Unbundling Labor

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This Paper

- Has technological change made jobs more or less similar?
- What are the implications for wage inequality?
- When does such technological change arise?

1970 - Cafe

2020 - Starbucks

Today

1. Facts

A. Heterogeneity in skill requirements *across* occupations

$\downarrow$ Low skill jobs , $\uparrow$ High skill jobs

B. Inequality in wages *within* occupations

$\downarrow$ Low skill jobs , $\uparrow$ High skill jobs

2. Theory

- Technological change consistent with **A.** causes **B.**
- Nests three standard frameworks that are silent on links b/w **A.** and **B.**
- Endogenize **A.** as appropriate technology choice

3. Additional Facts (time permitting)

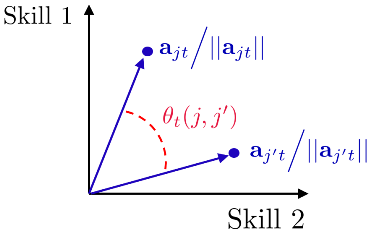
- Declining *experience premium* in low skill jobs
- Declining *overtime premium / part-time penalty* in low skill jobs
- Increasing *occupation switching* in low skill jobs

Fact A. - Technology

High skill jobs have become more different
Low skill jobs have become more similar

Approach

1. O*NET data on 250+ skills and J occupations. Split: 2003-09, 2010-18
2. Reduce to $4 \times J$ matrix of skills $\mathbf{A}_t = \left[\mathbf{a}_{1t}, \ldots, \mathbf{a}_{Jt}\right]$ (Lise Postel-Vinay, 2020)
3. Distance between occupations (Gathmann Schönberg, 2010)



4. Compare the distribution of these distances $\theta(j, j')$ across periods

▸ Details - Dimension Reduction

Fact A. - Technology

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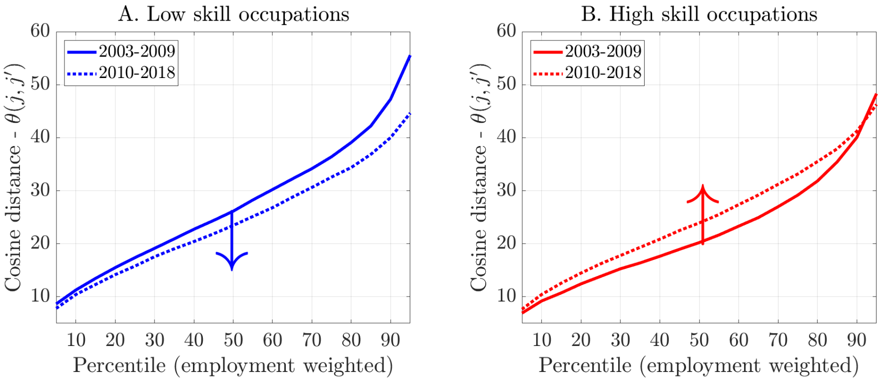
Low skill jobs have become more similar



Median distance between low skill occupations down ≈ 5 degrees

Fact B. - Wages

Wages in high skill jobs have become more different
Wages in low skill jobs have become more similar

Approach

- Log annual earnings from the CPS - $\log y_{it}$

- Residuals after controlling for observables - e_{it}

$$Year_t,\ NAICS1_{it},\ Ed_{it},\ Race_{it}\ ,Sex_{it}\ ,FirmSize_{it}\ ,Exp_{it}\ ,Exp_{it}^2\ ,Hours_{it}$$

- Estimate in 15 year windows. Separately for low and high skill occupations

- Decompose $var\,(e_{it})$ into within- and between-occupation components

Details

Fact B. - Wages

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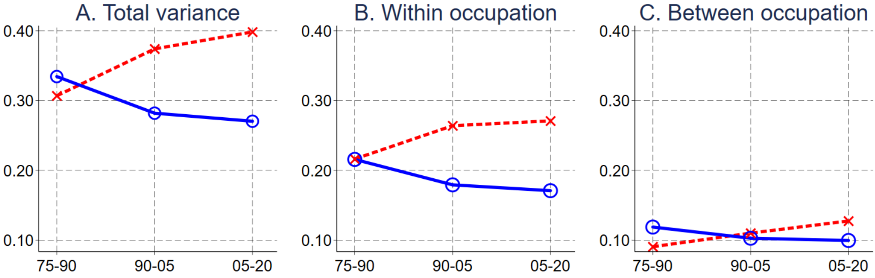
Wages in low skill jobs have become more similar



Variance of residuals. Red = High wage occupations, Blue = Low wage occupations

Robust across {All,Male,Female}×{Fix occupations in 1980, 2010}

Theory

Overview

- Builds on Rosen (1983), Heckman Scheinkman (1987)
- Workers supply multiple skills, *heterogeneity in comparative advantage*
- Tasks/occupations demand multiple skills
- Workers must supply skills to *single task/occupation*
- "*More diversity in skill supply than skill demand* "

Model

- Static competitive equilibrium model

- Two skills, workers $i \in [0,1]$ endowed with $x(i), y(i) \sim H(x,y)$

- Two occupations $j = 1, 2$ with *different skill intensities*

- Competitive equilibrium wages

$$w_j(i) = \lambda_{jX} x(i) + \lambda_{jY} y(i) \quad \rightarrow \quad var\left(\log w_j(i) \middle| j\right)$$

- Within occupation inequality determined by two forces

  1. Distribution of skills conditional on selection
  2. Gradient of within-occupation skill prices $\{\lambda_{jX},\, \lambda_{jY}\}$

Production

- Final good

$$U(C_1, C_2)$$

- Production of task/occupation j

$$C_j = F_j\Big(X_j, Y_j\Big) = \Big[\,\alpha_j X_j^{\sigma} \quad + \; (1-\alpha_j)\, Y_j^{\sigma}\Big]^{\frac{1}{\sigma}} \quad , \quad \sigma < 1$$

$$X_j = \int x(i)\phi_j(i)\, di, \qquad Y_j = \int y(i)\phi_j(i)\, di, \qquad \phi_j(i) \in \{0, 1\}$$

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BUNDLED - *Worker i must allocate $x(i), y(i)$ to the same task j*

