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

This paper

1. Data

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. Competitive theory

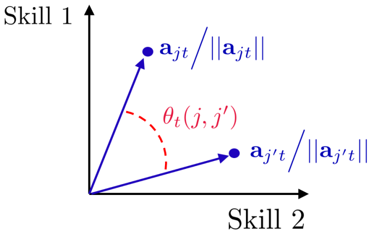
- Extend Rosen (1983), Heckman Scheinkman (1987)
- Technological change consistent with **A.** causes **B.**
- Nests three standard frameworks that are silent on links b/w **A.** and **B.**
- Endogenize **A.** as appropriate technology choice (Caselli Coleman, 2006)

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

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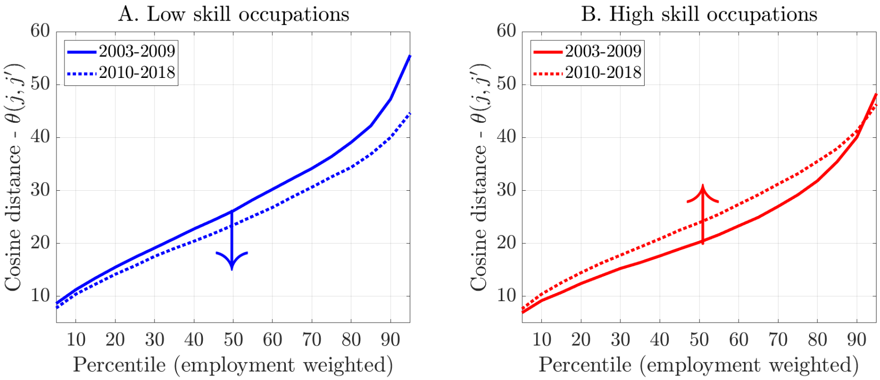
Low skill jobs have become more similar



- E.g. 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 $var\left(e_{it}\right)$ into within- and between-occupation components

Fact B. - Wages

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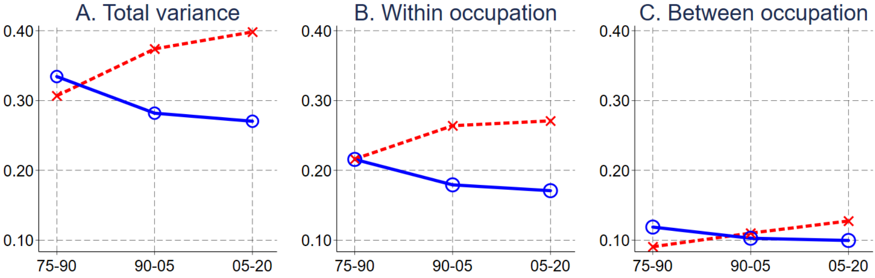
Wages in low skill jobs have become more similar



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

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

Details

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Model

- General equilibrium environment
  - Individual skills $\Big(x(i), y(i)\Big)$
  - Two occupations $j \in \{1, 2\}$, with different skill intensities

- Competitive equilibrium wages

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

- Within occupation inequality determined by two forces
  1. Distribution of skills conditional on selection
  2. Gradient of within-occupation skill prices $\{\lambda_{jX},\ \lambda_{jY}\}$

  Mandelbrot (1962) - Paretian Distributions and Income Maximization

Model

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Mandlebrot (1962) - Paretian Distributions and Income Maximization

Suppose that $w_j(i)$, which is the rental price which the occupation j is ready to pay for the use of a man's abilities, can be written as a linear form for K independent factors $x_k(i)$, each of which is randomly distributed in the population, and "measures" one of several "abilities". Then one can write:

$$w_j(i) = \sum_{k=1}^{K} \lambda_{jk} x_k(i)$$

... (The fact that the same commodity may have different prices with respect to different buyers $w_j(i)$, is a result of the impossibility of renting the different factors to different employers; we intend to discuss this question elsewhere)

Environment

- Workers $i \in [0,1]$ endowed with two skills $k \in \{x, y\}$

$$\Big(x(i), y(i)\Big) \sim H\Big(x, y\Big)$$

- Final good

$$U\Big(C_1, C_2\Big)$$

- Task / Occupation j technology:

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

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

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

Rosen (1983), Heckman Scheinkman (1987)

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

Let λ_{jX} be the shadow price of X_j

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

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

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

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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

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

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

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

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

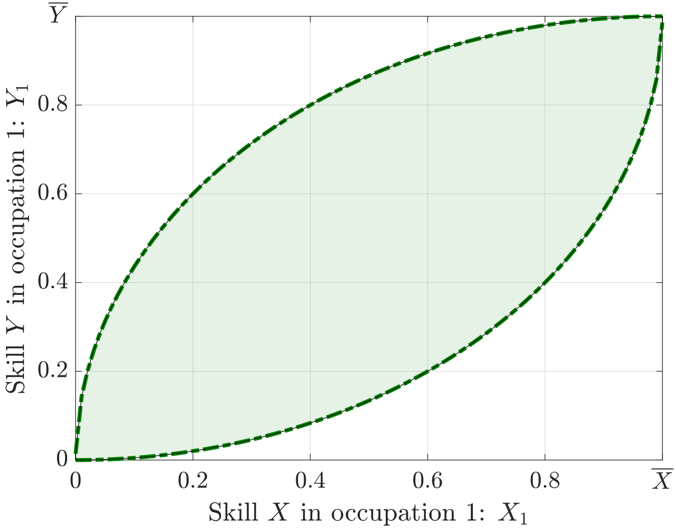
$$X_1 = \int_0^{i^*} x(i)\,di \quad , \quad \underline{B}(X_1) = \int_0^{i^*} y(i)\,di$$

Result - *If the skill distribution H 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* $\underline{B}'(X_1) = \dfrac{y(i^*)}{x(i^*)}$

Feasible allocations

Feasible allocations must satisfy aggregate *bundling constraint* $Y_1 \in [\underline{B}(X_1), \overline{B}(X_1)]$.
Determined by distribution of skill endowments only. Example: $x(i) \sim \textit{Fréchet}(\theta)$.



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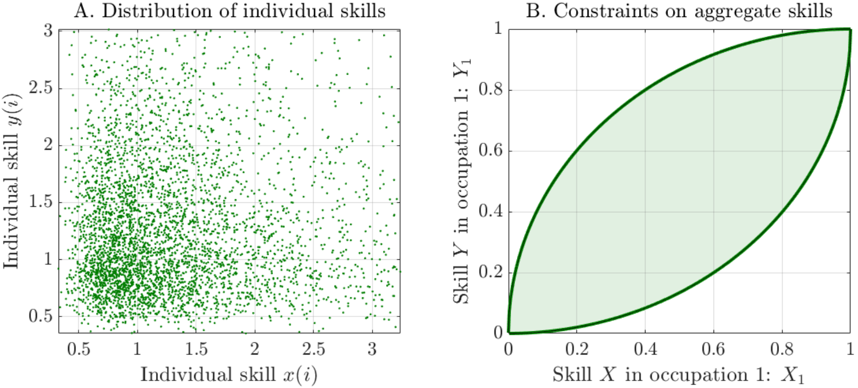

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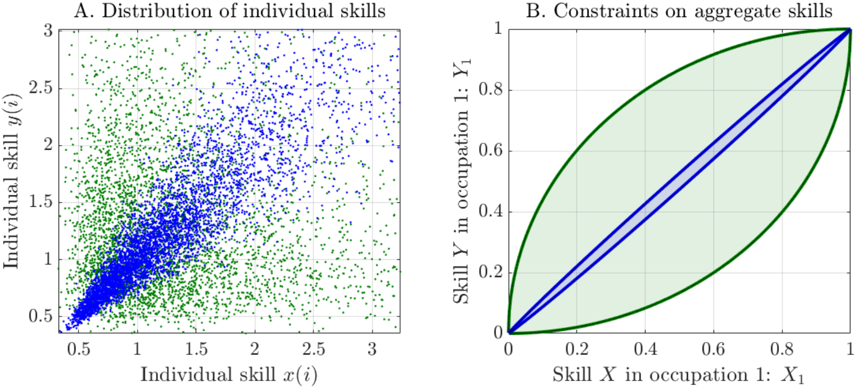

