Job Polarization and Structural Change

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May 2015

Introduction

Job polarization is a widely documented phenomenon in developed countries since the 1980s:

- employment has been shifting from middle to low- and high-income occupations
- average wage growth has been slower for middle-income occupations than at both extremes

Main explanation: routinization; ICT substituting for middle-skill occs

In this paper

1. we document a set of facts
   $\rightarrow$ ICT routinization is not the sole driving force behind this phenomenon
2. based on these facts we propose a novel perspective on the polarization of labor markets
   $\rightarrow$ one based on structural change

This paper empirically

1. shows that polarization has started as early as the 1950-1960s
   $\rightarrow$ started before ICT or increased trade could have impacted the labor market
2. shows that polarization is also present in terms of broadly defined sectors: low-skilled services, manufacturing, high-skilled services

+1 shows that a significant part of occupational employment polarization is driven by employment shifts between industries

Observing that

1. polarization seems to be a long-run phenomenon
2. middle earning jobs are in manufacturing
3. the structural shift from manufacturing to services started in the 1950-1960s

$\rightarrow$ is structural change driving the polarization of the labor market?

This paper theoretically

- proposes a structural change driven explanation for the joint polarization of employment and wages
- parsimonious model where the joint analysis of wages and employment is possible
  - multi-sector growth model, similar to Ngai & Pissarides (2007)
  - with a Roy-type self-selection mechanism:
    workers with heterogeneous skills optimally select sector of work
  - three sectors: manufacturing, low- and high-skilled services
    - ⋆ splitting services in two driven by production & consumption side
  - as goods and services are complements in consumption,
    when relative manufacturing productivity increases:
    - ⋆ labor reallocates to both service sectors
    - ⋆ wages in expanding sectors have to increase

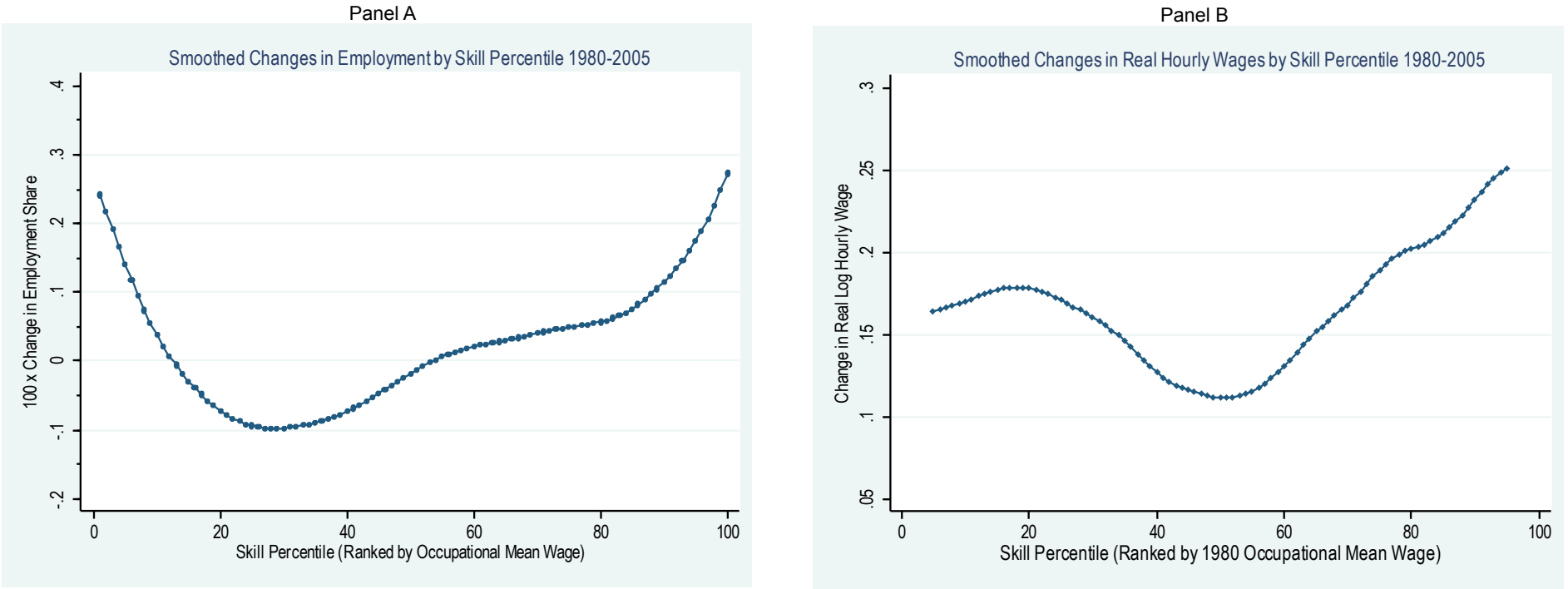
manufacturing jobs tend to be in the middle $\Rightarrow$ polarization pattern

Roadmap

1. Literature
2. Empirical evidence
3. Model
4. Quantitative Results

Evidence – polarization

US: Autor, Katz, Kearney (2006); Acemoglu, Autor (2010); Autor, Dorn (2013); UK: Goos, Manning (2007), Germany: Dustmann, Ludsteck, Schonberg (2009), Europe: Spitz-Oener (2006); Goos, Manning, Salomons (2009, 2014); Michaels, Natraj, Van Reenen (2013)



Source: Figure 1. from Autor, Dorn (2013)

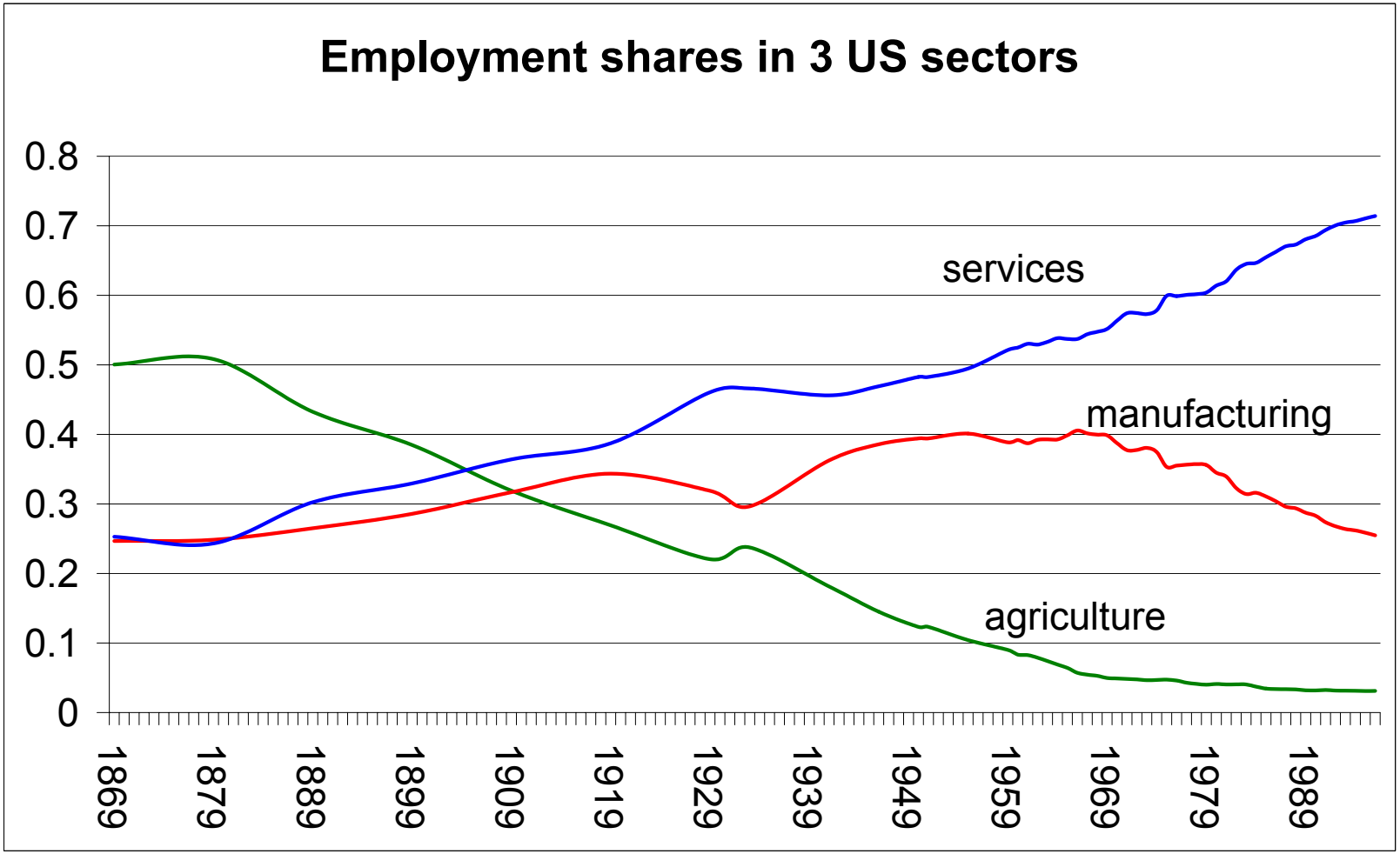
Proposed explanations for polarization

- routinization: information and communication technologies (ICT) displace labor in tasks that can be described as routine
  Autor, Levy, Murnane (2003); Goos, Manning (2007); Michaels, Natraj, Van Reenen (2013); Autor, Dorn (2013); Goos, Manning, Salomons (2014)

- off-shoring: middle earning occupations tend to be more off-shorable
  Grossmann, Rossi-Hansberg (2008); Blinder and Krueger (2009); Goos, Manning, Salomons (2014)

- demand effects: the rise in the share of income going to the rich increases the demand for low-skilled service workers
  Manning (2004); Mazzolari, Ragusa (2013)

