Consumption Upgrading and Wage Inequality

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A secular rise in wage inequality

- Large increase in wage inequality between high- and low-skill labor
  - Leading explanation: Skill-biased technical change(SBTC)

- Consumption upgrading: shifts towards skill-intensive goods and services as incomes increase $\Rightarrow$ increase in relative wage of skilled workers

- How important is the consumption upgrading channel relative to SBTC?
  - Multi-industry GE model with capital-skill complementarity, industry-specific production technology and nonhomothetic preferences

  - SBTC: capital accumulation of equipments (ΔK_t)
    81.8%
  - Consumption upgrading: skill-neutral technology growth (ΔA_t, ΔS_t, ΔA_{it})
    14.6% = 9.6% (ΔA_{it}: price effect) + 5.0% ($\Delta A_t + \Delta S_t$: income effect)

Literature review

- **Skill-biased technical change.** Katz and Murphy 1992, Berman, Bound, and Griliches 1994, Autor, Levy, and Murnane 2003 ...
- **Sources of structural change.** Acemoglu and Guerrieri 2008, Ngai and Pissarides 2007, Kongsamut, Rebelo, and Xie 2001, Boppart 2014...
- **Structural change and wage inequality.** Leonardi 2015, Buera et al. 2022, Comin, Danieli, and Mestieri 2022
- **Quality upgrading within a good.** Jaimovich, Rebelo, and Wong 2019
- **Estimation of capital-skill complementarity.** Raval 2019, Karabarbounis and Neiman 2014, Hubmer 2023

Data

- Classification of skill
  - O*NET *Job Zones*
  - Separate low-skill service following Acemoglu and Autor 2011

- Wage and employment data
  - OEWS (Occupational Employment and Wage Statistics)

- Construction of skill intensity:

$$\bar{\theta}_j = \frac{W^j_{2003} N^j_{2003}}{\sum\limits_{j \in \{H, M, L_s, L_o\}} W^j_{2003} N^j_{2003}}$$

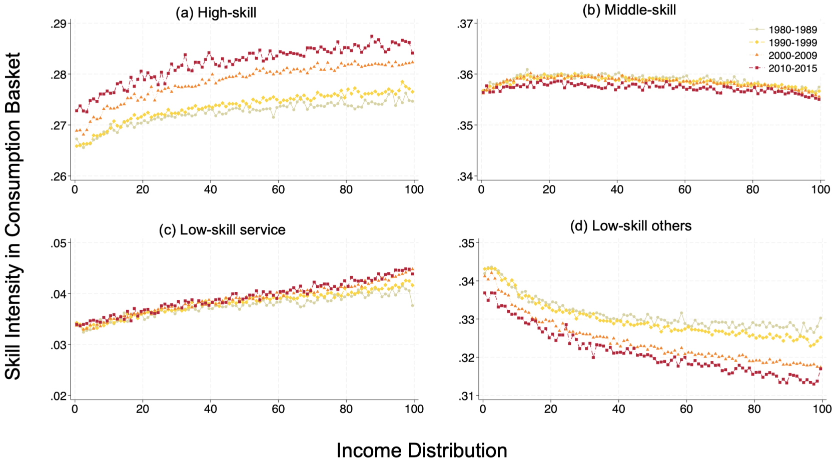
	High-skill	Middle-skill	Low-skill Service	Low-skill others
Employment share	17.68%	33.26%	12.59%	36.47%
Wage bill share	32.32%	36.08%	6.26%	25.35%