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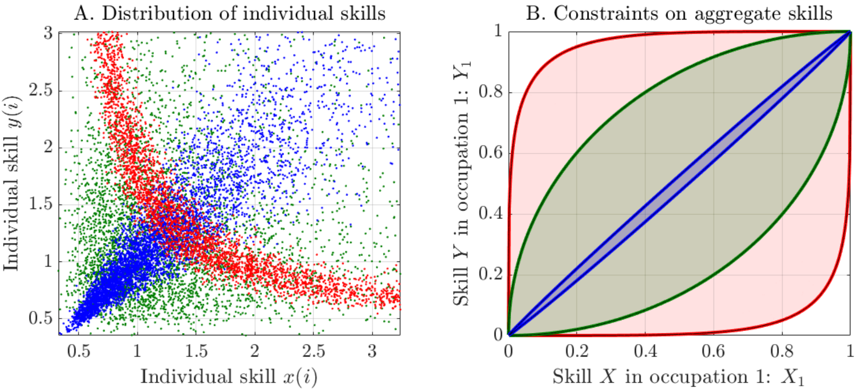

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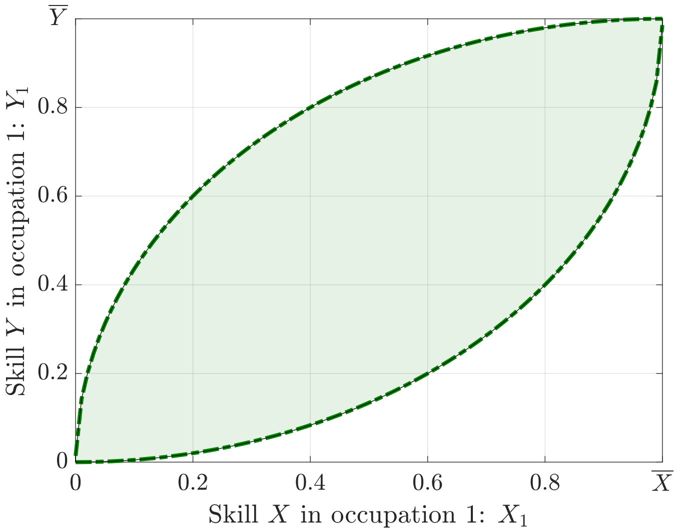

Efficient allocation

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

subject to

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

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First order conditions

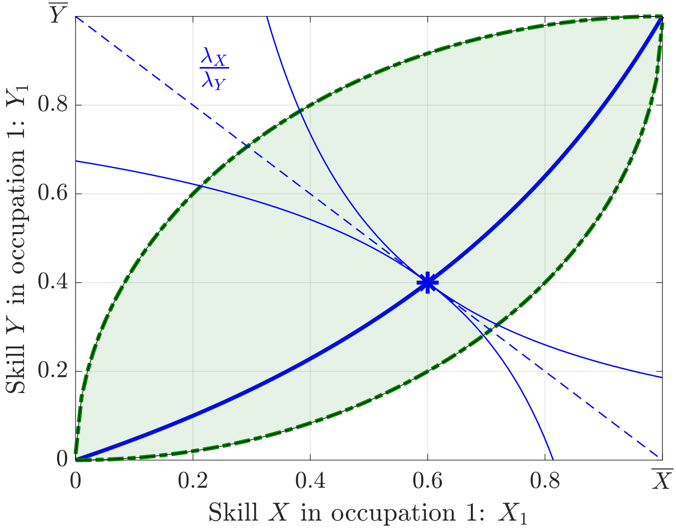
$$\begin{aligned} X_1: \quad & \lambda_{1X} = \lambda_{2X} + \underline{\mu}\,\underline{B}'(X_1) \\ Y_1: \quad & \lambda_{1Y} = \lambda_{2Y} - \underline{\mu} \end{aligned}$$

Results

1. Same allocation as ‘full’ problem, 2. Decentralization
3. Analytical comp. statics for $\underline{\mu}$ under Fréchet + Cobb-Douglas

Unbundled allocation

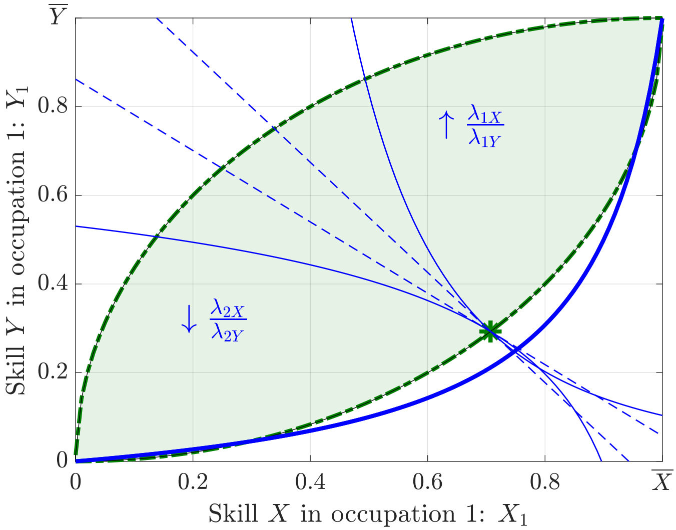
'Contract curve' equates marginal rates of technical substitution: $F_{1X}/F_{1Y} = F_{2X}/F_{2Y}$.
Unbundled allocation $(*)$ equates U_1/U_2 to marginal rate of transformation F_{2k}/F_{1k}.



Bundled allocation

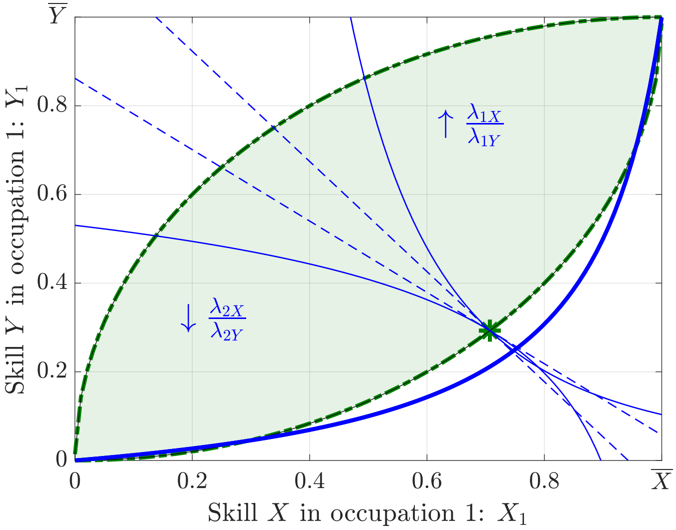
Bundling constraint binds. Cannot ‘break open’ workers to get at underlying skill content.

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



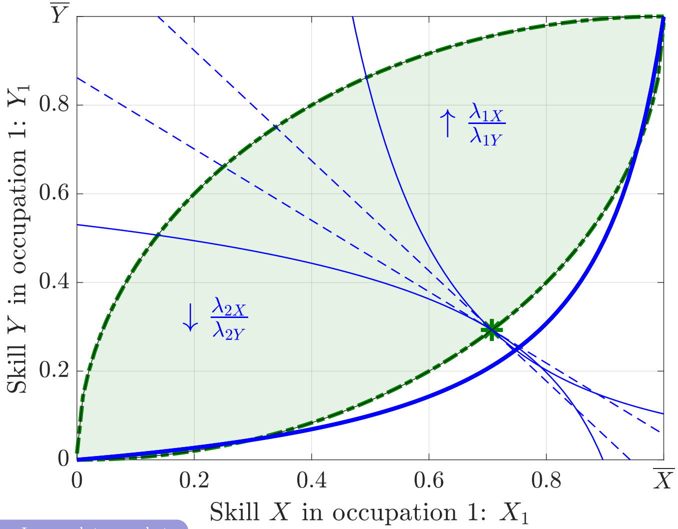
Wages

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



Wages

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



▸ Aside - Incomplete markets

Wages

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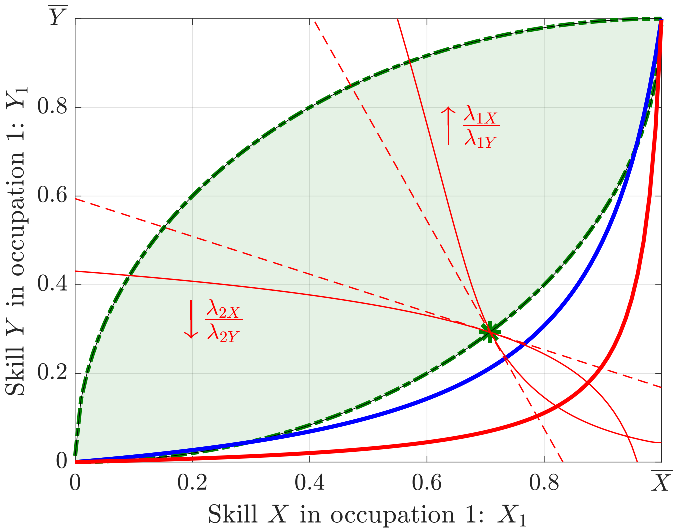


