Capital-Skill Complementarity in Firms and in the Aggregate Economy

Giuseppe Berligieri*, Filippo Boeri†, Danial Lashkari‡, Jonathan Vogel§

*ESSEC, †LSE, ‡BC, §UCLA

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Capital-skill complementarity?

Hypothesis:

capital-skill complementarity + ↓ equipment prices ⇒ ↑ inequality
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- Offers conceptually intuitive mechanism with measurable SBTC shock
- Under calibrated aggregate elasticities, accounts for evolution of U.S. skill premium
  Krusell, Ohanian, Rios-Rull, & Violante (2000)
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Critiques: hypothesis faces two central critiques

- *Identification*: aggregate elasticities not identified in aggregate time series
  - Acemoglu (2002)
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- \textbf{Generality}: global \downarrow \text{equipment price}, yet weak cross-country evidence (e.g., France)
  Duffy et al. (2004); Henderson (2009)
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This paper: tackle both issues using theory + empirics using French manufacturing data
This Paper

Micro-to-Macro identification of capital-skill complementarity:

- Credibly estimate substitution elasticities within firms using micro data

Study French manufacturing (1997-2007) where equipment price ↓ + skill premium stable

- Moderate capital-skill complementarity: predicted 6% ↑ skill premium (3% w. homog. price shock)

Additional questions:

- Impact of equipment prices on the labor share
- Beyond equipment shock (in progress): impact of changes in wage “wedges” across firms
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\text{equipment price} \downarrow \Rightarrow \text{skill premium} \uparrow \equiv \text{within-firm complementarity}
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+ cross-firm cov. of capital and skill intensity

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+ cross-firm cov. of capital and **skill intensity**
+ cross-firm cov. of capital intensity and **price shocks**

- **Study French manufacturing (1997-2007) where equipment price } \downarrow + \text{ skill premium stable}
- **Moderate capital-skill complementarity: predicted 6%**
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A Sample of Prior Work

**SBTC**: vast literature measures SBTC as a residual
Katz & Murphy (1992); and numerous followup contributions

**Capital-skill complementarity**: provides empirical proxy
Grilliches (1969); Greenwood & Yorukoglu (1997); Krusell, Ohanian, Rios-Rull, & Violante (2000); and many more

**Aggregate elasticities from micro elasticities**: alternative to time-series identification
Oberfield & Raval (2021); Baqee & Farhi (2019); Lashkari, Bauer, & Boussard (2022)

**Alternative approaches to observing SBTC**: focus on IT, automation, etc
Caroli & Van Reenen (2001); Bresnahan, Brynjolfsson, & Hitt (2002); Akerman, Gaarder, & Mogstad (2015), Acemoglu & Restrepo (2018, 2020, 2022); Caunedo, Jaume, & Keller (2021); Adao, Beraja, & Pandalai-Nayar (2022), and many more
Roadmap

Theory

Data and Estimation

Results

Conclusion
Environment: Firms, Production, and Demand

Firms and production:

- Continuum of monopolistically competitive single-prod firms $i \in I$
- Factor inputs $X_{fi}$ with $f \in \{\ell, h, e\}$: low-skill labor ($X_{\ell i}$), high-skill labor ($X_{hi}$), and equipment ($X_{ei}$)
- Arbitrary CRS technologies given by unit factor demand ($A_{\ell i}, A_{hi}, A_{ei}$) such that $X_{fi} = A_{fi}Y_i$
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Demand:

- Nested consumer demand over outputs of firms (sector $s$ firms $\mathcal{I}_s \subseteq \mathcal{I}$):

$$Y_i = \Phi_i \left( \frac{P_i}{P_s} \right)^{-\epsilon} \left( \frac{P_s}{P} \right)^{-\eta} Y$$

- $\Phi_i$ & $P_i$: firm demand shifter & price
- $P_s$: sector-specific price index
- $P$: aggregate price index
Simplified Environment: Factor Markets

Factor supplies: inelastic aggregate supplies $X_\ell$, $X_h$, and $X_e$

Factor prices equate aggregate supply and demand (assume common factor prices) ($W_\ell \equiv 1$)

$$X_\ell = \sum_i X_{\ell i} \quad X_h = \sum_i X_{hi} \quad X_e = \sum_i X_{ei}$$
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Goal: study shock to $X_e$ that lowers equipment price $W_e$
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Skill premium: $W_h/W_\ell = W_h$
Response of skill premium to equipment price shock with common factor prices:

\[
\frac{d \ln \left( \frac{W_h}{W_\ell} \right)}{d \ln W_e} = -\frac{\sigma_{\ell e} - \sigma_{he}}{\sigma_{\ell h}}
\]

Macro (aggregate-level) factor demand elasticity of substitution:

\[\sigma_{ff'} \equiv \frac{\partial \ln \left( \frac{X_f}{X_{f'}} \right)}{\partial \ln W_{f'}}\]
Micro to Macro Elasticities

Aggregate elasticity between factors $f$ and $f'$:

$$
\sigma_{ff'} = \sum_i \left( \Lambda_i^{ff'} \sigma_{ff',i} - \Lambda_i^{f'} \sigma_{f'f,i} \right) \theta_{f'i} + \varepsilon \sum_i \left( \Lambda_i^{f'} - \Lambda_i^f \right) \theta_{fi} - (\varepsilon - \eta) \sum_s \left( \Lambda_s^{f'} - \Lambda_s^f \right) \theta_{f's}
$$

- **within-firm substitution**
- **cross-firm substitution**
- **cross-sector substitution**

Micro (firm-level) characteristics:

- **Factor intensity** (share of all firm’s factor payments that goes to factor $f$)
  $$\theta_{fi} \equiv \frac{W_{fi} X_{fi}}{\sum_{f'} W_{f'i} X_{f'i}}$$
- **Share of factor** (firm’s share of aggregate factor demand)
  $$\Lambda_i^f \equiv \frac{X_{fi}}{\sum_i X_{fi}}$$
- **Elasticity of substitution between factors**
  $$\sigma_{ff',i} \equiv \frac{1}{\theta_{f'i}} \frac{\partial \ln A_{fi}}{\partial \ln W_{f'}}$$
Baseline Environment: Heterogeneous Equipment Prices

Equipment prices: firm-specific price $W_{ei} = W_e T_{ei}$

“Shadow” equipment price: $W_e$

Firm-specific equipment price “wedge”: $T_{ei}$
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“Shadow” equipment price: $W_e$