Evidence – structural change



Source Figure 1. from Ngai and Pissarides (2008)

Proposed explanations for structural change

focus on changes in output and in employment shares of sectors

1. preferences
   income elasticity of demand for services greater than one $\Rightarrow$ changing relative demands as income increases
   Matsuyama (1991); Kongsamut et al (2001); Foellmi, Zweimuller (2008); Buera, Kaboski (2012)
2. technology
   faster TFP growth in manufacturing or different input-intensity across sectors and changing relative supply of inputs $\Rightarrow$ relative sectoral prices change
   Ngai, Pissarides (2007); Caselli, Coleman (2001); Acemoglu, Guerrieri (2008)

$\rightarrow$ we introduce a Roy-type selection into Ngai and Pissarides (2007) to analyze the joint evolution of sectoral employment and wages
$\rightarrow$ we distinguish between high- and low-skilled services

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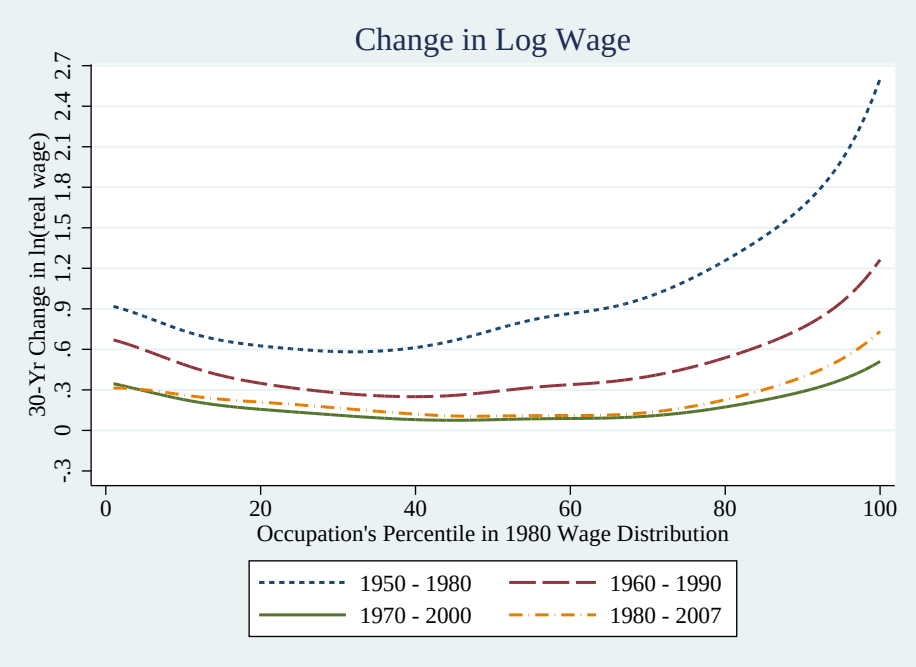
Two new facts, plus one

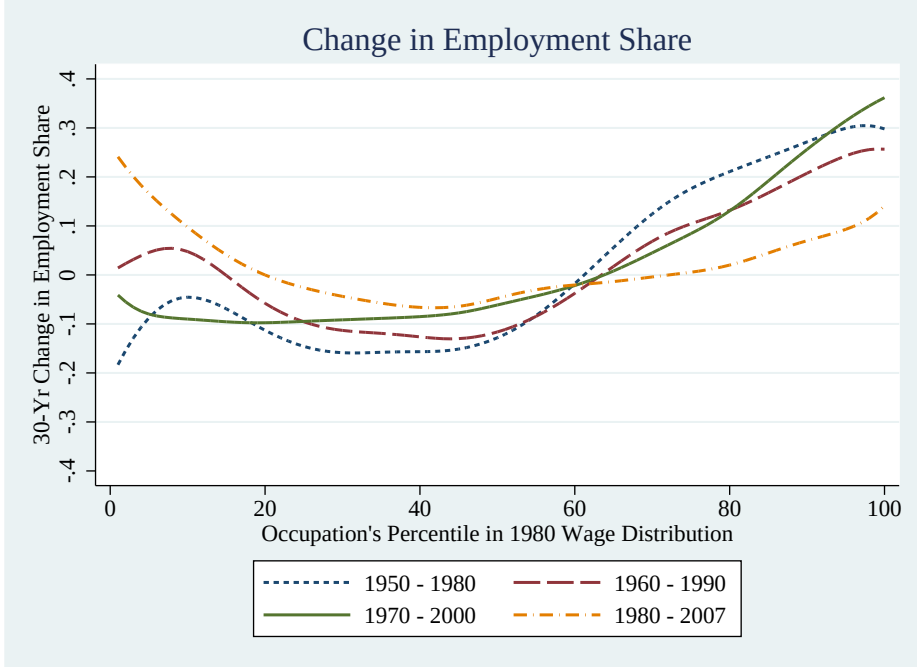
1. polarization started as early as 1950/1960

2. it is present across broadly defined sectors

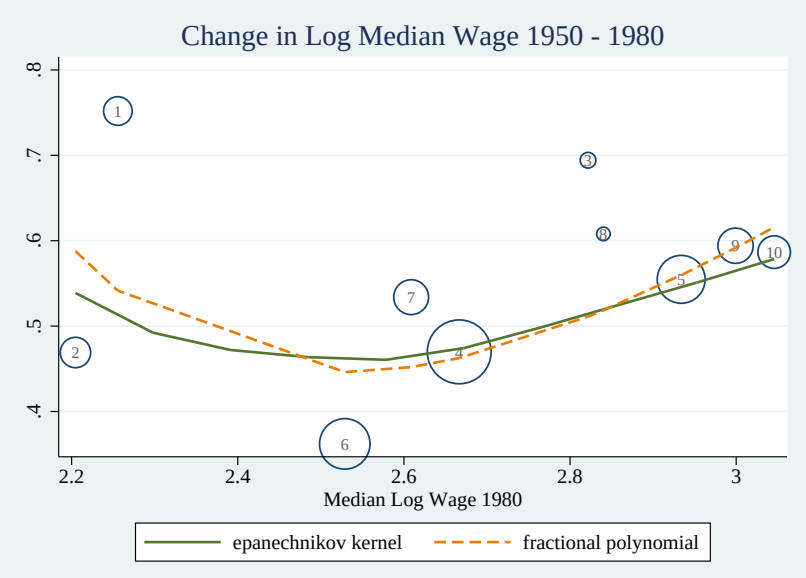
+1 between industry shifts important for occupational employment