Table: Skill intensity summary statistics

Data

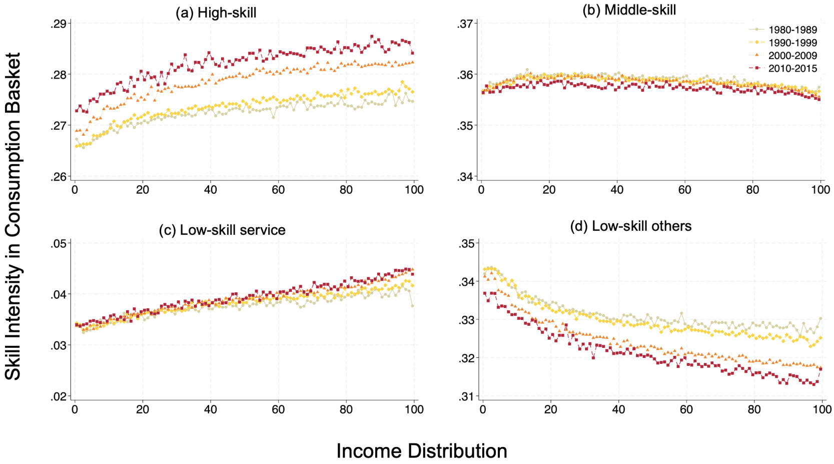
- Adjust for intermediate inputs
  - BEA I-O table
- Match to final demand consumption
  - Consumption expenditure survey
- Final dataset
  - Household-good-year level expenditure and skill intensity

1. Richer households spend a higher share of their total expenditure on skill-intensive goods and services



Source: CEX, OEWS, O*NET, I-O table

2. Household consumption shifts towards skill-intensive goods and services over time



Source: CEX, OEWS, O*NET, I-O table

Model overview

- Multi-industry GE model with four inputs:
  - Capital equipment and capital structure
  - High and low-skill labor
- Capital-skill complementarity
  - Equipments substitute for low-skill and complements high-skill
- Industry-specific production technology
  - Industry-specific production functions and productivity processes
- Good-level expenditure elasticities
  - Generates shifts in consumption as income increases

GE Model of Structural Change

Nested CES Production Function

- Nested CES production function for good i:

$$Y_{it} = A_{it} \left(S_{it}\right)^{\beta_i} X_{it}^{1-\beta_i} \tag{1}$$

$$X_{it} = \left[\alpha_i^{\frac{1}{\eta}} H_{it}^{\frac{\eta-1}{\eta}} + (1-\alpha_i)^{\frac{1}{\eta}} \left(\delta_i^{\frac{1}{\rho}} L_{it}^{\frac{\rho-1}{\rho}} + (1-\delta_i)^{\frac{1}{\rho}} \left(K_{it}\right)^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{2}$$

  - S: capital structure K: capital equipment H: high-skill L: low-skill
- Firms optimize:

$$P_{it} = \frac{1}{A_{it}} \left(\frac{R_t^S}{\beta_i} \right)^{\beta_i} \left(\frac{P_{it}^X}{1-\beta_i} \right)^{1-\beta_i} \tag{3}$$

$$P_{it}^X = \left[\alpha_i \left(W_t^H \right)^{1-\eta} + (1-\alpha_i) \left[\delta_i \left(W_t^L \right)^{1-\rho} + (1-\delta_i) \left(R_t^K \right)^{1-\rho} \right]^{\frac{1-\eta}{1-\rho}} \right]^{\frac{1}{1-\eta}} \tag{4}$$

- Skill-neutral productivity A_{it}: aggregate + industry-specific component
- Industry-specific factor share: α_i, δ_i
- Capital-skill complementarity: $\rho > \eta$

GE Model of Structural Change

Nonhomothetic demand

- Nonhomothetic log-demand system for good *i* (following Hubmer 2023)
- Consumption share for each good ω_{it} follows

$$d\ln\omega_{it}^{h} = (1-\sigma)d\ln\frac{P_{it}}{P_t^h} + (\gamma_{it}-1)d\ln\frac{E_t^h}{P_t^h}, \quad h \in \{H, L\} \tag{5}$$