Firm-specific equipment price “wedge”: $T_{ei}$

Microfoundation: $X_{ei}$ a CRS aggregate across $J$ varieties of equipment, $G_i (X_{ei1}, \cdots, X_{eij})$

- Firm×variety-specific price distortions ($\sim$ iceberg costs) $\Rightarrow$ $W_{eij} = T_{eij} W_{ej}$
Baseline Environment: Heterogeneous Equipment Prices

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- Firm × variety-specific price distortions (≈ iceberg costs) \( \Rightarrow W_{eij} = T_{eij} W_{ej} \)

Empirical Setting: use customs data to identify firm-level composition of equipment investment

- variety \( j \) ≡ equipment product × origin country of product
Skill Premium, Equipment Prices, and Macro Elasticities

Response of skill premium to **heterogeneous** equipment price shocks:

\[
\frac{d \ln \left( \frac{W_h}{W_L} \right)}{d \ln W_e} = -\frac{\sigma_{le}^\omega - \sigma_{he}^\omega}{\sigma_{lh}}
\]
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Response of skill premium to heterogeneous equipment price shocks:

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\]

Heterogeneous equipment price shocks: firm \( i \) experiences price change \( d \ln W_{ei} \)

\[
d \ln W_e \equiv \sum_i \Lambda_{ei}^* \ d \ln W_{ei} \quad \quad \quad \Lambda_{ei}^* \equiv \frac{W_{ei} X_{ei}}{\sum_{i'} W_{ei'} X_{ei'}}
\]

Generalized aggregate elasticity of substitution w.r.t. equipment price shocks:

\[
\sigma_{fe}^\omega \equiv \frac{\partial \ln \left( \frac{X_f}{X_e} \right)}{\partial \ln W_e}
\]
Micro to Generalized Macro Elasticities

Generalized aggregate elasticity of substitution w.r.t. equipment price shocks:

\[ \sigma_{fe}^{\omega} \equiv \frac{\partial \ln \left( X_f / X_e \right)}{\partial \ln W_e} \]

From micro to macro:

\[ \sigma_{fe}^{\omega} = \sum_i \left( \Lambda_{fi} \sigma_{fe,i} - \Lambda_{ei} \sigma_{ee,i} \right) \theta_{ei} \omega_{ei} + \varepsilon \sum_i \left( \Lambda_{ei} - \Lambda_{fi} \right) \theta_{ei} \omega_{ei} - (\varepsilon - \eta) \sum_s \left( \Lambda_{es} - \Lambda_{fs} \right) \theta_{es} \omega_{es} \]

where

\[ \omega_{ei} \equiv \frac{d \ln W_{ei}}{d \ln W_e} \quad \Rightarrow \quad d \ln W_{ei} = \omega_{ei} \ d \ln W_e \]

\[ \omega_{es} \equiv \sum_{i \in I_s} \Lambda^*_{ei|s} \omega_{ei} \]

Decomposition of Capital-Skill Complementarity
Roadmap

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Requirements

Elasticities:

- Nested CES demand: $\varepsilon, \eta$
- Production function elasticities by firm and factor pair: $\sigma_{ff',i}$

Equilibrium “shares”:

- Firm-level factor intensities: $\theta_{fi}$
- Firm-level shares of factor demand: $\Lambda_{fi}$

Additional requirements for heterogeneous shocks:

- Firm-level equipment payment share: $\Lambda_{ei}^*$
- Elasticity of firm-level equipment price change to average: $\omega_{ei}$
CRESH Firm-Level Technology

CRESH firm-level production function:

Hanoch (1971)

\[ \sum_f \left( \frac{Z_{fi}X_{fi}}{Y_i} \right)^{\frac{\sigma_f-1}{\sigma_f}} = 1 \]
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Micro-level elasticity of substitution for CRESH firm-level technology ($\sigma_i \equiv \sum_f \theta_{fi} \sigma_f$):

\[
\sigma_{ff',i} = \frac{\sigma_f \sigma_{f'}}{\sigma_i} - \frac{\sigma_f}{\theta_{f,i}} \Pi_{ff'} \Rightarrow \frac{\sigma_{le,i}}{\sigma_{he,i}} = \frac{\sigma_l}{\sigma_h}
\]

Generalizes CES, where $\sigma_f \equiv \sigma$ for all $f$

Relative to nested CES: no a priori nesting choice required
Requirements

Elasticities:

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- Production function elasticities: $\sigma_\ell, \sigma_h, \sigma_e$

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Data

Administrative records from the universe of French firms (1994-2007)

**FICUS Data**: firm balance sheet information (based on tax records)
- Value added (Revenue) $R_{it} = P_{it} Y_{it}$
- Total equipment investment of firms

**DADS Data**: employee-level data matched to employer firms
- Composition-adjusted wage and employment of skill groups $W_{f it}$ and $X_{f it}$ for $f \in \{\ell, h\}$

**Customs Data**: firm export/import quantities and unit values
- Use import composition to build firm-level equipment stocks and prices $W_{e it}$ and $X_{e it}$

Details

Data further used to construct instruments needed for identifying micro elasticities

Summary Stats

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Data

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Data further used to construct instruments needed for identifying micro elasticities
Estimating Equations #1

Demand elasticity $\varepsilon$: sectoral CES demand gives firm revenue

$$\Delta r_{it} = - (\varepsilon - 1) \Delta p_{it} + \alpha_{st} + \Delta \phi_{it}$$

- Use firm-level export quantities and prices (five-year differences everywhere)
- Endogeneity concern: firm-specific demand shifter $\Delta \phi_{it}$ correlated with price $\Delta p_{it}$
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- IV for price change $\Delta p_{it}$: import exposure to exchange rate shocks
Estimating Equations #2

Production function elasticities $\sigma_f$: CRESH factor demand implies

$$\Delta x_{eit} - \Delta x_{\ell it} = -\sigma_\ell \left( \Delta w_{eit} - \Delta w_{\ell it} \right) + \left( \frac{\sigma_f}{\sigma_e} - 1 \right) \left( \frac{\varepsilon}{\varepsilon - 1} \Delta r_{it} - \Delta x_{eit} \right) + \beta_\ell t + \nu_{\ell it}$$

$$\Delta x_{eit} - \Delta x_{h it} = -\sigma_h \left( \Delta w_{eit} - \Delta w_{hit} \right) + \left( \frac{\sigma_h}{\sigma_e} - 1 \right) \left( \frac{\varepsilon}{\varepsilon - 1} \Delta r_{it} - \Delta x_{eit} \right) + \beta_{ht} + \nu_{hit}$$

