

# ECB FORUM ON CENTRAL BANKING

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### Capital Intensity and Firm Dynamics



EUROPEAN CENTRAL BANK

EUROSYSTEM

# Capital Intensity and Firm Dynamics

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## Overview

- ▶ Why do firms grow?
  - ▶ Why do some firms outgrow their competitors?
- ▶ Usual answer: Innovation.
- ▶ My research: Successful firms adapt their production methods to adopt efficient capital goods (cutting-edge machines, software).
  - ▶ Example: Uber; taxi business but with geolocation developed by Google.
- ▶ Roadmap:
  - ▶ Empirical evidence.
  - ▶ Theoretical modeling.
  - ▶ Macro and policy implications.

## 1. Empirical Evidence

- ▶ Data: Public firms' balance sheet data in the US between 1980 and 2019 (Compustat).

### Fact 1. Falling relative cost of capital

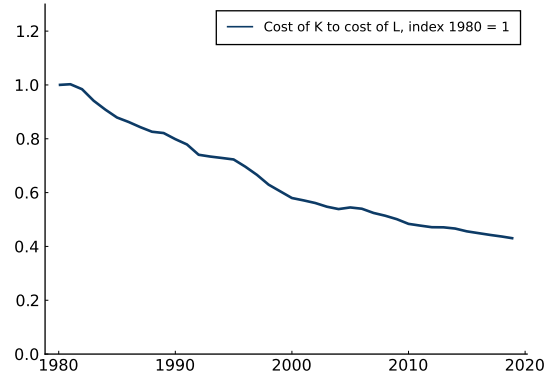


Figure 1: Cost of capital goods to cost of labor - quality adjusted.

- ▶ A well-known fact.
  - ▶ High productivity gains by capital-goods producers.
- ▶ Expected implication: All firms see their capital intensity (capital-to-labor ratio:  $K/L$ ) increase.

### Fact 2. Rising capital intensity in level and dispersion

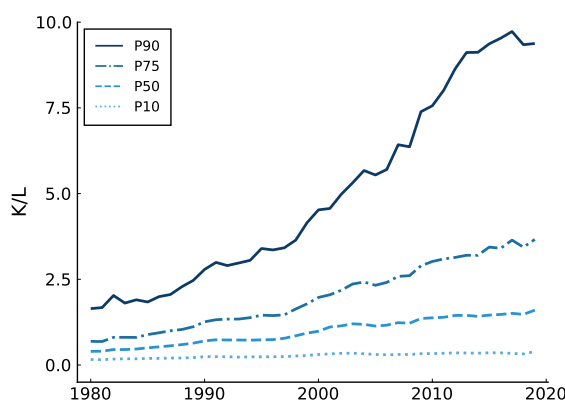


Figure 2: Moments of the distribution of firms' capital intensity.

### Fact 3. Capital-intensive firms are larger

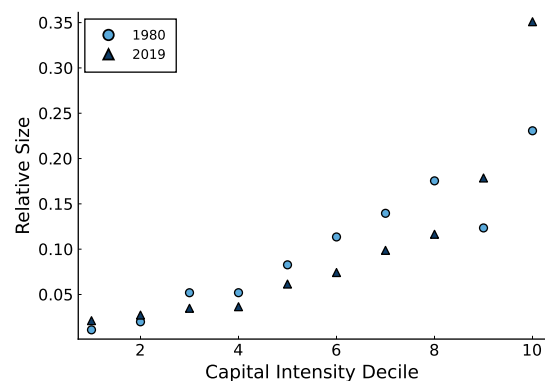


Figure 3: Market share by capital-intensity decile.

- ▶ Facts 2 and 3 carry within sectors.

## Takeaway of empirics

- ▶ As the efficiency of capital goods rose over the past decades, we expect firms to increase their capital intensity ( $K/L$ ).
  - ▶ Yet, firms increased their capital intensity with very different amplitudes.
  - ▶ More capital-intensive firms are larger than their labor-intensive peers.

- ▶ Why such heterogeneity?
  - ▶ Theory.

## 2. Theory

- ▶ Representing technological updating:

$$\underbrace{Y}_{\text{Output}} = F\left(\alpha \underbrace{K}_{\text{Capital}}, (1-\alpha) \underbrace{L}_{\text{Labor}}\right)$$

- ▶  $\alpha$  is the weight of capital in production  $\rightarrow$  what the firm updates.
- ▶ A useful corollary:

$$\underbrace{mc}_{\text{Marginal cost}} = C\left(\alpha \underbrace{c(K)}_{\text{Cost of Capital}}, (1-\alpha) \underbrace{c(L)}_{\text{Cost of Labor}}\right)$$

- ▶ Firms who update their technologies the most use a cheaper technology, can post lower prices, and hence attract more demand.

- ▶ Then, why don't all firms choose higher  $\alpha$ ?
  - ▶ General equilibrium model.

### Overview of model

- ▶ Rising productivity of a capital-goods producer  $\Rightarrow$  Falling cost of capital ( $c(K)$ ).
- ▶ Firms must pay a fixed cost to update their technology ( $\alpha$ ).
- ▶ Oligopoly: higher market share  $\Rightarrow$  higher markup.

### Mechanism

- ▶ Firms with lower fixed costs update more: stylized way to represent intrinsic firm differences (e.g. managerial ability). Calibrated to the data.
- ▶ Strategic interactions (endogenous): Laggard firms do not catch up because it would place them in a segment already crowded by first movers, implying market-share and markup gains too small to justify the fixed cost.

- ▶ What does this imply?

## 3. Macroeconomic Implications

- ▶ Methodology: target the distribution of firms' capital intensity, then infer other firm-level distributions and aggregate outcomes.

