barriers to the use of intermediate inputs in Agriculture (Restuccia et. al, 2008).
  - Barriers to international trade that directly affect industries that produce tradables (Herrendorf and Teixeira, 2005).
  - Financial frictions that affect manufactures more than services. (Buera et. al, 2009).
  - Informality leads to resource misallocation (e.g. Prado, 2011, and Moscoso and D'Erasmo, 2012).
- Literature that shows that the productivity gap is larger in manufactures than in services.
  - Inklaar and Timmer (2012)
  - Herrendorf and Valentinyi (2012)

# Problem of the representative firm in sector i

The problem of the representative firm in industry $i$ is given by

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$$\left. - \sum_{j=1}^{N} p_j x_{ij} - p_{M,i} M_i \right\}$$

# FOCs

$$\frac{1}{\psi_i}\alpha_i(1-\sigma_i-\lambda_i)\frac{p_i Q_i}{H_i} = \phi_i w, \ \forall i \tag{9}$$

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# Household problem

- Problem:

$$\max\{u(C)\} \quad s.t. \quad C = wH + \Pi + T$$

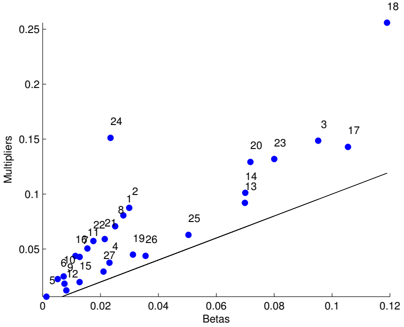
  - where $T = Rents\ from\ distortions$.
- Resource constraint:
  - If rents from distortions are given back, $T > 0$ : $Q_j = c_j + \sum_{i=1}^{N} x_{ij}$.
  - If rents from distortions are not given back, and $T = 0$: $\left(\frac{1}{\psi_i}\right) Q_j = c_j + \sum_{i=1}^{N} x_{ij}$.

Given wedges and import prices, a competitive equilibrium consists on quantities $Y$, $\{Q_i, H_i, c_i, x_{ij}, M_i\}_{i=1}^{N}$; and prices $w$, and$\{p_j\}$, $\forall i, j = 1, ..., N$; such that:

1. $\{c_i\}$ solves the representative final good producer problem at the equilibrium prices.
2. $H_i$,$\{x_{ij}\}$ and $M_i$ solve sector's $i$ producer problem at the equilibrium prices and taking $p_{M,i}$ as given.
3. Markets for labor, and goods $j = 1, ..., N$ clear.

# Equilibrium Characterization: multipliers vs. weights

Figure: Multipliers vs. weights



# Equilibrium Characterization

- Assume: $\tau_i = 0$ and $\psi_i = \phi_i = 1$. Then:

$$\sigma_{ij} = \frac{p_j x_{ij}}{p_i Q_i}.$$

$$\Longrightarrow \sigma_i = \sum_{j=1}^{N} \sigma_{ij} = \sum_{j=1}^{N} \left( \frac{p_j x_{ij}}{p_i Q_i} \right) = \left( \frac{1}{p_i Q_i} \right) \sum_{j=1}^{N} p_j x_{ij}.$$

is the share of domestic intermediate inputs in gross output.

- Similarly:

$$\sigma_i + \lambda_i = \left( \frac{\sum_{j=1}^{N} p_j x_{ij}}{p_i Q_i} \right) + \frac{p_{M,i} M_i}{p_i Q_i}; \tag{15}$$

is the share of domestic and imported intermediate inputs in gross output.

# Equilibrium Characterization

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is the share of domestic intermediate inputs in gross output.

- Similarly, when $\psi_i \neq 1$:

$$\left(\frac{1}{\psi_i}\right)(\sigma_i + \lambda_i) = \left( \frac{\sum_{j=1}^{N} p_j x_{ij}}{p_i Q_i} \right) + \frac{p_{M,i} M_i}{p_i Q_i}; \qquad (16)$$

is the share of domestic and imported intermediate inputs in gross output.

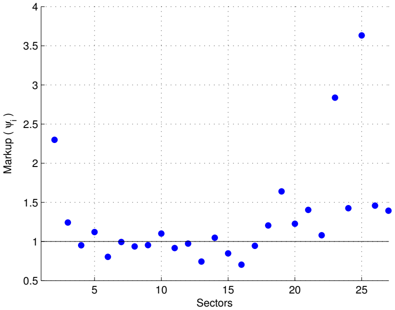
# Calibrate distortions

- Given parameters in the US, I can compute distortions using Mexico's FOC:
  - I match the value added shares in Mexico

$$\psi_i = \frac{\sigma_i}{\left(\frac{\sum_{j=1}^{N} p_j x_{ij}}{p_i Q_i}\right)^{MX}} = \frac{\left(\frac{\sum_{j=1}^{N} p_j x_{ij}}{p_i Q_i}\right)^{US}}{\left(\frac{\sum_{j=1}^{N} p_j x_{ij}}{p_i Q_i}\right)^{MX}}, \ \forall i.$$

# Calibrated distortions

Figure: Distortions



# Calibrate productivity gaps, not levels.

- Problem: we don't have import prices, we can not calculate productivity levels.
- It can be shown that in equilibrium:

$$ln\left(\frac{Q_i^{mx}}{Q_i^{us}}\right) \propto ln\left(\frac{A_i^{mx}}{A_i^{us}}\right), \tag{17}$$

- Since, I observe $(Q_i^{mx}/Q_i^{us})$ there is no need to calibrate productivity levels.