- **Endogeneity concern:** residual a function of
  - firm-level factor-augmenting productivity shocks + demand shifters
  - sector-level price index
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$$

$$
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$$

- **Endogeneity concern:** residual a function of
  - firm-level factor-augmenting productivity shocks + demand shifters
  - sector-level price index

- **IV for equipment:** equipment import exposure to bilateral transport cost shocks
- **IV for revenues:** import exposure to origin supply shocks
- **IVs for wages:** local exposure to sector-level labor demand shocks in France
### Estimation Results: Demand Elasticity $\epsilon$

<table>
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<td>3.63</td>
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<tr>
<td>Year-Sector FE</td>
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Estimation Results: Production Function Elasticities $\sigma_f$

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<td>0.86</td>
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Joint Estimation
Roadmap

Theory

Data and Estimation

Results

Conclusion
Elasticities of substitution with equipment $\sigma_{fe,i} \equiv \sigma_f \sigma_e / \bar{\sigma}_i$ slightly fall in firm size
Factor Intensities and Firm Size

Larger firms have lower intensities in low-skilled labor and higher intensities of equipment.

Low-skill shares ($\theta_{\ell i}$)  
High-skill shares ($\theta_{hi}$)  
Equipment shares ($\theta_{ei}$)
Aggregation Results: Predicted Skill Demand - Manufacturing

![Graph showing the predicted skill demand for manufacturing over the years 1997 to 2007. The graph compares uniform shocks and equipment shocks with a decomposition highlighting the trend over time.](image)

- Red dots represent uniform shocks.
- Blue squares represent equipment shocks.

Decomposition
Aggregation Results: Predicted Skill Premium/Uniform Shock

![Graph showing predicted skill premium over time with data and model prediction]

- Data
- Model Prediction

Alternative Specifications  Aggregate Elasticities  Labor Share
Aggregation Results: Predicted Skill Premium/Heterogeneous Shock

Graph showing the time series of skill premium from 1997 to 2007, with linear trends for data, uniform shock, and equipment shocks. The graph illustrates the impact of shocks on skill premium decomposition.
Aggregation Results: Predicted Skill Premium - Entire Economy

![Graph showing predicted skill premium over time with data and decomposed components.](image-url)
Comparison with KORV

Our benchmark result (French manufacturing):

\[ \sigma_{le} - \sigma_{he} = 0.06 \]
Comparison with KORV

Our benchmark result (French manufacturing):

\[ \sigma_{le} - \sigma_{he} = 0.06 \]

KORV specification: composite factor \( X_c \) aggregates \( X_h \) and \( X_e \)

Krusell, Ohanian, Rios-Rull, & Violante (2000)

\[ Y = CES(Z_lX_l, X_c; \bar{\sigma}_{lc}) \quad X_c \equiv CES(Z_hX_h, Z_eX_e; \bar{\sigma}_{he}) \]
Comparison with KORV

Our benchmark result (French manufacturing):

\[ \sigma_{le} - \sigma_{he} = 0.06 \]

KORV specification: composite factor \( X_c \) aggregates \( X_h \) and \( X_e \)

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\[ Y = CES (Z_\ell X_\ell, X_c; \bar{\sigma}_{lc}) \quad X_c \equiv CES (Z_h X_h, Z_e X_e; \bar{\sigma}_{he}) \]

○ Calibration with aggregate time-series data

US (1963-2000): \[ \sigma_{le} - \sigma_{he} = 0.93 \]

French manufacturing (1997-2007): \[ \sigma_{le} - \sigma_{he} = 0.76 \]
Comparison with KORV

Our benchmark result (French manufacturing):

\[ \sigma_{\ell e} - \sigma_{he} = 0.06 \]

**KORV specification:** composite factor \( X_c \) aggregates \( X_h \) and \( X_e \)

Krusell, Ohanian, Rios-Rull, & Violante (2000)

\[ Y = CES \left( Z_\ell X_\ell, X_c; \tilde{\sigma}_{\ell c} \right) \quad X_c \equiv CES \left( Z_h X_h, Z_e X_e; \tilde{\sigma}_{he} \right) \]

- Calibration with aggregate time-series data

  **US (1963-2000):** \( \sigma_{\ell e} - \sigma_{he} = 0.93 \)
  
  **French manufacturing (1997-2007):** \( \sigma_{\ell e} - \sigma_{he} = 0.76 \)

Our strategy (micro estimation + aggregation) implies lower capital-skill complementarity
Roadmap

Theory

Data and Estimation

Results

Conclusion
Conclusion

**Theory:** multi-factor/sector model with arbitrary CRS technologies + het. equipment prices
- Skill premium response to factor price shock in terms of generalized agg. substitution elasticities
- Characterized aggregate elasticities in terms of firm-level elasticities + demand elasticity

**Estimation:** matched employer-employee + customs data from France (1997-2007)
- Credibly estimate micro elasticities using trade + labor market instruments
- Aggregate to predict response of skill premium to observed fall in equipment price(s)

Moderate agg. capital-skill complementarity: observed shock leads to 6% rise in skill premium
Microfoundations for Equipment Wedges

Equipment inputs for firm $i$ is a CRS aggregate across $J$ varieties of equipment capital

$$X_{ei} = G_i (X_{e1}, \ldots, X_{ej}, \ldots, X_{eJ})$$

- Firm $\times$ variety-specific price distortions ($\sim$ iceberg costs) $\Rightarrow$ $W_{eij} = T_{eij} W_{ej}$
- Marginal products bounded above $\Rightarrow$ variety demand has a choke price

$$\frac{\partial G_i}{\partial X_{eij}} \leq B < \infty, \quad \forall i, j$$

Empirical Setting: use customs data to identify firm-level composition of equipment investment

- variety $j \equiv$ equipment product $\times$ origin country of product
Composite Factors

Composite factor defined as a combination of other factors

\[ X_c \equiv \sum_{f \in \mathcal{F}_c} X_f \]

○ Example: labor \( n \) as a composite of both high and low skilled labor \( \mathcal{F}_n \equiv \{ \ell, h \} \)

Factor \( f \) share of income \( \theta_f \equiv \frac{W_f X_f}{\sum_{f'} W_{f'} X_{f'}} \)

Elasticities of Substitution (defined in terms of payments):

\[ \sigma_{cf'}^* \equiv 1 + \frac{\partial \ln (\theta_c / \theta_{f'})}{\partial \ln W_{f'}} = \sum_{f \in \mathcal{F}_c} \frac{\theta_f}{\theta_c} \sigma_{ff'} \quad \text{where} \quad \theta_c \equiv \sum_{f \in \mathcal{F}_c} \theta_f \]
Response of Composite Factor Shares