Symmetric Frechet example

1. Skills

$$x(i) \sim \mathit{Frechet}(\theta) \quad , \quad y(i) \sim \mathit{Frechet}(\theta) \quad , \quad \text{Tail: } 1/\theta \, , \, \theta > 1$$

2. Technology

$$F_1 = \Big[\alpha X_1^\sigma + (1-\alpha) Y_1^\sigma\Big]^{1/\sigma} \quad , \quad F_2 = \Big[(1-\alpha)\Big(1-X_1\Big)^\sigma + \alpha\Big(1-Y_1\Big)^\sigma\Big]^{1/\sigma}$$

- Bundling constraint

$$\underline{B}\Big(X_1\Big) = 1 - \Big(1 - X_1^{\frac{\theta}{\theta-1}}\Big)^{\frac{\theta-1}{\theta}} \quad , \quad \lim_{\theta\to\infty} \underline{B}(X_1) = X_1 \quad , \quad \lim_{\theta \searrow 1} \underline{B}(X_1) = 0$$

- If $\alpha < \alpha^*$ then *unbundled equilibrium*

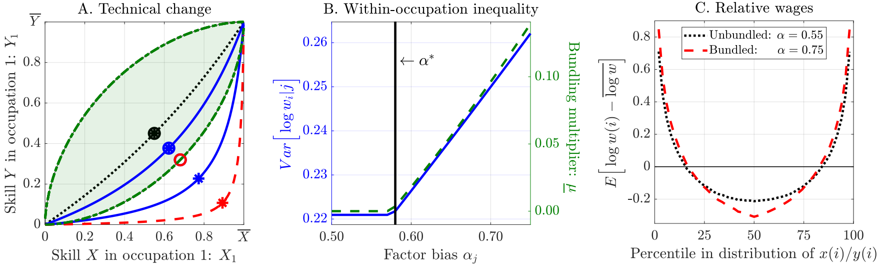
$$\uparrow\alpha^* = \frac{\uparrow\psi^{1-\sigma}}{1+\uparrow\psi^{1-\sigma}} \quad , \quad \uparrow\psi = \frac{1}{2^{1-\uparrow 1/\theta} - 1} \in \left[\frac{1}{2}, 1\right]$$

1. More dispersion of skills $\uparrow (1/\theta)$, increase $\alpha^* \to$ Unbundled

2. More complementary skills $\downarrow \sigma$, increase $\alpha^* \to$ Unbundled

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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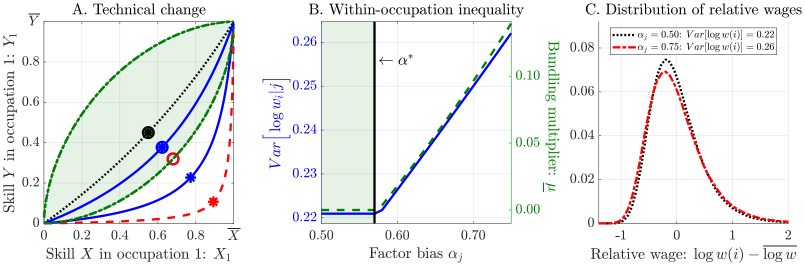

General symmetric case

Definition - Symmetric economy

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

Proposition 2

For a *symmetric economy*, $\exists$ a unique factor intensity α^* such that:

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

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

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

Proposition 3

For each occupation j there is a unique factor intensity $\alpha_j^{**} \geq \alpha^*$, that depends on moments of H, on the 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^{**}

General symmetric case

- 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

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

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

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

▸ Back - Propositions

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

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

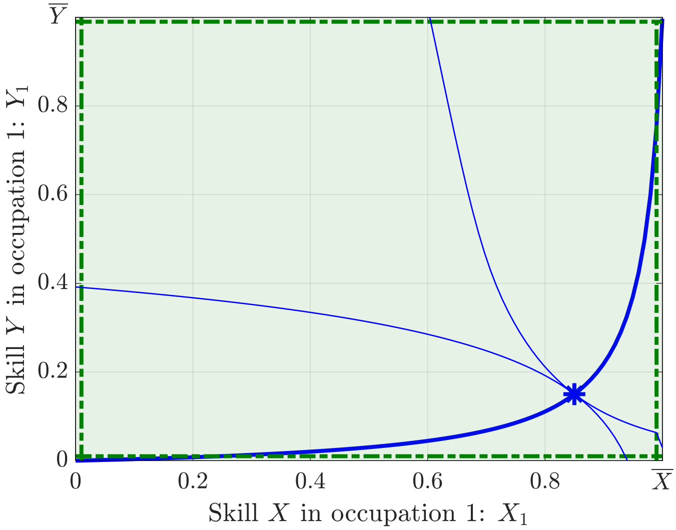
- *'Complete' skill supply* $\Rightarrow$ Always unbundled
- Law of one price holds for each skill

$$w(i) \quad = \quad \lambda_L l(i) + \lambda_H h(i)$$

$$var\Big(\log w(i) \,\Big|\, 1 \Big) \quad = \quad var\Big(\log w(i) \Big)$$

1. Katz-Murphy

Entire set feasible. Equilibrium always unbundled, regardless of technology. Workers not sorted. All workers indifferent. No rents due to comparative advantage. $w_j(i) = \lambda_X x(i)$



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

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

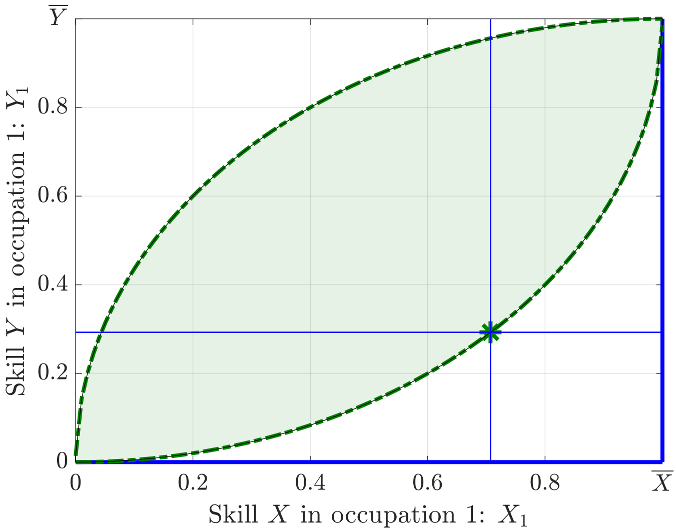
- *Extreme factor bias* $\Rightarrow$ Always bundled
- One positive price for each 'skill' composite

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

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

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, i^*. $w_1(i) = \lambda_{1X}x(i)$



Technology→Skill Prices→Inequality

- Roy - 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

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

Changes 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

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

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

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

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

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

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

- Continuum $\alpha(j) \in [0,1]$ $\Rightarrow$ *1:1 matching* $\Rightarrow$ All workers are marginal
- Suppose $\alpha(0) = 1$, all weight on X, then

$$\lambda_X(j) \;=\; \lambda_X(0) - \int_0^j \underline{\mu}_j \times \left(\frac{y(i^*(j))}{x(i^*(j))}\right) dj$$

E.g. *technology more diverse*, constraints tighten, $\uparrow$ gradient, $\uparrow$ inequality

This paper

1. Data

A. Heterogeneity in skill requirements across occupations

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

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- Extend Rosen (1983), Heckman Scheinkman (1987)
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  - Expand set of available technologies
  - Endogenous unbundling when skills X and Y are substitutes
  - Endogenous bundling when skills X and Y are complements

Thank you!

Appendix

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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1. Production function

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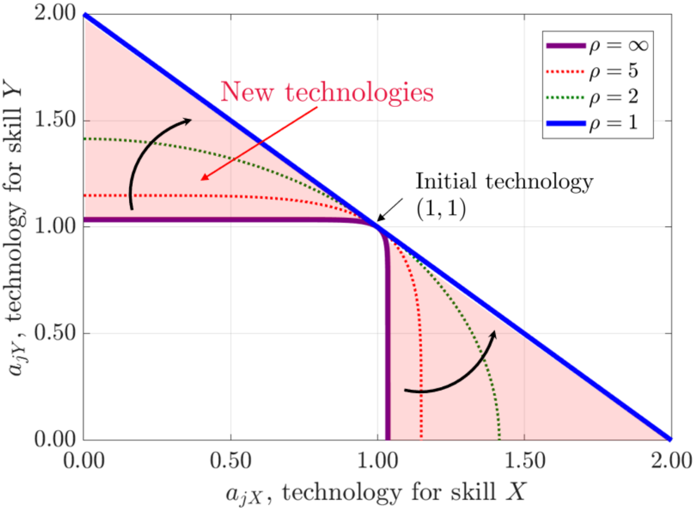
2. Minimize marginal cost subject to *available technologies*

$$\min_{a_{jX}, a_{jY}} \left[\left(\frac{\lambda_{jX}}{\alpha_j^{1/\sigma} a_{jX}}\right)^{\frac{\sigma}{\sigma-1}} + \left(\frac{\lambda_{jY}}{(1-\alpha_j)^{1/\sigma} a_{jY}}\right)^{\frac{\sigma}{\sigma-1}}\right]^{\frac{\sigma-1}{\sigma}}$$

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

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 $\overline{A}_j$.