Efficient Allocation – Relaxed Problem

$$\max_{\phi_{1x}(i)\in\{0,1\},\phi_{1y}(i)\in\{0,1\}} U\Big(F_1(X_1,Y_1),F_2(X_2,Y_2)\Big)$$

subject to with shadow prices $\lambda_{jX},\lambda_{jY}$

$$X_1 = \int \phi_{1x}(i)\, x(i)\, di \quad \longrightarrow \quad \lambda_{1X} = U_1 F_{1X}$$

$$X_2 = \int \Big[1-\phi_{1x}(i)\Big]\, x(i)\, di \quad \longrightarrow \quad \lambda_{2X} = U_2 F_{2X}$$

$$Y_1 = \int \phi_{1y}(i)\, y(i)\, di \quad \longrightarrow \quad \lambda_{1Y} = U_1 F_{1Y}$$

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and person-by-person bundling constraints

$$\phi_{1x}(i) = \phi_{1y}(i) \qquad \text{for all} \quad i\in[0,1]$$

Feasible Allocations

- Result. Can replace continuum of person-by-person constraints with single aggregate constraint

- Given X_1 what is *minimum* and *maximum* Y_1 bundled along with it?

$$\text{Aggregate bundling constraint:} \quad Y_1 \in \left[\underline{B}(X_1)\,,\, \overline{B}(X_1)\right]$$

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- Construct X_1 using workers with highest $x(i)\Big/y(i)$ first

$$X_1 = \int_0^{i^*} x(i)\,di, \qquad \underline{B}(X_1) = \int_0^{i^*} y(i)\,di$$

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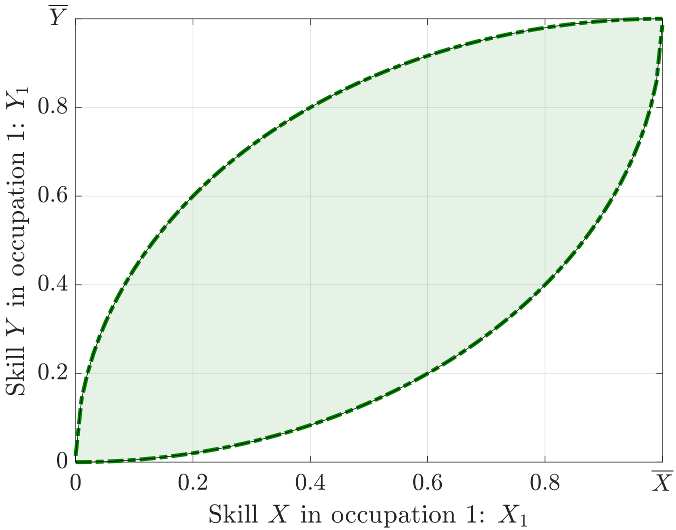
- Result. If the skill distribution $H(x, y)$ has no mass points, then

  1. $\underline{B}$ is strictly increasing, strictly *convex*
  2. $\overline{B}$ is strictly increasing, strictly *concave*
  3. Continuously differentiable, with derivative $\underline{B}'(X_1) = y(i^*) \big/ x(i^*)$

Feasible Allocations

Feasible allocations must satisfy *aggregate bundling constraint* $Y_1 \in [\underline{B}(X_1), \overline{B}(X_1)]$.
Determined by joint distribution of skills $H(x, y)$, independent of technology.



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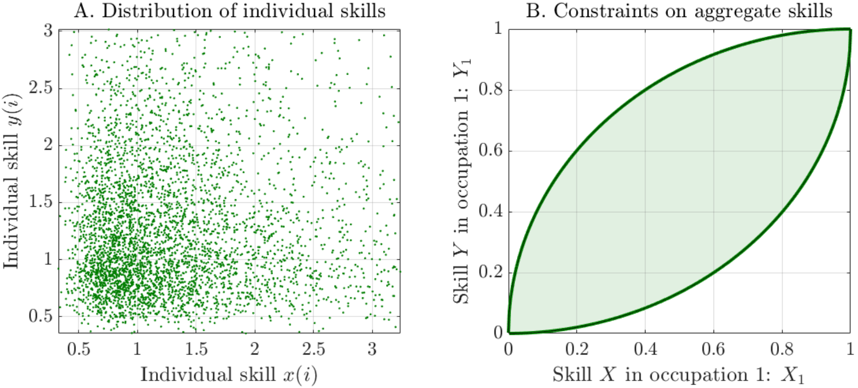

Independent skills $H(x, y) = H_X(x)H_Y(y)$.

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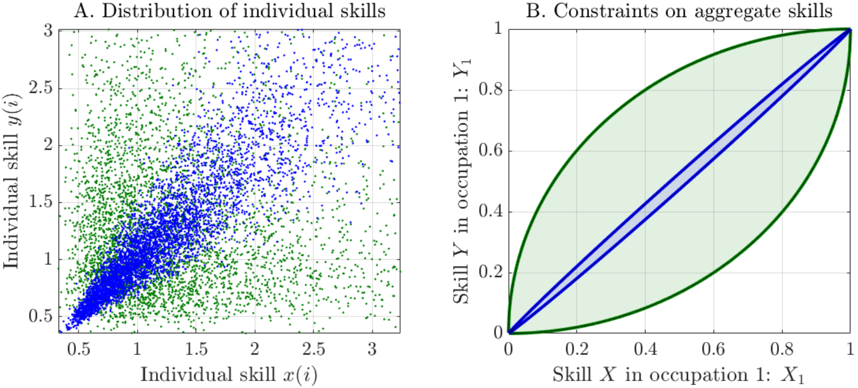

Positively correlated skills $H(x,y)$, shrinks feasible set.

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Feasible allocations must satisfy *aggregate bundling constraint* $Y_1 \in [\underline{B}(X_1), \overline{B}(X_1)]$.
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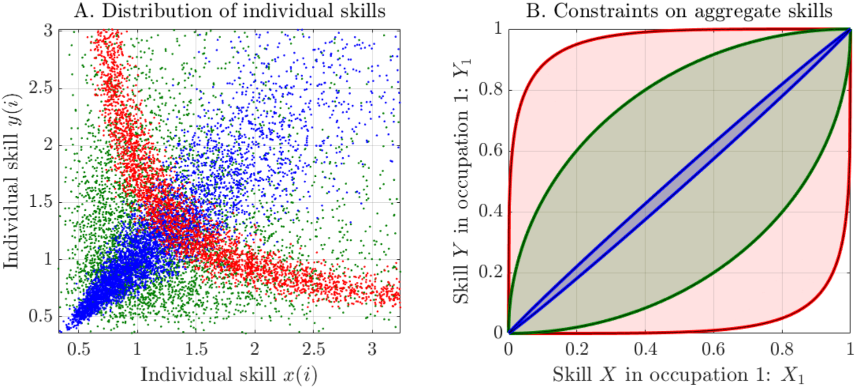

Negatively correlated skills $H(x, y)$, expands feasible set.

