Accounting for Changes in Between-Group Inequality

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Accounting for changes in between-group inequality

- Large changes in U.S. between-group inequality over the last few decades, aggregated measures

skill premium
0.18

Table : Changes in log relative wages btw education groups: 84-03

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skill premium	HSG/HSD	SMC/HSD	CLG/HSD	GTC/HSD
0.18	0.03	0.06	0.18	0.28

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Table : Changes in log relative wages btw education groups: 84-03

- Major changes affecting relative wages
  - growth of educated workforce
  - computerization
  - shifting importance of tasks
    - structural transformation, offshoring...
  - other skill-biased technical change
- **Question**: What accounts for between-group wage changes?

Accounting for changes in between-group inequality

- Discrete choice model: many worker types, equipment, tasks
  - open black box of relative demand
    - "capital equipment productivity" (and trade in equipment)
    - "task shifters"
    - "labor productivity"
- Estimate model using data on
  - allocation of each labor type to computers×tasks
  - average wage of each labor type
    - wage changes only affect "labor productivity" estimate

Preview of results

Data	Labor supply	Labor prod.	Task shifters	Capital prod.
0.180	-0.066	0.074	0.087	0.084

Table : Decomposing changes in the log skill premium: 84-03

- Majority of changes in between-education-group inequality driven by changes in non-wage observables
  - capital-skill complementarity + changing capital productivity
    - debated b/c had been estimated off changes in wages
  - worker-task complementarity + changing task shifters
    - different from standard conclusion
- Residual (SB)TC important for other patterns:
  - e.g. wage polarization and gender premium

Most related literature

- **Labor:** Katz and Murphy (1992), Autor, Levy, and Murnane (2003), Acemoglu and Autor (2011), Autor and Dorn (2013)

- **Macro:** Griliches (1967), Krusell, Ohanian, Rios-Rull, and Violante (2000), Caselli and Wilson (2004), Restuccia and Vandenbrouke (2012), Hsieh, Hurst, Jones, and Klenow (2013)

- **International trade:** Eaton and Kortum (2002), Costinot and Vogel (2010), Burstein, Cravino, and Vogel (2013), Grossman, Helpman, and Kircher (2013), Parro (2013)

Environment

- Final good aggregates tasks, σ

$$Y_t = \left(\sum_{\sigma} \mu_t^{\frac{1}{\rho}} (\sigma) y_t (\sigma)^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}$$

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- Consumption + investment in capital type κ

$$q_t (C) \, C_t + \sum_{\kappa} q_t (\kappa) \, I_t (\kappa) = Y_t$$

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- Workers $\omega \in \Omega$ divided into labor types $\lambda_1, ..., \lambda_{n_\Lambda}$

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- Workers $\omega \in \Omega$ divided into labor types $\lambda_1, ..., \lambda_{n_\Lambda}$
- Output of worker $\omega \in \Omega (\lambda)$ in σ with k_t units of κ

$$\left[T_t (\lambda, \kappa, \sigma) \, \varepsilon_t (\omega, \kappa, \sigma) \right]^{1-\alpha(\sigma)} k_t (\kappa)^{\alpha(\sigma)}$$

  - $T_t (\lambda, \kappa, \sigma) = T_{\lambda t} (\lambda) \, T_{\kappa t} (\kappa) \, T_{\sigma t} (\sigma) \, T (\lambda, \kappa, \sigma)$
  - $\varepsilon_t (\omega, \kappa, \sigma)$ distributed Frechet: $G (\varepsilon) = \exp \left(-\varepsilon^{-\theta(\lambda)} \right)$

Alternative Env. Standard Frameworks

Partial equilibrium

- First, take $p_t(\sigma)$ and $r_t(\kappa)$ as given
- Worker chooses κ, σ, k to maximize income

$$\max_{\kappa,\sigma,k} \left\{ p_t(\sigma) \left[T_t(\lambda, \kappa, \sigma) \varepsilon_t(\omega, \kappa, \sigma) \right]^{1-\alpha(\sigma)} k^{\alpha(\sigma)} - k r_t(\kappa) \right\}$$

- Optimal k (given κ, σ) $\Rightarrow$ standard discrete choice problem

$$\max_{\kappa,\sigma} \left\{ T_t(\lambda, \kappa, \sigma) v_t(\kappa, \sigma) \varepsilon_t(\omega, \kappa, \sigma) \right\}$$

where $v_t(\kappa, \sigma) \equiv (1 - \alpha(\sigma)) \left(\frac{\alpha(\sigma)}{r_t(\kappa)} \right)^{\frac{\alpha(\sigma)}{1-\alpha(\sigma)}} p_t(\sigma)^{\frac{1}{1-\alpha(\sigma)}}$

Partial equilibrium: allocations and avg wages

- Probability arbitrary worker $\omega \in \Omega(\lambda)$ chooses κ, σ

$$\pi_t(\lambda, \kappa, \sigma) = \frac{\left[T_t(\lambda, \kappa, \sigma)\, v_t(\kappa, \sigma)\right]^{\theta(\lambda)}}{\sum_{\kappa', \sigma'} \left[T_t(\lambda, \kappa', \sigma')\, v_t(\kappa', \sigma')\right]^{\theta(\lambda)}}$$
$$= \frac{\tau_t(\lambda, \kappa, \sigma)}{\sum_{\kappa', \sigma'} \tau_t(\lambda, \kappa', \sigma')}$$

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$$= \frac{\tau_t(\lambda, \kappa, \sigma)}{\sum_{\kappa', \sigma'} \tau_t(\lambda, \kappa', \sigma')}$$

- Avg wage of λ choosing κ, σ is independent of κ, σ

$$w_t(\lambda) = \gamma(\lambda) \left[\sum_{\kappa, \sigma} \tau_t(\lambda, \kappa, \sigma)\, \pi_t(\lambda, \kappa, \sigma) \right]^{1/\theta(\lambda)}$$

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- Next: Equilibrium $r_t(\kappa)$ and $p_t(\sigma) \Rightarrow v_t(\kappa, \sigma)$

General equilibrium

- Task market equilibrium

$$\mu_t(\sigma)\left(\frac{p_t(\sigma)}{P_t}\right)^{1-\rho} E_t = \frac{1}{1-\alpha(\sigma)} \sum_{\lambda,\kappa} w_t(\lambda) L_t(\lambda) \pi_t(\lambda,\kappa,\sigma)$$

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- Capital prices and rental rates
  - $P_t(C)/q_t(C) = P_t(\kappa)/q_t(\kappa)$ + Euler eqn $\Rightarrow$ *across BGPs*:

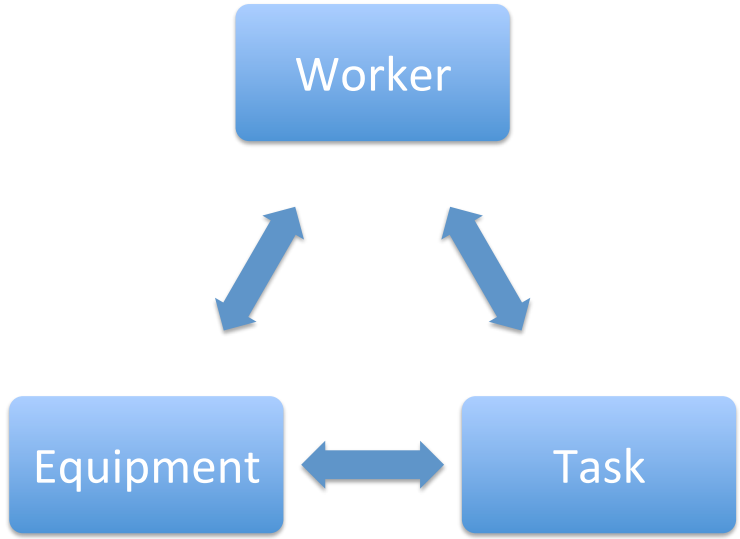
$$\frac{r_{t'}(\kappa)/r_t(\kappa)}{r_{t'}(\kappa')/r_t(\kappa')} = \frac{q_{t'}(\kappa)/q_t(\kappa)}{q_{t'}(\kappa')/q_t(\kappa')}$$

  - Letting $\hat{x} = x_{t'}/x_t$, we have

$$\frac{\hat{r}(\kappa)}{\hat{r}(\kappa')} = \frac{\hat{q}(\kappa)}{\hat{q}(\kappa')}$$