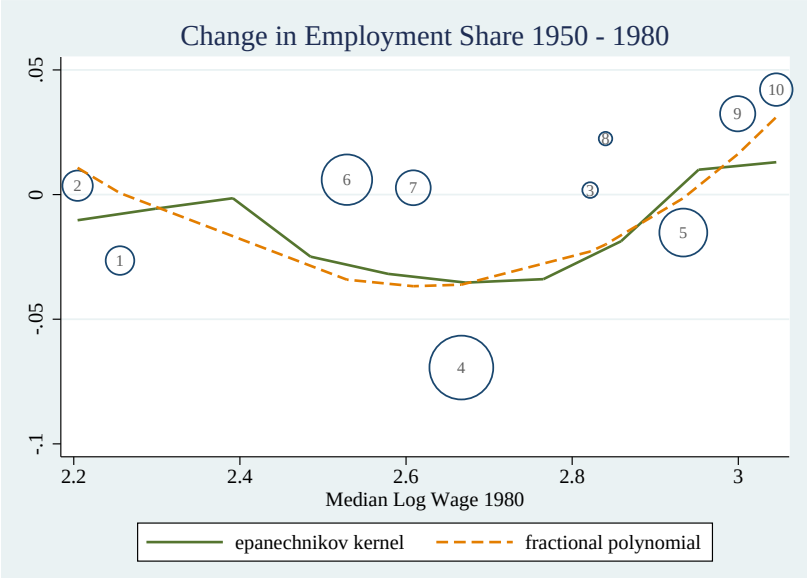
Polarization in terms of occupations

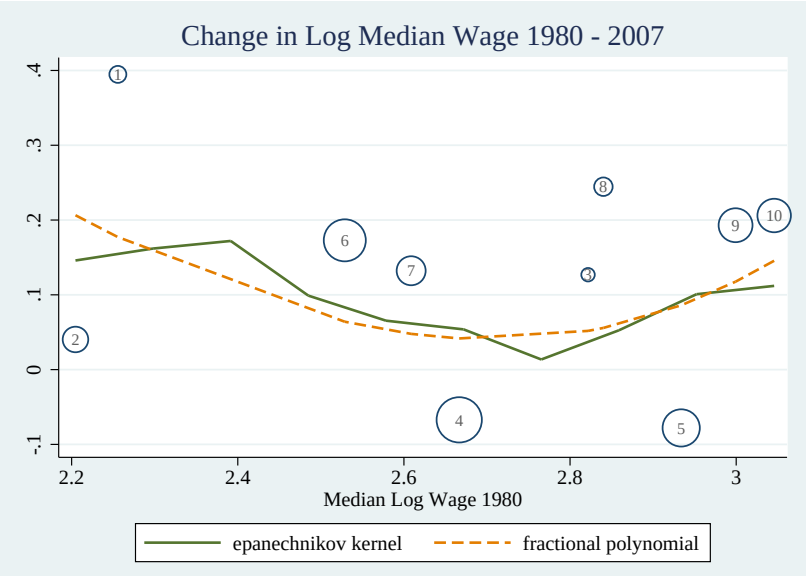


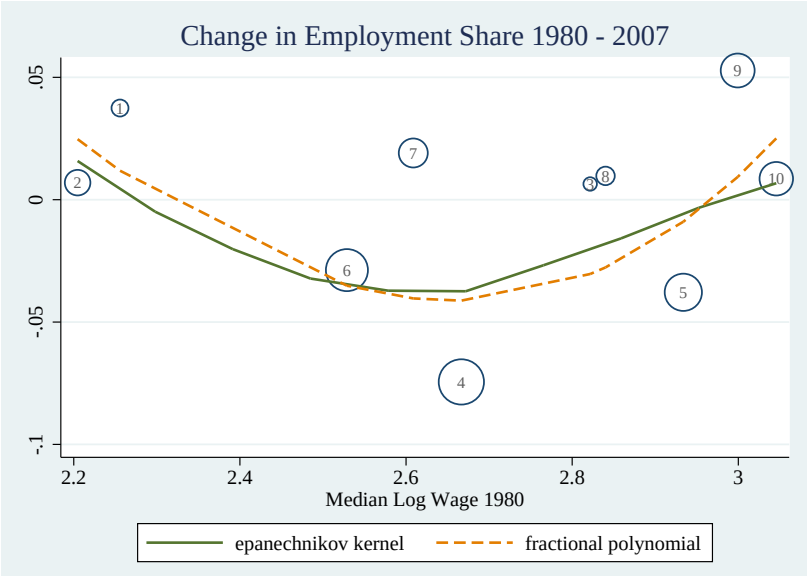


Polarization in broad occupational categories



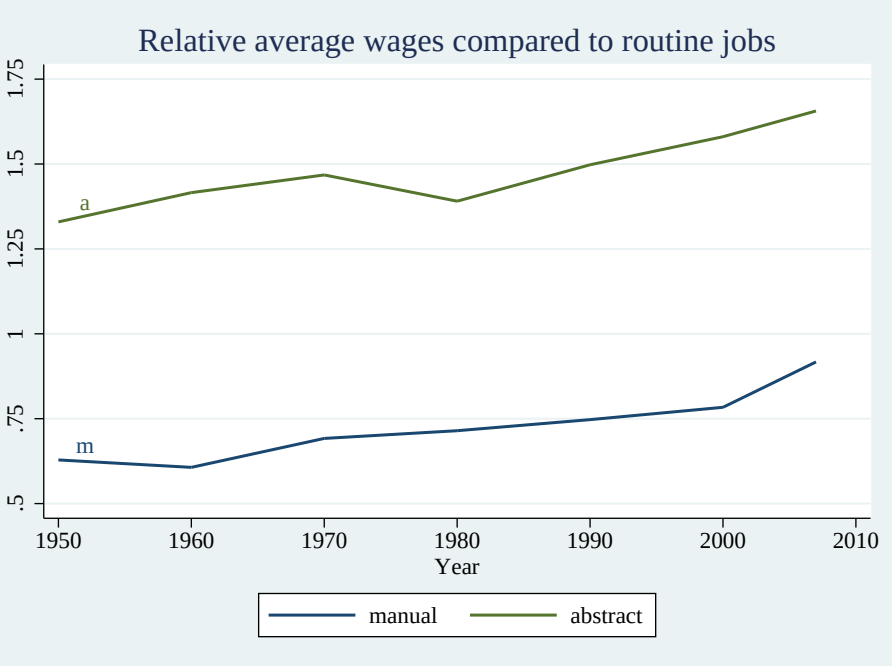


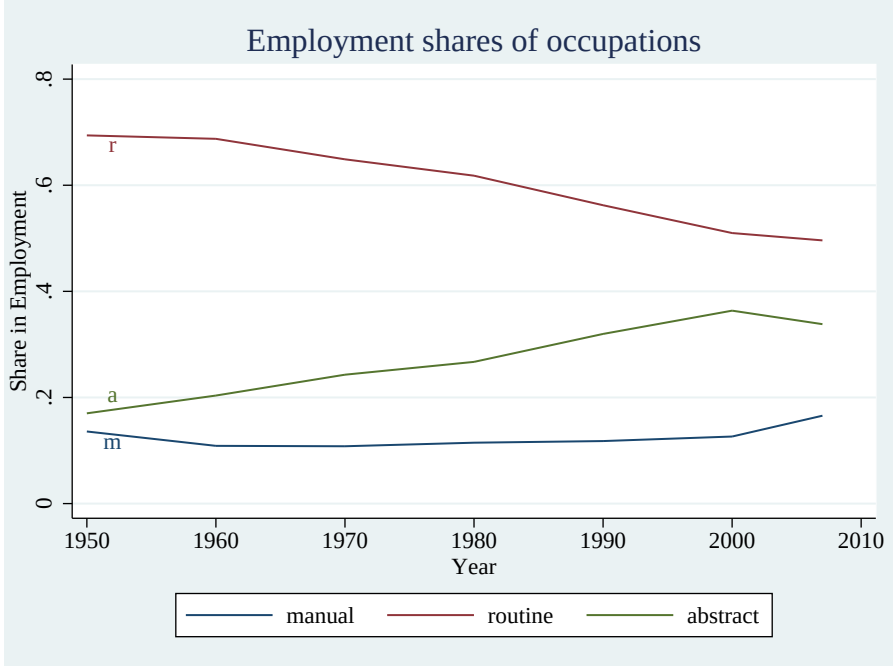




▸ classification

Polarization for broad occupations





▸ classification

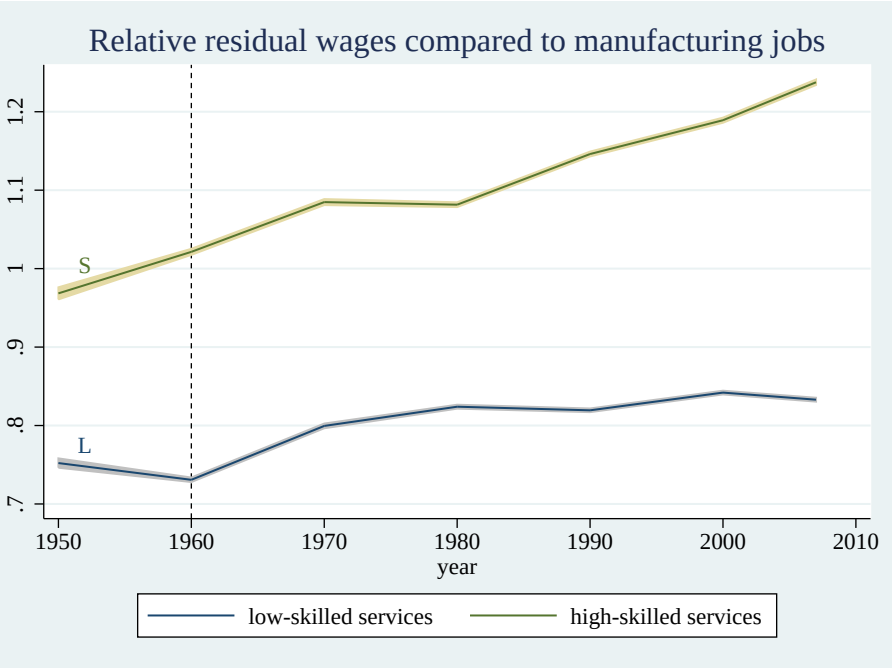
Two new facts, plus one

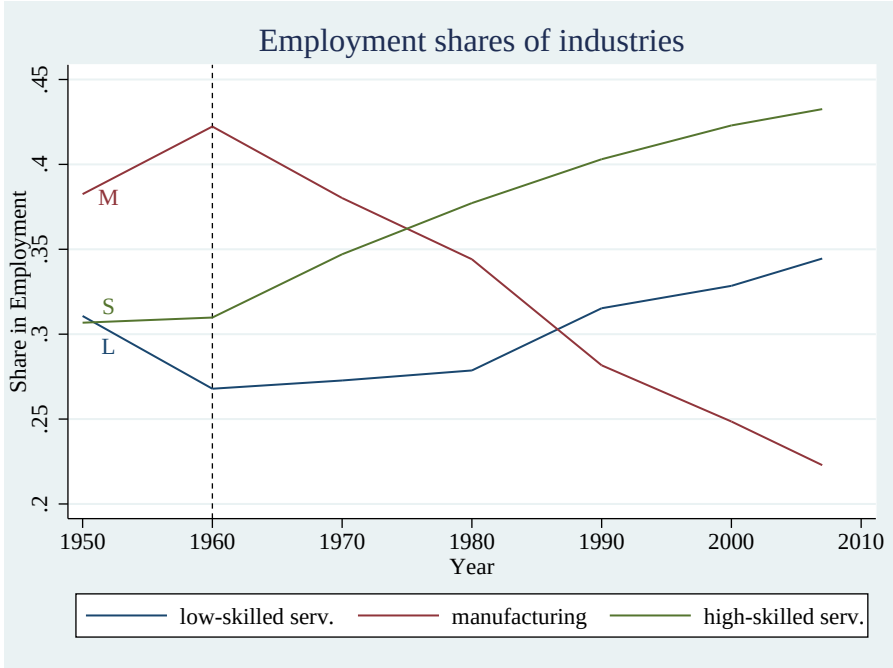
1. polarization started as early as 1950/1960

2. it is present across broadly defined sectors

+1 between industry shifts important for occupational employment

Polarization for broad industries





- classification
- regression
- gender and age effects

Two new facts, plus one

1. polarization started as early as 1950/1960

2. it is present across broadly defined sectors

+1 between industry shifts important for occupational employment

Shift-share decomposition

$$\Delta E_{ot} = \underbrace{\sum_i \lambda_{oi} \Delta E_{it}}_{\equiv \Delta E^B_{ot}} + \underbrace{\sum_i \Delta \lambda_{oit} E_i}_{\equiv \Delta E^W_{ot}},$$

Decompose the change in an occupation's employment share to

- a between industry component
- a within industry component

Shift-share Decomposition of Employment Shares

	3 x 3		10 x 13	
	1950-2007	1960-2007	1950-2007	1960-2007
Manual				
Total Δ	2.98	5.68	3.12	6.41
Between Δ	2.30	3.07	4.30	5.92
Within Δ	0.67	2.61	-1.18	0.49
Routine				
Total Δ	-19.79	-19.14	-25.80	-24.26
Between Δ	-5.66	-6.32	-12.22	-13.06
Within Δ	-14.13	-12.82	-13.58	-11.20
Abstract				
Total Δ	16.81	13.46	19.79	16.02
Between Δ	3.35	3.24	8.72	7.53
Within Δ	13.46	10.21	11.07	8.49
Average				
Total Δ	-7.05	-6.90	-2.00	-1.85
Between Δ	-2.17	-2.44	-0.86	-0.98
Within Δ	-4.89	-4.46	-1.14	-0.87

▸ only within shifts

Summary of key observations

1. polarization started as early as 1950/1960

2. it is present across broadly defined sectors:
   low-skilled services, manufacturing, high-skilled services

+1 between industry shifts important for occupational employment

$\Rightarrow$ structural shift of the economy might be the driving force behind the polarization of the labor market
$\Rightarrow$ how much of the polarization of sectors can a (parsimonious) model of structural change explain?