Elasticities of Substitution (defined in terms of payments) for composite factor

\[
\frac{\partial \ln \theta_c}{\partial w_f} = \begin{cases} 
\sigma^*_c \theta f - \theta \sigma^*_f f - \theta f, & f \notin \mathcal{F}_c \\
\frac{\theta f}{\theta c} \sigma^*_c f - \theta \sigma^*_f f + \theta f \frac{1-\theta c}{\theta c}, & f \in \mathcal{F}_c
\end{cases}
\]

where we have defined two composite factors

\[
\bar{f} : \quad \mathcal{F}_{\bar{f}} \equiv \mathcal{F} \setminus \{f\}
\]

\[
\bar{c}_f : \quad \mathcal{F}_{\bar{c}_f} \equiv \mathcal{F}_c \setminus \{f\}
\]
Labor \( X_n \equiv X_\ell + X_h \) as composite of both high and low skilled labor

Factor \( f \) share of income \( \theta_f \equiv \frac{W_f X_f}{\sum_{f'} W_{f'} X_{f'}} \) and we have \( \theta_n \equiv \theta_\ell + \theta_h \)
Labor Share and Equipment Price

Labor $X_n \equiv X_\ell + X_h$ as composite of both high and low skilled labor

Factor $f$ share of income $\theta_f \equiv \frac{W_f X_f}{\sum_{f'} W_{f'} X_{f'}}$ and we have $\theta_n \equiv \theta_\ell + \theta_h$

Labor-Equipment Elasticity of Substitution:

$$\sigma^*_{ne} \equiv 1 + \frac{\partial \ln (\theta_n/\theta_e)}{\partial \ln W_e} \equiv \frac{\theta_\ell}{\theta_n} \sigma_{le} + \frac{\theta_h}{\theta_n} \sigma_{he}$$
Labor Share and Equipment Price

Labor $X_n \equiv X_\ell + X_h$ as composite of both high and low skilled labor

Factor $f$ share of income $\theta_f \equiv \frac{W_f X_f}{\sum_{i'} W_{i'} X_{i'}}$ and we have $\theta_n \equiv \theta_\ell + \theta_h$

Labor-Equipment Elasticity of Substitution:

$$\sigma_{ne}^* \equiv 1 + \frac{\partial \ln \left( \frac{\theta_n}{\theta_e} \right)}{\partial \ln W_e} \equiv \frac{\theta_\ell}{\theta_n} \sigma_{le} + \frac{\theta_h}{\theta_n} \sigma_{he}$$

Response of the Labor Share:

$$\frac{1}{1 - \theta_n} \frac{d \ln \theta_n}{d \ln W_e} = \sigma_{ne}^* - 1 - \left( \frac{\theta_\ell}{\theta_n} (\sigma_{lh} - 1) - (\sigma_{eh} - 1) \right) \frac{\sigma_{le} - \sigma_{he}}{\sigma_{lh}}$$
Macro Elasticities: Many Factors

Shock to equipment price, holding factor wedges and other factor supplies constant

Let $\mathbf{W} \equiv (W_f)_{f \in \mathcal{F}/\{\ell,e\}}$ be vector of factor prices, and define matrix and vectors ($\sigma_{ff} \equiv 0$):

$$\Sigma \equiv (\sigma_{ff'})_{f, f' \in \mathcal{F}/\{\ell,e\}} \quad \sigma_f. \equiv (\sigma_{ff'})_{f \in \mathcal{F}/\{\ell,e\}} \quad \sigma.f. \equiv (\sigma_{f'f})_{f \in \mathcal{F}/\{\ell,e\}}$$
Macro Elasticities: Many Factors

Shock to equipment price, holding factor wedges and other factor supplies constant

Let \( \mathbf{W} \equiv (W_f)_{f \in \mathcal{F} / \{\ell, e\}} \) be vector of factor prices, and define matrix and vectors \( (\sigma_{ff} \equiv 0) \):

\[
\Sigma \equiv (\sigma_{ff'})_{f, f' \in \mathcal{F} / \{\ell, e\}} \quad \sigma_f. \equiv (\sigma_{ff'})_{f \in \mathcal{F} / \{\ell, e\}} \quad \sigma_{.f} \equiv (\sigma_{f'f})_{f \in \mathcal{F} / \{\ell, e\}}
\]

Response of skill premium:

\[
\frac{d \ln \mathbf{W}}{d \ln W_e} = (1 \sigma_{.\ell} - \Sigma)^{-1} (\sigma_{.e} - \sigma_{\ell e})
\]
Macro Elasticities: Many Factors

Shock to equipment price, holding factor wedges and other factor supplies constant

Let \( W \equiv (W_f)_{f \in \mathcal{F}/\{\ell,e\}} \) be vector of factor prices, and define matrix and vectors (\( \sigma_{ff} \equiv 0 \)):

\[
\Sigma^* \equiv (\sigma_{ff'})_{f,f' \in \mathcal{F}/\{\ell,e\}} \quad \sigma_f^* \equiv (\sigma_{ff'})_{f \in \mathcal{F}/\{\ell,e\}} \quad \sigma_f^* \equiv (\sigma_{f'f})_{f \in \mathcal{F}/\{\ell,e\}}
\]

Response of skill premium:

\[
\frac{d \ln W}{d \ln W_e} = (1 \sigma_\ell' - \Sigma)^{-1} (\sigma_e - \sigma_{\ell e})
\]
Labor Share and Equipment Prices

Labor-Equipment Elasticity of Substitution:

$$\sigma_{ne}^{*,\omega} \equiv 1 + \frac{\partial \ln \left( \frac{\theta_n}{\theta_e} \right)}{\partial \ln \overline{W}_e} \equiv \frac{\theta_{\ell}}{\theta_n} \sigma_{\ell e}^{\omega} + \frac{\theta_h}{\theta_n} \sigma_{he}^{\omega}$$

Response of the Labor Share:

$$\frac{1}{1 - \theta_n} \frac{d \ln \theta_n}{d \ln \overline{W}_e} = \sigma_{ne}^{*,\omega} - 1 - \left( \frac{\theta_{\ell}}{\theta_n} (\sigma_{\ell h} - 1) - (\sigma_{eh} - 1) \right) \frac{\sigma_{\ell e}^{\omega} - \sigma_{he}^{\omega}}{\sigma_{\ell h}}$$
Macro Elasticities: Many Factors