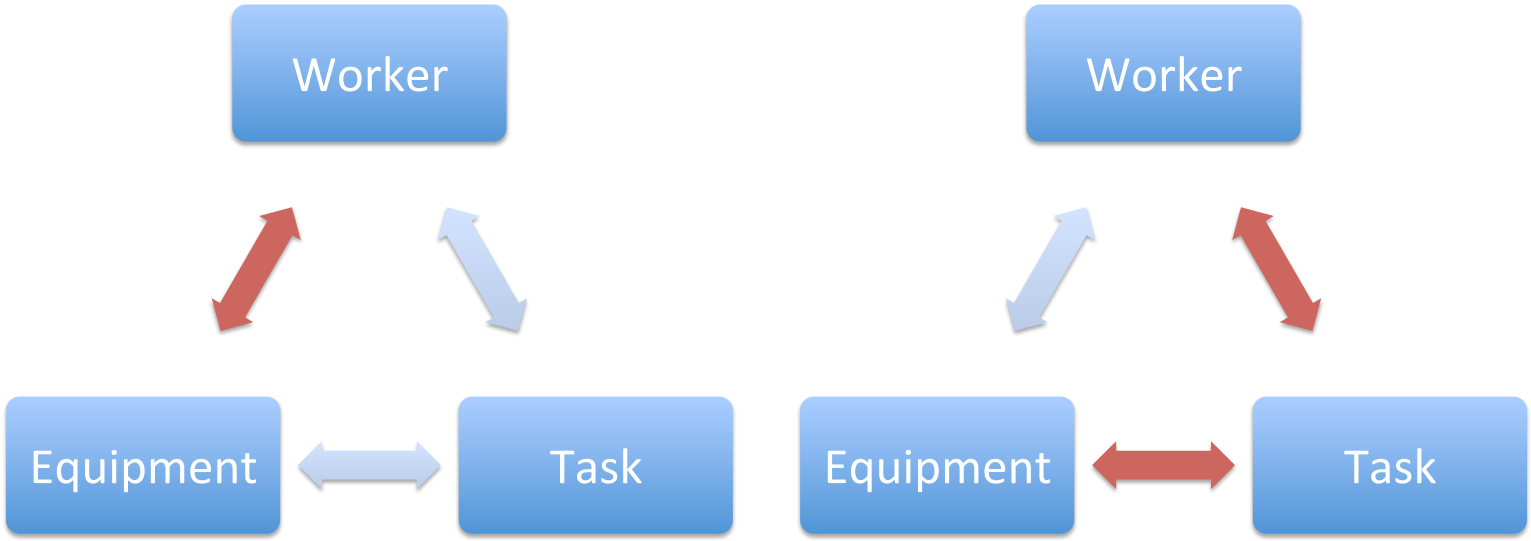
Model intuition: comparative advantage

- Comparative advantage (CA) shapes
  - factor allocation
  - wage changes
- Three types of comparative advantage



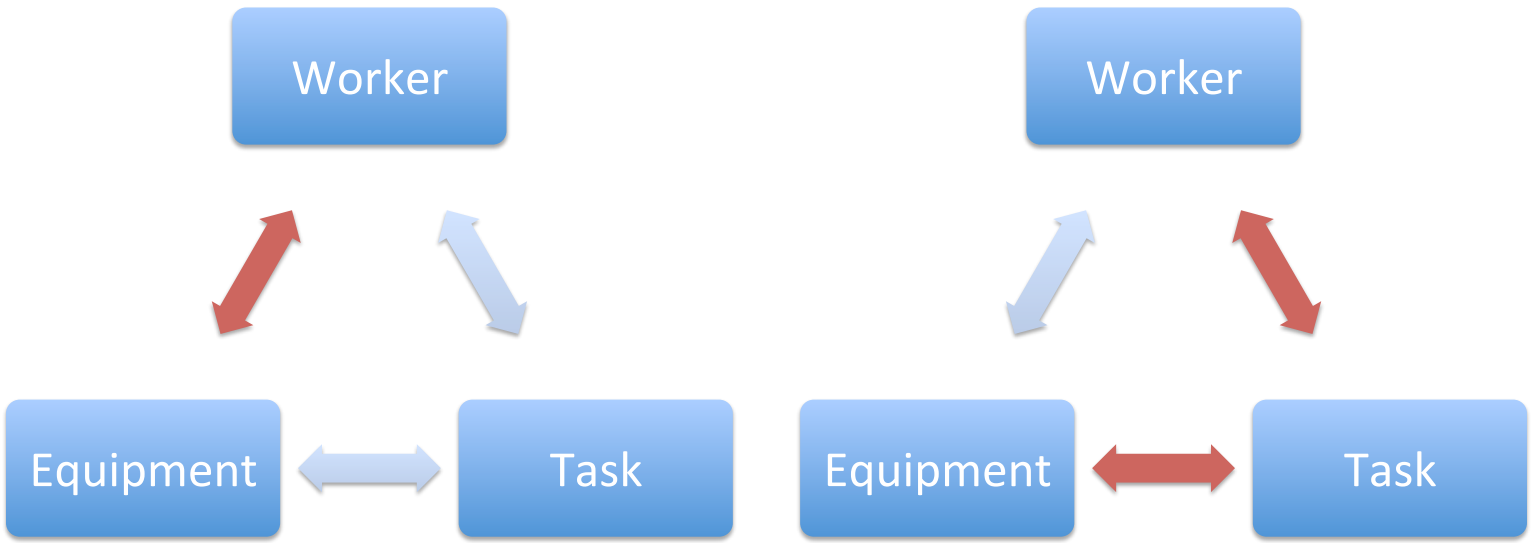
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- e.g.: Why do more educated workers use computers more?
- They use computer more either b/c



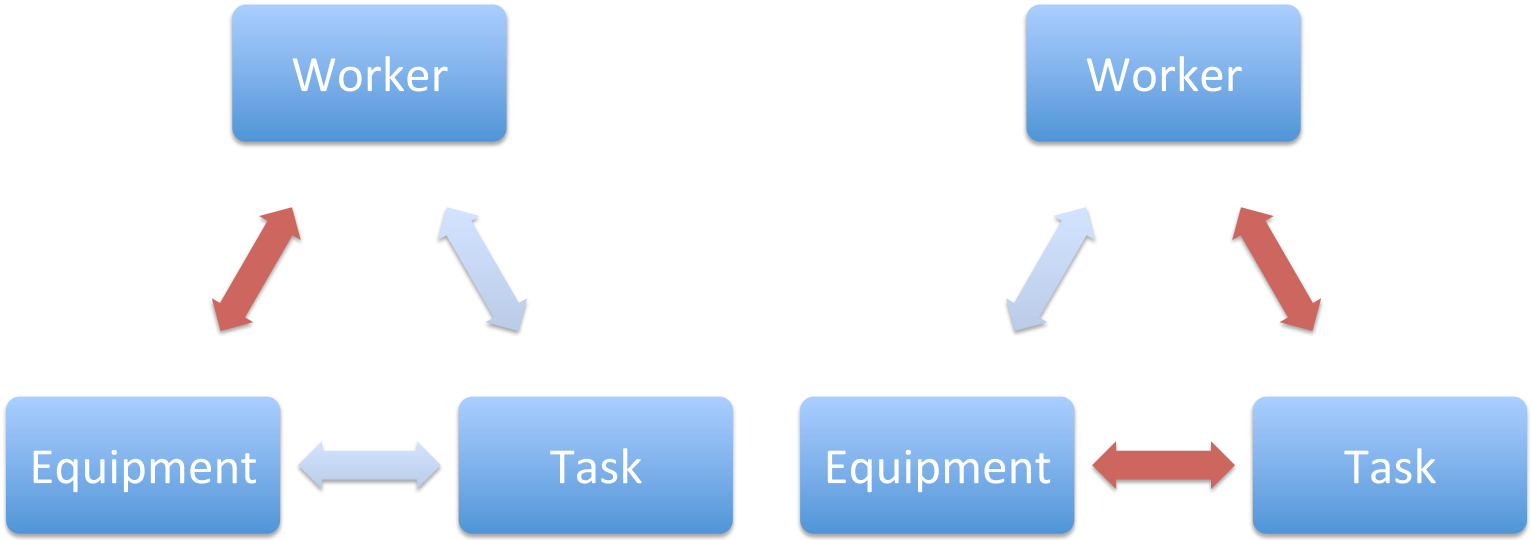
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- e.g.: Why do more educated workers use computers more?
- They use computer more either b/c
  1. They have a CA with computers
     - λ has a CA (relative to λ') with κ (rel. to κ') in σ
     - $\Leftrightarrow \frac{T(\lambda,\kappa,\sigma)}{T(\lambda,\kappa',\sigma)} > \frac{T(\lambda',\kappa,\sigma)}{T(\lambda',\kappa',\sigma)} \Leftrightarrow \frac{\pi(\lambda,\kappa,\sigma)}{\pi(\lambda,\kappa',\sigma)} > \frac{\pi(\lambda',\kappa,\sigma)}{\pi(\lambda',\kappa',\sigma)}$
     - $\Rightarrow$ more educated use computers relatively more *within tasks*



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     - $\Rightarrow$ more educated use computers relatively more *within tasks*
  2. They have a CA in tasks in which computers have a CA
     - $\Rightarrow$ More educated are employed relatively more in tasks in which computers are used more frequently (*across tasks*)



Model intuition: CA and wage changes

$$\hat{w}(\lambda) = \hat{T}_{\lambda}(\lambda) \left\{ \sum_{\kappa,\sigma} \left[\left(\hat{r}(\kappa)^{-\alpha(\sigma)} \hat{p}(\sigma) \right)^{\frac{1}{1-\alpha(\sigma)}} \hat{T}_{\kappa}(\kappa) \hat{T}_{\sigma}(\sigma) \right]^{\theta(\lambda)} \pi_t(\lambda, \kappa, \sigma) \right\}^{\frac{1}{\theta(\lambda)}}$$

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1. worker$\times$equipment CA:
   - $q\left(\kappa^{C}\right)\downarrow \Rightarrow r\left(\kappa^{C}\right)\downarrow \Rightarrow$
   - educated wages rise if educated have CA with κ^{C}