Efficient Allocation

$$\max_{X_1, Y_1} U\Big(F_1\Big(X_1, Y_1\Big), F_2\Big(\overline{X} - X_1, \overline{Y} - Y_1\Big)\Big)$$

subject to aggregate bundling constraint

$$\underbrace{Y_1 \geq \underline{B}(X_1)}_{\text{Multiplier: } \underline{\mu}} \qquad \underbrace{Y_1 \leq \overline{B}(X_1)}_{\text{Multiplier: } \overline{\mu}}$$

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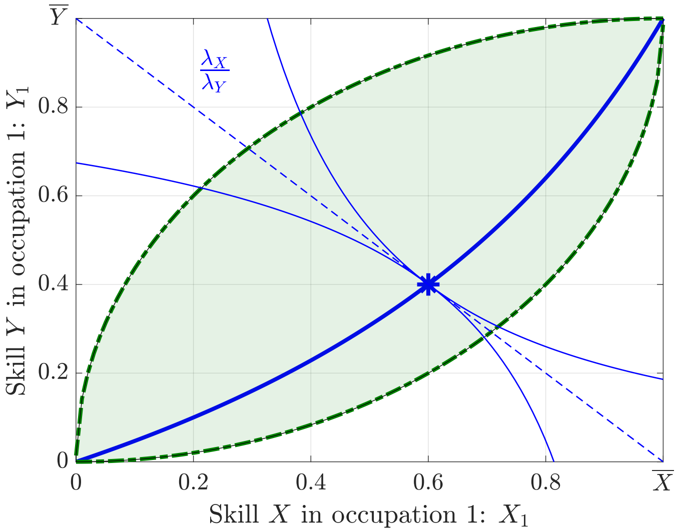
- First order conditions

$$\begin{aligned} X_1: &\quad \lambda_{1X} &= &\quad \lambda_{2X} + \underline{\mu}\, \underline{B}'(X_1) \\ Y_1: &\quad \lambda_{1Y} &= &\quad \lambda_{2Y} - \underline{\mu} \end{aligned}$$

- Multiplier $\underline{\mu}$ does not appear in original problem, but is key to skill prices

Unbundled Allocation

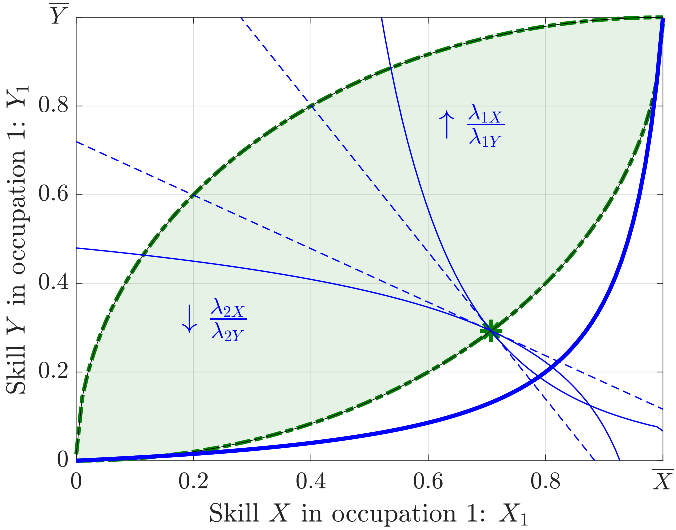
'Contract curve' equates marginal rates of technical substitution: $F_{1X}/F_{1Y} = F_{2X}/F_{2Y}$.
Unbundled allocation $(*)$ equates U_1/U_2 to marginal rate of transformation F_{2k}/F_{1k}.



Bundled Allocation

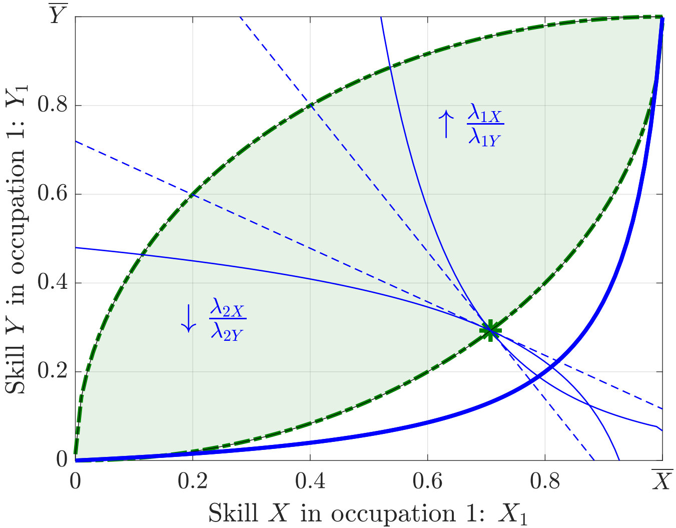
Bundling constraint binds. Cannot 'break open' workers to get at underlying skill content.

$$U_1\left[F_{1X} + \underline{B}'(X_1)F_{1Y}\right] = U_2\left[F_{2X} + \underline{B}'(X_1)F_{2Y}\right], \qquad Y_1 = \underline{B}(X_1)$$



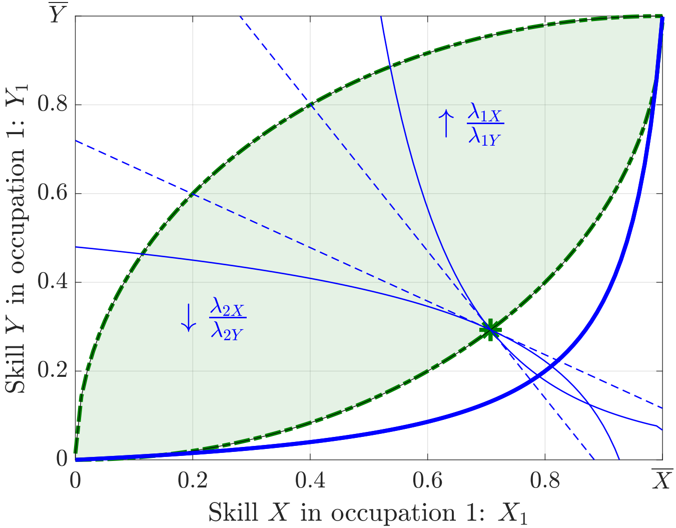
Wages

$$w_1(i) = \lambda_{1X} x(i) + \lambda_{1Y} y(i)$$



Wages

$$\log w_1(i) = \log \lambda_{1Y} + \log y(i) + \log\left(1 + \uparrow\left(\frac{\lambda_{1X}}{\lambda_{1Y}}\right)\left(\frac{x(i)}{y(i)}\right)\right)$$