Shock to equipment prices, holding other factor wedges and supplies constant

Let $W \equiv (W_f)_{f \in \mathcal{F}/\{\ell,e\}}$ be vector of factor prices, and define matrix and vectors ($\sigma_{ff} \equiv 0$):

\begin{align*}
\Sigma^\omega & \equiv (\sigma_{ff'}^\omega)_{f,f' \in \mathcal{F}/\{\ell,e\}} \\
\sigma^\omega_f & \equiv (\sigma_{ff'}^\omega)_{f \in \mathcal{F}/\{\ell,e\}} \\
\sigma^\omega_{f'} & \equiv (\sigma_{ff'}^\omega)_{f \in \mathcal{F}/\{\ell,e\}}
\end{align*}
Macro Elasticities: Many Factors

Shock to equipment prices, holding other factor wedges and supplies constant

Let \( W \equiv (W_f)_{f \in {\mathcal{F}}/\{\ell, e}\} \) be vector of factor prices, and define matrix and vectors \((\sigma_{ff} \equiv 0)\):

\[
\Sigma^\omega \equiv (\sigma^\omega_{ff'})_{f, f' \in {\mathcal{F}}/\{\ell, e}\} \quad \sigma^\omega_f \equiv (\sigma^\omega_{f f'})_{f \in {\mathcal{F}}/\{\ell, e}\} \quad \sigma^\omega_e \equiv (\sigma^\omega_{f'e})_{f \in {\mathcal{F}}/\{\ell, e}\}
\]

Response of skill premium:

\[
\frac{d \ln W}{d \ln \overline{W}_e} = \left[ 1 \ (\sigma^\omega_{\ell})' - \Sigma^\omega \right]^{-1} \ (\sigma^\omega_e - \sigma^\omega_{\ell e})
\]
Macro Elasticities: Many Factors

Shock to equipment prices, holding other factor wedges and supplies constant

Let \( \mathbf{W} \equiv (W_f)_{f \in \mathcal{F}/\{\ell,e\}} \) be vector of factor prices, and define matrix and vectors (\( \sigma_{ff} \equiv 0 \)):

\[
\Sigma^{*,\omega} \equiv (\sigma_{ff'})_{f,f' \in \mathcal{F}/\{\ell,e\}} \quad \sigma^{*,\omega}_f \equiv (\sigma_{ff'})_{f \in \mathcal{F}/\{\ell,e\}} \quad \sigma^{*,\omega} \equiv (\sigma_{f'f})_{f \in \mathcal{F}/\{\ell,e\}}
\]

Response of skill premium:

\[
\frac{d \ln \mathbf{W}}{d \ln \mathbf{W}_e} = \left[ \mathbf{1} \ (\sigma^{\omega}_\ell)' - \Sigma^{\omega} \right]^{-1} \ (\sigma^{\omega}_e - \sigma^{\omega}_{\ell e})
\]
Decomposition of Capital-Skill Complementarity

Homogenous Equipment Price:

$$\frac{d \ln \left( \frac{W_h}{W_e} \right)}{d \ln W_e} = -\frac{1}{\sigma_{h\ell}} \left[ \sum_i \Lambda_{\ell i} (\sigma_{\ell e,i} - \sigma_{he,i}) \theta_{ei} + \sum_i (\varepsilon - \sigma_{he,i}) (\Lambda_{hi} - \Lambda_{\ell i}) \theta_{ei} + (\eta - \varepsilon) \sum_s (\Lambda_{hs} - \Lambda_{\ell s}) \theta_{es} \right]$$

- within-firm complementarity
- cross-firm complementarity
- cross-sector complementarity
Decomposition of Capital-Skill Complementarity

Homogenous Equipment Price:

\[
\frac{d \ln (W_h/W_\ell)}{d \ln W_e} = -\frac{1}{\sigma_{h\ell}} \left[ \sum_i \Lambda_{\ell i} \left( \sigma_{\ell e,i} - \sigma_{he,i} \right) \theta_{ei} \right. \\
\left. + \sum_i \left( \varepsilon - \sigma_{he,i} \right) \left( \Lambda_{hi} - \Lambda_{li} \right) \theta_{ei} + (\eta - \varepsilon) \sum_s \left( \Lambda_{hs} - \Lambda_{ls} \right) \theta_{es} \right] 
\]

within-firm complementarity

cross-firm complementarity

cross-sector complementarity

Heterogenous Equipment Price:

\[
\frac{d \ln (W_h/W_\ell)}{d \ln W_e} = -\frac{1}{\sigma_{h\ell}} \left[ \sum_i \Lambda_{\ell i} \left( \sigma_{\ell e,i} - \sigma_{he,i} \right) \theta_{ei} \omega_{ei} \right. \\
\left. + \sum_i \left( \varepsilon - \sigma_{he,i} \right) \left( \Lambda_{hi} - \Lambda_{li} \right) \theta_{ei} \omega_{ei} + (\eta - \varepsilon) \sum_s \left( \Lambda_{hs} - \Lambda_{ls} \right) \theta_{es} \omega_{es} \right] 
\]

within-firm complementarity

cross-firm complementarity

cross-sector complementarity
Macro Elasticities: CES Firm-Level Technology

Micro-level elasticity of substitution for CES firm-level technology:

\[
\sigma_{f f', i} = \begin{cases} 
\sigma, & f \neq f' \\
\sigma \frac{\theta_{f f,i} - 1}{\theta_{f f,i}}, & f = f'
\end{cases}
\]

Macro-level elasticities of substitution assuming single sector (\(\varepsilon = \eta\)):

\[
\sigma_{f f'} = \sigma + (\varepsilon - \sigma) \sum_i (\Lambda_{f f', i} - \Lambda_{f f, i}) \theta_{f f', i}
\]

\[
\sigma_{f f'}^* = \sigma + (\varepsilon - \sigma) \sum_i (\Lambda_{f f', i}^* - \Lambda_{f f, i}^*) \theta_{f f', i}
\]
Macro Elasticities: CRESH Firm-Level Technology