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2. worker$\times$task + equipment$\times$task CA:
   - $q\left(\kappa^C\right)\downarrow \Rightarrow r\left(\kappa^C\right)\downarrow \Rightarrow p(\sigma)\downarrow$ if κ^C has a CA in σ

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$$\hat{w}(\lambda) = \hat{T}_{\lambda}(\lambda)\left\{\sum_{\kappa,\sigma}\left[\left(\hat{r}(\kappa)^{-\alpha(\sigma)}\hat{p}(\sigma)\right)^{\frac{1}{1-\alpha(\sigma)}}\hat{T}_{\kappa}(\kappa)\,\hat{T}_{\sigma}(\sigma)\right]^{\theta(\lambda)}\pi_t(\lambda,\kappa,\sigma)\right\}^{\frac{1}{\theta(\lambda)}}$$

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2. worker$\times$task + equipment$\times$task CA:
   - $q\left(\kappa^C\right)\downarrow \Rightarrow r\left(\kappa^C\right)\downarrow \Rightarrow p(\sigma)\downarrow$ if κ^C has a CA in σ
     - if $\rho < 1 \Rightarrow$ relative wage of educated workers falls
     - if $\rho > 1 \Rightarrow$ relative wage of educated workers rises

What follows

- Decomposition between t and t'
  - Labor supplies: $\hat{L}(\lambda)$
  - Labor-specific productivities: $\hat{T}_{\lambda}(\lambda)$
  - Capital-specific productivities: $\hat{T}_{\kappa}(\kappa)$ and $\hat{q}(\kappa)$
  - Task shifters: $\hat{T}_{\sigma}(\sigma)$ and $\hat{\mu}(\sigma)$

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- Decomposition between t and t'
  - Labor supplies: $\hat{L}(\lambda)$
  - Labor-specific productivities: $\hat{T}_{\lambda}(\lambda)$
  - Capital-specific productivities: $\hat{T}_{\kappa}(\kappa)$ and $\hat{q}(\kappa)$
  - Task shifters: $\hat{T}_{\sigma}(\sigma)$ and $\hat{\mu}(\sigma)$
- Our approach
  - impose $\alpha(\sigma) = \alpha$ and $\theta(\lambda) = \theta$
  - observe $\hat{L}(\lambda)$
  - estimate $\hat{\tau}_{\lambda}(\lambda), \hat{\tau}_{\kappa}(\kappa), \hat{\tau}_{\sigma}(\sigma)$
    - these depend on $\hat{T}$s, prices, and rental rates
  - conduct decomposition w/ $\hat{L}(\lambda), \hat{\tau}_{\lambda}(\lambda), \hat{\tau}_{\kappa}(\kappa), \hat{\tau}_{\sigma}(\sigma)$
    - equivalent to feeding in changes in primitives

Parameterization overview

- "Standard" parameters: calibrated
  - θ using wage dispersion within λ
    - impose $\theta = 3.1$ in line with Hsieh et al. (2013)
  - Set $\rho = 1$
    - consider a wide range of alternatives
  - Impose $\alpha = 0.24$
    - irrelevant given $\rho = 1$
- Estimation of remaining parameters to follow

Estimation details

- We allow for sampling error in allocations:

$$\pi_t^*(\lambda, \kappa, \sigma) = \pi_t(\lambda, \kappa, \sigma)\, \iota_{t1}(\lambda, \kappa, \sigma)$$

  where ι_1 is mean one (conditional on observables) and i.i.d.

- In robustness, also consider weaker restrictions:
  - don't observe all characteristics
  - sampling error in allocations and wages

Alternative

Estimation: step 1

Comparative advantage

- We have for each $t = 1, ..., T$

$$w_t(\lambda)^{\theta} \pi_t(\lambda, \kappa, \sigma) = \tau_t(\lambda, \kappa, \sigma)$$

Estimation: step 1

Comparative advantage

- We have for each $t = 1, ..., T$

$$w_t(\lambda)^{\theta} \pi_t(\lambda, \kappa, \sigma) = \tau_t(\lambda, \kappa, \sigma)$$
$$= \tau_{\lambda t}(\lambda) \tau_{\kappa t}(\kappa) \tau_{\sigma t}(\sigma) \tau(\lambda, \kappa, \sigma)$$

  - where we have normalized, WLOG,

$$\prod_{t=1}^{T} \tau_{xt}(x) = 1 \text{ for each } x = \lambda, \kappa, \sigma$$

Estimation: step 1

Comparative advantage

- We have for each $t = 1, ..., T$

$$\begin{aligned} w_t(\lambda)^{\theta} \pi_t(\lambda, \kappa, \sigma) &= \tau_t(\lambda, \kappa, \sigma) \\ &= \tau_{\lambda t}(\lambda) \tau_{\kappa t}(\kappa) \tau_{\sigma t}(\sigma) \tau(\lambda, \kappa, \sigma) \end{aligned}$$

  - where we have normalized, WLOG,

$$\prod_{t=1}^{T} \tau_{xt}(x) = 1 \text{ for each } x = \lambda, \kappa, \sigma$$

- Hence, $\log \tau$ is simply the average over time of $\log \tau_t$

$$\tau(\lambda, \kappa, \sigma) = \left(\prod_{t'=1}^{T} \tau_t(\lambda, \kappa, \sigma) \right)^{1/T}$$

Estimation: step 2

Capital and task fixed effects

- Identify $\uparrow$ in $\delta(\kappa_1)$ if share of workers using κ_1 $\uparrow$?

$$\log \frac{\tau_t(\lambda, \kappa_1, \sigma)}{\tau_t(\lambda, \kappa_2, \sigma)} = \log \tau_{t\kappa}(\kappa_1) - \log \tau_{t\kappa}(\kappa_2) + \log \frac{\tau(\lambda, \kappa_1, \sigma)}{\tau(\lambda, \kappa_2, \sigma)}$$

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- Not exactly. Two others reasons share may $\uparrow$
  1. $\uparrow$ in employment in σ in which κ_1 has a CA
  2. $\uparrow$ in labor supply of workers who have CA with κ_1

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  2. $\uparrow$ in labor supply of workers who have CA with κ_1
- Identify $\uparrow$ in $\delta(\kappa_1)$ if
  - share of workers using κ_1 $\uparrow$ within $\lambda \times \sigma$ pairs
  - controlling for CA

Estimation: step 2

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  1. $\uparrow$ in employment in σ in which κ_1 has a CA
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- Identify $\uparrow$ in $\delta(\kappa_1)$ if
  - share of workers using κ_1 $\uparrow$ within $\lambda \times \sigma$ pairs
  - controlling for CA
- Data on wages drop out from both LHS and RHS
  - $\Rightarrow$ estimated $\tau_{t\kappa}(\kappa)$ independent of wages
- Task fixed effects estimated similarly

Identification: step 3

Labor fixed effects

- Labor fixed effect

$$\log \frac{w_t(\lambda)}{w_t(\lambda')} = \log \tau_{\lambda t}(\lambda) - \log \tau_{\lambda t}(\lambda') + ...$$

  where "..." contains all previously estimated parameters
  - comparative advantage: $\tau(\lambda, \kappa, \sigma)$
  - fixed effects: $\tau_{\kappa t}(\kappa), \tau_{\sigma t}(\sigma)$
- Identify $\delta(\lambda)/\delta(\lambda') \uparrow$ if $w(\lambda)/w(\lambda') \uparrow$?
  - Not quite... Two other explanations:
    - $w(\lambda)/w(\lambda') \uparrow$ if $\delta(\sigma) \uparrow$ and λ has a CA in σ
    - $w(\lambda)/w(\lambda') \uparrow$ if $\delta(\kappa) \uparrow$ and λ has a CA in κ
- Identify $\delta(\lambda)/\delta(\lambda') \uparrow$ if $w(\lambda)/w(\lambda') \uparrow$ conditional on CA and changes in fixed effects

Data overview

- Data sources:
  - Oct. CPS Computer Use Supplement (84, 89, 93, 97, 03): π_t
  - March CPS: $w_t(\lambda), L_t(\lambda)$

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  - March CPS: $w_t(\lambda), L_t(\lambda)$
- 30 worker types: age (3) $\times$ gender (2) $\times$ education (5)
- 20 occupations or 47 sectors; e.g.
  - occupations:
    - executive, administrative, and managerial
    - technicians and related support
    - administrative support
    - precision production...
  - sectors:
    - machinery
    - primary metal products
    - construction
    - legal services...