Roadmap

1. Literature
2. Empirical evidence
3. Model
4. Quantitative Results

Production - perfect competition

Low-skilled service goods

$$Y_l = A_l L_l \quad \Rightarrow \quad \omega_l = p_l A_l$$

Manufacturing goods

$$Y_m = A_m N_m \quad \Rightarrow \quad \omega_m = p_m A_m$$

N_m – efficiency units of labor

ω_m – wage per efficiency unit of labor

High-skilled service goods

$$Y_s = A_s N_s \quad \Rightarrow \quad \omega_s = p_s A_s$$

Note: * in producing M and S efficiency units of labor matter $\Rightarrow$ income of someone with a efficiency units in M/S is $a\omega_m/a\omega_s$

* in L raw labor is used and income is ω_l if working in L

Labor Supply

- every individual works full time in one of the market sectors
- continuum of different types
- heterogeneity in innate ability $(a_m, a_s) \in \mathbf{R}^2_+$
- for simplicity assume:
  - a_m: efficiency units of labor in $M \rightarrow$ earn $a_m \omega_m$ if in M
  - a_s: efficiency units of labor in $S \rightarrow$ earn $a_s \omega_s$ if in S
  - all individuals equally productive in $L \rightarrow$ earn ω_l if in L
- each agent chooses, given ability, the sector that provides the highest income

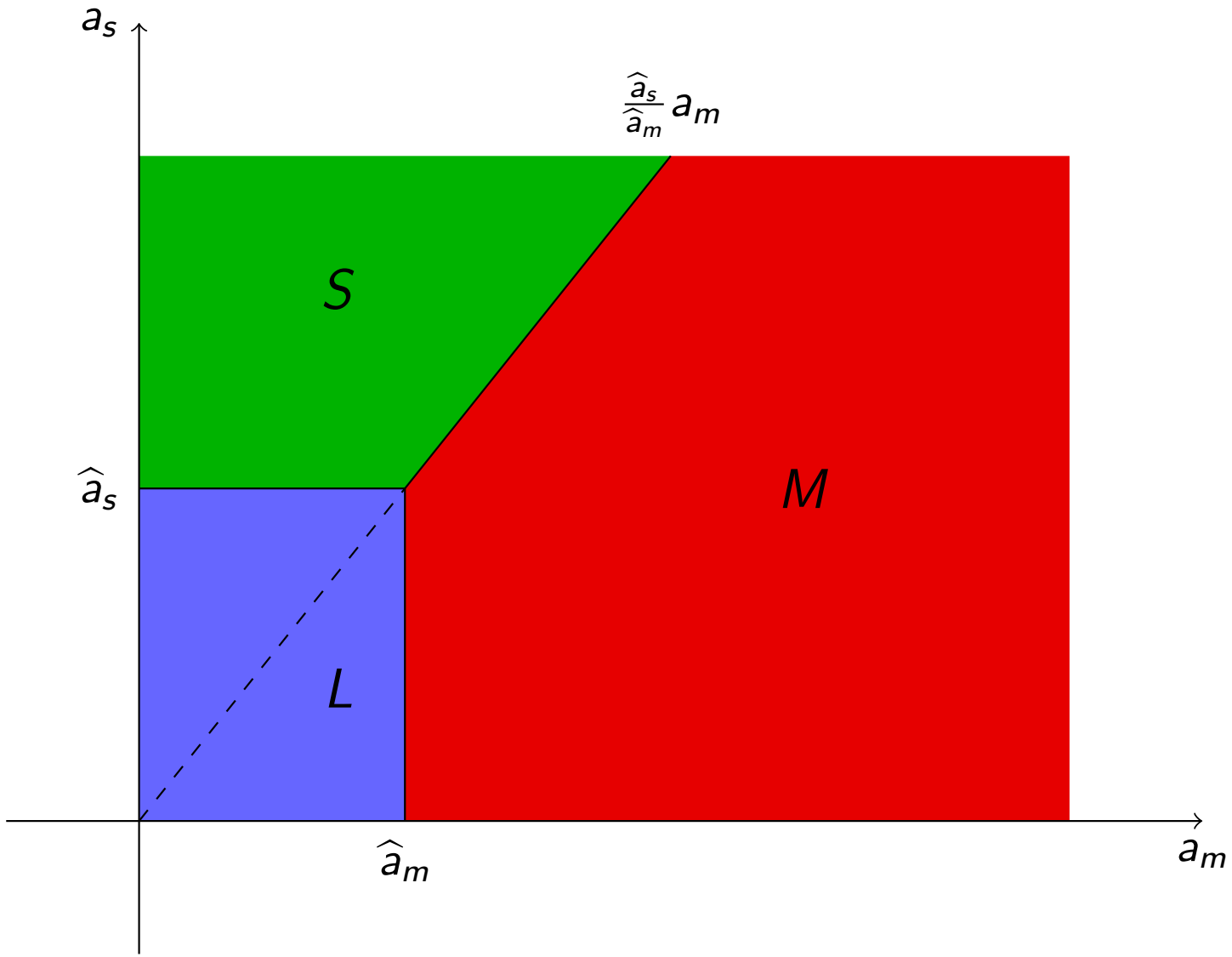
Sector of work decision

The earnings of an individual given wage rates ω_l, ω_m and ω_s with innate ability (a_m, a_s) is ω_l in L, $a_m\omega_m$ in M and $a_s\omega_s$ in S.

The optimal sector choice of individuals can be characterized by two cutoff values:

$$\widehat{a}_m \equiv \frac{\omega_l}{\omega_m}$$
$$\widehat{a}_s \equiv \frac{\omega_l}{\omega_s}.$$

Sector of work decision: endogenous sorting



Demand

The stand-in household solves:

$$\max_{C_l, C_m, C_s} u\left(\left[\theta_l C_l^{\frac{\varepsilon-1}{\varepsilon}} + \theta_m C_m^{\frac{\varepsilon-1}{\varepsilon}} + \theta_s C_s^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}\right)$$

$$\text{s.t.} \quad p_l C_l + p_m C_m + p_s C_s \leq \omega_l L_l + \omega_m N_m + \omega_s N_s$$

Demand

The household's optimal consumption bundle has to satisfy:

$$\frac{C_l}{C_m} = \left(\frac{p_l}{p_m} \frac{\theta_m}{\theta_l} \right)^{-\varepsilon},$$

$$\frac{C_s}{C_m} = \left(\frac{p_s}{p_m} \frac{\theta_m}{\theta_s} \right)^{-\varepsilon}.$$

Equilibrium

The **equilibrium** is defined as a set of

- cutoff sector of work abilities $\{\widehat{a}_m, \widehat{a}_s\}$
- wages per (efficiency) unit $\{\omega_l, \omega_m, \omega_s\}$
- prices $\{p_l, p_m, p_s\}$
- consumption demands $\{C_l, C_m, C_s\}$

given

- the level of productivities $\{A_l, A_m, A_s\}$

such that

- workers choose sector of work optimally
- the labor markets clear (for L, M, and S labor)
- the goods markets clear (for L, M, and S goods)

Structural change

Using market clearing conditions in household demands:

$$\frac{A_l}{A_m}\frac{L_l}{N_m} = \Big(\underbrace{\frac{\omega_l}{\omega_m}\frac{A_m}{A_l}}_{=p_l/p_m}\frac{\theta_m}{\theta_l}\Big)^{-\varepsilon},$$

$$\frac{A_s}{A_m}\frac{N_s}{N_m} = \Big(\underbrace{\frac{\omega_s}{\omega_m}\frac{A_m}{A_s}}_{=p_s/p_m}\frac{\theta_m}{\theta_s}\Big)^{-\varepsilon}.$$

a change in relative productivities has two direct effects: on supply and demand

Structural change

Using optimal sector of work cutoffs:

$$\frac{L_l(\widehat{a}_m, \widehat{a}_s)}{N_m(\widehat{a}_m, \widehat{a}_s)} \widehat{a}_m^{\varepsilon} = \left(\frac{A_m}{A_l}\right)^{1-\varepsilon} \left(\frac{\theta_m}{\theta_l}\right)^{-\varepsilon}, \tag{1}$$

$$\frac{N_s(\widehat{a}_m, \widehat{a}_s)}{N_m(\widehat{a}_m, \widehat{a}_s)} \left(\frac{\widehat{a}_m}{\widehat{a}_s}\right)^{\varepsilon} = \left(\frac{A_m}{A_s}\right)^{1-\varepsilon} \left(\frac{\theta_m}{\theta_s}\right)^{-\varepsilon}. \tag{2}$$

These two equations implicitly define $\widehat{a}_m, \widehat{a}_s$, which fully characterize the equilibrium.