# Calibrate distortions

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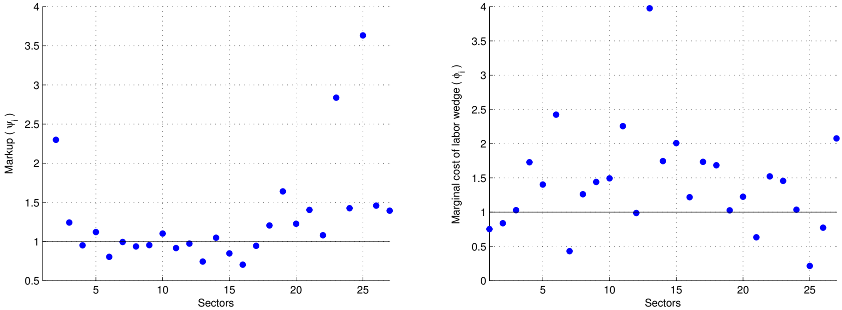
  - I match the value added shares in Mexico

$$\psi_i = \frac{\sigma_i + \lambda_i}{\left(\frac{\sum_{j=1}^{N} p_j x_{ij}}{p_i Q_i}\right)^{MX} + \left(\frac{p_i Q_i}{p_{M,i} M_i}\right)^{MX}} = \frac{\left(\frac{\sum_{j=1}^{N} p_j x_{ij}}{p_i Q_i}\right)^{US} + \left(\frac{p_i Q_i}{p_{M,i} M_i}\right)^{US}}{\left(\frac{\sum_{j=1}^{N} p_j x_{ij}}{p_i Q_i}\right)^{MX} + \left(\frac{p_i Q_i}{p_{M,i} M_i}\right)^{MX}}, \ \forall i.$$

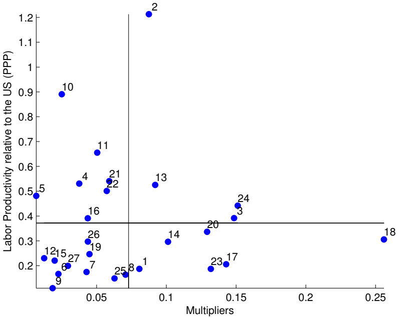
# Calibrated distortions

Figure: Distortions



# Key sectors (naive definition)

Figure: Key Sectors



# Counter-factual exercises

- Modify the productivity gap in sector $i$, and compute the change in aggregate output $Y$:

$$ln\left(\frac{Y^1}{Y^0}\right) \propto ln\left(\frac{A_i^1}{A_i^0}\right). \tag{18}$$

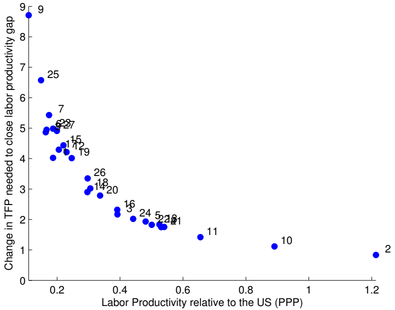
- Additionally, it can be shown that in equilibrium:

$$ln(\frac{Y^1}{Y^0}) = f_\psi(\psi_i^0, \psi_i^1), \tag{19}$$

$$ln(\frac{Y^1}{Y^0}) = f_\phi(\phi_i^0, \phi_i^1). \tag{20}$$

# Closing productivity gaps

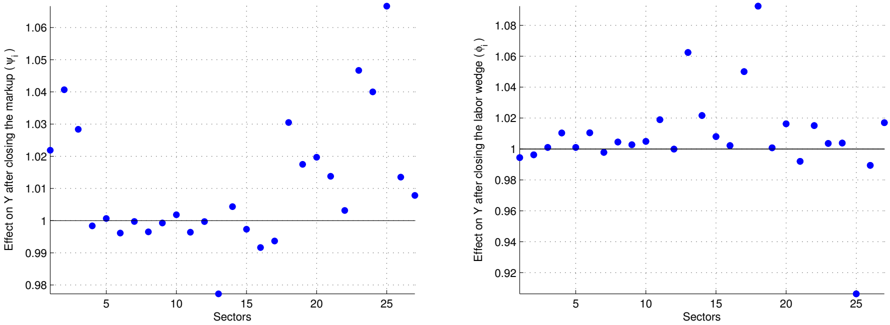
Figure: Change in $A_i$ needed to close the labor productivity gap.




- Two typical industries
  - rubber and plastics (manufactures)
  - wholesale and retail trade (services)
- Productivity

# Reducing distortions

Figure: Reducing distortions




- Two didactic cases
  - post and telecommunications
  - wholesale and retail trade (services)

# Markups

$$\min\{wl + rk\}$$
$$st$$
$$Q = f(k,l)$$

FOC

$$L = wl + rk + \lambda\,(Q - f(k,l))$$
$$FOC:$$
$$l:\; w - \lambda f_l = 0$$
$$k:\; r - \lambda f_k = 0$$

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$$w - \lambda f_l = 0$$
$$w = \lambda f_l Q/Q$$

# Conceptual framework