Competitive equilibrium

- Skill prices determine technology adoption

$$\lambda_{jk} \qquad \Longrightarrow \qquad a^*_{jk}$$

Caselli-Coleman (2006)

- Adopted technology determines sorting and skill premia

$$a^*_{jk} \qquad \Longrightarrow \qquad \underline{\mu} \geq 0 \qquad \Longrightarrow \qquad \lambda_{jk}$$

Rosen (1983), Heckman Scheinkman (1987)

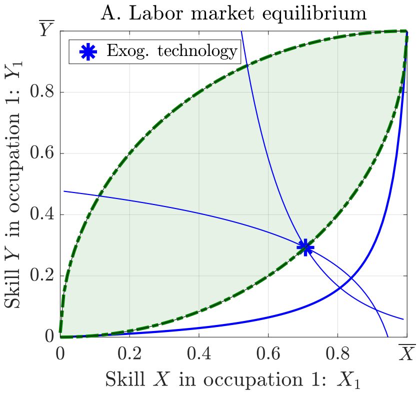
Example

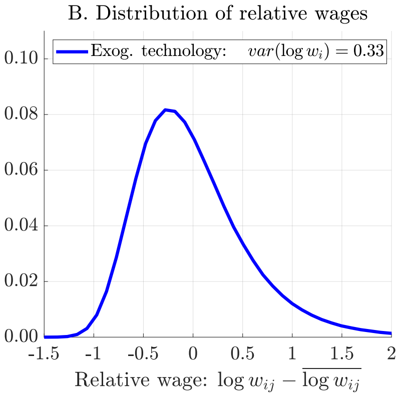
- Symmetric sectors
- Innate skill bias $\alpha_j = 0.8$
- Short-run $\rho = \infty \implies a_{jk} = 1$
- Long-run $\rho = 1$, choose technologies
- Production function CES with e.o.s. σ
- Result

$\sigma > 0$	skills are substitutes	$\rightarrow$ *bundling*	$\sim$ High skill occupations
$\sigma < 0$	skills are complements	$\rightarrow$ *unbundling*	$\sim$ Low skill occupations

Bundling labor: $\sigma > 0$

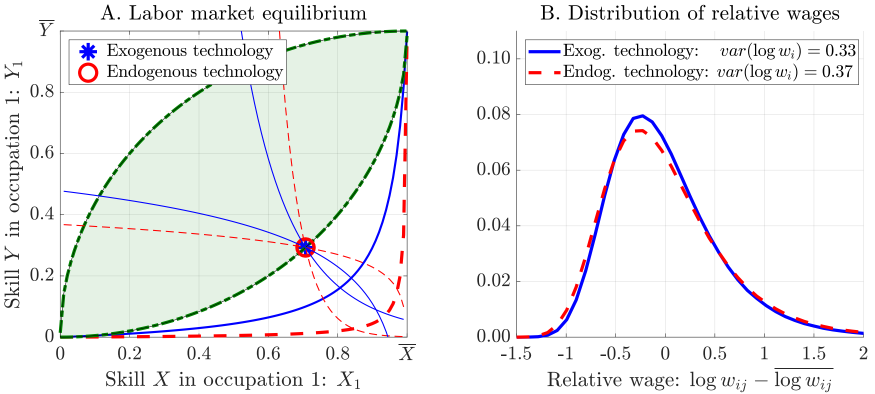
Skills are <u>substitutes</u>, $\sigma > 0$.





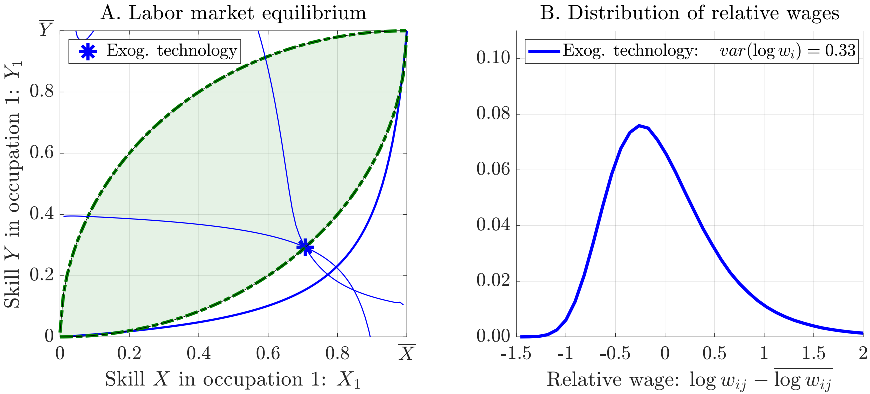
Bundling labor: $\sigma > 0$

Skills are substitutes, $\sigma > 0$. Choose technology more skill biased. *Endogenously more 'Roy-like'. Bundling constraints tighter. Specialist wages increase. Increasing inequality.*



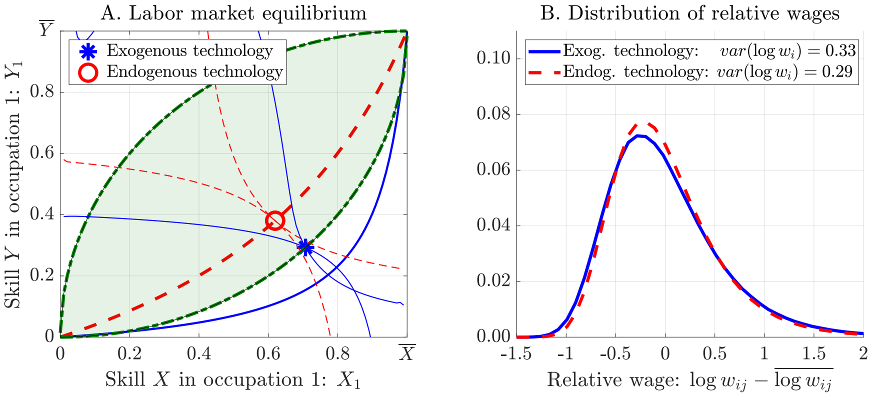
Unbundling labor: $\sigma < 0$

Skills are complements, $\sigma < 0$.



Unbundling labor: $\sigma < 0$

Skills are complements, $\sigma < 0$. Choose technology less skill biased. *Bundling constraints slack. Wage gains for generalists. Wage losses for specialists. Decreasing inequality.*



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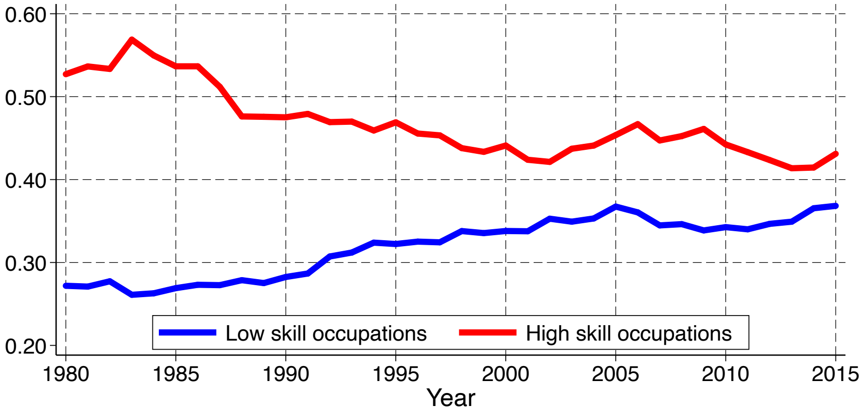
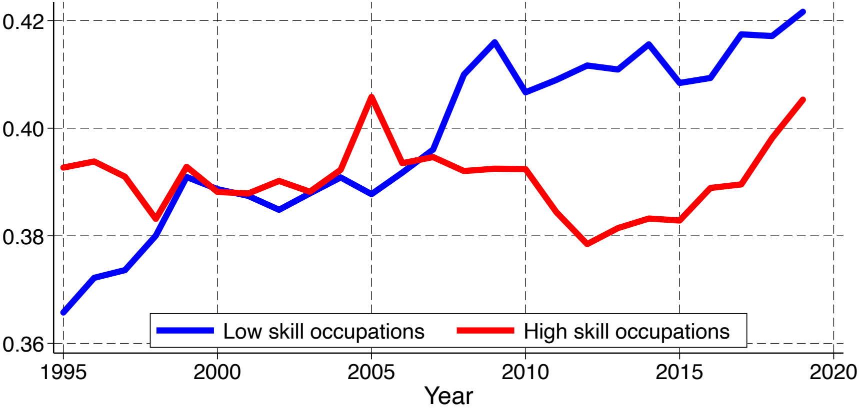
1. Occupation switching