where

$$E_t^h = W_t^h + R_t^K \bar{K}_t + R_t^S \bar{S}_t \tag{6}$$

$$d\ln P_t^h = \sum_i \omega_{it}^h d\ln P_{it} \tag{7}$$

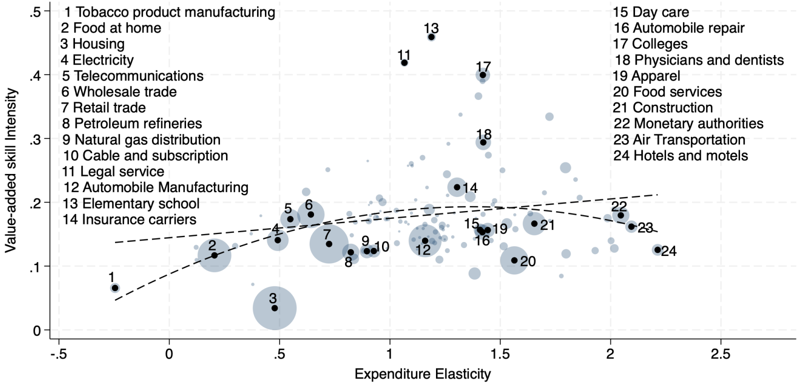
- Price substitution: $\sigma > 1$
- Nonohomothetic demand: industry-specific expenditure elasticity γ_{it}

The competitive equilibrium consist of factor prices $\{R_t^K, R_t^S, W_t^H\}$, intermediate good prices $\{P_{it}^X\}_{i\in I}$, final good prices $\{P_{it}\}_{i\in I}$, consumer demand $\{C_{it}^H, C_{it}^L\}_{i\in I}$ and expenditure $\{E_t^H, E_t^L\}$, final good output $\{Y_{it}\}_{i\in I}$ and factor input choices $\{H_{it}, L_{it}, K_{it}, S_{it}\}_{i\in I}$, such that given fixed labor supply:

1. consumer demand is given by $C_{it} = \frac{\omega_{it} E_t}{P_{it}}$, where ω_{it} is endogenously given at $t = 0$ and evolves according to equation 5;
2. final good output $\{Y_{it}\}_{i\in I}$ and factor inputs choices $\{H_{it}, L_{it}, X_{it}\}_{i\in I}$ are consistent with profit maximization subject to equation 1 to 4;
3. all final good markets clear
4. all factor markets clear

1. Income-Driven Shifts in Consumption: A_t, S_t

- If $Cov(\alpha_i, \gamma_i) > 0$, skill-intensive goods have higher expenditure elasticity
- $A_t \uparrow S_t \uparrow \Rightarrow$ Higher income $\Rightarrow$ Higher demand for skill-intensive goods $\Rightarrow$ Higher demand for skilled workers

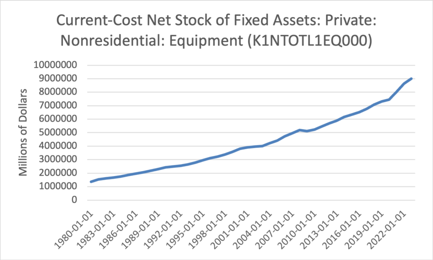


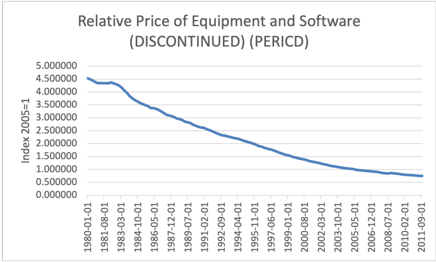
Skill intensity vs. Expenditure elasticity

Source: CEX, OEWS, O*NET, I-O table

2. Capital-Skill Complementarity: K_t

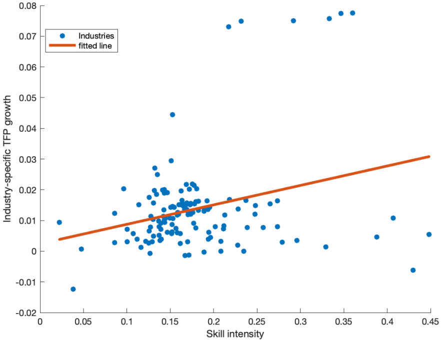
- If $\rho > 1 > \eta$, capital equipment substitutes for low-skill workers and complements for high-skill workers
- $K_t \uparrow \Rightarrow$ Cheaper capital equipment $\Rightarrow$ Higher demand for skilled labor *within each industry*