Structural change

Proposition

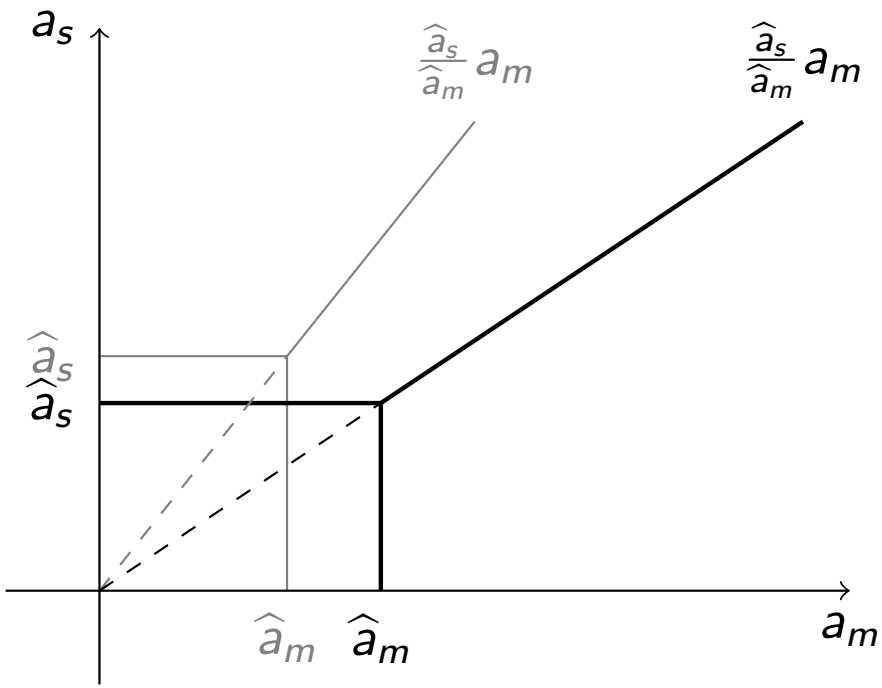
When manufacturing goods and the two types of services are complements ($\varepsilon < 1$), then faster productivity growth in manufacturing than in both types of services ($dA_m/A_m > dA_s/A_s = dA_l/A_l$), leads to a change in the optimal sorting of individuals across sectors. In particular

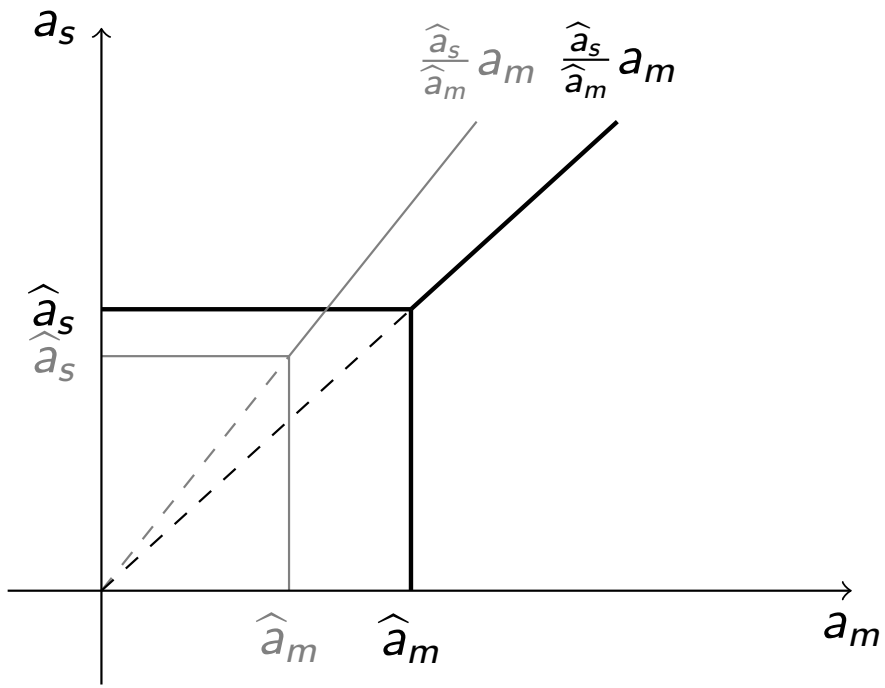
- $\widehat{a}_m = \omega_l/\omega_m$ *and* $\widehat{a}_m/\widehat{a}_s = \omega_s/\omega_m$ *unambiguously increase,*
- $\widehat{a}_s = \omega_l/\omega_s$ *can rise or fall.*

This leads to

- *an increase in employment in L,*
- *an increase in efficiency labor in S,*
- *a fall in effective and raw labor in M.*

Structural change – optimal sorting





Structural change – relative average wages

Low-skilled service relative to manufacturing:

$$\frac{\overline{w}_l}{\overline{w}_m} = \frac{\omega_l}{\frac{\omega_m N_m}{L_m}} = \frac{\omega_l}{\omega_m} \frac{1}{\frac{N_m}{L_m}} = \frac{\widehat{a}_m}{\overline{a}_m}.$$

High-skilled service relative to manufacturing:

$$\frac{\overline{w}_s}{\overline{w}_m} = \frac{\frac{\omega_s N_s}{L_s}}{\frac{\omega_m N_m}{L_m}} = \frac{\omega_s}{\omega_m} \frac{\frac{N_s}{L_s}}{\frac{N_m}{L_m}} = \frac{\widehat{a}_m}{\widehat{a}_s} \frac{\overline{a}_s}{\overline{a}_m}.$$

▸ rel. value added

Roadmap

1. Literature
2. Empirical evidence
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Calibration Strategy

- data targets:
  - we categorize workers as low-skilled service, manufacturing, or high-skilled service based on their industry code (*ind1990*) in the Census/ACS
  - four key moments of the US economy in 1960
    - ★ sectoral employment shares (in terms of hours worked)
    - ★ relative average sectoral wages
- all parameters are time-invariant
  - incl. ability distribution (a bivariate uniform distribution) ▸ Details
- only exogenous change over time is productivity growth
  - similarly to Ngai and Petrongolo (2014) we calculate labor productivity
    - ★ by dividing sectoral value added output data from Herrendorf, Rogerson, Valentinyi (2013)
    - ★ with sectoral employment data from the BEA
  - due to data limitations we cannot break the labor productivity growth of services into low- and high-skilled
  - possibilities: raw/adjusted, average/decennial

Calibration of utility function and initial productivities

parameters of the utility function: $\varepsilon, \theta_l, \theta_m, \theta_s$
initial productivities: $A_l(0), A_m(0), A_s(0)$

- take ε, the elasticity of substitution from the literature
  - ε estimated by Herrendorf, Rogerson, Valentinyi (2013); when sectoral output is measured in value added terms, $\varepsilon = 0.002$
  - Ngai and Pissarides (2008) find that plausible estimates are in the range $[0, 3]$
- calibrate $\tau_l \equiv \left(\frac{A_m(0)}{A_l(0)}\right)^{1-\varepsilon} \left(\frac{\theta_m}{\theta_l}\right)^{-\varepsilon}$ and $\tau_s \equiv \left(\frac{A_m(0)}{A_s(0)}\right)^{1-\varepsilon} \left(\frac{\theta_m}{\theta_s}\right)^{-\varepsilon}$
- to match 1960 relative average wages and employment shares

Calibrated parameters

	Description	Value
$[\underline{a}_m, \tilde{a}_m]$	range of manufacturing efficiency	$[0.40, 1.60]$
$[\underline{a}_s, \tilde{a}_s]$	range of high-skilled service efficiency	$[0.02, 1.98]$
ε	CES b/w L, M and S in consumption	0.002
τ_l	relative weight on M	0.49
τ_s	relative weight on S	0.91

Adjustment for average labor efficiency changes

- due to the self-selection of individuals into sectors
- expanding sectors increase by soaking up relatively less efficient workers
- contracting sectors decrease by shedding relatively less efficient workers
- $\Rightarrow$ average efficiency of labor in expanding sectors fall, while in contracting sectors it increases
- $\Rightarrow$ manufacturing productivity growth might be *overestimated*; services productivity growth might be *underestimated* when calculating from raw employment data

pointed out in the context of measuring productivity growth across sectors by Young (2014 AER), estimated for the bias in skill premium estimates by Carneiro and Lee (2011 AER)

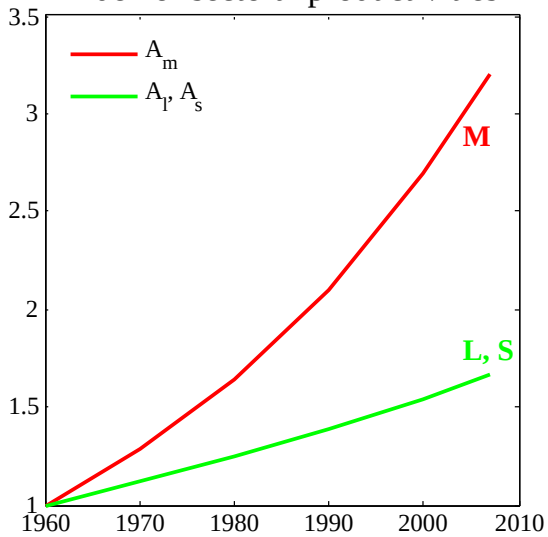
▸ Details

Annual average labor productivity growth

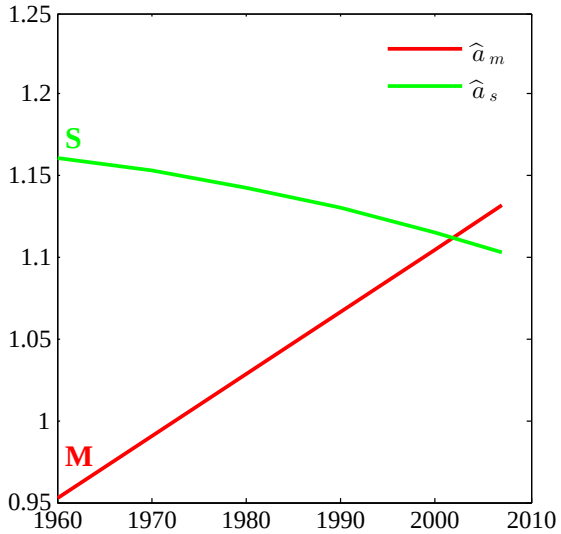
	Based on raw labor		Adjusted by average efficiency	
	Manufacturing	**Services**	**Manufacturing**	**Services**
1960-1970	1.0220	1.0130	1.0210	1.0137
1970-1980	1.0155	1.0078	1.0145	1.0085
1980-1990	1.0304	1.0060	1.0277	1.0064
1990-2000	1.0316	1.0143	1.0303	1.0149
2000-2007	1.0263	1.0143	1.0245	1.0146
1960-2007	**1.0251**	**1.0109**	**1.0235**	**1.0114**