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

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

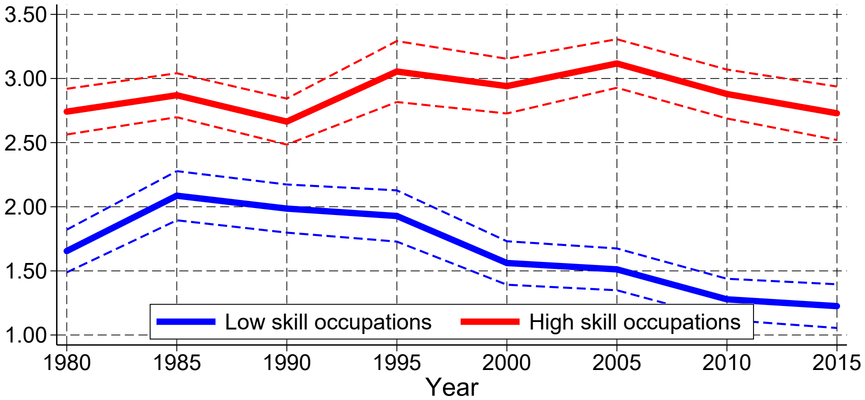
1. Occupation switching



Fraction of **male** workers experiencing $\left\{E_{Month}, E_{Month+1}\right\}$

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

2. Experience premium

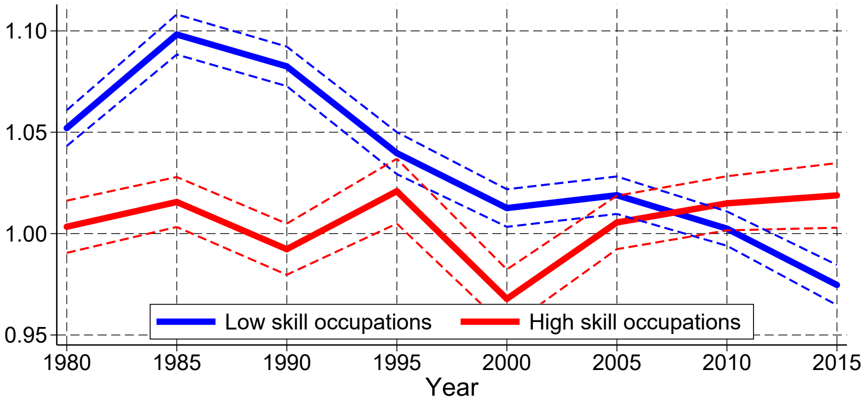


One extra year experience associated with 2 to 3 percent higher wage

$$\log Inc_{it} = \alpha + \beta^{\tau}_{Exp} Exp_{it} + \beta^{\tau}_{Exp^2} Exp^2_{it} + \beta^{\tau}_{Hours} \log Hours_{it} + \beta^{\tau}_{Size} Size_{it} \ldots$$

$$+ \beta^{\tau}_{X} \left[Year_t, Race_{it}, NAICS1_{it}, Ed_{it}, Sex_{it} \right]$$

3. Hours premium



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

$$\log Inc_{it} \quad = \quad \alpha + \beta^{\tau}_{Exp} Exp_{it} + \beta^{\tau}_{Exp^2} Exp^2_{it} + \beta^{\tau}_{Hours} \log Hours_{it} + \beta^{\tau}_{Size} Size_{it} \ldots$$

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Interpreting other facts

1. Increasing *occupation switching* in low skill jobs

2. Declining *experience premium* in low skill jobs

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

Interpreting other facts

1. Increasing *occupation switching* in low skill jobs

- Unbundled equilibrium features indeterminate occupational choice

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Interpreting other facts

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2. Declining *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

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

Interpreting other facts

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- Unbundling labor reduces gradient of primary / secondary skill prices
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3. Declining *overtime premium / part-time penalty* in low skill jobs

- Requires more work to extend the model
- Unbundling labor $\leftrightarrow$ Workers are more ‘substitutable’

Conclusions

- Deviations from law of one price for skills if either
  (i) technologies sufficiently factor biased, or
  (ii) weak pattern of comparative advantage in skills

- Can generate opposite trends in *within-occupation wage inequality* from technology adoption consistent with the data

- If skills *substitutes*, technology adoption *tightens bundling constraints*
  $\uparrow$ returns to comparative advantage, $\uparrow$ sorting
  $\uparrow$ within-occupation wage inequality
  Consistent with experience of *high skill occupations*

- If skills *complements*, technology adoption *can cause unbundling*
  $\downarrow$ returns to comparative advantage, $\downarrow$ sorting
  $\downarrow$ within-occupation wage inequality
  Consistent with experience of *low skill occupations*

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

Comparative statics

1. *Symmetric change in factor bias* - $\boldsymbol{\alpha}$
2. *Task-biased change* - Z_1
3. *Skill-biased change* - ψ_A
4. *Task-skill-biased change* - ζ_{1A}

$$U\left(Y_1, Y_2\right) = \left[\eta Y_1^{\frac{\phi-1}{\phi}} + (1-\eta) Y_2^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}} \qquad \phi > 1$$

$$Y_1 = Z_1\left[\zeta_{1A}\,\psi_A\,\alpha X_1^\sigma + (1-\alpha) Y_1^\sigma\right]^{\frac{1}{\sigma}}$$

$$Y_2 = \left[\psi_A\,(1-\alpha) X_2^\sigma + \alpha Y_2^\sigma\right]^{\frac{1}{\sigma}}$$

Within-occupation skill prices and inequality

1. Wages

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

2. Sorting
   - Occupation 1 chosen by individuals with high $\Uparrow x(i) \Big/ y(i)$

3. Inequality
   - Increases as gradient of skill prices steepens $\Uparrow \lambda_{1X} \Big/ \lambda_{1Y}$
   - Decreases as gradient of skill prices flattens $\Downarrow \lambda_{1X} \Big/ \lambda_{1Y}$

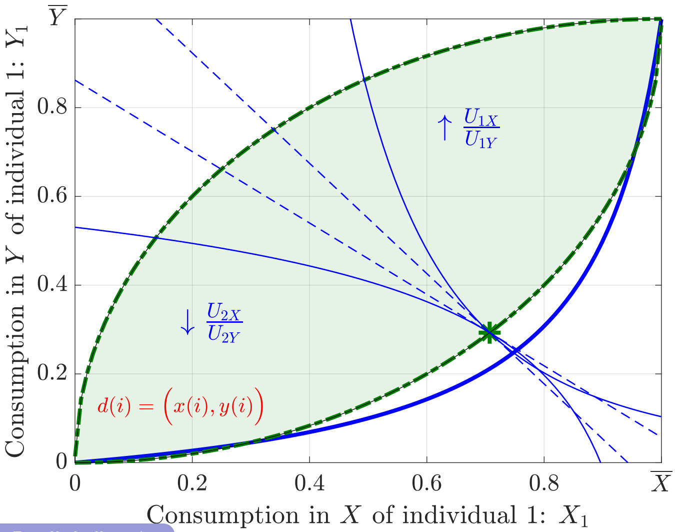
   In the paper
   - Closed form example under $\big(x(i), y(i)\big) = \big(e^{\alpha(1-i)}, e^{\alpha i}\big)$
   - Log-linear approximation to compute conditional variance
   - Decomposes $var\,(\log w(i)|j)$ into (i) Endowments, (ii) Prices

Results - Closed form example

Incomplete markets allocation

Bundling constraint binds. Cannot 'break open' assets to get at underlying arrow securities

$$U_{1A} + \underline{C}'(C_{1A})U_{1B} = U_{2A} + \underline{C}'(C_{1A})U_{2B}$$



Back - Bundled allocation

Link to Bais, Hombert, Weill (2020)

- Setup - Two agents $j \in \{1,2\}$ consume in two states $k \in \{A,B\}$
- Preferences - Expected utility of consumption

$$F_j\left(C_{jA}, C_{jB}\right) = \pi_A \alpha_j \frac{C_{jA}^{1-\gamma}}{1-\gamma} + \pi_B \left(1-\alpha_j\right) \frac{C_{jB}^{1-\gamma}}{1-\gamma} \quad , \quad \alpha_1 > \frac{1}{2} > \alpha_2$$

- Trees - Physical assets indexed $i \in [0,1]$ have payoffs

$$d(i) = \left(d_A(i), d_B(i)\right) \quad , \quad d_A(i)/d_B(i) \text{ decreasing in } i$$