Data overview

- $\pi_t(\lambda, \kappa_1, \sigma)$: "Do you use a computer at/for your main job?"
  - construct $\pi_t(\lambda, \kappa_2, \sigma) = \pi_t(\lambda, \sigma) - \pi_t(\lambda, \kappa_1, \sigma)$
- Two related issues with π_t data:
  1. Do more productive workers use more of all equipment?
  2. Not using data on non-computer allocation

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- Two related issues with π_t data:
  1. Do more productive workers use more of all equipment?
     - Germany: "How much of your total work time do you spend on computers?"
  2. Not using data on non-computer allocation
     - BEA: allocation of disaggregated equipment across sectors

Patterns of CA in the data

- $\tau(\lambda, \kappa, \sigma)$ is a matrix with dimension
  - occupation: $30 \times 2 \times 20$
  - sector: $30 \times 2 \times 47$
- To summarize patterns of CA in the data
  - we impose a functional form for τ
  - project τ onto observable characteristics

Summarizing patterns of CA

Estimation results: changes in FEs

	Sectors					Occupations				
	84-89	89-93	93-97	97-03	**84-03**	84-89	89-93	93-97	97-03	**84-03**
κ_1/κ_2	0.57	0.45	0.15	0.24	**1.41**	0.53	0.49	0.15	0.49	**1.66**

Table : Changes over time in log equipment fixed effect

- Computerization: a large rise in $\ln(\hat{\tau}(\kappa_1)/\hat{\tau}(\kappa_2))$
  - corresponding changes in quantity indices (BEA)
    - computer equipment: 49.9
    - non-computer equipment: 1.7
    - structures: 1.4

Results: skill premium

	Sectors				Occupations			
Data	Labor supply	Labor prod.	Task shifters	Capital prod.	Labor supply	Labor prod.	Task shifters	Capital prod.
0.180	-0.032	0.046	0.045	0.121	-0.066	0.074	0.087	0.084

Table : Decomposing changes in the log skill premium: 84-03

- Changes in (non-wage) observables drive most changes in relative demand across education groups
  - of forces $\uparrow$ skill premium, account for
    - Sectors: $(.045 + .121)/(.045 + .121 + .046) \approx 78\%$
    - Occupations: $(.087 + .084)/(.087 + .084 + .074) \approx 70\%$
  - at least when highly aggregated

Results: skill premium

	Sectors				Occupations			
Data	Labor supply	Labor prod.	Task shifters	Capital prod.	Labor supply	Labor prod.	Task shifters	Capital prod.
0.180	-0.032	0.046	0.045	0.121	-0.066	0.074	0.087	0.084

Table : Decomposing changes in the log skill premium: 84-03

- Why are task & labor more important w/ occupations?
  - Sectors aggregate over very different occupations
    - $\Rightarrow$ weaker worker-task CA
    - $\Rightarrow \downarrow$ impact on $w(\lambda)$s of changes in task shifters, labor prod

Results: skill premium

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  - Sectors aggregate over very different occupations
    - $\Rightarrow$ weaker worker-task CA
    - $\Rightarrow \downarrow$ impact on $w(\lambda)$s of changes in task shifters, labor prod
- Similarly, why is capital more important w/ sectors?
  - sectors more aggregated $\Rightarrow$ w/in occupations, more similar computer use across labor groups

Results: skill premium and task shifters

- We find first-order importance of task shifters on wages
- Alternative approach: "manpower requirements" index (MPRI) ***SHIFT-SHARE ANALYSIS?**** (see autor, katz, krueger 1998)
  - Freeman 75, Katz and Murphy 92, etc... MPRI details
  - Decompose Δs in share of labor income for λ into Δs in
    1. share of total labor payments in each task σ
    2. share of payments within each task σ accruing to λ
  - Standard finding: 1 very small relative to 2
  - Forms basis of consensus: only *within* "task" changes crucial for explaining SBTC
  - Our data consistent with standard finding

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  - Forms basis of consensus: only *within* "task" changes crucial for explaining SBTC
  - Our data consistent with standard finding
- $\Rightarrow$ MPRI not sufficient to infer importance of task shifters for btw-group inequality

Results: five education groups

	Data	Sectors				Occupations			
		Labor supply	Labor prod.	Task shifters	Capital prod.	Labor supply	Labor prod.	Task shifters	Capital prod.
HSG/HSD	0.033	-0.009	-0.059	0.018	0.086	-0.027	-0.020	0.039	0.051
SMC/HSD	0.063	-0.022	-0.106	0.038	0.156	-0.053	-0.049	0.077	0.010
CLG/HSD	0.177	-0.041	-0.053	0.063	0.210	-0.091	0.013	0.126	0.139
GTC/HSD	0.283	-0.049	0.040	0.072	0.222	-0.105	0.105	0.142	0.146

Table : Decomposing changes log relative wages btw education groups: 84-03

- Conclusions for skill premium hold at more disaggregated level

Results: five education groups

	Data	Sectors				Occupations			
		Labor supply	Labor prod.	Task shifters	Capital prod.	Labor supply	Labor prod.	Task shifters	Capital prod.
HSG/HSD	0.033	-0.009	-0.059	0.018	0.086	-0.027	-0.020	0.039	0.051
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Table : Decomposing changes log relative wages btw education groups: 84-03

- One important additional insight:
  - labor productivity has U-shaped effect over full sample

Results: (male) wage polarization

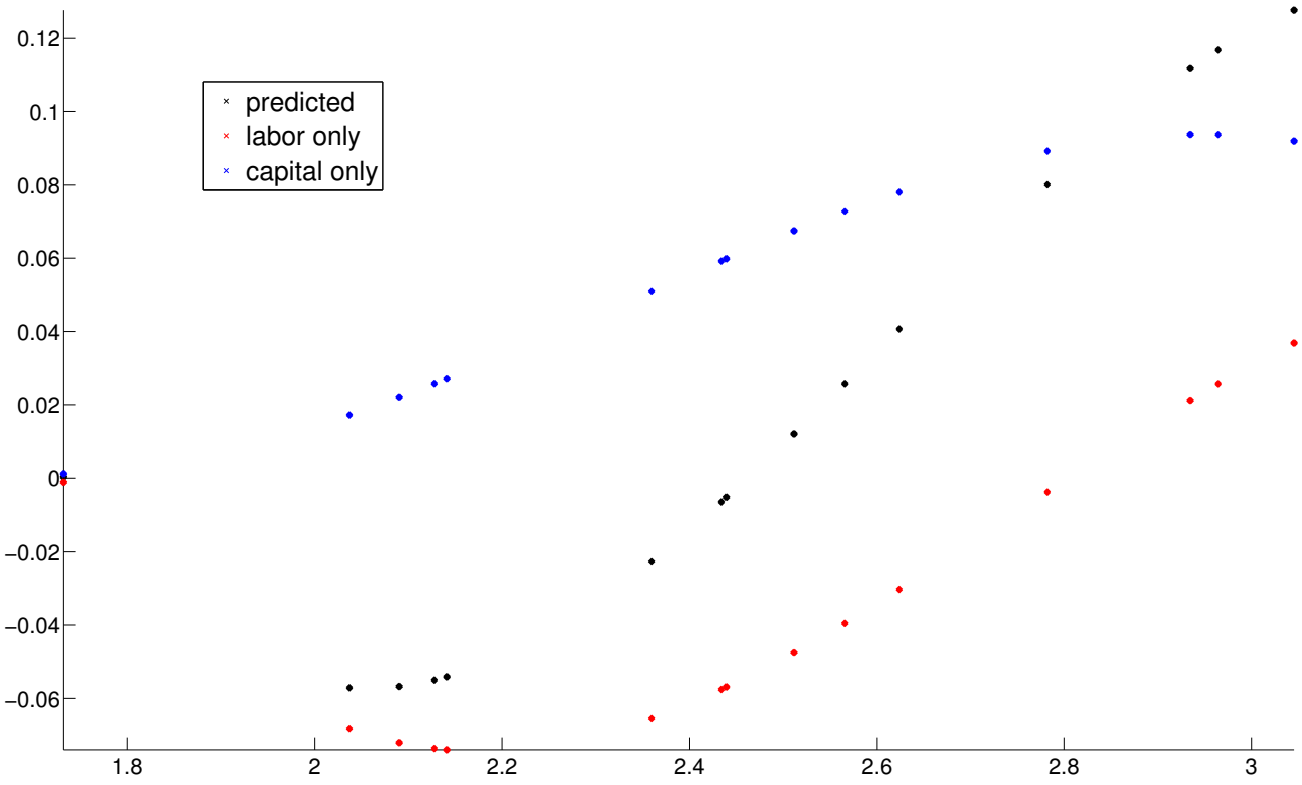


Figure : log $\hat{w}(\lambda)$ btw 89-03 (3rd degree polynomial fit) against log wage levels in 1989 (males)

Results: gender gap

Data	Sectors				Occupations			
	Labor supply	Labor prod.	Task shifters	Capital prod.	Labor supply	Labor prod.	Task shifters	Capital prod.
-0.127	0.026	-0.058	-0.046	-0.049	0.018	-0.082	-0.049	-0.012

Table : Decomposing changes in log gender gap: 84-03

- Capital productivity substantial only in sectors
  - females allocated to occupations intensive in computers
  - if tasks=sectors $\Rightarrow$ use computers more within task

Results: gender gap

Data	Occupations			
	Labor supply	Labor prod.	Task shifters	Capital prod.
-0.127	0.018	-0.082	-0.049	-0.012

Table : Decomposing changes in the log gender gap: 84-03

- Labor productivity dominant force $\downarrow$ gender gap
  - of forces $\downarrow$ gender gap, accounts for $\approx 57\%$
- However, task shifters also important
  - ... $\approx 34\%$

Choose your own adventure

- Equipment trade
- Alternative estimation
- Alternative parameter values
- Conclusions

Conclusions

- Quantitative framework w/ many worker, equip, task types
  - break open black box of changes in relative demand
- Estimate model: OLS with fixed effects in multiple years
  - identify equip prod, task shifters from cross-sectional allocation
  - explain most of the evolution of between-education inequality
- Impact of international trade in capital easily quantified
  - small effect on U.S., but potentially very large elsewhere
- Ongoing work: Germany
  - using data with allocation across multiple equipment types
  - and, for 2006, share of hours allocated to computers

Alternative estimation overview

1. We assume we may not observe some characteristics,
   - we observe only $n_\sigma \leq n'_\sigma$ and $n_\lambda \leq n'_\lambda$

$$T(\lambda,\kappa,\sigma) = \delta'(\lambda)\,\delta'(\kappa)\,\delta'(\sigma) \times exp\left(\sum_{i=1}^{n_\lambda}\sum_{j=1}^{n_\sigma}\beta'_{ij}X_i(\lambda)\,X_j(\sigma)\right)$$
$$\times exp\left(\sum_{i=1}^{n_\lambda}\beta'_{\lambda i}(\kappa)X_i(\lambda)\right) \times exp\left(\sum_{j=1}^{n_\sigma}\beta'_{\sigma i}(\kappa)X_j(\sigma)\right)\iota'_3(\lambda,\kappa,\sigma)$$

   - ι'_3: all interactions w/ unobserved characteristics
     - constant across time
     - a linear function of observed interactions

Details

Alternative estimation overview

1. We assume we may not observe some characteristics,
2. allow for sampling error in allocations and wage,

$$\pi^*(\lambda, \kappa, \sigma) = \pi(\lambda, \kappa, \sigma)\, \iota_1(\lambda, \kappa, \sigma)$$

$$w^*(\lambda) = w(\lambda)\, \iota_2(\lambda)$$

where ιs are mean zero (conditional on observables) and i.i.d.