### Macro Imp. 1: Firm dynamics and markups

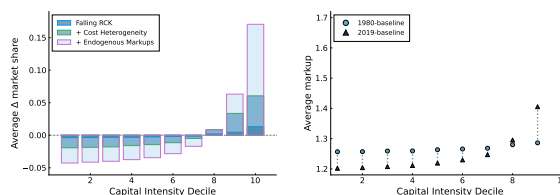


Figure 4: Market share and markups by capital-intensity.

- ▶ Heterogeneity in capital intensity as a micro-foundation for rising concentration and market power.

### Macro Imp. 2: Falling Labor Share

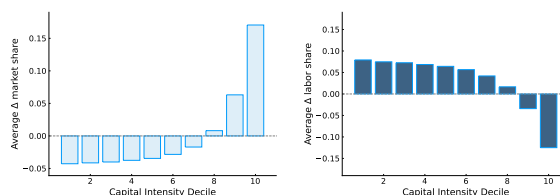


Figure 5: Market share and labor-share by capital-intensity.

- ▶ Aggregate labor share falls because rising capital intensity of top firms implies both:
  - ▶ Rising market share.
  - ▶ Falling labor share (rising capital and profit shares).

### Macro Imp. 3: Concentration: Sales vs. Employment

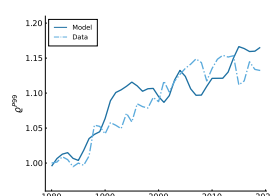


Figure 6: Sales-to-employment concentration of the top 1% of firms.

- ▶ Large firms concentrate a growing share of sales but a stable share of employment.

## Takeaway of Macroeconomic Implications

- ▶ Heterogeneous capital intensity helps explain three puzzling trends documented by the empirical literature.
  - ▶ Rising markups in level and dispersion.
  - ▶ Falling aggregate labor share due to covariance of labor share and market share dynamics at the firm level.
  - ▶ Rising concentration of sales and capital but stable concentration of employment.

## 4. Policy Implications

### Industrial Policy in Europe

- ▶ Cross-Atlantic growth gap often explained by lack of innovation in Europe (Aghion, Draghi).
- ▶ But Europe has also experienced slower growth in capital intensity than the US since the 2000s.

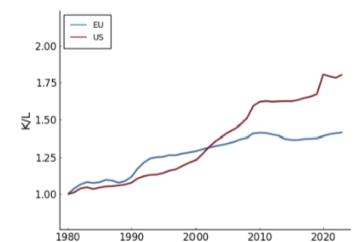


Figure 7: Aggregate Capital Intensity: US vs. EU.

- ▶ Industrial policy mix: target both innovation and adoption?

### Monetary Policy

- ▶ Interest rates affect the cost of capital goods through a cost channel:
  - ▶  $c(K) = rp^K$  where  $r$  is the interest rate.

$$\underbrace{mc}_{\text{Marginal cost}} = C\left(\alpha \underbrace{c(K)}_{\text{Cost of Capital}}, (1-\alpha) \underbrace{c(L)}_{\text{Cost of Labor}}\right)$$

- ▶ If  $\uparrow \alpha$ , the cost channel gains weight compared to the usual channels.
  - ▶ The higher the  $\alpha$  the lower the increase in firms' cost following a cut in the interest rate.  $\Leftrightarrow \uparrow \alpha \Rightarrow$  flattening of the Phillips curve.

## Extra

- ▶ For firm  $i$ , in sector  $j$ , at time  $t$ . Suppose the production function:

$$Y_{i,j,t} = z_{i,j,t} \left( \alpha_{i,j,t} K_{i,j,t}^{\frac{\psi-1}{\psi}} + (1-\alpha_{i,j,t}) L_{i,j,t}^{\frac{\psi-1}{\psi}} \right)^{\frac{\psi}{\psi-1}}$$

$$\Rightarrow \frac{K_{i,j,t}}{L_{i,j,t}} = \left( \frac{\alpha_{i,j,t} w_t}{1-\alpha_{i,j,t} r_t^K} \right)^{\psi}$$

$$\Rightarrow mc_{i,j,t} = \frac{1}{z_{i,j,t}} \left( \alpha_{i,j,t}^{\psi} r_t^{K(1-\psi)} + (1-\alpha_{i,j,t})^{\psi} w_t^{(1-\psi)} \right)^{\frac{1}{1-\psi}}$$

- ▶ Choice of  $\alpha$ .

$$\max_{\alpha_{i,j,t}} \overbrace{\left( 1 - \frac{1}{\mu(s_{i,j,t})} \right) p_{i,j,t} Y_{i,j,t} - c_{i,j}(\alpha_{i,j,t})}^{\pi_{i,j,t}}$$

s.t: static problem

Where:

- ▶  $s_{i,j,t} = \frac{p_{i,j,t} Y_{i,j,t}}{p_{j,t} Y_{j,t}}$ : market share.
- ▶  $\mu(s_{i,j,t})$ : markup endogenous to size.
- ▶  $c_{i,j}(\alpha_{i,j,t})$ : fixed technology cost.
  - ▶ Optimal  $\alpha_{i,j,t}$ :

$$\frac{1}{1-\beta} \frac{\partial s_{i,t}}{\partial \alpha_{i,j,t}} \left( 1 - \frac{1}{\mu(s_{i,j,t})} \right) + \frac{\text{Volume effect}}{\frac{\partial \mu(s_{i,j,t})}{\partial s_{i,j,t}}} + \frac{\text{Strategic interaction}}{\frac{\partial s_{i,j,t}}{\mu(s_{i,j,t})^2}} = \frac{\partial c_{i,j}(\alpha_{i,j,t})}{\partial \alpha_{i,j,t}}$$