- Budget constraints - Period-0 and Period 1, State-k

$$\int Q(i)\phi_j(i)\, di + q_A a_{jA} + q_B a_{jB} \quad \leq \quad \phi_j^0 \int Q(i)\, di$$

$$C_{jk} \quad = \quad \int \phi_j(i) d_k(i)\, di + a_{jk}$$

- Incentive compatibility - Only short arrow securities up to $(1-\delta)$ of tree payoffs

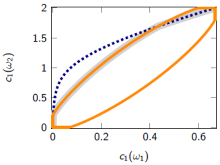
$$C_{jk} \geq \delta \int \phi_j(i) d_k(i)\, di \quad , \quad k \in \{A,B\}$$ Slack if $\delta = 0$. No shorts if $\delta = 1$

- Feasibility - What IC (C_{1A}, C_{2A}) can be supported by a set of trees?

$$C_{1A} = \delta \int_0^{k^*} d_A(i)\, di \rightarrow k^*(C_{1A}) \rightarrow \underline{C}_{1B}\left(C_{1A}\right) \geq \delta \int_0^{k^*(C_{1A})} d_B(i)\, di$$

Link to Bais, Hombert, Weill (2020)

the model in an edgeworth box



a graphical analysis of the incentive feasible set (IF set)

- area inside the orange curve: IF set with many trees and $\delta < 1$
- dotted-blue curve: Pareto set without IC constraints
- highlighted-grey curve: Pareto set with IC constraints

- Here w/out IC, trees redundant. Trade in Arrow securities. $Q(i) = \sum_k q_k d_k(i)$.
- If IC binds, ratios of marginal utilities not equated: $\lambda_{1X}/\lambda_{1Y} > \lambda_{2X}/\lambda_{2Y}$
- The price of tree i depends on which agent j holds it

$$Q_1(i) = q_A d_A(i) + (q_B - \delta\mu_{1B})\, d_B(i)\;,\; Q_2(i) = (q_A - \delta\mu_{1A})\, d_A(i) + q_B d_B(i)$$

- In equilibrium $\lambda_{1X} > \lambda_{2X}$ and $\lambda_{1Y} < \lambda_{2Y}$, which implies $\lambda_{1X} > \lambda_{1Y}$
- Result - Securities with more extreme pay-offs (specialists) are more expensive
- Result - Price of tree encodes constraint, lower than replicating arrow securities

Competitive equilibrium

$$\Pi_1 = \max_{X_1, Y_1} P_1 F_1\Big(X_1, Y_1\Big) - \text{Cost}_1\Big(X_1, Y_1\Big)$$

$$\text{Cost}_1\Big(X_1, Y_1\Big) = \min_{\widetilde{\phi}_1(i)} \int \widetilde{\phi}_1(i) w_1(i)\, di$$

subject to

$$X_1 = \int \widetilde{\phi}_1(i)\, x(i)\, di \quad \Big[\widetilde{\lambda}_{1X}\Big] \quad \longrightarrow \quad \widetilde{\lambda}_{1X} = P_1 F_{1X} \quad \Big(MC_{1X} = MRPL_{1X}\Big)$$

$$Y_1 = \int \widetilde{\phi}_1(i)\, y(i)\, di \quad \Big[\widetilde{\lambda}_{1Y}\Big] \quad \longrightarrow \quad \widetilde{\lambda}_{1Y} = P_1 F_{1Y} \quad \Big(MC_{1Y} = MRPL_{1Y}\Big)$$

Labor demand for each type

$$\widetilde{\phi}_1(i) = \begin{cases} 1 & , \quad \text{if} \quad \widetilde{\lambda}_{1X} x(i) + \widetilde{\lambda}_{1Y} y(i) > w_1\big(i\big) \\ 0 & , \quad \text{if} \quad \widetilde{\lambda}_{1X} x(i) + \widetilde{\lambda}_{1Y} y(i) < w_1\big(i\big) \\ \in (0,1) & , \quad \text{if} \quad \widetilde{\lambda}_{1X} x(i) + \widetilde{\lambda}_{1Y} y(i) = w_1\big(i\big) \end{cases}$$

Back - Two allocations

Competitive equilibrium

- Prices per efficiency unit of skill

$$\begin{aligned} w_j\left(l_A, l_B\right) &= \omega_{jA} l_A + \omega_{jB} l_B \\ \omega_{jk} &= P_j F_{jk} = U_j F_{jk} \end{aligned}$$

- Worker (l_A, l_B) chooses occupation $j = 1$ only if

$$w_1\left(l_A, l_B\right) > w_2\left(l_A, l_B\right)$$

- Cutoff worker indifferent

$$\underbrace{\frac{\lambda_{1X} - \lambda_{2X}}{\lambda_{2Y} - \lambda_{1Y}}}_{\text{Benefit of } j=1} = \underbrace{\left(\frac{l_B}{l_A}\right)^*}_{\text{Relative skill in } j=2} = \underline{B'}\left(X_1\right)$$

Under $\{\omega_{jk} = U_j F_{jk}\}$, this is the same condition as in the planner's problem

Back - Two allocations

Competitive equilibrium

- *Bundled equilibrium*: Sorting premia are increasing in $\underline{\mu}$

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

– Inframarginal workers earn rents due to comparative advantage, determined by sorting premia.

– Additional source of within-occupation wage inequality

- *Unbundled equilibrium*: Sorting premia are zero, indeterminate sorting

$$\begin{aligned} \lambda_{1X} - \lambda_{2X} &= 0 \\ \lambda_{2Y} - \lambda_{1Y} &= 0 \end{aligned}$$

– All workers are marginal. No rents due to comparative advantage.

Back - Two allocations

Generalized Roy model

- Individual-occupation specific output

$$y_j(i) = \exp\Big(\alpha_{j1}\xi_1(i) + \alpha_{j2}\xi_2(i)\Big) \quad , \quad Y_j = \int \phi_j(i) y_j(i)\, di$$

- The *only* priced objects are $y_1(i)$, $y_2(i)$ with prices w_1, w_2

$$\log w_j(i) = \log w_j + \alpha_{jA} x(i) + \alpha_{jB} y(i)$$

- In our case

$$\log w_j(i) \approx \log \overline{w}_j + \widetilde{\omega}_{jA} \widehat{l}_A(i) + \widetilde{\omega}_{jB} \widehat{l}_B(i)$$

1. Technology affects wages directly through the technology coefficients
2. Within occupation inequality effects are silo-ed:
   - Suppose that technology changes in occupation 2
   - All changes in the economy are encoded in the *occupation skill price* w_j, i.e. the occupation fixed effect
   - No change in incumbent *within occupation inequality* in occupation 1

▸ Back - Roy special case

Wage inequality - Closed form example

- Skills for individuals $i \in [0,1]$

$$\Big(x(i), y(i)\Big) = \Big(\gamma e^{\alpha(1-i)}, \gamma e^{\alpha i}\Big) \quad \rightarrow \quad y(i)/x(i) = e^{\alpha(2i-1)}$$

- Approximate log wage around mean log skills conditional on selection i^*

$$\log w(i,j) = \log \left[\lambda_{1X} e^{\log x(i)} + \lambda_{1Y} e^{\log y(i)}\right]$$

- Within occupation inequality

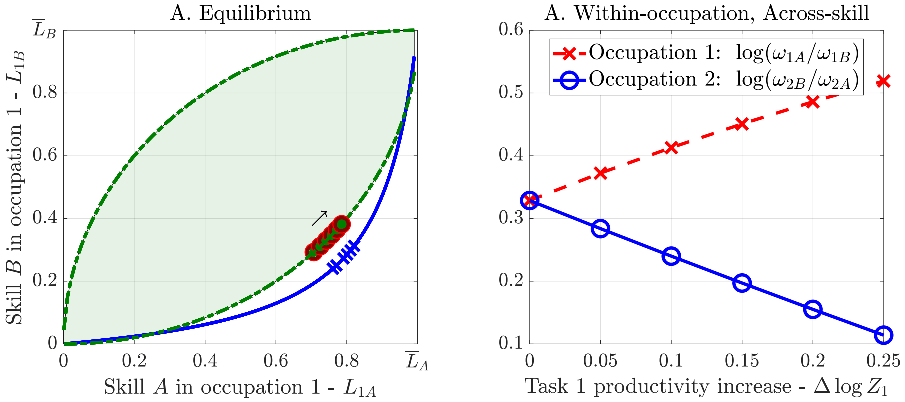
$$var\Big(\log(w(i)) \,\Big|\, j^*(i) = 1\Big) = \underbrace{\left(\frac{\left(\frac{\lambda_{1X}}{\lambda_{1Y}}\right) e^{\alpha(1-i^*)} - 1}{\left(\frac{\lambda_{1X}}{\lambda_{1Y}}\right) e^{\alpha(1-i^*)} + 1}\right)}_{\text{Bundling}} \underbrace{\alpha^2 \frac{i^{*\,2}}{12}}_{\text{Roy}}$$

1. Roy — As $\lambda_{1X}/\lambda_{1Y} \rightarrow \infty$, bundling terms goes to zero
2. Bundling — With finite $\lambda_{1X}/\lambda_{1Y}$, inequality increasing in ratio

▸ Back - Wage inequality

2. Task-Biased Change

Exogenous $\uparrow Z_1$, with $\phi > 1$: $\uparrow Y_1$, $\downarrow Y_2$.
Marginal worker has more Skill B, pushes up $\lambda_{1X}/\lambda_{1Y}$. Opposite for task 2.



