ON THE WELFARE IMPLICATIONS OF AUTOMATION

Maya Eden (The World Bank)
Paul Gaggl (UNC Charlotte)

Main Question

- How does ICT change the distribution of income across factors of production?
- **ICT**: **I**nformation and **C**ommunication **T**echnology

Two main effects on income shares

- Labor → Capital
  - Karabarbounis and Neiman (2014, QJE)
- Routine labor → Non-routine labor
  - Autor and Dorn (2013, AER)
  - Krusell, Ohanian, R´ıos-Rull and Violante (2000, ECMA)

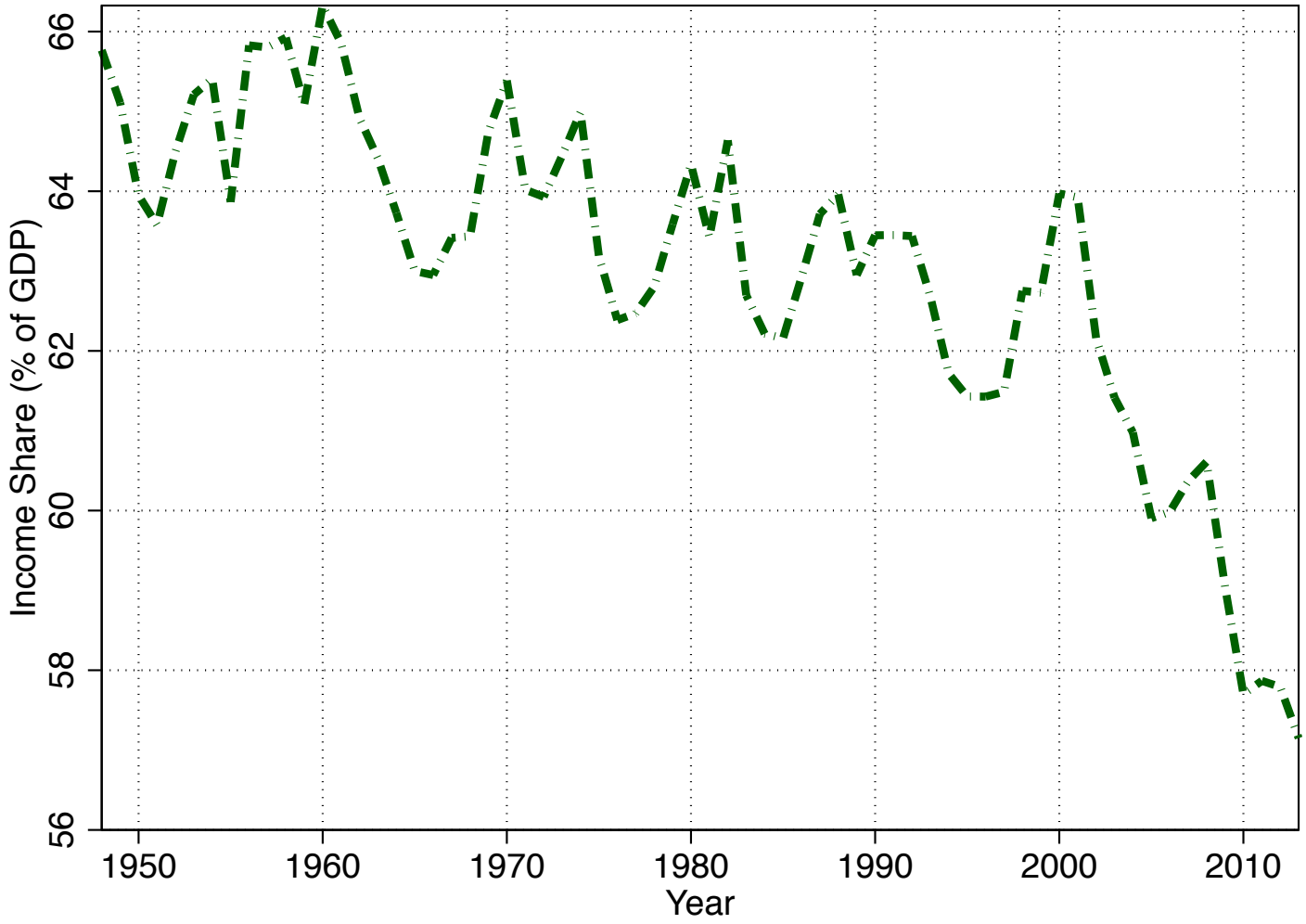
This Paper: Agenda

- Part 1: Document the evolutions of disaggregated **income shares**
  - Capital (ICT/non-ICT)
  - Labor (Routine/Non-Routine)
- Part 2: Use trends to calibrate production structure
  - Embed in standard neo-classical growth model
  - Conduct counterfactual simulations