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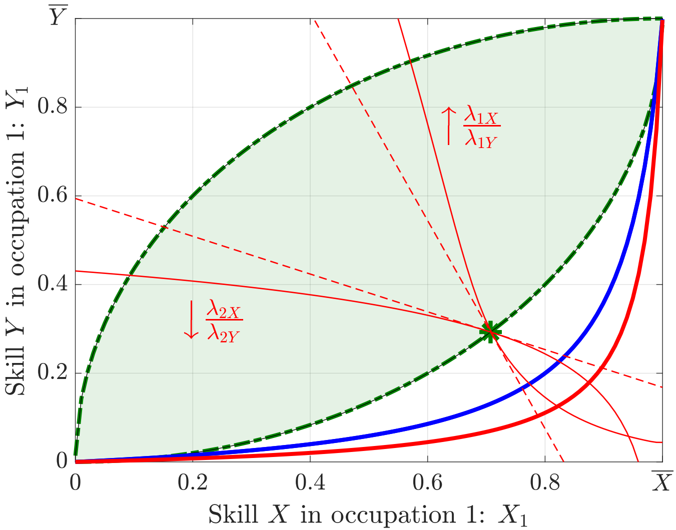


Analytics - Symmetry

- *When is the equilibrium bundled or unbundled?*

- Definition - *symmetric economy*. Weight α on primary skill, $\overline{X} = \overline{Y}$, no other restrictions on $H(x, y)$

- Result. For each symmetric economy unique factor intensity α^* such that:

  (i) The equilibrium is unbundled if and only if $\alpha \leq \alpha^*$.

  (ii) If unbundled, then $X'(\alpha) > 0$, and $\mu(\alpha) = 0$.

  (iii) If bundled, then $X(\alpha) = X(\alpha^*)$ and $\mu(\alpha) > 0$ with $\mu'(\alpha) > 0$.

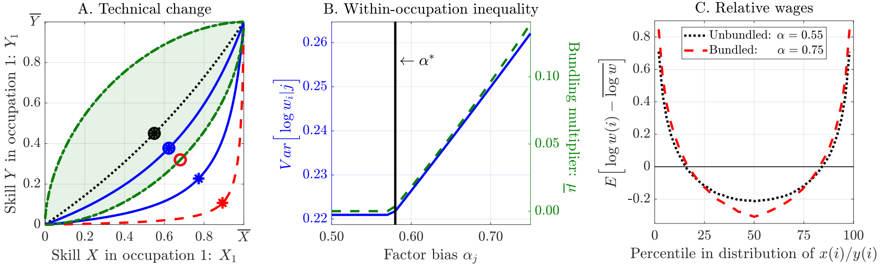
- *What implications does this have for wages?*

- Result. For each occupation j there is a unique factor intensity $\alpha_j^{**} \geq \alpha^*$, that depends on moments of $H(x, y)$, such that $\uparrow \alpha$ increases the *variance of log wages* in occupation j if and only if $\alpha > \alpha_j^{**}$

▸ Details - Formulas for α^* and α^{**}

Skill Bias and Inequality

Varying $\alpha \in \{0.50, \ldots, 0.75\}$. As occupations become more different, bundling constraint binds and *primary* skill prices increase relative to *secondary* skill prices.



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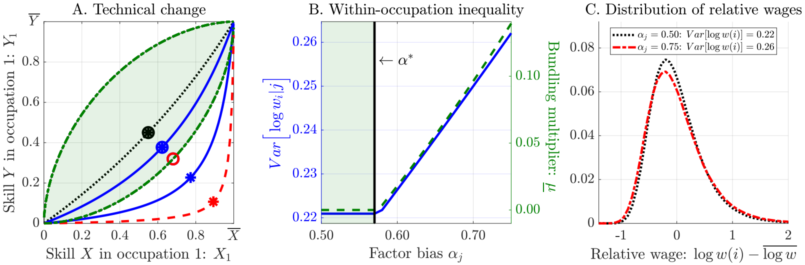

Low Skill Occupations in the US: 1970 vs 2020

$\Uparrow$ *Skill bias* $\rightarrow$ *Bundled / Sorted Equilibrium* $\rightarrow$ $\Uparrow$ *Inequality*

$\Downarrow$ *Skill bias* $\rightarrow$ *Unbundled / Unsorted Equilibrium* $\rightarrow$ $\Downarrow$ *Inequality*

Three Special Cases

$$\underbrace{\textit{Katz-Murphy}}_{\theta\ \to 1},\ \underbrace{\textit{Roy}}_{\alpha_j \to 1},\ \underbrace{\textit{Lindenlaub}}_{J \to \infty}$$

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1. *Katz-Murphy*

$$F_1 = \Big[\, \alpha_{1L} L^{\sigma} \quad + \ \alpha_{1H} H^{\sigma} \Big]^{\frac{1}{\sigma}}, \qquad \boldsymbol{x}(i) \in \Big\{ \Big(l(i), 0 \Big)\ ,\ \Big(0, h(i) \Big) \Big\}$$