Other parameters: $\alpha_{1A} = \alpha_{2B} = 0.80$, $\sigma = 0.20$, $\theta = 2$, $\overline{L}_1 = \overline{L}_2 = 1$, $Z_2 = 1$.

▸ Back - Comparative statics

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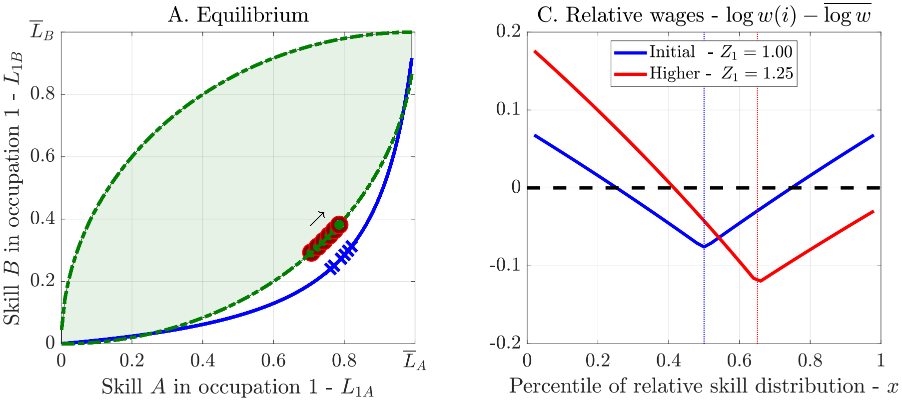

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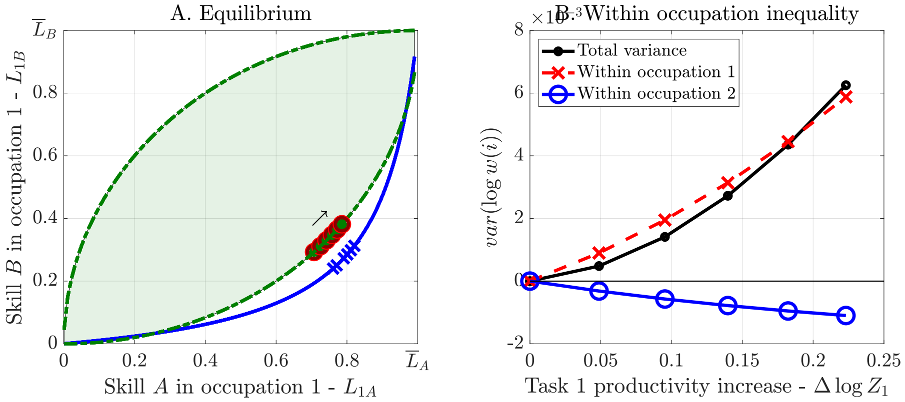

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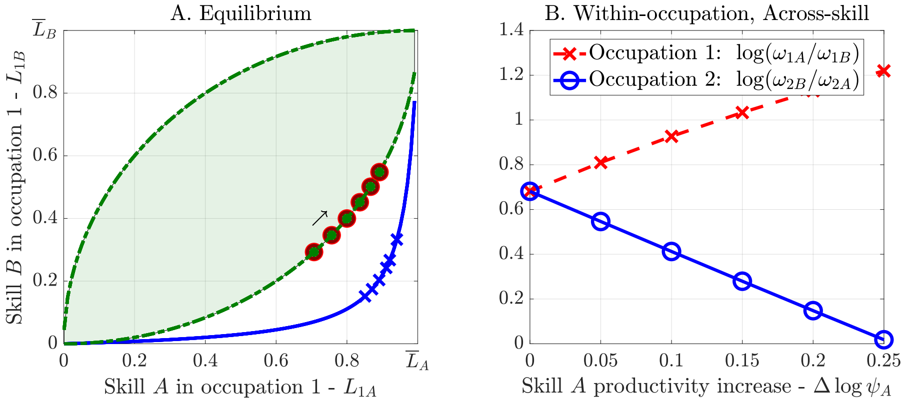
Back - Comparative statics

3. Skill-Biased Change

Exogenous $\uparrow \psi_A$, with $\phi > 1$, $\sigma > 0$: $\uparrow Y_1$, $\downarrow Y_2$.
Marginal worker has more Skill B, pushes up $\lambda_{1X}/\lambda_{1Y}$. Opposite for task 2.



Other parameters: $\alpha_{1A} = \alpha_{2B} = 0.80$, $\sigma = 0.20$, $\theta = 2$, $\overline{L}_1 = \overline{L}_2 = 1$, $Z_1 = Z_2 = 1$.

▸ Back - Comparative statics

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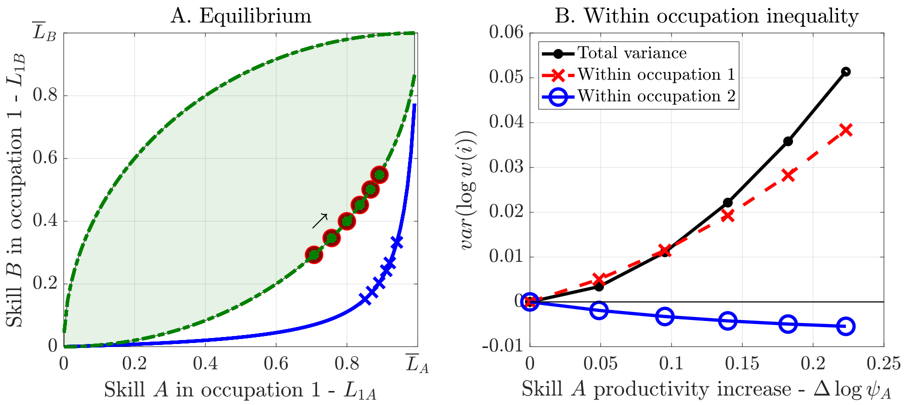
Exogenous $\uparrow \psi_A$, with $\phi > 1$, $\sigma > 0$: $\uparrow Y_1$, $\downarrow Y_2$.
Marginal worker has more Skill B, pushes up $\lambda_{1X}/\lambda_{1Y}$. Opposite for task 2.



Other parameters: $\alpha_{1A} = \alpha_{2B} = 0.80$, $\sigma = 0.20$, $\theta = 2$, $\overline{L}_1 = \overline{L}_2 = 1$, $Z_1 = Z_2 = 1$.

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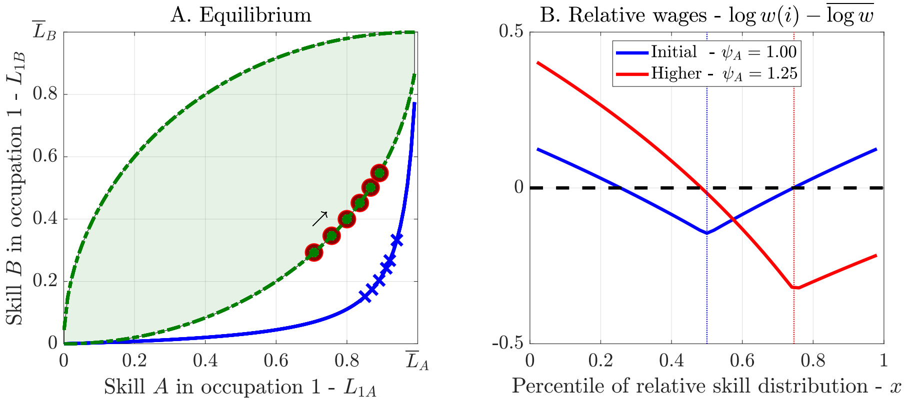
3. Skill-Biased Change

Exogenous $\uparrow \psi_A$, with $\phi > 1$, $\sigma > 0$: $\uparrow Y_1$, $\downarrow Y_2$.
Marginal worker has more Skill B, pushes up $\lambda_{1X}/\lambda_{1Y}$. Opposite for task 2.