Details

Basic Estimation

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$$w^*(\lambda) = w(\lambda)\, \iota_2(\lambda)$$

where ιs are mean zero (conditional on observables) and i.i.d.

Details

3. and assume (for consistency proofs)

$$n_\Lambda, n_\Sigma \to \infty$$
$$N(\lambda, \kappa, \sigma) \to \infty$$

Basic Estimation

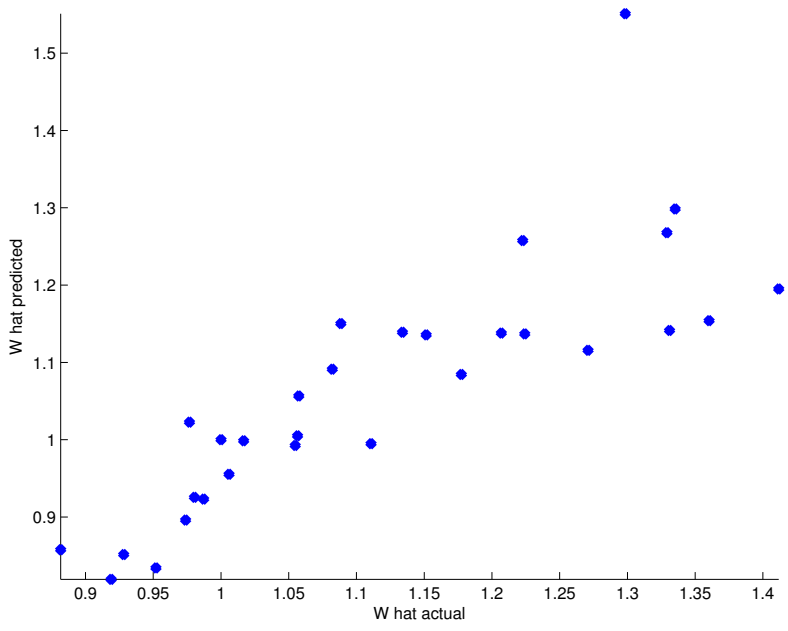
Alternative estimation overview

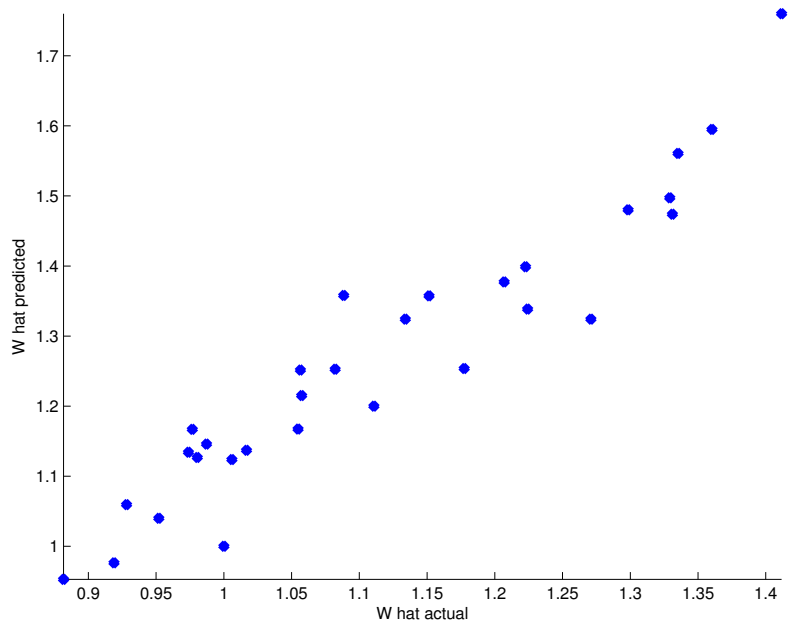
- All estimating equations are identical except for $\delta(\lambda)$

$$\ln\left(\frac{\pi(\lambda,\kappa,\sigma)w(\lambda)^{\theta}}{\pi(\lambda',\kappa,\sigma)w(\lambda')^{\theta}}\right) = \ln\delta(\lambda) - \ln\delta(\lambda') + ...$$

Estimation results: fit of changes in wages

Correlation $\hat{w}(\lambda)/\hat{w}(\lambda_1)$ btw 84-03: 0.83 occupations & 0.95 in sectors





Results: skill premium

	Sectors					Occupations				
	Total predicted	Labor supply	Labor prod.	Task shifters	Capital prod.	Total predicted	Labor supply	Labor prod.	Task shifters	Capital prod.
84-03	0.173	-0.032	0.037	0.047	0.120	0.161	-0.065	0.059	0.086	0.084

Table : Decomposing changes in the log skill premium

- Capital prod + task shifters dominant forces ↑ skill premium
  - of forces ↑ skill premium, account for
    - Sectors: $(.047 + .12) / (.047 + .12 + .037) \approx 82\%$
    - Occupations $(.086 + .084) / (.086 + .084 + .059) \approx 74\%$

Results: five education groups

	Sectors					Occupations				
	Total Predicted	Labor supply	Labor prod.	Task shifters	Capital prod.	Total Predicted	Labor supply	Labor prod.	Task shifters	Capital prod.
HSG/HSD	0.084	-0.010	-0.009	0.019	0.086	0.018	-0.027	-0.036	0.040	0.051
SMC/HSD	0.114	-0.023	-0.056	0.040	0.156	0.064	-0.053	-0.047	0.079	0.100
CLG/HSD	0.204	-0.042	-0.028	0.066	0.210	0.163	-0.090	0.002	0.126	0.139
GTC/HSD	0.328	-0.050	0.083	0.076	0.222	0.238	-0.103	0.065	0.141	0.146

Table : Decomposing changes log relative wages btw education groups: 84-03

- Conclusions are robust to alternative estimation
  - task shifters, capital prod drive relative demand changes
  - labor productivity has U-shaped effect over full sample

Choose your own adventure

Alternative estimation details

1. We assume we may not observe some characteristics,
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$$T(\lambda,\kappa,\sigma) = \delta'(\lambda)\,\delta'(\kappa)\,\delta'(\sigma) \times exp\left(\sum_{i=1}^{n_\lambda}\sum_{j=1}^{n_\sigma}\beta'_{ij}X_i(\lambda)\,X_j(\sigma)\right)$$
$$\times exp\left(\sum_{i=1}^{n_\lambda}\beta'_{\lambda i}(\kappa)X_i(\lambda)\right) \times exp\left(\sum_{j=1}^{n_\sigma}\beta'_{\sigma i}(\kappa)X_j(\sigma)\right)\iota'_3(\lambda,\kappa,\sigma)$$

   - ι'_3: all interactions w/ unobserved characteristics

$$\iota'_3(\lambda,\kappa,\sigma) = \iota'_3(\lambda,\kappa)\iota'_3(\kappa,\sigma)\iota'_3(\lambda,\sigma)$$

   - with ι'_3 constant across t and

$$\mathbb{E}\left[\ln \iota'_3(j,\kappa)|\mathscr{X}^o(j),j\right] = \gamma_j(\kappa)\mathscr{X}^o(j),\ j = \{\lambda,\sigma\}$$
$$\mathbb{E}\left[\ln \iota'_3(\lambda,\sigma)|\mathscr{X}^o(\lambda\sigma)\right] = \gamma\mathscr{X}^o(\lambda,\sigma)$$

Alternative estimation overview

Alternative estimation details

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$$\pi^*(\lambda, \kappa, \sigma) = \pi(\lambda, \kappa, \sigma)\, \iota_1(\lambda, \kappa, \sigma)$$

$$w^*(\lambda) = w(\lambda)\, \iota_2(\lambda)$$

where

$$\mathbb{E}[\ln \iota_1(\lambda, \kappa, \sigma) \,|\, \mathscr{X}^o, \lambda, \kappa, \sigma] = 0$$
$$\mathbb{E}[\ln \iota_2(\lambda) \,|\, \mathscr{X}^o, \lambda] = 0$$

and ι_j is i.i.d. for $j = 1, 2$ and ι_1 is independent of ι_2

Alternative estimation overview

Identification: CA

Step 1: Comparative advantage (e.g. labor capital)