Macro-level elasticities of substitution assuming single sector \((\epsilon = \eta)\):

\[
\sigma_{ff'} = \sigma_{f'} \left[ 1 - \sum_i \left( \Lambda_{f'i} \frac{\sigma_{f'}}{\sigma_i} - \Lambda_{fi} \frac{\sigma_f}{\sigma_i} \right) \theta_{f'i} \right] + \epsilon \sum_i (\Lambda_{f'i} - \Lambda_{fi}) \theta_{f'i}
\]

\[
\sigma_{f'f}^* = \sigma_{f'} \left[ 1 - \sum_i \left( \Lambda_{f'i}^* \frac{\sigma_{f'}}{\sigma_i} - \Lambda_{fi}^* \frac{\sigma_f}{\sigma_i} \right) \theta_{f'i} \right] + \epsilon \sum_i (\Lambda_{f'i}^* - \Lambda_{fi}^*) \theta_{f'i}
\]
Within and Between-Firm Substitution: Examples

Response of the skill premium to an equipment price shock with uniform factor prices

\[
\frac{d \ln \left( \frac{W_h}{W_\ell} \right)}{d \ln W_e} = -\frac{\sigma_{le} - \sigma_{he}}{\sigma_{\ell h}}
\]
Response of the skill premium to an equipment price shock with uniform factor prices

\[
\frac{d \ln \left( \frac{W_h}{W_\ell} \right)}{d \ln W_e} = -\frac{\sigma_{le} - \sigma_{he}}{\sigma_{\ell h}}
\]

Only within-firm: homogenous firms with a CRESH production function:

\[
\frac{d \ln \left( \frac{W_h}{W_\ell} \right)}{d \ln W_e} = -\frac{\sigma_{le,i} - \sigma_{he,i}}{\sigma_{\ell h,i}} = -\frac{\sigma_{l} - \sigma_{h}}{\sigma_{\ell} \sigma_{h}} \sigma_{e}
\]
Within and Between-Firm Substitution: Examples

Response of the skill premium to an equipment price shock with uniform factor prices

\[
\frac{d \ln (W_h/W_\ell)}{d \ln W_e} = -\frac{\sigma_{Le} - \sigma_{he}}{\sigma_{\ell h}}
\]

Only within-firm: homogenous firms with a CRESH production function:

\[
\frac{d \ln (W_h/W_\ell)}{d \ln W_e} = -\frac{\sigma_{Le,i} - \sigma_{he,i}}{\sigma_{\ell h,i}} = -\frac{\sigma_{\ell} - \sigma_{h}}{\sigma_{\ell} \sigma_{h}} \sigma_{e,i}
\]

Only cross-firm: heterogenous firms with CES production functions \((\sigma_f \equiv \sigma)\) and single sector:

\[
\frac{d \ln (W_h/W_\ell)}{d \ln W_e} = -\frac{(\varepsilon - \sigma) \sum_i (\Lambda_{hi} - \Lambda_{\ell i}) \theta_{ei}}{\sigma + (\varepsilon - \sigma) \sum_i (\Lambda_{hi} - \Lambda_{\ell i}) \theta_{hi}}
\]
## Summary Statistics

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<th>Source</th>
<th>Obs. (Nb)</th>
<th>Mean</th>
<th>Std</th>
<th>p25</th>
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<th>Obs. (Nb)</th>
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<td><strong>Low-Skill Working Hours</strong></td>
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<td>332,594,816</td>
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<td>96,841</td>
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<td>475,338,376</td>
<td>2,958,942</td>
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<td><strong>Exports - Total</strong></td>
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<td></td>
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<tr>
<td>Customs</td>
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<td><strong>Imports - Total</strong></td>
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<td><strong>Imports - Intermediate products</strong></td>
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<td>Customs</td>
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<td><strong>Imports - Equipment products</strong></td>
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<td>21,786,515</td>
<td>3,627</td>
<td>69,098</td>
<td>488,002</td>
</tr>
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</table>
Skill groups: assign workers to skill groups based on occupation
Caliendo et al. (2015), Caluccio et al. (2015)
- High-skilled: Managers, Middle managers and professionals, Qualified workers
- Low-skilled: Clerks, Blue-collar

Change in firm-skill-specific wages:
- Estimate firm-level wage changes by running worker-level wage regression on stayers:

$$w_{ji,t} - w_{ji,t-1} = \beta_t' X_{jit} + FE_{fit} + e_{jit}$$

$$\Delta w_{fit} \equiv \sum_{\tau=0}^{4} FE_{fit,t-\tau}$$

Worker-j characteristics $X_{jit}$: age, sex, 2-digit occupation category belonging to skill type $f$
- Find firm-level change in demand for each skill type by deflating wage bill change with wage change
Data: Equipment Data

Equipment investment: infer using change in the book value of two asset types in FICUS-BRN

- Machinery, equipment and tools (AR - Installations techniques, matriel et outillage industriels)
- Other tangible fixed assets (AT - Autres immobilisations corporelles)

Sources of equipment investment: use imports information in customs data:

- BEC codes: Imported Capital goods–except transport equipment (41) & Parts and accessories (42)
- Define domestic equipment investment as the BRN total minus the customs total

Prices:

- Imported: unit values at firm-year-origin-product level
- Domestic: INSEE series at sector-year-asset level (transport, hardware, & other machinery)
Data: Equipment Stocks and Prices

Firm-level Price Index for Equipment Investment:

- Sato-Vartia index $P_{it}^e$ aggregates price change across origin/products (domestic $≡$ one product)
- Quantity of equipment investment $Q_{it}^e = I_{it}^e / P_{it}^r$ with $P_{it}^e ≡ \prod_{\tau=1}^{t} P_{i\tau}^e$

Perpetual Inventory Method:

\[
X_{it}^e = \begin{cases} 
\frac{1}{\delta_{st}^e} \sum_{\tau=0}^{T_i-1} \frac{Q_{i\tau}^e}{T_i}, & \text{if } t = 0, \\
(1 - \delta_{st}^e)Q_{it-1}^e + Q_{it}^e, & \text{if } t > 0,
\end{cases}
\]

with $\delta_{it}^e$ sector-specific depreciation rate (KLEMS), $T_i − 1$ number of periods firm in data

User Cost of Equipment:

\[
W_{eit} = P_{it}^e \left( R_t^e + \delta_{st}^e - \frac{p_{s,t+1}^e - p_{s,t-2}^e}{3} \right)
\]
Instruments: RER Shocks As Cost Shifters

Instrument for Firm-level Prices: shifts marginal costs & uncorrelated with demand shocks $\Delta \phi_{it}$

$$\Delta RER_{it} = \sum_c \frac{M_{ci,t-5}}{M_{i,t-5}} \Delta \ln \left( \frac{NER_{ct} \cdot CPI_{ct}}{CPI_{FR,t}} \right)$$