Other parameters: $\alpha_{1A} = \alpha_{2B} = 0.80$, $\sigma = 0.20$, $\theta = 2$, $\overline{L}_1 = \overline{L}_2 = 1$, $Z_1 = Z_2 = 1$.

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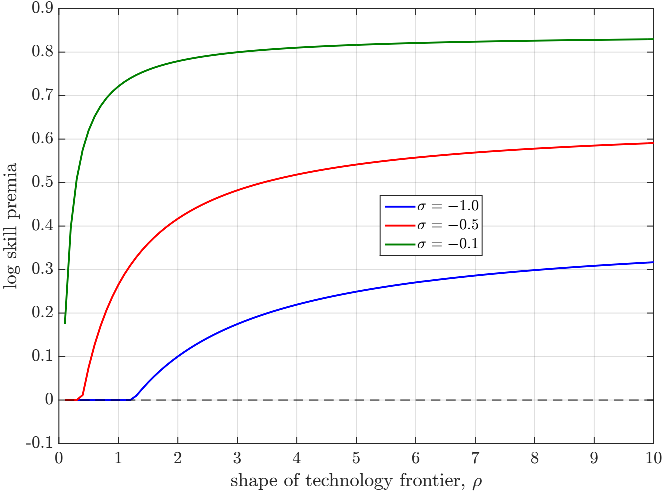
Unbundling Labor: $\downarrow \rho$, $\sigma < 0$

As ρ falls, technologies become 'more substitutable'. If $\sigma < 0$, firms undo existing skill bias, bundling constraints loosen, skill premia fall, wage gains for generalists. $p_A = \lambda_{1X} - \lambda_{2X}$



Extensions I

- Absolute vs. comparative advantage

$$\Big(l_1, l_2\Big) = \Big(\psi, \psi x\Big) \quad , \quad \Big(\psi, x\Big) \sim H\Big(\psi, x\Big)$$

  + fixed utility of being out of the labor market

- Selection on *x margin* (occupation) and on *ψ margin* (participation)

- RESULT: Competitive equilibrium allocation is efficient

Extensions I

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- What are the effects of adding a mass of *low-productivity unspecialized workers* ($\downarrow \psi$, $x \approx 1$)?

  (sr) wages and allocations for fixed technology

  (lr) wages and allocations for endogenous technology

Empirics - Details

- All data based on March CPS 'last year' questions

- Occupation, Industry - Dorn's 1990 harmonized cross-walk
  - Drop military
  - Occupation skill = Fraction of workers with high-school or less
  - Occupations sorted on occupation skill

- Use HPV (RED, 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

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Empirics - Regressions

1. Workers in low skill occupations getting paid more 'similarly'.

   - Reduced form empirical evidence from the CPS

$$\log Earnings_{i,t} = \gamma_t + \delta^{Occ}_{period} + \boldsymbol{\beta}'_{period}\mathbf{X}_{i,t} + \varepsilon_{i,t}$$

$$\mathbf{X}_{i,t} = \left[Year_t, NAICS1_{it}, Ed_{it}, Race_{it}, Sex_{it}, FirmSize_{it}, Exp_{it}, Exp^2_{it}, Hours_{it}\right]$$

   - Low skill: Decline in $\downarrow \widehat{\beta}_{period}$ for (i) experience, (ii) hours, (iii) large firm
   - High skill: No change

2. Anecdotal evidence from US labor market

   - Goldin Katz (2012) vs. David Weil (2014)
   - Hard to explain declining level of 'attachment' of working age men

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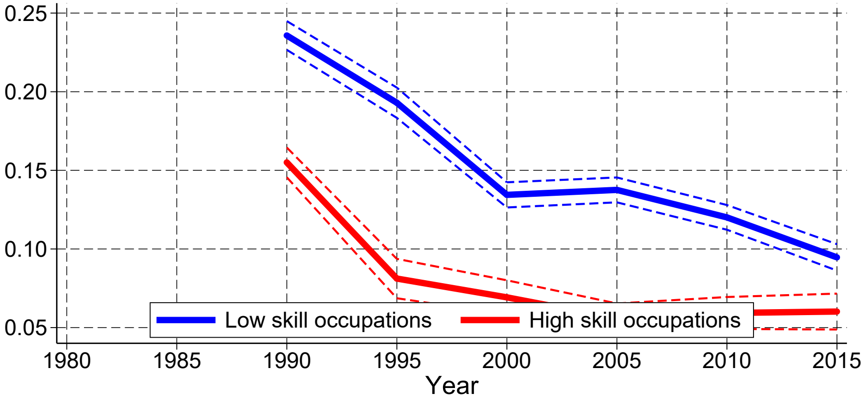
Decreasing size premium in low skill occ



1000+ employee firms associated with a 10 to 15 percent premium

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

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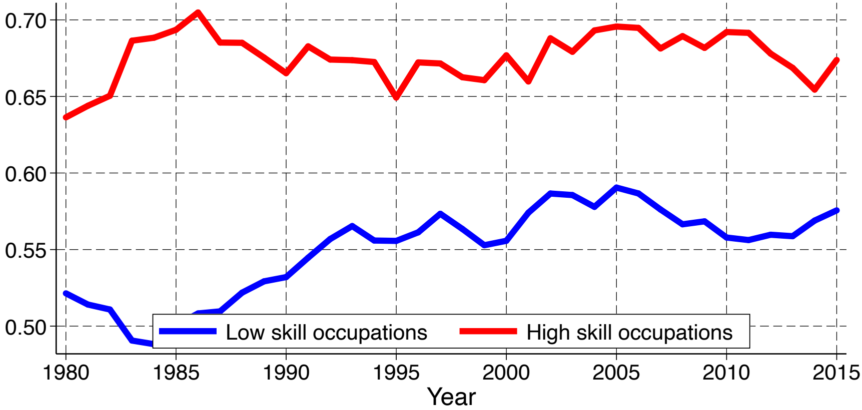
Increasing switching in low skill occ



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

that swap **3-digit** occupations across $\left\{E_{March}, E_{March'}\right\}$

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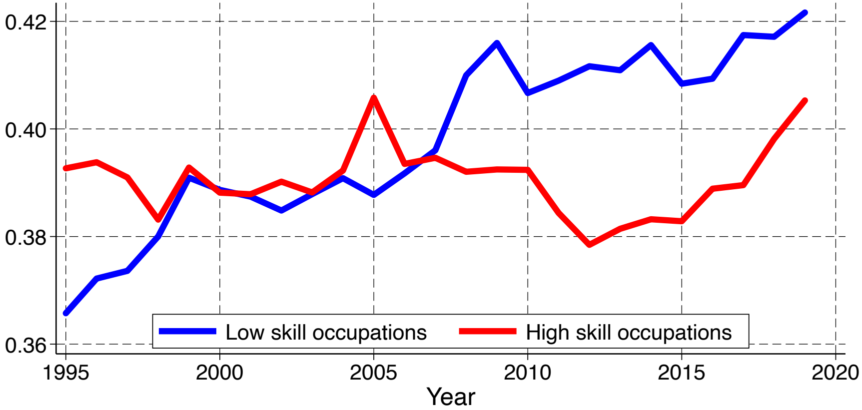
Increasing switching in low skill occ



Fraction of **male** workers experiencing $\left\{E_{Month}, E_{Month+1}\right\}$

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

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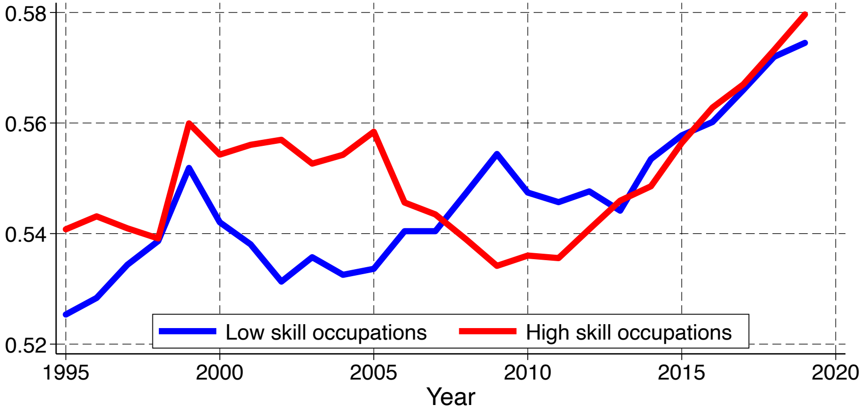
Increasing switching in low skill occ



Fraction of **male** workers experiencing $\left\{E_{Month}, E_{Month+1}\right\}$

that swap **3-digit** occupations across $\left\{E_{Month}, E_{Month+1}\right\}$

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