Main Insights: Preview

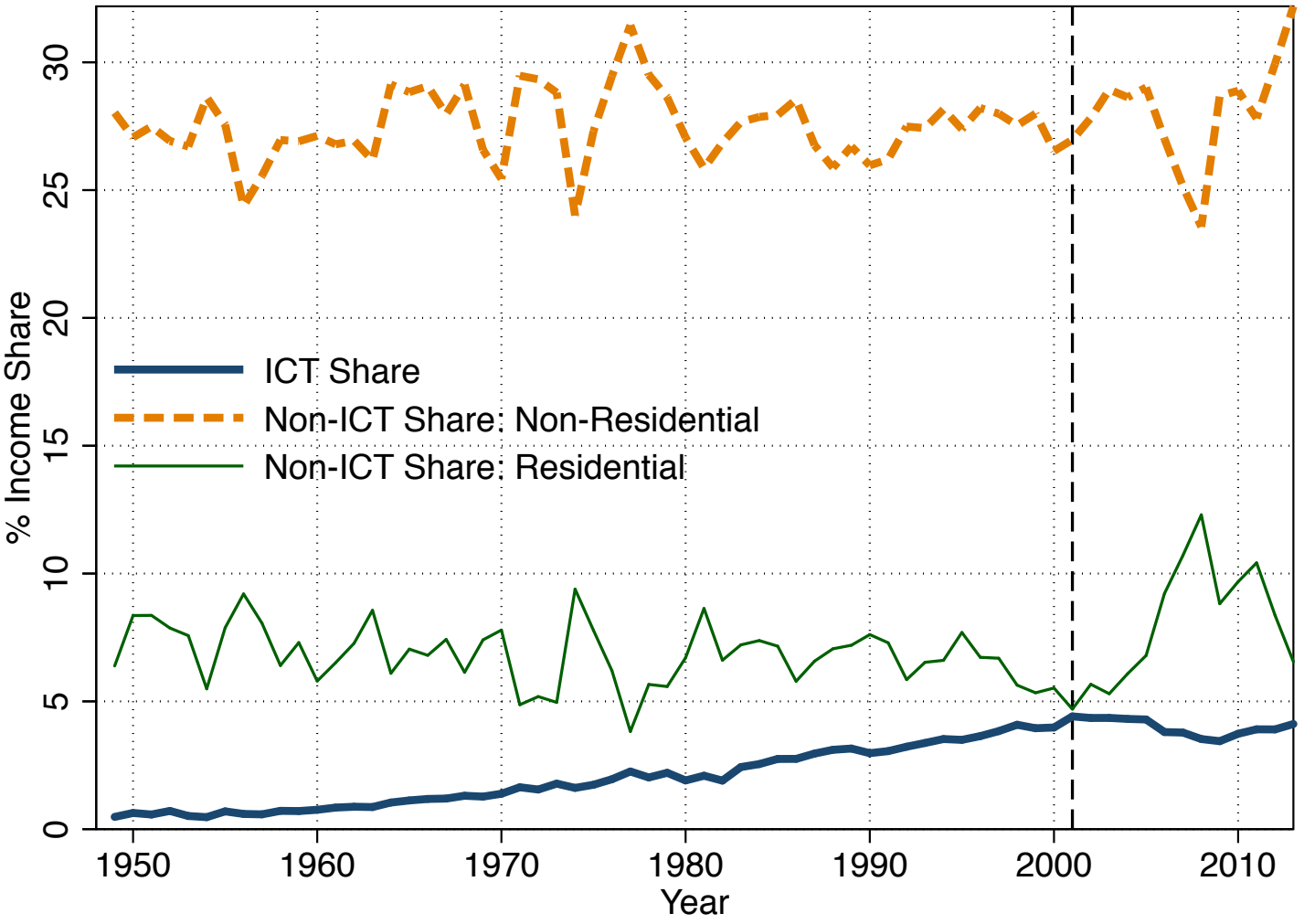
- Of the 15 pp decline in the routine labor share, 12 pp can be attributed to automation:
  - 10 pp increase in the non-routine labor share
  - 2 pp increase in the ICT share
- The main effect of ICT is ***within*** labor income, rather than *between* capital and labor

Aggregate Labor Share



Data: BLS

Capital Income Share



Data: BEA detailed asset accounts & author's computations

Construction of Capital Shares

- Data: BEA's estimates from detailed asset accounts
  - Gross Returns Equalize

$$\frac{p_t MPK_{i,t} + p_{i,t}(1-\delta_{i,t})}{p_{i,t-1}} = \frac{p_t MPK_{j,t} + p_{j,t}(1-\delta_{j,t})}{p_{j,t-1}}$$

  - Constant Returns to Scale

$$\frac{\sum_i MPK_{i,t} K_{i,t}}{Y_t} = 1 - \frac{w_t L_t}{Y_t}$$

  - Definitions

p_t: output price
$p_{i,t}$: price of capital of type i
δ_i depreciation rate of capital of type i