3. Technology-Driven Shift in Consumption A_{it}

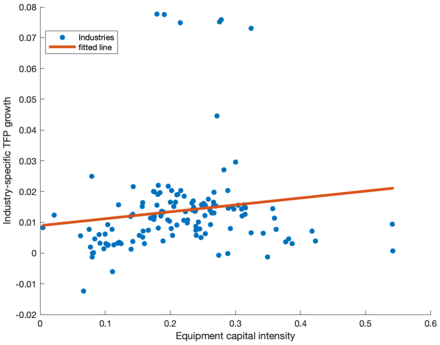
- If $Cov(A_{it}, \alpha_i) > 0$, industries with higher growth rely more heavily on skilled labor
- $A_{it} \uparrow \Rightarrow$ Cheaper prices P_{it}
- Substitution across goods ($\sigma > 1$) $\Rightarrow$ Higher demand for skill-intensive industries $\Rightarrow$ Higher demand for skilled workers



$$Corr(\Delta A_{it}, \theta_i^H) = 0.288$$

4: A_{it} Growth Amplifies Capital-Skill Complementarity

- If $Cov(A_{it}, \delta_i) < 0$, industries with higher growth rely more heavily on equipments
- Similarly, $A_{it} \uparrow \Rightarrow$ Higher demand for capital equipment
- Higher demand for skilled labor due to capital-skill complementarity



$$Corr(\Delta A_{it}, \theta_i^K) = 0.137$$

Calibration

- Sample period: 1982-2019

Elasticity of substitution

Parameter	Moment/Description	Value[1]	Sources
ρ	Elasticity of substitution between K^E and L	1.26	My estimation
η	Elasticity of substitution between K^E and H	0.46	My estimation
γ_{it}	Expenditure elasticity for Y_i		Hubmer 2023
σ	Elasticity of substitution between goods	1.55	Hubmer 2023
$\omega^H_{i,1982}$[2]	Initial consumption share of Y_i for H workers		Data(CEX)
$\omega^L_{i,1982}$	Initial consumption share of Y_i for L workers		Data(CEX)
δ_i	Governs L share in production in 2003	0.71	Data(IO+OEWS+ONET)
α_i	Governs H share in production in 2003	0.20	Data(IO+OEWS+ONET)
β_i	Governs K^S share in production in 2003	0.19	Data(IO+OEWS+ONET)
f	Share of H workers in 2003	0.25	Data(OEWS+ONET)

Table: Calibration

[1] I report the time-average of consumption weighted mean for δ_i, α_i and β_i

[2] calculated using consumption of top 30% HHs

Remaining Model Parameters

- Sample period: 1982-2019
- Calibrate ΔA_t to match per capita GDP growth
- Calibrate ΔA_{it} to match the change in relative prices
- Increase in capital stock (S and K) from BEA data
- Exogenously feed in ΔA_t, ΔA_{it}, ΔK_t, ΔS_t to study each of their contribution to the skill premium

Quantitative Exercises: Model-based decomposition

- Sources of increase in skill premium:
  - Capital accumulation: ΔK_t
  - Aggregate productivity growth: $\Delta A_t + \Delta S_t$
  - Industry-specific productivity growth: ΔA_{it}

	Homothetic (γ_{it} = 1, A_{it}^{GDP})		Nonhomothetic(A_{it}^{GDP})	
	ΔW_t^H	Decomposition	ΔW_t^H	Decomposition
Total	40.2%	100%	43.5%	100%
$\Delta A_t + \Delta S_t$	-0.3%	-0.7%	2.2%	5.0%
ΔK_t	35.0%	87.0%	35.5%	81.8%
ΔA_{it}	3.9%	9.7%	4.2%	9.6%

Conclusion

- Using good-level data, I empirically document:
  - richer households spend a relatively higher share of their expenditure on skill-intensive goods and services
  - overtime, households are consuming more skill-intensive goods and services
- Multi-industry GE model with nonhomotheticity and capital-skill complementarity
  - SBTC driven by ΔK_t is the dominant source: 81.8%
  - Skill-neutral productivity growth: ΔA_{it} 9.6%, $\Delta A_t + \Delta S_t$ 5%
  - Nonhomothetic preference amplify all channels