Transition under baseline productivity growth

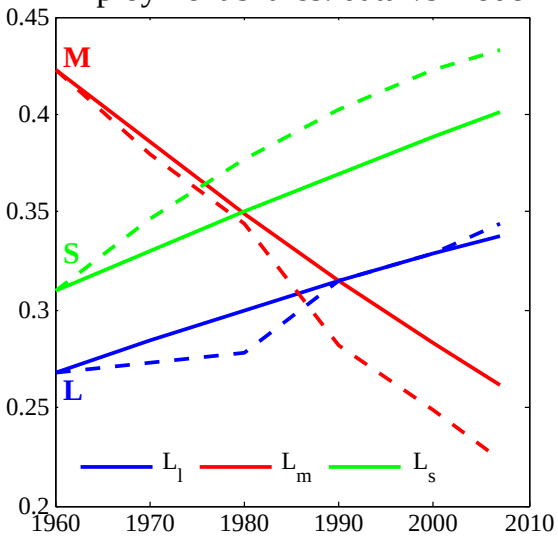
Index of sectoral productivities



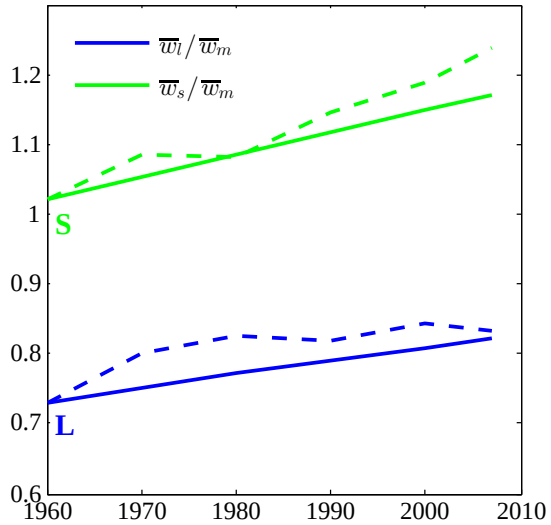
Sector of work cutoffs



Employment shares: data vs model



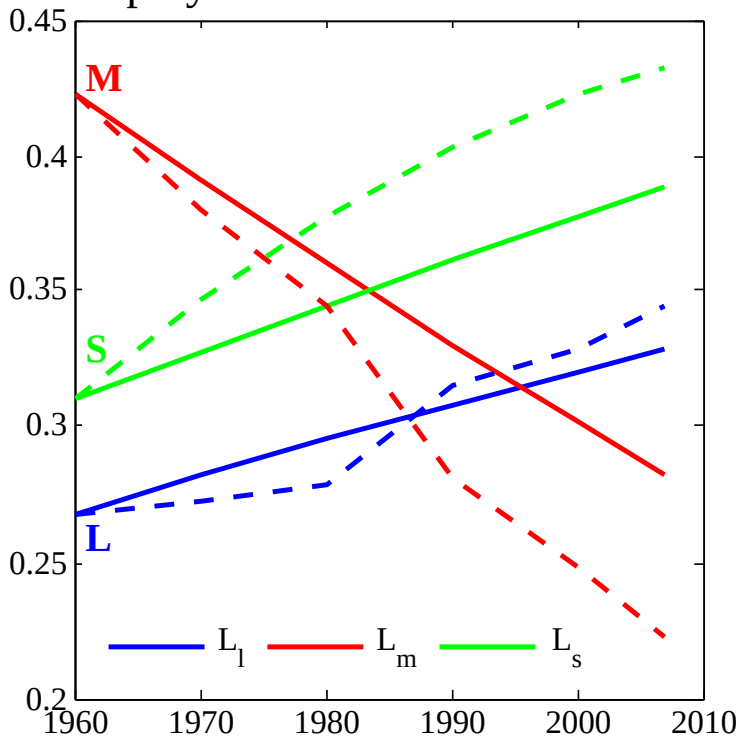
Relative average wages: data vs model



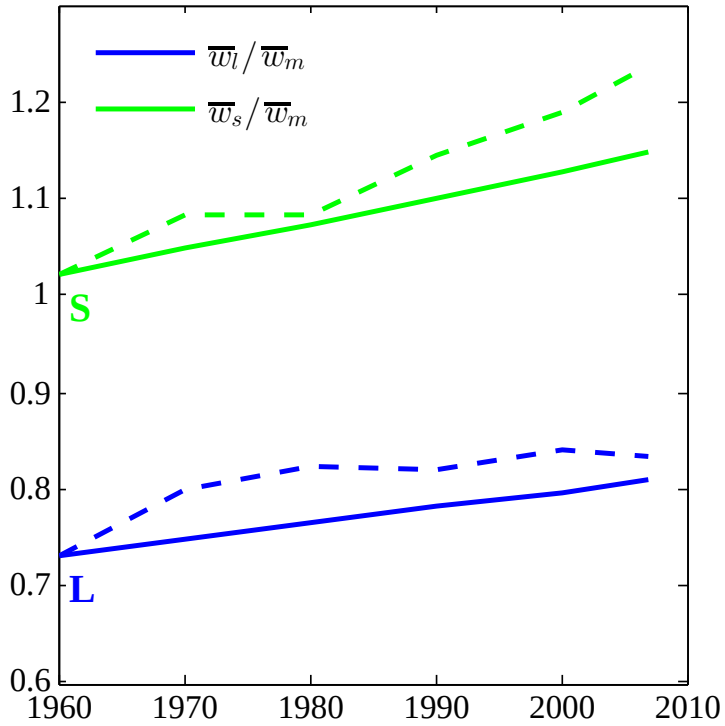
▸ value addded

Transition under selection-adj. productivity growth

Employment shares: data vs model

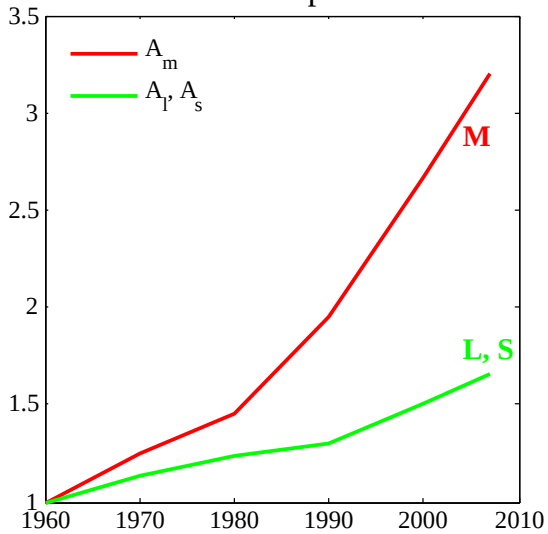


Relative average wages: data vs model

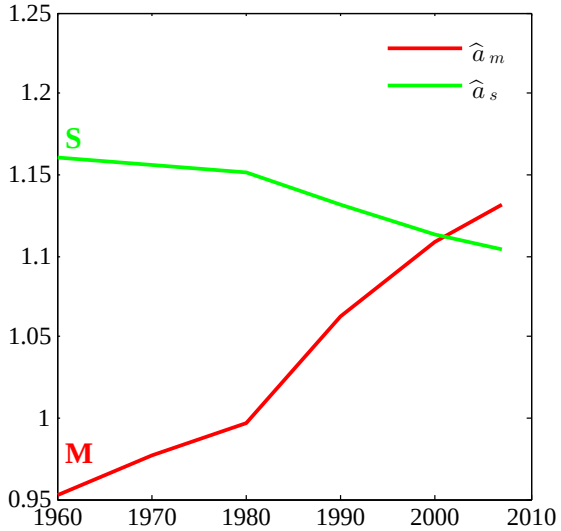


Transition under decennial productivity growth

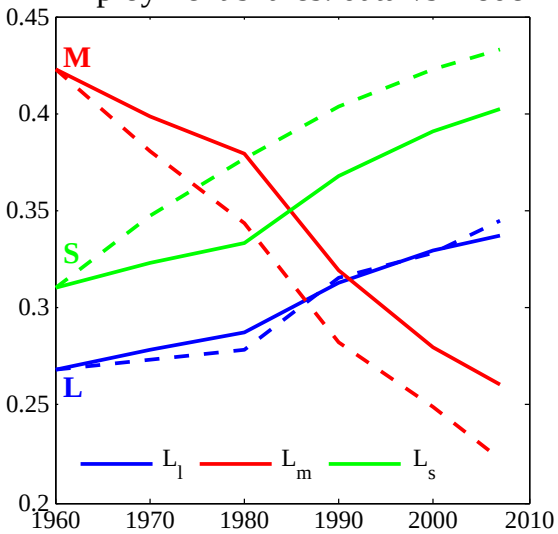
Index of sectoral productivities



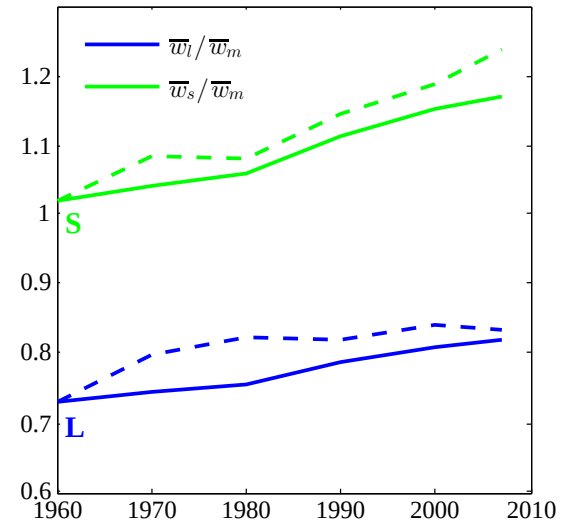
Sector of work cutoffs



Employment shares: data vs model



Relative average wages: data vs model



Robustness - distribution

				employment share Δ			rel. avg. wage Δ	
distrib.	*corr*	$Var(a_m)$	$Var(a_s)$	*L*	*M*	*S*	*L* to *M*	*S* to *M*
uniform	0	0.12	0.32	6.92	-16.10	9.18	12.28	14.58
lognorm.	0	0.106	0.143	6.97	-17.09	10.12	5.48	5.51
	0.3	0.095	0.122	7.06	-16.67	9.60	4.94	3.88
	0.5	0.089	0.110	7.12	-16.35	9.23	4.59	2.90
tr. norm.	0	0.143	0.229	6.93	-16.70	9.77	8.31	9.51
	0.3	0.122	0.184	7.04	-16.24	9.20	7.62	7.03
	0.5	0.110	0.156	7.11	-15.93	8.82	7.18	5.60
data				**7.67**	**-19.94**	**12.27**	**13.97**	**21.16**

- qualitative predictions unchanged
- quantitatively employment hardly change, but average wages do
- with higher correlation, calibration requires less dispersed distribution, and labor becomes more homogeneous $\Rightarrow$ towards wage equalization

Robustness - elasticity of substitution

				employment share Δ			rel. avg. wage Δ	
ε	τ_l	τ_s	prod.	L	M	S	L to M	S to M
0.002	0.49	0.91	raw	6.92	-16.10	9.18	12.28	14.58
	0.49	0.91	adj.	6.05	-13.97	7.92	10.60	12.38
0.02	0.49	0.91	raw	6.81	-15.77	8.97	12.03	14.21
	0.49	0.91	adj.	5.94	-13.67	7.73	10.38	12.07
0.2	0.48	0.88	raw	5.57	-12.52	6.95	9.53	10.83
	0.48	0.88	adj.	4.82	-10.79	5.97	8.19	9.21
data				**7.67**	**-19.94**	**12.27**	**13.97**	**21.16**

- qualitative predictions unchanged
- higher ϵ implies smaller changes in (effective) employment to meet equilibrium demands $\Rightarrow$ also less adjustment in wages

Summary

from data

1. polarization started as early as 1950-1960
2. polarization present also across sectors
3. between industry shifts important for occupational employment

$\rightarrow$ structural change possible force driving polarization

the model

- introduce heterogeneous labor via Roy-type selection into a multi-sector growth model
- unbalanced technological change affects not only employment and expenditure shares, but also sectoral average wages
- if productivity growth is highest in jobs that are in middle of the distribution, it leads to polarization
- *quantitatively*, simple model does very well over the last 50 years
  - around 70% of the relative average wage gain of high- and low-skilled services compared to manufacturing
  - about 75% of changes in employment shares

Thank you!

Occupation categories

The 10 occupational codes are:

1. personal care;
2. food and cleaning services;
3. protective services;
4. operators, fabricators and laborers;