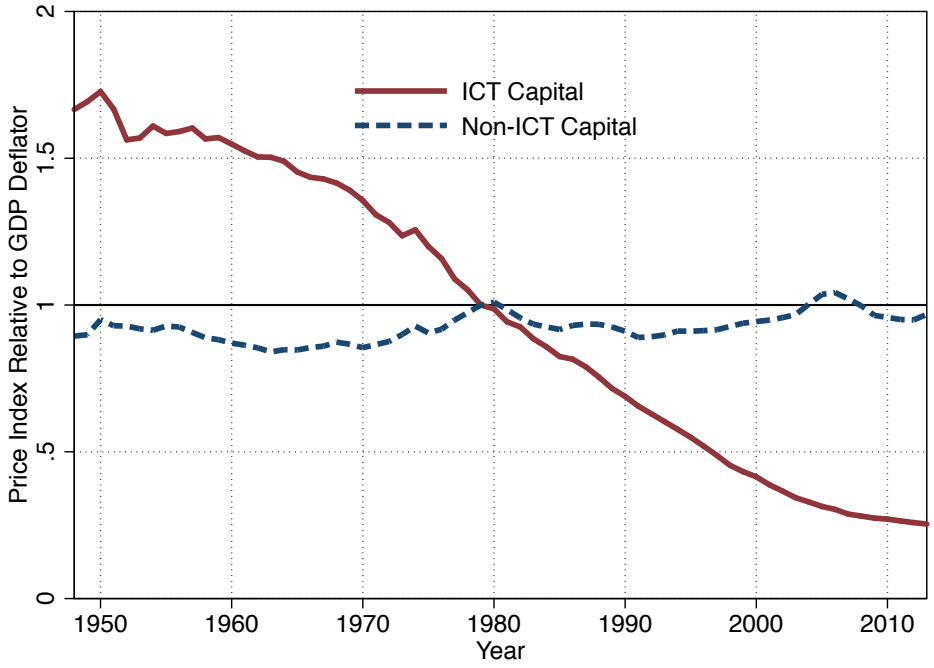
Information & Communication Technology (ICT)

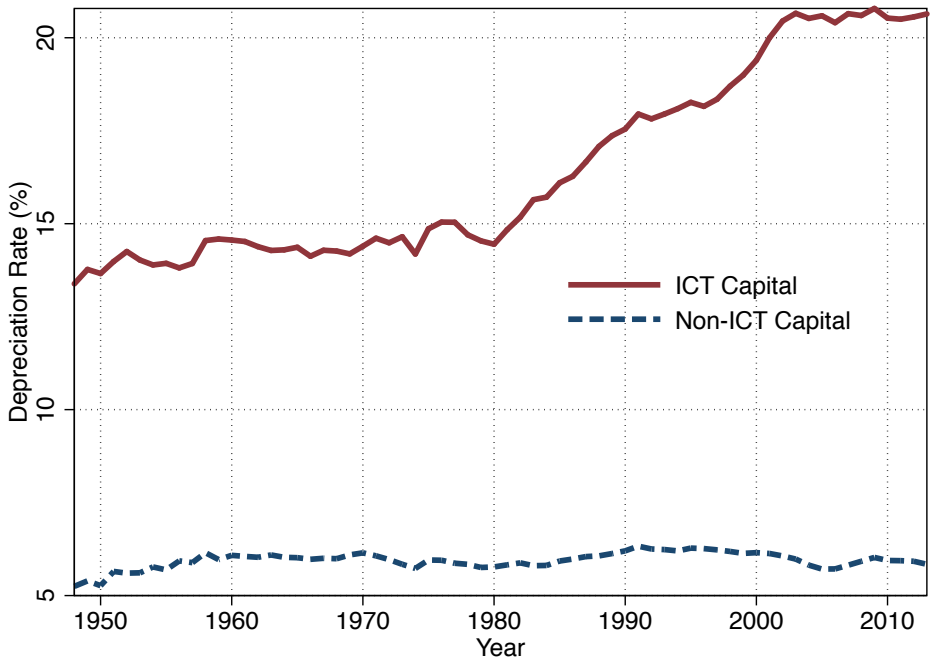
	Share of Aggregate Capital (%)			Average Growth in Share (%)		
ICT Assets	1960-1980	1980-2000	2000-2013	1960-1980	1980-2000	2000-2013
EP20: Communications	2.73	3.91	3.39	2.87	1.78	-2.63
ENS3: Own account software	0.24	0.75	1.56	27.26	6.68	2.58
ENS2: Custom software	0.11	0.61	1.40	34.82	8.49	2.06
EP34: Nonelectro medical instruments	0.35	0.76	1.08	4.87	2.97	2.30
EP36: Nonmedical instruments	0.51	0.92	0.92	0.62	2.41	-1.08
ENS1: Prepackaged software	0.02	0.33	0.83	32.28	14.63	-1.04
EP35: Electro medical instruments	0.11	0.36	0.66	7.25	3.43	4.28
EP1B: PCs	0.00	0.31	0.45		12.12	0.96
RD23: Semiconductor and other component manufacturing	0.05	0.23	0.43	6.58	8.21	2.75
RD22: Communications equipment manufacturing	0.26	0.21	0.27	3.27	0.89	0.24
EP31: Photocopy and related equipment	0.53	0.75	0.26	6.75	-2.11	-7.70
EP1A: Mainframes	0.19	0.36	0.24	24.00	1.91	-4.97
EP1H: System integrators	0.00	0.03	0.23		42.85	3.45
RD24: Navigational and other instruments manufacturing	0.05	0.19	0.22	3.20	5.78	-1.59
EP1D: Printers	0.07	0.22	0.19	20.75	7.20	-9.76
EP1E: Terminals	0.02	0.14	0.16	71.14	5.48	-4.62
EP1G: Storage devices	0.00	0.17	0.12		7.55	-9.55
EP12: Office and accounting equipment	0.48	0.32	0.12	-3.09	-5.00	-6.13
RD40: Software publishers	0.00	0.05	0.09		16.91	-1.13
RD21: Computers and peripheral equipment manufacturing	0.16	0.09	0.07	3.68	-3.07	-0.60
RD25: Other computer and electronic manufacturing, n.e.c.	0.01	0.01	0.02	0.91	3.24	-0.34
EP1C: DASDs	0.09	0.13	0.00	30.38	-36.26	-78.36
EP1F: Tape drives	0.06	0.03	0.00	22.77	-40.33	-186.06

Notes: The data are drawn from the BEA. Assets are ranked by their average share in aggregate capital during 2000-2013.