Bibliography I

Estimation of Capital-Skill Complementarity

Factor Intensities

- Factors measured in efficiency units: $H_{it} = A^H_{it} h_{it}$, $L_{it} = A^L_{it} l_{it}$, $K_{it} = A^E_t K_{it}$ and $S_{it} = A^S_{it} S_{it}$

$$\theta^S_{it} = \frac{R^S_t S_{it}}{P_{it} Y_{it}} = \beta_i \tag{8}$$

$$\theta^H_{it} = \frac{W^H_t h_{it}}{P_{it} Y_{it}} = \frac{\alpha_i}{1-\alpha_i} \left(\frac{P^M_{it}}{W^H_t / A^H_{it}} \right)^{\eta - 1} \theta^M_{it} \tag{9}$$

$$\theta^L_{it} = \frac{W^L_t l_{it}}{P_{it} Y_{it}} = \delta_i \left(\frac{P^M_{it}}{W^L_t / A^L_{it}} \right)^{\rho - 1} \theta^M_{it} \tag{10}$$

$$\theta^E_{it} = \frac{R^E_t K_{it}}{P_{it} Y_{it}} = (1-\delta_i) \left(\frac{P^M_{it}}{R^E_t / A^E_{it}} \right)^{\rho - 1} \theta^M_{it} \tag{11}$$

- $\theta^S_{it} + \theta^E_{it} + \theta^H_{it} + \theta^L_{it} = 1$ and $\theta^E_{it} + \theta^L_{it} = \theta^M_{it}$.

Estimation of Capital-Skill Complementarity

OLS equations

- Identification strategy: the variation of industry-level exposure to the secular change in capital equipment prices and wages. (Karabarbounis and Neiman 2014), (Raval 2019), (Hubmer 2023)

- Estimation of $\rho - \eta$:

$$ln\frac{\theta_{it}^L}{\theta_{it}^H} = \tilde{\alpha}_i + \lambda_t + (\rho - \eta)\left[\frac{\theta_i^L}{\theta_i^M}\hat{w}_t^L + \frac{\theta_i^E}{\theta_i^M}\hat{r}_t^E\right] + \overbrace{-(\rho-\eta)\left[\frac{\theta_i^L}{\theta_i^M}a_{it}^L + \frac{\theta_i^E}{\theta_i^M}a_{it}^E\right] - (\eta-1)a_{it}^H - (1-\rho)a_{it}^L}^{\xi_{it}} \quad (12)$$

- Estimation of η:

Calibration

$$ln(\theta_{it}^H) = \tilde{\alpha}_i + \lambda_t + (\eta - 1)\left[\frac{\theta_i^H}{1-\beta_i}\hat{w}_t^H + \frac{\theta_i^E}{1-\beta_i}\hat{r}_t^E + \frac{\theta_i^L}{1-\beta_i}\hat{w}_t^L\right] + \overbrace{-(\eta-1)\left[\frac{\theta_i^H}{1-\beta_i}a_{it}^H + \frac{\theta_i^E}{\beta_i-1}a_{it}^E + \frac{\theta^L}{1-\beta_i}a_{it}^L\right] + (\eta-1)a_{it}^H}^{\xi_{it}} \quad (13)$$

Estimation of Capital-Skill Complementarity

Data and results

- $\hat{w}_t^H$ and $\hat{w}_t^L$: OEWS-O*NET
- $\hat{r}_t^E$: Relative price of equipments from Fred (PERIC)

Table: Estimates

	2002-2018 (1)		**2002-2018** (2)
$\rho - \eta$	0.811* (0.015)	$\eta - 1$	-0.544* (0.056)
N	2128		2128

Note: All columns weigh goods by final demand shares. Time and good fixed effects are used in all specifications.

Standard errors, in parentheses, are clustered at the good level.

- $\rho = 1.26$ $\eta = 0.46$

Calibration