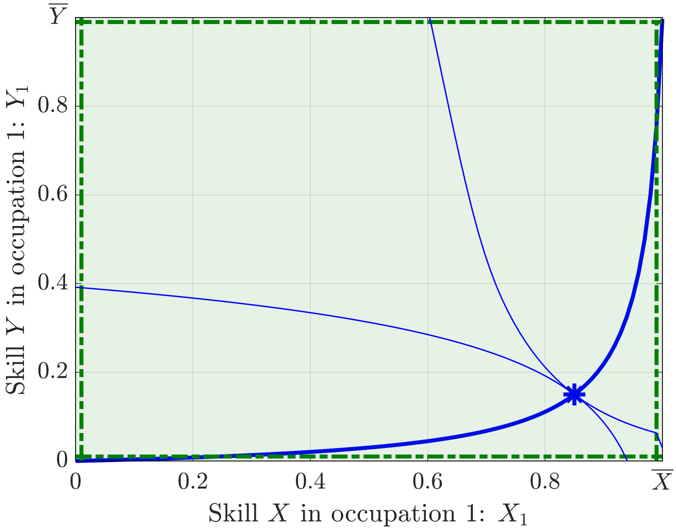
- *"Complete" skill supply* $\Rightarrow$ *Always unbundled*

- Law of one price holds for each skill

$$\begin{aligned} w(i) &= \lambda_L l(i) + \lambda_H h(i) \\ var\Big(\log w(i) \,\Big|\, 1 \Big) &= var\Big(\log w(i) \Big) \end{aligned}$$

1. Katz-Murphy

Entire set feasible. Equilibrium always unbundled, regardless of technology. Workers not sorted. All workers indifferent. No returns to comparative advantage.



Three Special Cases

$$\underbrace{\textit{Katz-Murphy}}_{\theta\ \to 1},\ \underbrace{\textit{Roy}}_{\alpha_j \to 1},\ \underbrace{\textit{Lindenlaub}}_{J \to \infty}$$

2. *Roy model*

$$F_1 = Z_1 X_1, \qquad X_1 = \int x(i)\phi_1(i)\, di, \qquad x(i) = \exp\Big(\boldsymbol{\beta}'_X \boldsymbol{\xi}(i)\Big)$$

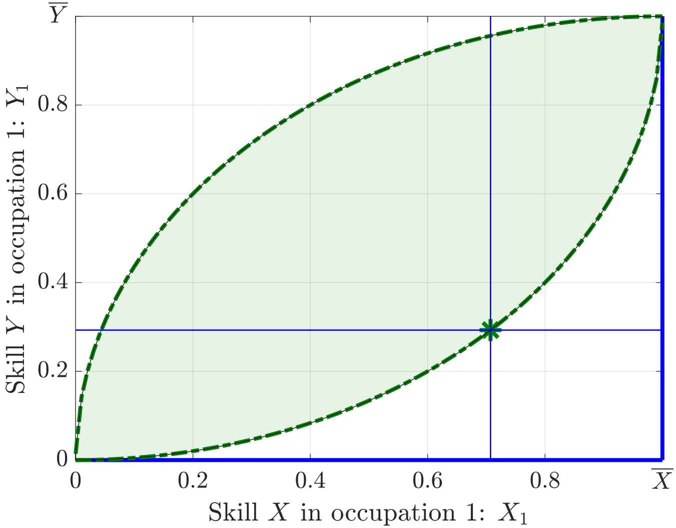
- *Extreme factor bias* $\Rightarrow$ *Always bundled*
- One positive price for each "skill composite"

$$w_1(i) \quad = \quad \lambda_{1X} x(i)$$

$$var\Big(\log w(i) \Big| 1\Big) \quad = \quad var\Big(\log x(i) \Big| i < i^*\Big)$$

2. Roy Model

Equilibrium always bundled. Workers sorted by comparative advantage. Skill prices $\lambda_{1X}/\lambda_{2Y}$ pinned down by relative skills of marginal worker. $w_1(i) = \lambda_{1X} x(i)$



Technology → Skill Prices → Inequality

- *Roy model* - Returns to individual characteristics $\boldsymbol{\xi}(i)$ are exogenous:

$$\log w_1(i) \quad = \quad \log \lambda_{1X} + \boldsymbol{\beta}'_X \boldsymbol{\xi}(i)$$

Skill prices enter only through occupation fixed effect

- *Our model* - To a first order approximation

$$\log w_1(i) \quad \approx \quad \log \overline{w}_1 + \widetilde{\boldsymbol{\beta}}'_1 \boldsymbol{\xi}(i), \qquad \widetilde{\boldsymbol{\beta}}_1 = \widetilde{\lambda}_1 \boldsymbol{\beta}_X + \left(1 - \widetilde{\lambda}_1\right) \boldsymbol{\beta}_Y$$

Returns to individual characteristics $\boldsymbol{\xi}(i)$ are endogenous to skill prices

$$\widetilde{\lambda}_1 = \frac{\lambda_{1X}\overline{x}_1}{\lambda_{1X}\overline{x}_1 + \lambda_{1Y}\overline{y}_1}$$

Shocks re-weight characteristics $\boldsymbol{\xi}(i)$ via changes in skill prices $\lambda_{1X}, \lambda_{1Y}$.
Roy model is special case where $\lambda_{1Y} = 0$ always.

Three Special Cases

$$\underbrace{\textit{Katz-Murphy}}_{\theta\ \to 1},\ \underbrace{\textit{Roy}}_{\alpha_j \to 1},\ \underbrace{\textit{Lindenlaub}}_{J\to\infty}$$

3. *Lindenlaub*

$$\int_0^j Y(j')\,dj' = \int_0^j X(j')\,dj' \quad \text{for all } j \in [0, J] \quad \rightarrow \quad \underline{\mu}_j$$

- *Continuum* $\alpha(j) \in [0,1]$ $\Rightarrow$ *1:1 matching* $\Rightarrow$ *All workers are marginal*

- Continuum of skill prices

$$w_j(i) \quad = \quad \lambda_X(j)x(i) + \lambda_Y(j)y(i)$$

$$var\Big(\log w(i)\,\Big|\,j\Big) \quad = \quad 0$$

Endogenous Technology

Endogenous Technology

Under what conditions do these changes in factor intensities emerge endogenously from an expansion in the set of available technologies?