- λ has a CA (relative to λ_1) with κ_1 (relative to κ_2) if
  - λ uses κ_1 relatively more within tasks
- Specifically, we have

$$\frac{\pi(\lambda,\kappa_1,\sigma)}{\pi(\lambda,\kappa_2,\sigma)} \Big/ \frac{\pi(\lambda_1,\kappa_1,\sigma)}{\pi(\lambda_1,\kappa_2,\sigma)} = \left(\frac{T(\lambda,\kappa_1)}{T(\lambda,\kappa_2)} \frac{T(\lambda_1,\kappa_2)}{T(\lambda_1,\kappa_1)} \right)^{\theta}$$

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- Hence

$$\ln\left(\frac{\pi^*(\lambda,\kappa_1,\sigma)}{\pi^*(\lambda,\kappa_2,\sigma)}\Big/\frac{\pi^*(\lambda_1,\kappa_1,\sigma)}{\pi^*(\lambda_1,\kappa_2,\sigma)}\right)=\sum_{i=1}^{n_\lambda}\beta_{\lambda i}(\kappa_2)\left(X_i(\lambda_1)-X_i(\lambda)\right)+...$$

where "..." contains (only) error terms $\Rightarrow$

$$\mathbb{E}\left[\beta^*_\lambda(\kappa_2)-(\beta_\lambda(\kappa_2)+\gamma_\lambda(\kappa_2))|\mathscr{X}^o(\lambda),\lambda,\kappa_2\right]=0$$

$\gamma_\lambda(\kappa_2)$: projection of unobservable interactions onto observable

Identification CA

Robustness

Alternative values for θ

- $\theta \uparrow \Rightarrow$ less dispersion in ε
  - $\Rightarrow \uparrow$ elasticity of π with respect to $p(\sigma), r(\kappa), T(\lambda, \kappa, \sigma)$
  - $\Rightarrow \downarrow$ elasticity of w ...

		Sectors				Occupations			
value of θ	Data	Labor supply	Labor prod.	Task shifters	Capital prod.	Labor supply	Labor prod.	Task shifters	Capital prod.
$\theta = 2$	0.180	-0.047	-0.017	0.066	0.179	-0.094	0.030	0.123	0.119
$\theta = 2.9$	0.180	-0.034	0.038	0.048	0.128	-0.069	0.068	0.092	0.088
$\theta = 3.1$	**0.180**	**-0.032**	**0.046**	**0.045**	**0.121**	**-0.066**	**0.074**	**0.087**	**0.084**
$\theta = 3.3$	0.180	-0.030	0.054	0.043	0.114	-0.062	0.079	0.083	0.079
$\theta = 4$	0.180	-0.025	0.074	0.036	0.095	-0.053	0.095	0.070	0.067

Table : Skill premium decomposition for alternative values of θ: 84-03

Robustness

Alternative values for ρ

value of ρ	Data	Sectors				Occupations			
		Labor supply	Labor prod.	Task shifters	Capital prod.	Labor supply	Labor prod.	Task shifters	Capital prod.
$\rho = 1/2$	0.180	-0.037	0.045	0.056	0.116	-0.078	0.071	0.122	0.061
$\rho = 1$	**0.180**	**-0.032**	**0.046**	**0.045**	**0.121**	**-0.066**	**0.074**	**0.087**	**0.084**
$\rho = 2$	0.180	-0.025	0.048	0.031	0.127	-0.050	0.078	0.043	0.110

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- $\downarrow\rho \Rightarrow$ effect of task $\uparrow$, capital $\downarrow$, labor unchanged

Choose your own adventure

Robustness

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- $\downarrow\rho \Rightarrow$ effect of task $\uparrow$, capital $\downarrow$, labor unchanged
- labor + capital growth biased towards particular (similar) σs
  - if ρ is low, these tasks should shrink
    - $\Rightarrow$ fall (rise) in effect of capital prod (labor supply)

Choose your own adventure

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- labor + capital growth biased towards particular (similar) σs
  - if ρ is low, these tasks should shrink
    - $\Rightarrow$ fall (rise) in effect of capital prod (labor supply)
  - to match observed σ shares: counteracting changes in σ prod
    - $\Rightarrow$ rise in effect of task shifters

Choose your own adventure

Alternative environment

- Output of worker $\omega \in \Omega(\lambda)$ in σ with $k(\lambda, \kappa, \sigma)$ units of κ

$$[T(\lambda,\sigma)\varepsilon(\omega,\sigma)]^{1-\alpha(\sigma)} K(\lambda,\sigma)^{\alpha(\sigma)}$$

where

$$K(\lambda,\sigma) = \left[\sum_{\kappa} T(\lambda,\kappa,\sigma)\, k(\lambda,\kappa,\sigma)^{\frac{\theta(\lambda)-1}{\theta(\lambda)}}\right]^{\frac{\theta(\lambda)}{\theta(\lambda)-1}}$$

  - $\sum_{\kappa} T(\lambda,\kappa,\sigma) = 1$
  - $\varepsilon(\omega,\sigma)$ distributed Frechet with parameter $\theta(\lambda)$

Environment

Two standard frameworks

- Nest two standard frameworks to study btw-group inequality
  - *CES model* ("*canonical model*"); e.g. Goldin and Katz 2010

$$Y = \left[A_1 L(\lambda_1)^{\frac{\rho-1}{\rho}} + A_2 L(\lambda_2)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}$$

  - *Nested CES model*; e.g. Krusell et al. 2000

$$Y = \left[A_1 L(\lambda_1)^{\frac{\rho-1}{\rho}} + A_2 \left(L(\lambda_2)^{1-\alpha(\sigma_2)} K(\kappa)^{\alpha(\sigma_2)} \right)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}$$

- Strong restrictions on production functions at the level of $(\lambda, \kappa, \sigma)$, at aggregate level yields rich interactions btw workers types and btw worker and capital types
  - see e.g. Jones (2005)

Decomposition: our approach

- Labor supplies: feed in $\hat{L}(\lambda)$

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- Labor-specific productivities: feed in $\hat{\delta}'(\lambda)$

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- Labor-specific productivities: feed in $\hat{\delta}'(\lambda)$
- Capital-specific "productivities": feed in $\hat{\delta}(\kappa)$

$$\hat{\delta}(\kappa) = \left(\hat{\delta}'(\kappa)\,\hat{r}(\kappa)^{\frac{-\alpha}{1-\alpha}}\right)^{\theta} \Rightarrow \frac{\hat{\delta}(\kappa_2)}{\hat{\delta}(\kappa_1)} = \left(\frac{\hat{\delta}'(\kappa_2)}{\hat{\delta}'(\kappa_1)}\left(\frac{\hat{q}(\kappa_2)}{\hat{q}(\kappa_1)}\right)^{\frac{-\alpha}{1-\alpha}}\right)^{\theta}$$

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- Task-shifters:

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- Task-shifters:
  - Goods mkt clearing $\Rightarrow$

$$\frac{\hat{\mu}(\sigma)}{\hat{\mu}(\sigma_1)} = \left(\frac{\hat{\delta}'(\sigma_1)}{\hat{\delta}'(\sigma)}\left(\frac{\hat{\delta}(\sigma)}{\hat{\delta}(\sigma_1)}\right)^{\frac{1}{\theta}}\right)^{(\rho-1)(1-\alpha)} \frac{\zeta(\sigma)}{\zeta(\sigma_1)}$$

    - $\zeta(\sigma)$ (= income in σ in t') a function of estimates
  - Substitute out $\hat{\mu}(\sigma)$ from system using above expression

Our approach

Decomposition: our approach

- Labor supplies: feed in $\hat{L}(\lambda)$
- Labor-specific productivities: feed in $\hat{\delta}'(\lambda)$
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  - Goods mkt clearing $\Rightarrow$

$$\frac{\hat{\mu}(\sigma)}{\hat{\mu}(\sigma_1)} = \left(\frac{\hat{\delta}'(\sigma_1)}{\hat{\delta}'(\sigma)}\left(\frac{\hat{\delta}(\sigma)}{\hat{\delta}(\sigma_1)}\right)^{\frac{1}{\theta}}\right)^{(\rho-1)(1-\alpha)} \frac{\zeta(\sigma)}{\zeta(\sigma_1)}$$

    - $\zeta(\sigma)$ (= income in σ in t') a function of estimates
  - Substitute out $\hat{\mu}(\sigma)$ from system using above expression
  - $\hat{\delta}'(\sigma)$ enters system as $\widetilde{p}(\sigma) \equiv \hat{p}(\sigma)^{\frac{1}{1-\alpha}}\hat{\delta}'(\sigma)$
    - Solution of system depends on $\hat{\delta}(\sigma)$, not $\hat{\mu}(\sigma)$ or $\hat{\delta}'(\sigma)$

Our approach

German data

- Qualification and Working Conditions in Germany (2006):
  - "How much of your total work time do you spend on computers?"