Relative Price of ICT & Depreciation

- Implicit Price Deflators for capital
- BEA's estimate of depreciation



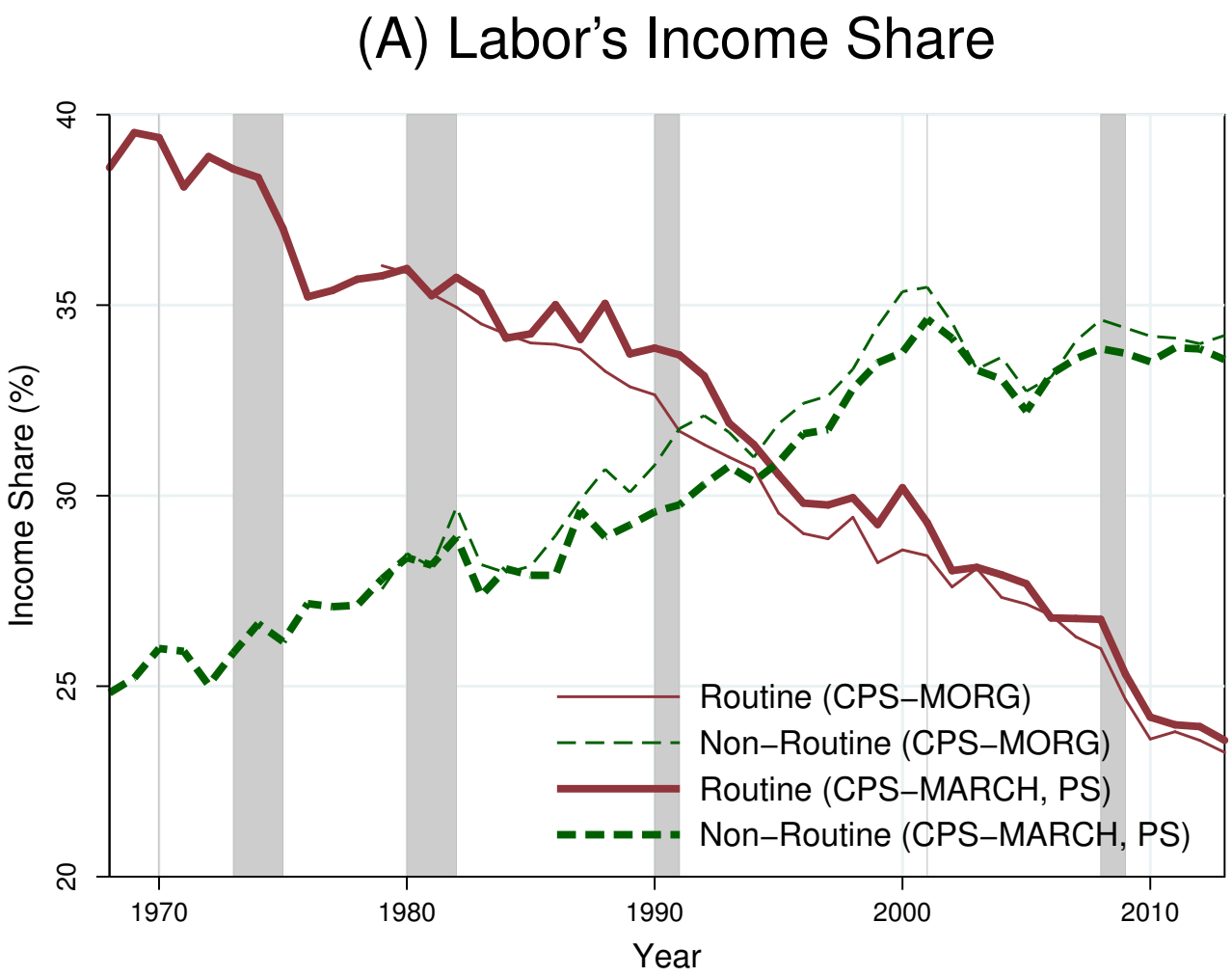


Data: BEA detailed fixed asset accounts & author's computations

Labor

- **Routine Labor vs. Non-Routine Labor**
  - "labor carrying out exact, **pre-specified procedures**" (Autor, Levy and Murnane 2003, Acemoglu and Autor, 2011)
- Examples
  - Routine: accountant, cashier
  - Non-Routine: manager, nanny