- $M_{ci,t}$: imports of firm $i$ from country $c$ in period $t$
- $NER_{ct}$: nominal exchange rate (euros per country $c$ currency)
- $CPI_{ct}$: consumer price index in country $c$ in period $t$

Real depreciation of country $c$ currency relative to euro raises $\Delta RER_{it}$ and lowers $\Delta p_{it}$
Instruments: Transport Cost Shocks as Equipment Price Shifters

**Instrument for Equipment Prices:** shifts costs of importing equipment goods

Hummels et al. (2014)

\[ \Delta ET C_{it} = \sum_{c} \sum_{k \in K_e} \frac{M_{cki,t-5}^e}{M_{i,t-5}^e} \Delta \ln TC_{ckt} \]

- \( M_{cki,t-5}^e \): equipment imports of firm \( i \) in equipment \( k \) from country \( c \) in period \( t \)
- \( \Delta \ln TC_{ckt} \): change in transport costs predicted due to oil/jet fuel price shocks

Transport costs \( TC_{ckt} \) predicted based on:

- Distance to country of origin \( c \)
- Product \( k \) frequency of the modes of transport
- Elasticity of mode of transport charges to oil/fuel prices
Instruments: World Supply Shocks as Value Added Shifters

Instrument for Firm-Level Value Added: shifts from revenues

Hummels et al. (2014)

\[
\Delta W E S_{it} = \sum_{c} \sum_{k \in K_i} \frac{M_{ck_i,t-5}}{M_{i,t-5}} \Delta \ln Exp_{ckt}
\]

- \( \Delta \ln Exp_{ckt} \): growth of exports of country \( c \) in product \( k \) in period \( t \) to all countries except France
- \( M_{ck_i,t-5} \): intermediate good imports of firm \( i \) from country \( c \) in period \( t \)

Productivity growth in origin uncorrelated with demand/factor augmenting productivity shocks
Instruments: Shift-Share Instruments for Local Wages

Generalized Bartik IV: shifts firm-level skill premium

\[ \Delta SSW_{it} = \sum_r \sum_s \left( \frac{X_{ni,t-5}^r}{X_{ni,t-5}} \right) \cdot \left( \frac{X_{ns,t-5}^r}{X_{n,t-5}} \right) \cdot \left( \frac{X_{hs,t-5}^r}{X_{\ell s,t-5}} \right) \cdot \Delta \ln GO_{st} \]

- \( X_{ni,t}^r \): firm \( i \) employment in region \( r \) at time \( t \) (firm exposure to local wage shocks)
- \( X_{ns,t}^r \): region \( r \) employment in sector \( s \) at time \( t \)
- \( X_{fs,t}^r \): region \( r \) employment of skill-type \( f \) in sector \( s \)
- \( \Delta \ln GO_{st} \): growth in French gross output of sector \( s \)

National expansion in a sector that is skill intensive in a given region raises local skill premium
## Estimation Results: Demand Elasticity $\varepsilon$ with Alternative IV

<table>
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<th>OLS</th>
<th>2SLS</th>
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<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
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<tr>
<td>$\varepsilon$</td>
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<td>(0.589)</td>
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<td>Year FE</td>
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<td>-</td>
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<tr>
<td>Year-Sector FE</td>
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<tr>
<td>Controls</td>
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<td>No</td>
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<tr>
<td>IV</td>
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<td>RER ($K_i$)</td>
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<td>KP F stat</td>
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<td>13.06</td>
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</table>

Only use intermediate inputs in the construction $\Delta RER_{\text{it}}$
Estimation Results: Joint Estimation of $\varepsilon$ and $\sigma_f$

<table>
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<th>(1)</th>
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<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta x_e - \Delta x_\ell$</td>
<td>-0.922</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.147)</td>
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</tr>
<tr>
<td>$\frac{\varepsilon}{\varepsilon - 1} \Delta r - \Delta x_e$</td>
<td>-0.0705</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0467)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta w_e - \Delta w_\ell$</td>
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<td>-0.817</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.128)</td>
<td></td>
</tr>
<tr>
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<td></td>
<td>-1.927</td>
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<td>(0.418)</td>
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<table>
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<td>Observations</td>
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<tr>
<td>Year FE</td>
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</tr>
<tr>
<td>$\sigma_\ell$</td>
<td>0.922</td>
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<tr>
<td>$\sigma_h$</td>
<td>0.817</td>
</tr>
<tr>
<td>$\sigma_e$</td>
<td>0.992</td>
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<tr>
<td>$\varepsilon$</td>
<td>1.93</td>
</tr>
<tr>
<td>$\Pr[\sigma_\ell \leq \sigma_h]$</td>
<td>0.015</td>
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</table>
Aggregation Results: Predicted Skill Premium/Uniform Shock

Alternative Specifications

Baseline $\epsilon = 2.3$, $\epsilon = 3.6$, Year-Sector FEs
Measuring Wedges

Firm-specific wages $W_{fi} \equiv W_f T_{fi} \ (f \in \{\ell, h\})$ give us wedges $T_{fi}$ subject to multiplicative factor

Shadow wage $\hat{W}_{ft} \equiv \hat{W}_{\ell t} W_{ft}$ in euros $\Rightarrow$ observed wages $\hat{W}_{fi,t} \equiv \hat{W}_{f,t} T_{fi,t}$ for $f \in \{\ell, h\}$

Assumption: two residuals (uniform wedge shocks) $\bar{T}_{f,t} \equiv \frac{1}{I} \sum_i T_{fi,t}$

- Observed unweighted mean wage rate
  $$\bar{W}_{f,t} \equiv \frac{1}{I} \sum_i \hat{W}_{fi,t} = \hat{W}_{f,t} \times \bar{T}_{f,t} \quad f \in \{\ell, h\}$$

- Observed wedge shocks
  $$\hat{T}_{fi,t} = \frac{\hat{W}_{fi,t}}{\hat{W}_{f,t}} = \frac{T_{fi,t}}{\bar{T}_{f,t}} \quad f \in \{\ell, h\}$$

- Observed numeraire $\bar{W}_{\ell,t} \equiv W_{\ell,t} \equiv 1 \Rightarrow \bar{W}_{h,t} \equiv W_{h,t}$
Aggregation Results: Heterogenous Price Shocks

Equipment Wedges ($\omega_{ei}$)

\[ \theta_{ei} \]
Aggregation Results: Heterogenous Price Shocks

Difference in the Change in Labor Wedges ($\omega_{hi} - \omega_{\ell i}$) by Low-Skilled Aggregate Payment Share ($\Lambda^*_\ell i$)
Aggregation Results: Predicted Labor Share/Uniform Shock

![Graph showing data and model predictions over time]

- **Points** represent data.
- **Line** represents model predictions.