German data

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  - "How much of your total work time do you spend on computers?"
- We construct π in Germany two ways:

$X(\lambda)$	US	DE	DE33
Age	0.004	0.014	
Female	-0.139	-0.078	
Education	-0.664	-0.584	
Education^2	0.015	0.020	

Table : Estimated worker-capital interactions

  - share of hours for each worker (DE)

Comparative Advantage

German data

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  - "How much of your total work time do you spend on computers?"
- We construct π in Germany two ways:

$X(\lambda)$	US	DE	DE33
Age	0.004	0.014	0.029
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Education	-0.664	-0.584	-0.493
Education^2	0.015	0.020	0.015

Table : Estimated worker-capital interactions

- share of hours for each worker (DE)
- worker uses computers iff share of hours $>$ 33% (DE33)

Comparative Advantage

Computer use

	Data					Sectors					Occupations				
	84	89	93	97	03	84	89	93	97	03	84	89	93	97	03
All	25.1	36.6	46.3	50.5	57.0	28.1	39.1	49.4	53.0	58.8	26.8	37.2	47.1	50.4	59.9
Gender															
Men	21.6	31.3	40.6	44.5	51.6	24.0	33.9	43.5	46.9	52.6	24.3	33.8	42.9	45.9	55.0
Women	30.6	44.2	54.4	59.0	64.3	34.2	46.6	57.5	61.3	67.1	30.7	42.0	52.9	56.5	66.4
Education															
HSD	5.2	7.3	10.4	12.2	15.9	4.7	7.8	11.3	12.6	15.3	4.3	7.0	9.9	10.9	15.2
HSG	19.5	28.2	33.9	36.2	40.5	19.8	29.2	37.9	40.8	46.1	18.0	26.3	34.1	36.3	45.9
SMC	32.5	45.8	53.3	56.6	59.5	35.6	48.1	58.1	61.1	66.5	32.6	44.4	54.2	57.0	66.6
CLG	42.6	58.3	70.3	75.8	83.4	50.7	63.7	72.4	75.1	79.2	49.6	62.2	71.4	74.1	81.2
GTC	42.6	58.4	71.3	79.1	87.8	53.8	66.7	75.0	77.6	81.5	54.3	66.6	75.4	78.0	84.4

Table : The probability of using a computer for several worker categories

- In general do well year-by-year, group-by-group Comparative Advantage

Equipment allocation across sectors

- **Do not use data on allocation of non-computer equip**
- BEA: detailed estimates for private nonresidential fixed assets by detailed industry and by detailed asset type
  - imperfect data & not disaggregated across workers
- In data and model:
  1. construct ratio of share of value of computers in σ relative to share of value of non-computer equipment in σ
  2. calculate correlation between these ratios for each year
- Median of correlation across years: 0.76
- **Model's predictions on equipment allocation line up reasonably well with limited available data**

Comparative Advantage

System in changes

- Express the system of equations in changes:
  - wage equation
  - task-market clearing equation
  - allocation equation
  - rental rate equation

Proposition: *Along a BGP, given*

1. *known values of all* $w(\lambda)L(\lambda)$ *and* $\pi(\lambda, \kappa, \sigma)$ *in period* t
2. ρ, $\alpha(\sigma)$, *and* $\theta(\lambda)$
3. *changes in technology and/or factor supply from* t *to* $t' > t$

system $\Rightarrow$ *changes in relative wages btw any worker types*

Manpower requirement index: our formulation

$$
\begin{aligned}
I_t(\lambda) &= \lambda' s \text{ share of total labor income} \\
\tilde{L}_t(\lambda) &= \lambda' s \text{ share of total hours} \\
\tilde{w}_t(\lambda) &= \lambda' s \text{ wage relative to weighted avg} \\
\zeta_t(\sigma) &= \text{total labor income in } \sigma \\
I_t(\lambda,\sigma) &= \lambda' s \text{ share of labor income in } \sigma
\end{aligned}
$$

- Accounting $\Rightarrow$

$$\Delta I(\lambda) = \bar{\tilde{w}}(\lambda)\Delta\tilde{L}(\lambda) + \bar{\tilde{L}}(\lambda)\Delta\tilde{w}(\lambda)$$

$$\Delta I(\lambda) = \sum_{\sigma} \bar{I}(\lambda,\sigma)\Delta\zeta(\sigma) + \sum_{\sigma} \bar{\zeta}(\sigma)\Delta I(\lambda,\sigma)$$

- MPRI: importance of task shifts given by

$$\sum_{\sigma} \bar{I}(\lambda,\sigma)\Delta\zeta(\sigma) \Big/ \bar{\tilde{w}}(\lambda)\Delta\tilde{L}(\lambda)$$

Skill premium and task shifters

International equipment trade

- Equipment trade shapes relative capital stocks...
  - Eaton and Kortum 2001
- ... and, therefore, between-group inequality
  - Burstein, Cravino, Vogel 2013 and Parro 2013

International equipment trade

- Equipment trade shapes relative capital stocks...
  - Eaton and Kortum 2001
- ... and, therefore, between-group inequality
  - Burstein, Cravino, Vogel 2013 and Parro 2013
- Consumption and equipment goods are traded
  - gravity model within each
  - no task trade: final good produced combining domestic σ
- Previous estimates unaffected
- Decompose estimated changes in capital productivity into domestic and foreign channels

International equipment trade

- Final good used to produce n's consumption and capital goods

$$Y_{n,t} = q_{n,t}(C)\, Y_{n,t}(C) + \sum_{\kappa} q_{n,t}(\kappa)\, Y_{n,t}(\kappa)$$

- For consumption (similarly investment):

$$Y_{n,t}(C) = \sum_{i} d_{ni,t}(C)\, C_{ni,t}$$

$$C_{n,t} = \left(\sum_{i} C_{in,t}^{\frac{\eta(C)-1}{\eta(C)}} \right)^{\frac{\eta(C)}{\eta(C)-1}}$$

- Law of motion for capital κ is

$$K_{n,t+1}(\kappa) = (1 - dep_n(\kappa))\, K_{n,t}(\kappa) + I_{n,t}(\kappa)$$

- Utility of the representative household given by $\sum_{t=0}^{\infty} u_{n,t}(C_{n,t})$

International equipment trade

- Autarkic task markets$\Rightarrow$trade only affects $w(\lambda)$ through $r(\kappa)$

International equipment trade

- Autarkic task markets⇒trade only affects $w(\lambda)$ through $r(\kappa)$
- Relative to baseline, the only change to system is

$$\frac{\hat{r}_n(\kappa)}{\hat{r}_n(\kappa')} = \frac{\hat{q}_n(\kappa)}{\hat{q}_n(\kappa')} \times \frac{\hat{s}_{nn}(\kappa)^{1/(\eta(\kappa)-1)}}{\hat{s}_{nn}(\kappa')^{1/(\eta(\kappa')-1)}}$$

where

$$s_{nn,t}(\kappa) = \frac{P_{nn,t}(\kappa) I_{nn,t}(\kappa)}{\sum_i P_{in,t}(\kappa) I_{in,t}(\kappa)}$$

is domestic absorption share in κ

Trade counterfactuals

- $\hat{w}_{n,t}^{A}(\lambda) =$ change in wage moving to autarky at time t
- **Proposition**: calculate $\hat{w}_{n,t}^{A}(\lambda)$ by substituting $\hat{s}_{nn}(\kappa) = s_{nn,t}(\kappa)^{-1}$ into system of equations

Trade counterfactuals

- $\hat{w}^A_{n,t}(\lambda) =$ change in wage moving to autarky at time t
- **Proposition**: calculate $\hat{w}^A_{n,t}(\lambda)$ by substituting $\hat{s}_{nn}(\kappa) = s_{nn,t}(\kappa)^{-1}$ into system of equations
- **Corollary**: Differential effects of changes in primitives btw t and t' on wages in n, relative to effects of same changes in primitives if n were in autarky: $\frac{\hat{w}^A_{n,t}(\lambda)}{\hat{w}^A_{n,t'}(\lambda)}$

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- Only need values for $\eta(\kappa)$ and $s_{nn,t}(\kappa)$ for U.S. in 84, 03
  - equipment trade elasticity = 4.5 Parro (2013)
    - $\Rightarrow \eta(\kappa) = 5.5$
  - $s_{nn,t}(\kappa)$ constructed using OECD's STAN
    - κ_1 : Office, Accounting, and Computing Machinery
    - κ_2 : Machinery and Equipment (less κ_1) + Transport
    - $\Rightarrow s_{nn,84}(\kappa_1) = 0.796$ and $s_{nn,84}(\kappa_2) = 0.830$
    - $\Rightarrow s_{nn,03}(\kappa_1) = 0.256$ and $s_{nn,03}(\kappa_2) = 0.650$

Trade results

Model	Year	HSG/HSD	SMC/HSD	CLG/HSD	GTC/HSD	Skill premium
Sectors	84	-0.000	-0.001	-0.002	-0.002	-0.001
	03	-0.022	-0.036	-0.045	-0.047	-0.023
Occupations	84	-0.000	-0.001	-0.001	-0.001	-0.001
	03	-0.012	-0.020	-0.025	-0.026	-0.013

Table : Impact on log relative wages of moving to autarky in 84 and 03

- $\Rightarrow$ Differential effects of changes in primitives btw $84-03$ on U.S. wages, relative to effects of same changes in primitives if U.S. were in autarky:
  - sectors: 2.2%
  - occupations: 1.2%
- While small, change in $\left(\hat{s}_{nn}(\kappa_1)/\hat{s}_{nn}(\kappa_2)\right)^{1/(\eta(\kappa)-1)}$ relatively small in U.S.
  - $\Rightarrow$ potentially large effects in other countries

Choose your own adventure

What is the pattern of CA?