Routine vs. Non-Routine Income Share

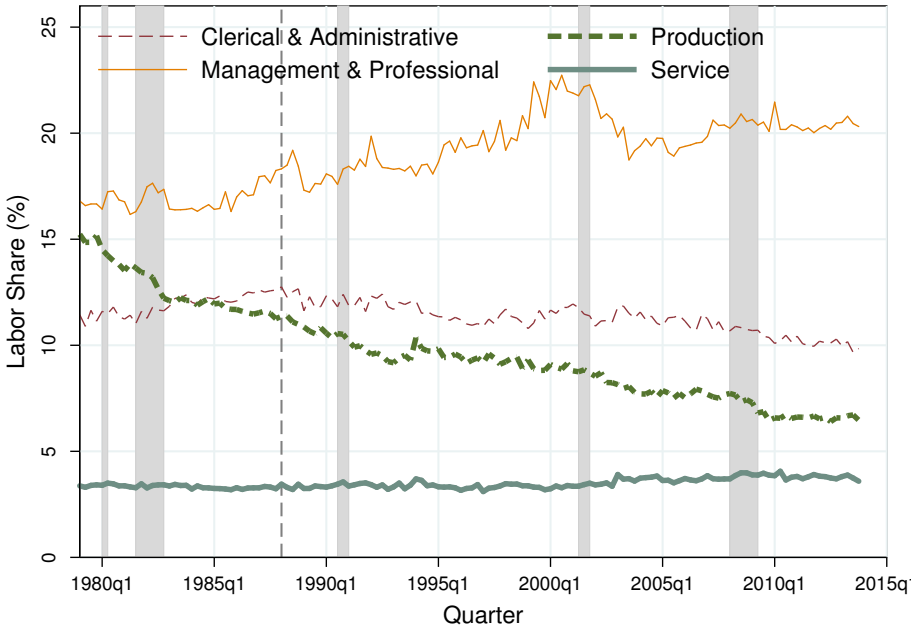


- Routine Jobs:
  - Production
  - Operative
  - Clerical
  - Support
  - Sales
- Non-Routine Jobs:
  - Professional
  - Managerial
  - Technical
  - Service

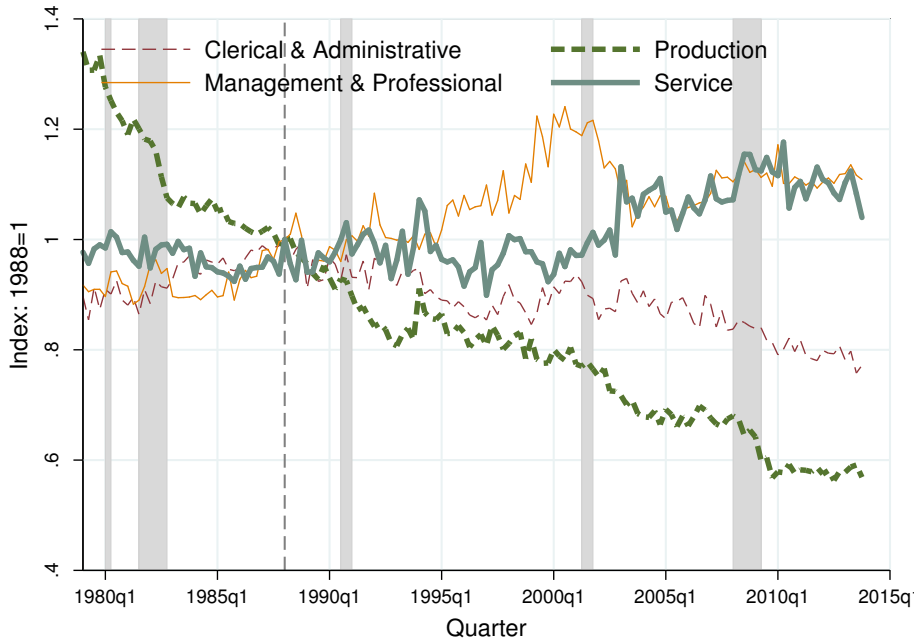
Data: CPS MARCH/ORG (1968/79-2013) & authors' computations