5. production, construction trades, extractive and precision production;
6. administrative and support occupations;
7. sales;
8. technicians and related support occupations;
9. professional specialty occupations;
10. managers.

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1. Manual: low-skilled non-routine
   housekeeping, cleaning, protective service, food prep and service, building, grounds cleaning, maintenance, personal appearance, recreation and hospitality, child care workers, personal care, service, healthcare support
2. Routine
   construction trades, extractive, machine operators, assemblers, inspectors, mechanics and repairers, precision production, transportation and material moving occupations, sales, administrative support, sales, administrative support
   sales, administrative support
3. Abstract: skilled non-routine
   managers, management related, professional specialty, technicians and related support

▸ back

Industry classification

1. Low-skilled services: personal services, entertainment, low-skilled transport (bus service and urban transit, taxicab service, trucking service, warehousing and storage, services incidental to transportation), low-skilled business and repair services (automotive rental and leasing, automobile parking and carwashes, automotive repair and related services, electrical repair shops, miscellaneous repair services), retail trade, wholesale trade
2. Manufacturing: mining, construction, manufacturing
3. High-skilled services: professional and related services, finance, insurance and real estate, communications, high-skilled business services (advertising, services to dwellings and other buildings, personnel supply services, computer and data processing services, detective and protective services, business services not elsewhere classified), communications, utilities, high-skilled transport (railroads, U.S. Postal Service, water transportation, air transportation), public administration

Regression of log hourly wages: industry effects

	1950	1960	1970	1980	1990	2000	2007
low s.	-0.28***	-0.31***	-0.22***	-0.19***	-0.20***	-0.17***	-0.18***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
high s.	-0.03***	0.02***	0.08***	0.08***	0.14***	0.17***	0.21***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Obs	113635	459564	579290	958318	1094458	1235282	1308885
R^2	0.21	0.25	0.21	0.21	0.21	0.18	0.19

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

controls: a polynomial in potential experience (defined as age - years of schooling - 6), dummies for gender, race, and born abroad

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Descriptive statistics

	low-sk. serv.	manuf.	high-sk. serv.
Highschool Dropout	20.66%	27.54%	8.27%
Highschool Graduate	36.76%	37.57%	24.36%
Some College	28.33%	21.19%	29.05%
College Degree	11.20%	10.37%	23.00%
Postgraduate	3.05%	3.34%	15.32%
Mean Years of Education	12.41	11.96	14.05
Female Share	44.35%	23.33%	51.37%
Foreign-Born Share	12.05%	11.21%	8.97%

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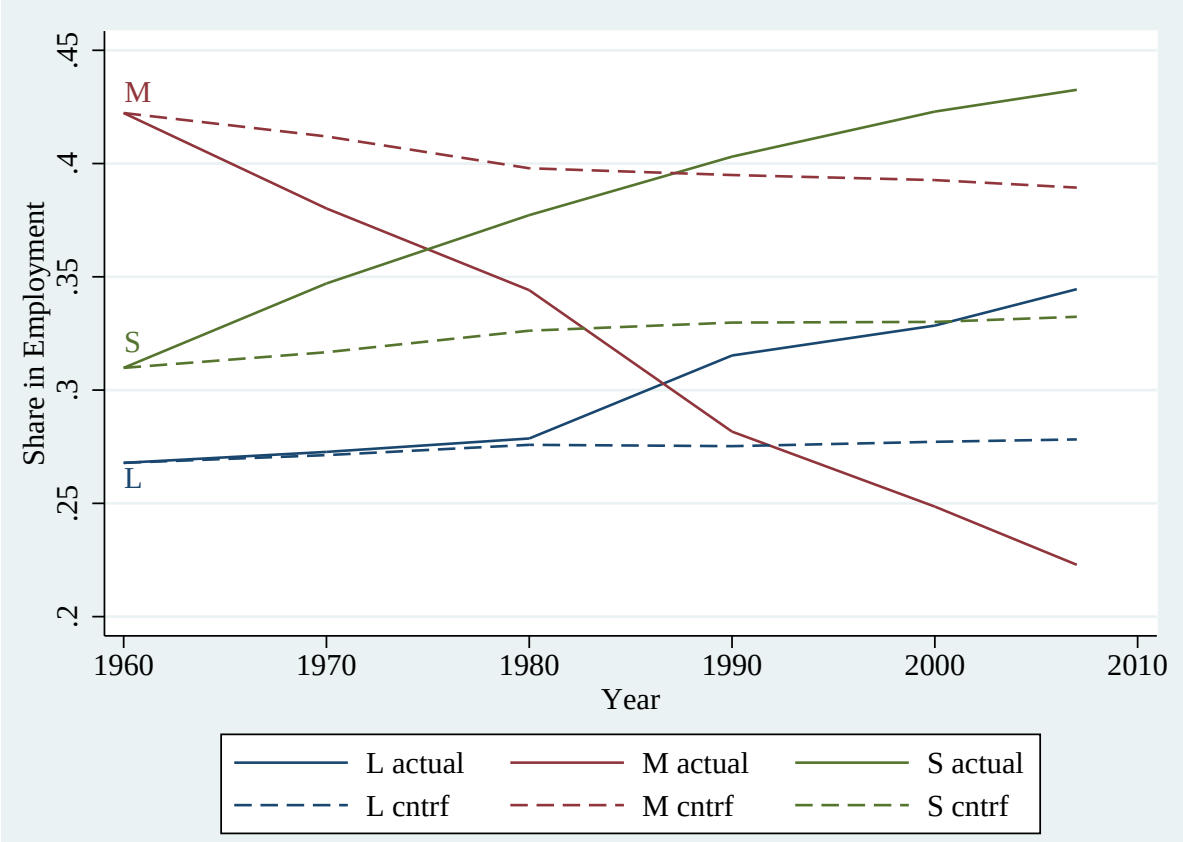
Gender and age effects in employment shares

Counterfactual exercise: only changes in the gender-age composition of the labor force