**X-axis:** Years from 1997 to 2007

**Y-axis:** Labor share calculations

**Legend:**
- **Data**
- **Model Prediction**

**Title:** Aggregation Results: Predicted Labor Share/Uniform Shock

**Subtitle:** Theory, Alternative Specifications, Aggregate Elasticities, back
Aggregation Results: Predicted Labor Share/Uniform Shock

Alternative Specifications

- Baseline
- $\epsilon = 2.3$
- $\epsilon = 3.6$
- Year-Sector FE
Aggregation Results: Cumulated Equipment Shocks

- Uniform shock
- Heterogenous shocks
Aggregation Results: Annual Equipment Shocks

- Uniform shock
- Heterogenous shocks
Aggregation Results: Average Annual Equipment Shocks

Note: bins defined over $(\Lambda_{hi} - \Lambda_{ei})\theta_{ei}$
Aggregation Results: Average Annual Equipment Shocks

Note: bins defined over \((\Lambda_{hi} - \Lambda_{\ell i})\theta_{ei}\)
Aggregation Results: Equipment Shocks by Skill Intensity

\[ \ln \Lambda_{hi}^* - \ln \Lambda_{li}^* \]
Aggregation Results: Equipment Shocks by Skill Intensity

Pre 2002

Post 2002

\[ \ln \Lambda_{hi}^* - \ln \Lambda_{\xi i}^* \]
Aggregation Results: Predicted Labor Share - Entire Economy
## Aggregation Results: Predicted Responses to Equipment Price Shock

### Decomposition of Predicted Skill Premium - Manufacturing

<table>
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<th>Uniform Shock</th>
<th>Heterogeneous Shock</th>
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<tbody>
<tr>
<td></td>
<td>$\Delta \ln W_h$</td>
<td>$\Delta \ln W_h$</td>
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<tr>
<td>Equipment</td>
<td>0.031</td>
<td>0.061</td>
</tr>
<tr>
<td>Within firm</td>
<td>0.027</td>
<td>0.034</td>
</tr>
<tr>
<td>Cross firm</td>
<td>0.034</td>
<td>0.061</td>
</tr>
<tr>
<td>Cross sector</td>
<td>-0.030</td>
<td>-0.034</td>
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<tr>
<td>Observed</td>
<td>-0.004</td>
<td>-0.004</td>
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### Aggregation Results: Predicted Responses to Equipment Price Shock

**Decomposition of Predicted Skill Demand - Manufacturing**

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<th>Uniform Shock $\Delta \ln(X_h/X_\ell)$</th>
<th>Heterogeneous Shock $\Delta \ln(X_h/X_\ell)$</th>
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<tr>
<td>Equipment</td>
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<td>0.064</td>
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<tr>
<td>Within firm</td>
<td>0.028</td>
<td>0.036</td>
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<td>Cross firm</td>
<td>0.036</td>
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<td>Cross sector</td>
<td>-0.031</td>
<td>-0.036</td>
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### Decomposition of Predicted Skill Premium - Entire Economy

<table>
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<td>$\Delta \ln W_h$</td>
<td>$\Delta \ln W_h$</td>
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<tr>
<td>Equipment</td>
<td>0.029</td>
<td>0.045</td>
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<tr>
<td>Within firm</td>
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<td>Cross firm</td>
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<td>Cross sector</td>
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<tr>
<td>Observed</td>
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### Aggregation Results: Predicted Responses to Equipment Price Shock

**Predicted Labor Share - Manufacturing**

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<tr>
<td><strong>Equipment</strong></td>
<td>-0.210</td>
<td>-0.264</td>
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<tr>
<td><strong>Observed</strong></td>
<td>-0.171</td>
<td>-0.171</td>
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### Aggregation Results: Predicted Responses to Equipment Price Shock

**Predicted Labor Share - Entire Economy**

<table>
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<th>Heterogeneous Shock</th>
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<tr>
<td></td>
<td>$\Delta \ln \theta_n/(1 - \theta_n)$</td>
<td>$\Delta \ln \theta_n/(1 - \theta_n)$</td>
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<tr>
<td>Equipment</td>
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<td>Observed</td>
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## Aggregation Results: Aggregate Elasticities

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<td>-0.045</td>
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<td>$\sigma_{le}^*$</td>
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<td>1.013</td>
<td>1.091</td>
<td>1.020</td>
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<td>$\frac{1}{1-\eta_e} \frac{d \ln \theta_e}{d\omega_e}$</td>
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<td>1.315</td>
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<td>[1.002, 1.549]</td>
<td>[1.150, 2.774]</td>
<td>[0.806, 2.357]</td>
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<tr>
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<td>2.321</td>
<td>3.627</td>
<td>2.92</td>
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<td>$\sigma_{t}$</td>
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<td>0.969</td>
<td>0.967</td>
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<td>$\sigma_{h}$</td>
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<td>$\sigma_{e}$</td>
<td>1.111</td>
<td>1.092</td>
<td>1.126</td>
<td>1.014</td>
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</table>
KORV Elasticities

KORV specification: composite factor $X_c$ aggregates $X_h$ and $X_e$

Krusell, Ohanian, Rios-Rull, & Violante (2000)

\[ Y = CES \left( Z_\ell X_\ell, X_c; \sigma_{\ell c} \right) \quad \text{and} \quad X_c = CES \left( Z_h X_h, Z_e X_e; \sigma_{he} \right) \]
KORV Elasticities

**KORV specification:** composite factor $X_c$ aggregates $X_h$ and $X_e$

Krusell, Ohanian, Rios-Rull, & Violante (2000)

$$Y = CES( Z_\ell X_\ell, X_c; \tilde{\sigma}_{\ell c} )$$

$$X_c \equiv CES( Z_h X_h, Z_e X_e; \tilde{\sigma}_{he} )$$

KORV elasticities based on different estimation/calibration strategies:

<table>
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<tr>
<th></th>
<th>Implied by our estimation</th>
<th>Calibrated in French manu.</th>
<th>Calibrated in US data</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tilde{\sigma}_{he}$</td>
<td>1.32</td>
<td>0.15</td>
<td>0.63</td>
</tr>
<tr>
<td>$\tilde{\sigma}_{\ell c}$</td>
<td>1.40</td>
<td>0.92</td>
<td>1.56</td>
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