Abstract vs. Manual Tasks

(A) Income Share

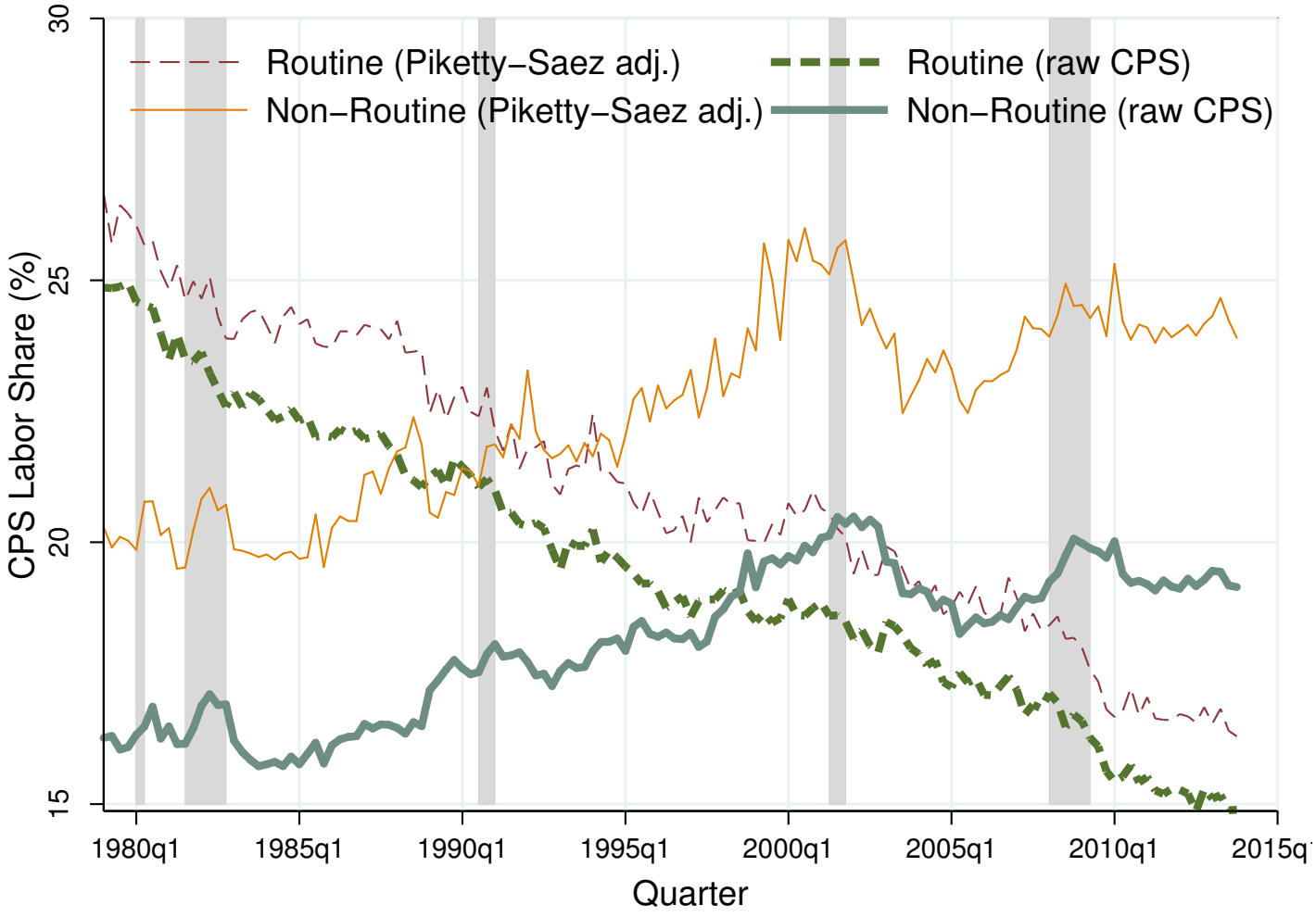


(B) Income Share Relative to 1988



Data: CPS MORG (1979-2013) & authors' calculations

Top-Coding & The One Percent

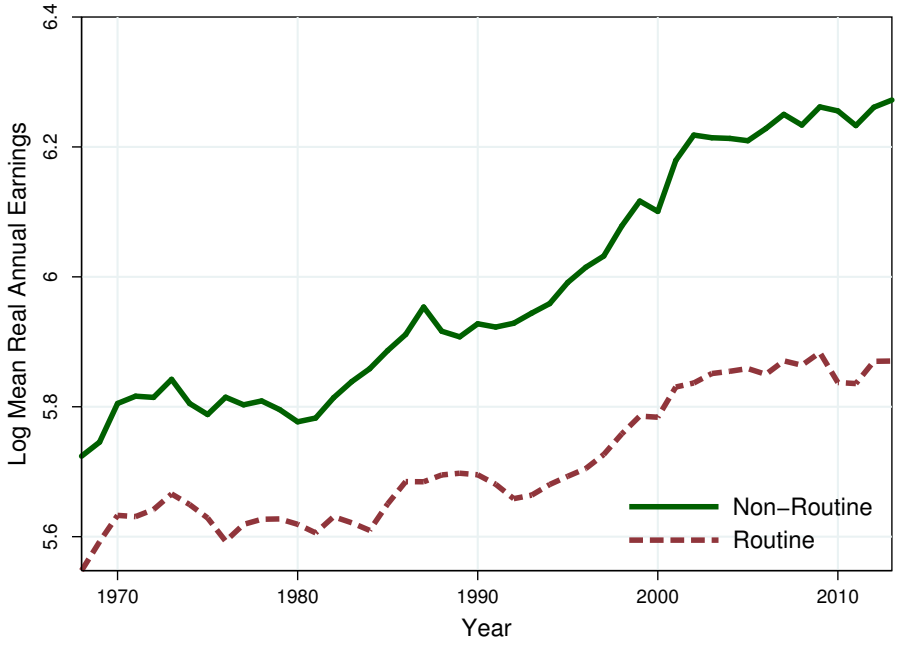


Data: CPS MORG (1979-2013) & Piketty-Saez (2003) & authors' calculations

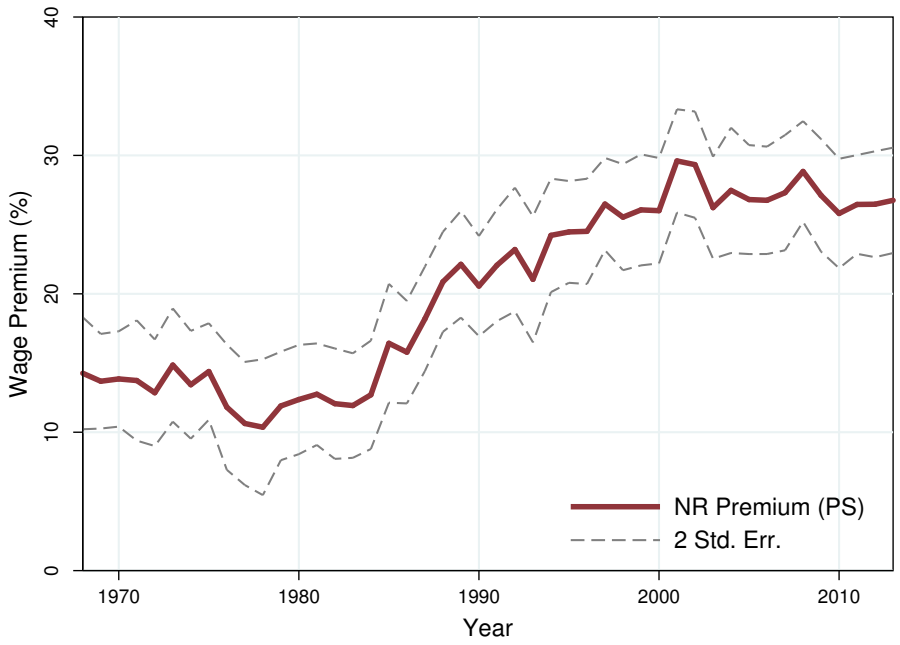
Wage-Employment Decomposition