Additional restrictions NOT imposed in our exercise

- To show more clearly what is the pattern of CA...
- ... impose $\tau(\lambda,\kappa,\sigma) = \tau(\lambda,\sigma)\,\tau(\lambda,\kappa)\,\tau(\kappa,\sigma)$ with

$$\tau(\lambda,\kappa,\sigma) = exp\left(\sum_{i=1}^{n_\lambda}\sum_{j=1}^{n_\sigma}\beta_{ij}X_i(\lambda)X_j(\sigma)\right) \times exp\left(\sum_{i=1}^{n_\lambda}\beta_{\lambda i}(\kappa)X_i(\lambda)\right) \times exp\left(\sum_{j=1}^{n_\sigma}\beta_{\sigma j}(\kappa)X_j(\sigma)\right)$$

$X(\lambda)$ and $X(\sigma)$: vectors of worker and task characteristics

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  $X(\lambda)$ and $X(\sigma)$: vectors of worker and task characteristics

- 7 task characteristics: (*i*) Analyzing data/information; (*ii*) Thinking creatively; (*iii*) Guiding, directing, and motivating subordinates; (*iv*) Importance of repeating the same tasks; (*v*) Pace determined by speed of equipment; (*vi*) Manual dexterity; and (*vii*) Social Perceptiveness
  - using O*NET
- Worker characteristics: age, gender, education, education^2

What is the pattern of CA?

e.g., labor-equipment CA w/ additional restrictions NOT imposed in our exercise

- Labor $\times$ equipment CA identified *within task*

$$\frac{\pi_t(\lambda, \kappa_1, \sigma)}{\pi_t(\lambda, \kappa_2, \sigma)} \Big/ \frac{\pi_t(\lambda_1, \kappa_1, \sigma)}{\pi_t(\lambda_1, \kappa_2, \sigma)} = \frac{\tau(\lambda, \kappa_1)}{\tau(\lambda, \kappa_2)} \frac{\tau(\lambda_1, \kappa_2)}{\tau(\lambda_1, \kappa_1)}$$

  - Note: using $\tau_t(\lambda, \kappa, \sigma)$ equivalent to using $\pi_t(\lambda, \kappa, \sigma)$...

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  - Note: using $\tau_t(\lambda, \kappa, \sigma)$ equivalent to using $\pi_t(\lambda, \kappa, \sigma)$...

- Together with specific functional form:

$$\log\left(\frac{\pi_t(\lambda, \kappa_1, \sigma)}{\pi_t(\lambda, \kappa_2, \sigma)} \Big/ \frac{\pi_t(\lambda_1, \kappa_1, \sigma)}{\pi_t(\lambda_1, \kappa_2, \sigma)} \right) = \sum_{i=1}^{n_\lambda} (\beta_{\lambda i}(\kappa_2) - \beta_{\lambda i}(\kappa_1))(X_i(\lambda_1) - X_i(\lambda))$$

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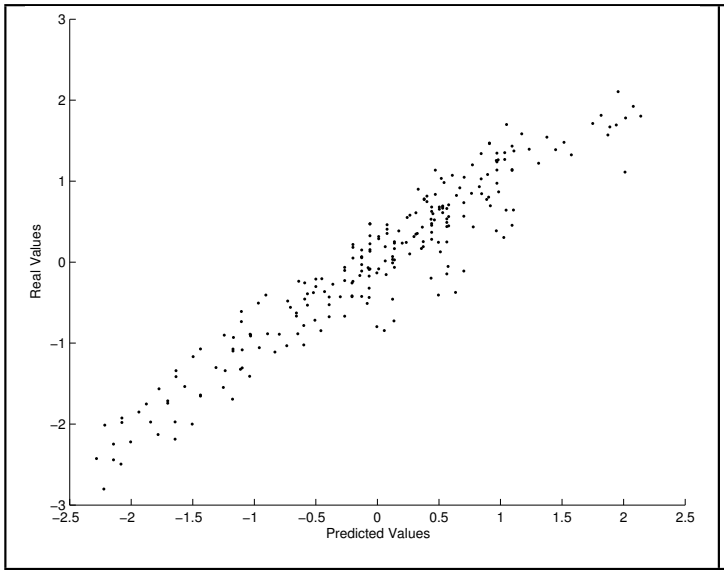
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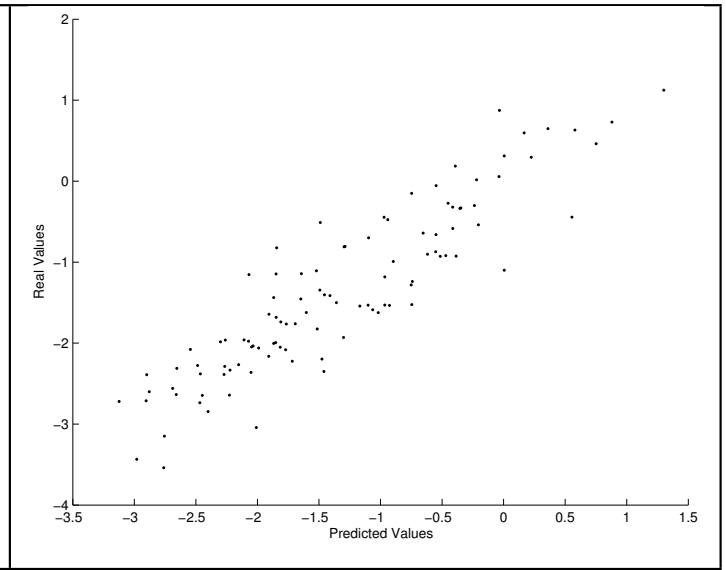
$$\log\left(\frac{\pi_t(\lambda,\kappa_1,\sigma)}{\pi_t(\lambda,\kappa_2,\sigma)} \Big/ \frac{\pi_t(\lambda_1,\kappa_1,\sigma)}{\pi_t(\lambda_1,\kappa_2,\sigma)}\right) = \sum_{i=1}^{n_\lambda} (\beta_{\lambda i}(\kappa_2) - \beta_{\lambda i}(\kappa_1))(X_i(\lambda_1) - X_i(\lambda))$$

- Similar strategies to identify two other types of CA

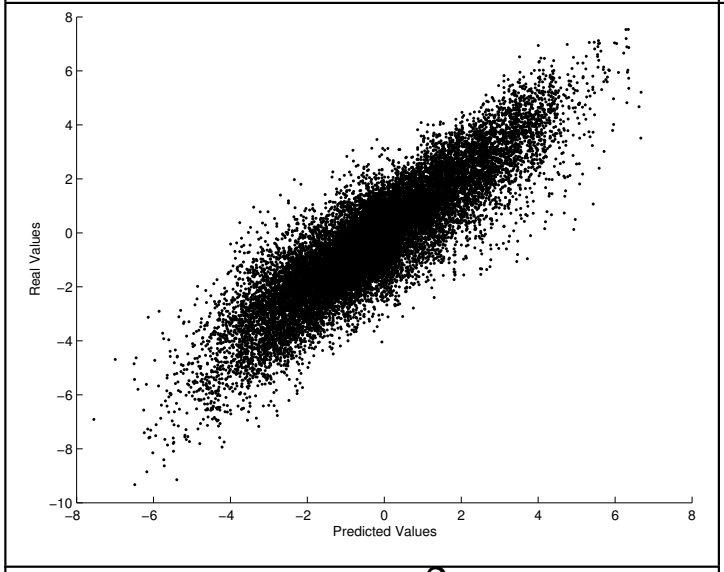
Estimation results: fit of CA (occupations)



$\beta_\lambda(\kappa)$ adjusted $R^2 = 0.90$



$\beta_\sigma(\kappa)$ adjusted $R^2 = 0.82$



β adjusted $R^2 = 0.78$

Estimation results: labor-equipment CA

$\beta_\lambda(\kappa_1)$		
$X(\lambda)$	Sector	Occupation
Age	-0.001	-0.004
Female	0.614	0.139
Education	0.861	0.664
Education^2	-0.018	-0.015

Table : Estimated worker-capital interactions

- Two workers w/ same age, gender, occupation, and ε:
  - CLG is $\exp\left(\frac{0.664}{\theta} \times 4 - \frac{0.015}{\theta} \times \left(16^2 - 12^2\right)\right) = 1.37$ times more productive with κ_1 (relative to κ_2) than HSG

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    - selection on unobservable ε:
    - if estimate CA using avg prod differences, find weaker CA

Germany

Estimation results: labor-equipment CA

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Age	-0.001	-0.004
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Table : Estimated worker-capital interactions

- Women use computers much more within sectors
  - but largely driven by occupational composition
  - difference much smaller within occupations

Estimation results: equipment-task CA

$\beta_\sigma(\kappa_1)$		
$X(\sigma)$	Sector	Occupation
Analyzing data/information	0.582	0.457
Thinking creatively	-0.036	0.336
Guiding, directing, motivating	-0.008	-0.076
Importance of repetition	0.917	0.639
Pace determined equipment	-0.576	-0.277
Manual dexterity	-0.366	-0.561
Social Perceptiveness	-0.602	-0.390

Table : Estimated capital-task interactions

- Computers have a CA in tasks intensive in
  - analyzing data/info
  - repetition

Computer use | Equipment allocation across sectors | Back to results