1. Production function

$$F_j = \left[\alpha_j \Big(a_{jX} X_j \Big)^{\sigma} + (1 - \alpha_j) \Big(a_{jY} Y_j \Big)^{\sigma} \right]^{1/\sigma}, \qquad \sigma < 1$$

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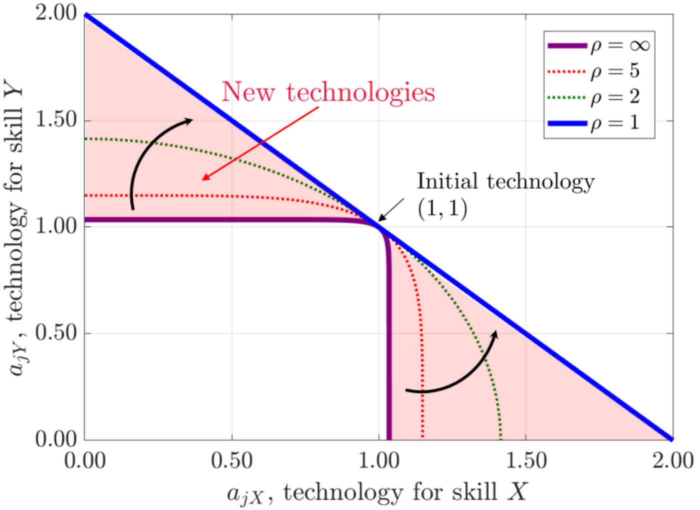
2. Technology frontier

$$\left[a_{jX}^{\rho} + a_{jY}^{\rho} \right]^{1/\rho} = \overline{A}_j, \qquad \rho > 1$$

- Problem. Taking skill prices $\lambda_{jX}, \lambda_{jY}$ as given, choose a_{jX}, a_{jY} to minimize marginal cost subject to technology frontier.

Available Technologies

Technology frontier $\left[a_{jX}^{\rho}+a_{jY}^{\rho}\right]^{1/\rho}=\overline{A}_j$. As $\rho\searrow 1$ can reach more combinations of a_{jX},a_{jY} for given $\overline{A}_j$.



Analytics - Symmetry

- Assumption. To rule out corner solutions:

$$\sigma < \frac{\rho}{1+\rho}$$

- Result. Bundling cutoff α^* is increasing in ρ if and only if $\sigma > 0$.

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- Application. Now consider reduction from $\rho = \infty$ to $\rho = 1$

  (i) *Short-run equilibrium*, $\rho = \infty$, as if exogenous $a_{jX}, a_{jY} = 1$

  (ii) *Long-run equilibrium*, $\rho = 1$, endogenous a_{jX}, a_{jY}

Analytics - Symmetry

- Result

  (i) If $\sigma > 0$, skills are *substitutes*, initially unbundled equilibrium becomes *endogenously bundled* if decrease in cutoff sufficiently large

$$\underbrace{\alpha^*_{\rho=1} \quad < \quad \alpha}_{\text{bundled in long run}} \quad < \quad \alpha^*_{\rho=\infty}$$

Analytics - Symmetry

- Result

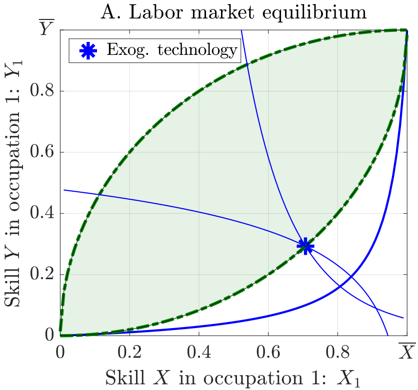
  (i) If $\sigma > 0$, skills are *substitutes*, initially unbundled equilibrium becomes *endogenously bundled* if decrease in cutoff sufficiently large

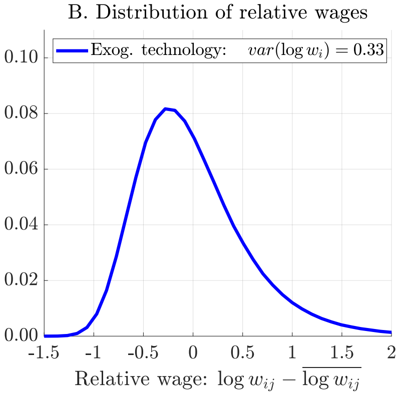
$$\underbrace{\alpha^*_{\rho=1} \quad < \quad \alpha}_{\text{bundled in long run}} \quad < \quad \alpha^*_{\rho=\infty}$$

  (ii) If $\sigma < 0$, skills are *complements*, initially bundled equilibrium becomes *endogenously unbundled* if increase in cutoff sufficiently large

$$\underbrace{\alpha^*_{\rho=1} \quad > \quad \alpha}_{\text{unbundled in long run}} \quad > \quad \alpha^*_{\rho=\infty}$$

Case (i) $\sigma > 0$. Bundling Labor

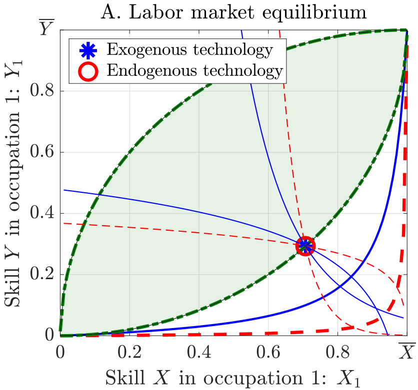


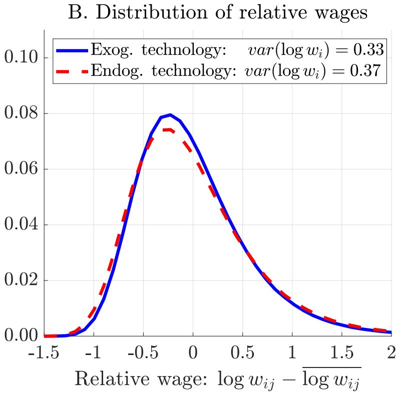


Skills are substitutes.

Case (i) $\sigma > 0$. Bundling Labor

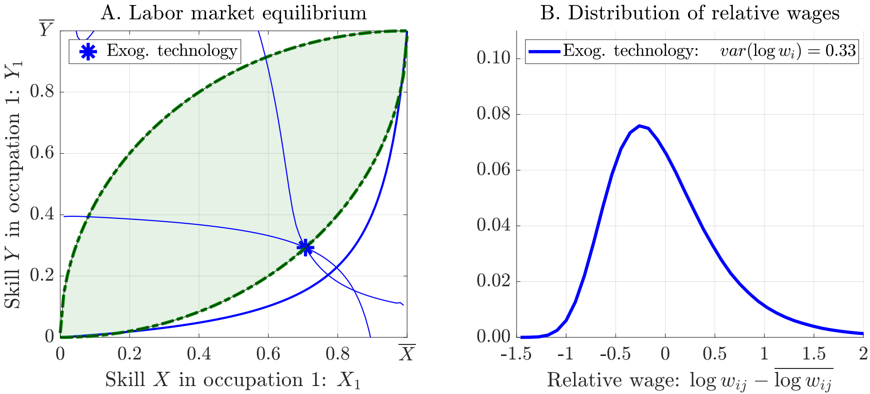
Endogenous technology more biased to primary skill, more "Roy-Like". Bundling constraints tighter. Greater returns to comparative advantage in primary skill. Increasing within-occupation wage inequality.