$$\frac{w_{nr}L_{nr}}{w_rL_r} = \left(\frac{w_{nr}}{w_r}\right)\left(\frac{L_{nr}}{L_r}\right) = (1 + \text{non-routine wage premium})\left(\frac{L_{nr}}{L_r}\right)$$

(A) Routine vs. Non-Routine Wages



(B) Non-Routine Wage Premium

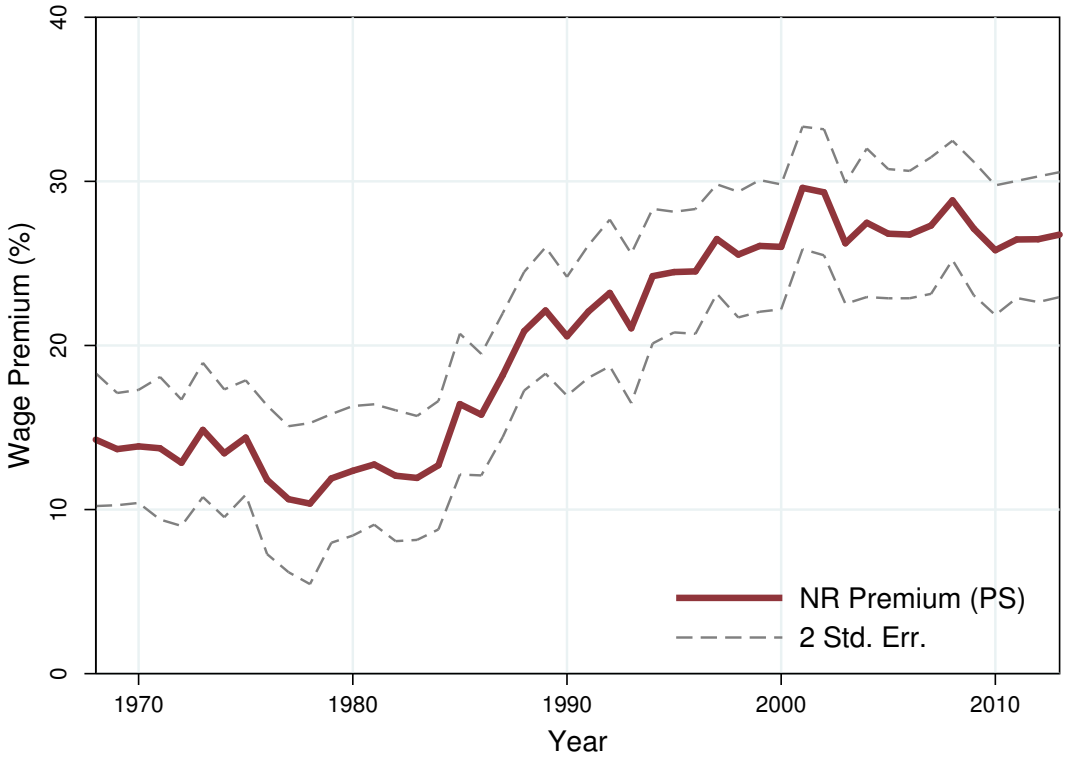


Data: CPS MARCH

Non-Routine Wage Premium

$$\ln w_{i,t} = \beta_{0,t} + \beta_{1,t} NR_{i,t} + \beta_{2,t} X_{i,t} + \epsilon_{i,t} \quad \text{for } t \in \{1968, \ldots, 2013\}$$