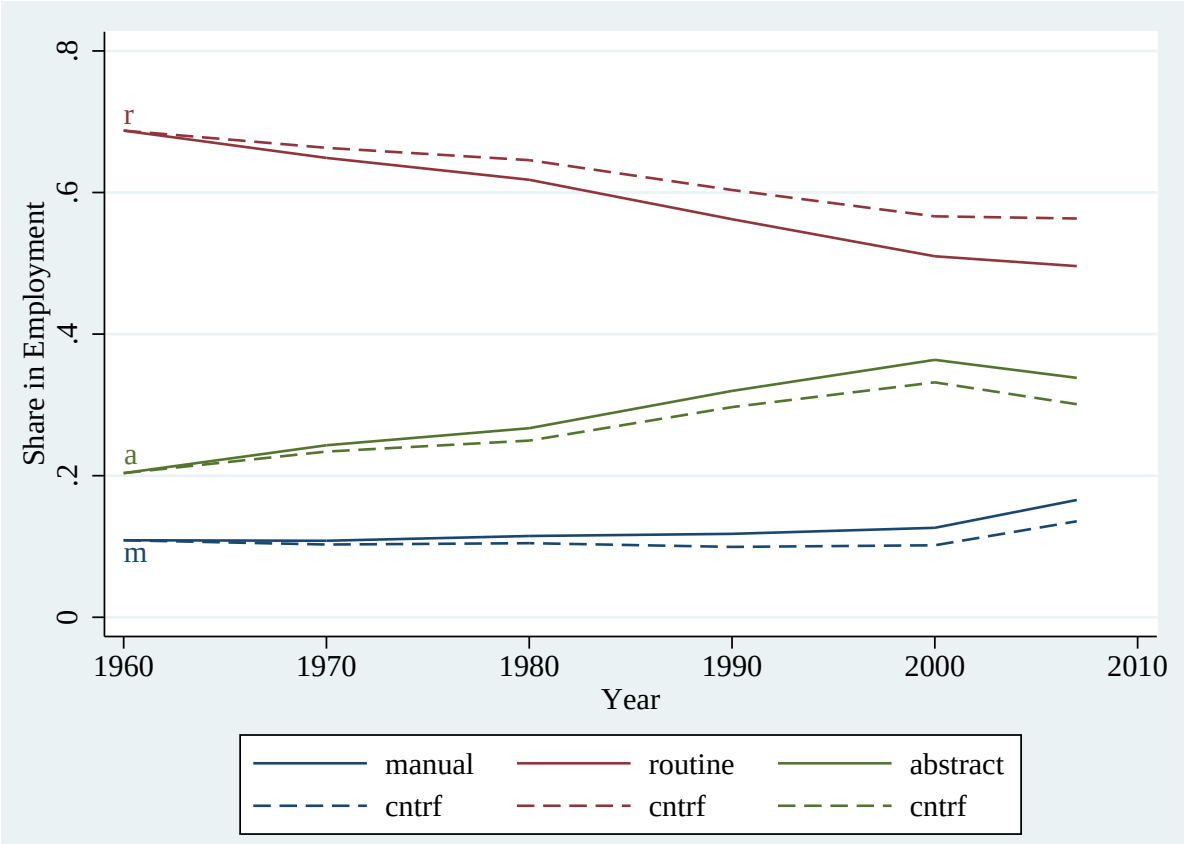


fix industry shares of gender-age cells at their 1960 level, let age and gender shares to follow their actual path

▸ back

How important are within-industry shifts in occ shares?

fix industry shares at 1960 level, let within-ind occ shares follow the actual path



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Structural change – relative value added

Proposition

When manufacturing goods and the two types of services are complements ($\varepsilon < 1$), then faster productivity growth in manufacturing than in both types of services ($dA_m/A_m > dA_s/A_s = dA_l/A_l$), increases the relative value added in both high- and low-skilled services compared to manufacturing:

$$d\frac{p_s Y_s}{p_m Y_m} > 0 \quad \text{and} \quad d\frac{p_l Y_l}{p_m Y_m} > 0.$$

Structural change – relative value added

Since $p_i Y_i = p_i A_i N_i = \omega_i N_i$, relative value added shares can be expressed as:

$$\frac{p_s Y_s}{p_m Y_m} = \frac{\omega_s}{\omega_m}\frac{N_s}{N_m} = \frac{\widehat{a}_m}{\widehat{a}_s}\frac{N_s}{N_m},$$
$$\frac{p_l Y_l}{p_m Y_m} = \frac{\omega_l}{\omega_m}\frac{L_l}{N_m} = \widehat{a}_m\frac{L_l}{N_m}.$$

Moreover, since $\omega_i N_i = \overline{w}_i L_i$, relative VA can be expressed as:

$$\frac{p_i Y_i}{p_j Y_j} = \frac{\overline{w}_i}{\overline{w}_j}\frac{L_i}{L_j}.$$

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Calibration of ability distribution

- assume $f(a_m, a_s)$ is uniform (which requires a minimal choice of parameters)
- normalize (w.o.l.g.) the mean of a_m and a_s to be unity (not separately identified) $\rightarrow$ need to find $\underline{a}_m$ and $\underline{a}_s$
- calibrate these such that the observed employment shares and relative average wages are consistent with each other
- given $f(a_m, a_s)$, the observed labor shares uniquely identify the sector-of-work cutoffs, the sector-of-work cutoffs in turn imply relative average wages

$\rightarrow$ pin down $\underline{a}_m, \underline{a}_s$ such that when matching the raw employment shares in 1960, the model also matches the relative average wages
$\rightarrow$ still have to calibrate other parameters to ensure that in equilibrium we are matching these moments in the first place

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Productivity growth adjustment based on our calibration

- use calibration for efficiency distribution, $f(a_m, a_s)$
- take raw employment shares from the data
- given cutoff structure in our model
  calculate the change in average labor efficiency in each sector
- overall efficiency gain in manufacturing: 4.8%
- overall efficiency loss in services: 3.4%
- adjust the annual change in raw employment by calculated annual labor efficiency gain/loss in the sector
- $\rightarrow$ adjusted labor productivity growth

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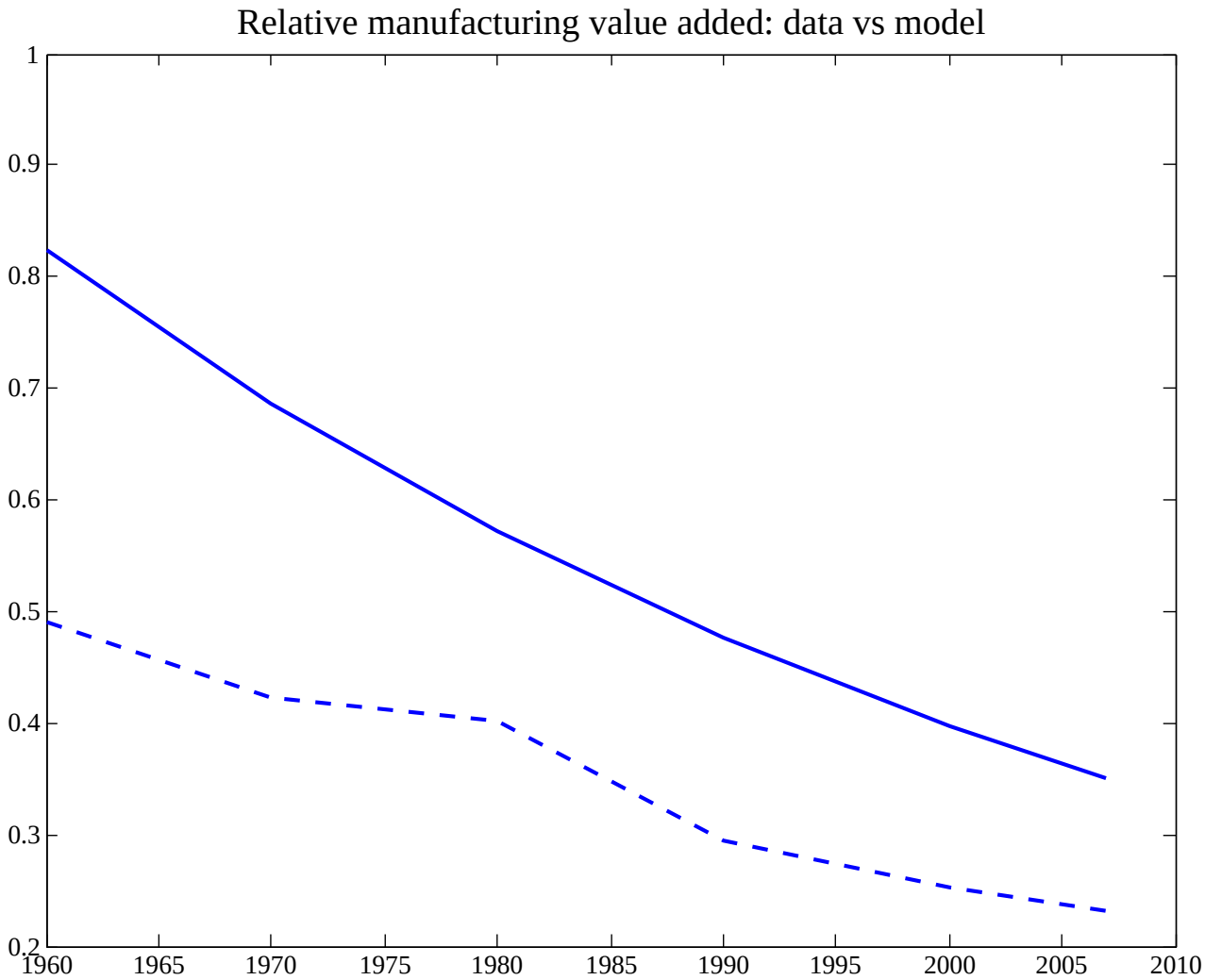
Value added shares



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