Skills are substitutes.

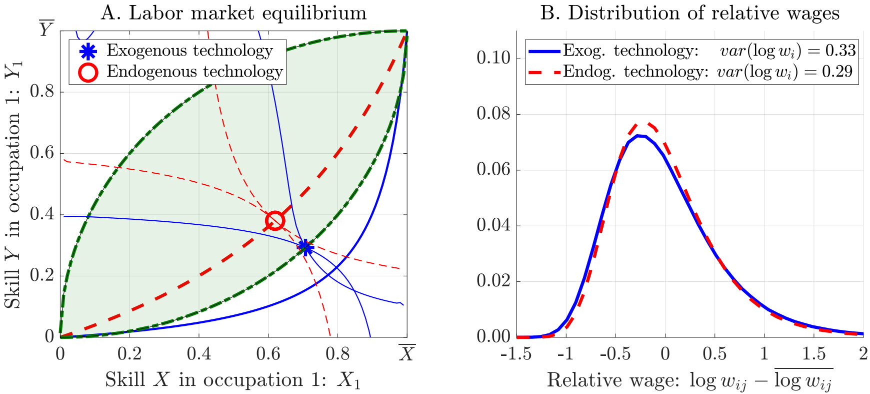
Case (ii) $\sigma < 0$. Unbundling Labor



Skills are complements.

Case (ii) $\sigma < 0$. Unbundling Labor

Endogenous technology less biased to primary skill, less "Roy-Like". Bundling constraints slacken. Lower returns to comparative advantage in primary skill. Decreasing within-occupation wage inequality.

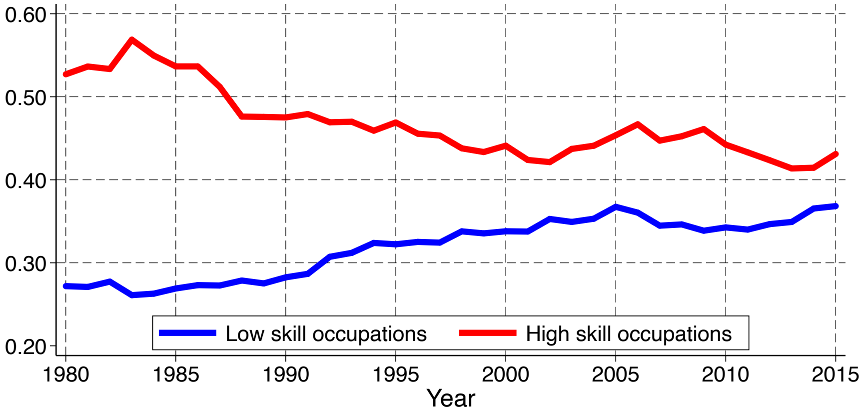


Skills are complements.

Additional Facts

Skip to End

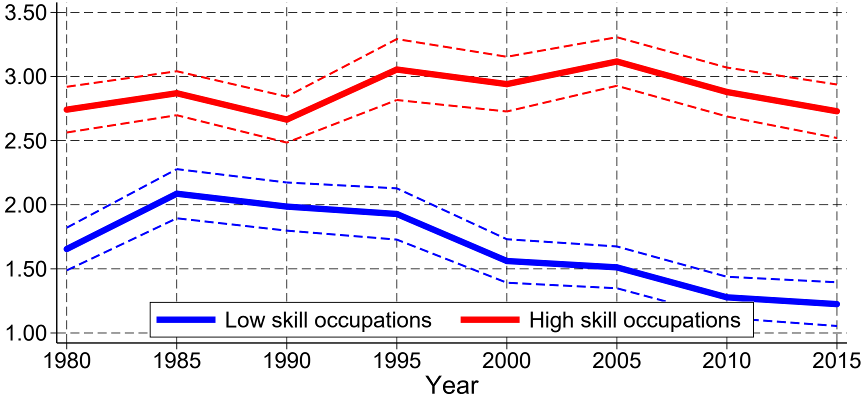
1. Occupation Switching



Fraction of ***male*** workers experiencing $\left\{E_{March}, \ldots, U_m, \ldots, E_{March'}\right\}$

that swap ***1-digit*** occupations across $\left\{E_{March}, E_{March'}\right\}$

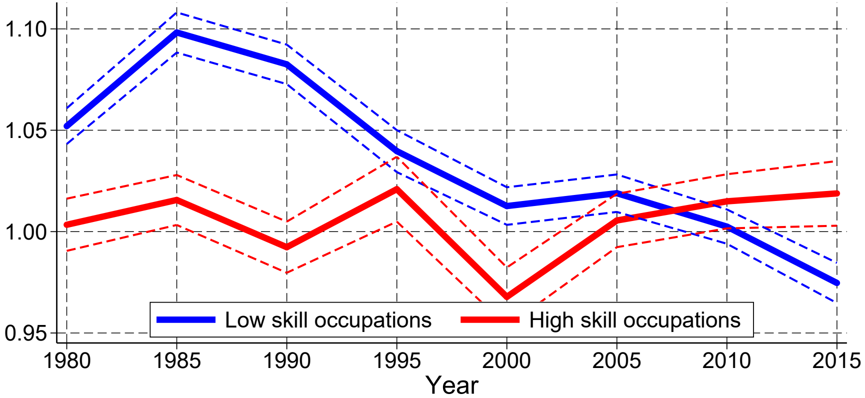
2. Experience Premium



One extra year experience associated with 2 to 3 percent higher wage

$$\log y_{it} \quad = \quad \alpha + \beta^{\tau}_{Exp} Exp_{it} + \beta^{\tau}_{Exp^2} Exp^2_{it} + \beta^{\tau}_{Hours} \log Hours_{it} + \beta^{\tau}_{Size} Size_{it} \ldots$$
$$+\beta^{\tau}_{X} \left[Year_t, Race_{it}, NAICS1_{it}, Ed_{it}, Sex_{it}\right]$$

3. Hours Premium



$(= 1)$: wage independent of hours, (≥ 1): wage increasing in hours

$$\log y_{it} = \alpha + \beta^{\tau}_{Exp} Exp_{it} + \beta^{\tau}_{Exp^2} Exp^2_{it} + \beta^{\tau}_{Hours} \log Hours_{it} + \beta^{\tau}_{Size} Size_{it} \ldots$$
$$+ \beta^{\tau}_{X} \left[Year_t, Race_{it}, NAICS1_{it}, Ed_{it}, Sex_{it} \right]$$

Interpreting These Facts

1. More *occupation switching* in low skill jobs

2. Smaller *experience premium* in low skill jobs

3. Smaller *overtime premium / part-time penalty* in low skill jobs

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- Unbundled equilibrium features indeterminate occupational choice

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1. More *occupation switching* in low skill jobs
   - Unbundled equilibrium features indeterminate occupational choice

2. Smaller *experience premium* in low skill jobs
   - Add learning by doing in the direction of occupation skill bias
     Cavounidis Lang (JPE, 2020)
   - Experience premium $\leftrightarrow$ Inframarginal rents
   - Unbundling labor reduces gradient of primary / secondary skill prices
   - Reduces observed experience premium

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3. Smaller *overtime premium / part-time penalty* in low skill jobs
   - Unbundlled equilibrium $\leftrightarrow$ Workers are more "substitutable"

Summary

1. Facts

A. Heterogeneity in skill requirements *across* occupations

$\downarrow$ Low skill jobs , $\uparrow$ High skill jobs

B. Inequality in wages *within* occupations

$\downarrow$ Low skill jobs , $\uparrow$ High skill jobs

2. Theory

- General equilibrium Rosen (1983), Heckman Scheinkman (1987)
- Technological change consistent with **A.** causes **B.**
- Nests three standard frameworks that are silent on links b/w **A.** and **B.**
- Endogenize **A.** as appropriate technology choice (Caselli Coleman 2006)
    - Expand set of available technologies
    - Endogenous unbundling when skills X and Y are substitutes
    - Endogenous bundling when skills X and Y are complements

Appendix

Fact A. - Technology

Input is a $J \times K$ normalized matrix of skill measures $\mathbf{A}$ from O*NET

1. Apply principal components with $K^* \ll K$

$$\mathbf{A}_{[J\times K]} = \widehat{\mathbf{A}}_{[J\times K^*]}\widehat{\mathbf{P}}_{[K^*\times K]} + \mathbf{U}_{[J\times K]}$$

2. To *name* skills, rotate principal components s.t. satisfy K^* orthogonality conditions

$$\mathbf{A}_{[J\times K]} = \left(\widehat{\mathbf{A}}_{[J\times K^*]}\Psi\right)\left(\Psi^{-1}\widehat{\mathbf{P}}_{[K^*\times K]}\right) + \mathbf{U}_{[J\times K]} \;\rightarrow\; \mathbf{A}^* = \widehat{\mathbf{A}}\Psi$$

$\Longrightarrow$ Final skill 1, places a weight of 1 on $k = 1$, and zero on $k \in \{2, \ldots, K^*\}$

3. Use as K^* 'anchoring' skills those used by Acemoglu Autor (2011)
   - Non-routine cognitive: Analytical - "Analyzing data / information"
   - Non-routine cognitive: Interpersonal - "Maintaining relationships"
   - Routine cognitive - "Importance of repeating the same tasks"
   - Routine manual - "Controlling machines and processes"

Back - Fact A. Technology

Empirics - Details

- All data based on March CPS "last year" questions
- Occupation, Industry - Dorn (1990) harmonized cross-walk
  - Drop military
  - Occupation skill = Fraction of workers with high-school or less
  - Occupations sorted on occupation skill
- Use Heathcote, Perri and Violante (2010)
  - Earnings = Wage income + $(2/3)\times$ Self employment income
  - Annual hours = *Weeks worked last year* $\times$ *Usual hours worked per week*
  - Wage = Earnings / Annual hours
  - Age 25-65, Wage > $0.5\times$ Federal minimum wage, Hours > One month of 8hr days
- Regression controls for residualized wage:
  - Worker education (3 levels), Industry (1 digit), Experience, Experience^2 Race, Log hours,
  - Experience = (age - max(years in school,12)) - 6

▸ Back - Wages

Analytics - Details

- Amount of X in occupation 1

$$X(\alpha) = \frac{\alpha^{\frac{1}{1-\sigma}}}{(1-\alpha)^{\frac{1}{1-\sigma}} + \alpha^{\frac{1}{1-\sigma}}}\,\overline{X}.$$

- Cut-off

$$\overline{X} - X(\alpha^*) = \underline{B}(X(\alpha^*))$$

- Variance of log wages - $\widehat{w}_j(i) = \zeta_{jX}\widehat{x}(i) + \zeta_{jY}\widehat{y}(i)$, within-$j$ deviations

$$\begin{aligned}\mathrm{Var}_j\left[\,\widehat{w}\,\right] &= \mathrm{Var}_j\left[\,\widehat{y}\,\right] + \zeta_{jX}^2\,\mathrm{Var}_j\left[\widehat{x} - \widehat{y}\right] + 2\zeta_{jX}\mathrm{Cov}_j\left[\,\widehat{y}\,,\,\widehat{x} - \widehat{y}\,\right] \\ \zeta_{jX} &= \frac{\lambda_{jX}\,\overline{x}_j}{\lambda_{jX}\,\overline{x}_j + \lambda_{jY}\,\overline{y}_j}\end{aligned}$$

- Cut-off - In symmetric economy RHS depends on distribution of skills

$$\left(\frac{\alpha_1^{**}}{1-\alpha_1^{**}}\right) \Big/ \left(\frac{\alpha^*}{1-\alpha^*}\right) = \underbrace{\left(\frac{\mathrm{Var}_1[\,\widehat{y}\,] - \mathrm{Cov}_1[\,\widehat{x}\,,\,\widehat{y}\,]}{\mathrm{Var}_1[\,\widehat{x}\,] - \mathrm{Cov}_1[\,\widehat{x}\,,\,\widehat{y}\,]}\right)\left(\frac{\overline{y}_1}{\overline{x}_1}\right)}_{\text{If this is } < 1\text{, then } \alpha^{**} = \alpha^*}$$

▸ Back - Propositions