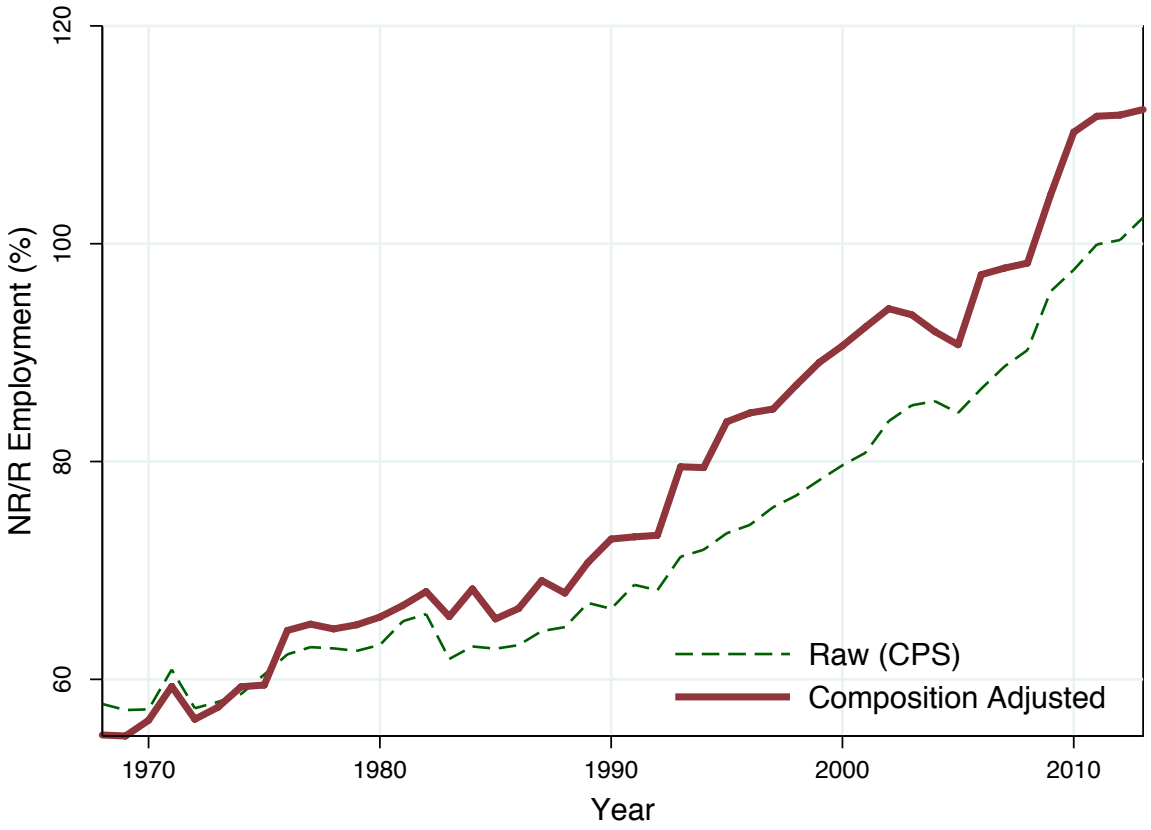
- Control Variables:
  - gender, race, full time, full year
  - Industry FEs (50 industries)
  - age x education 4th-order polynomials



Data: CPS MARCH

Wage-Employment Decomposition

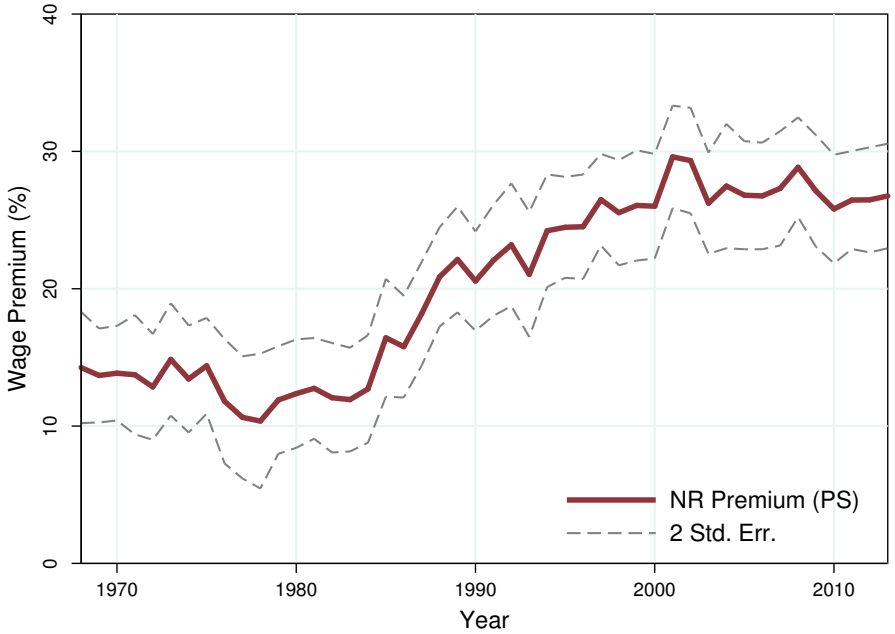
$$\frac{w_{nr} L_{nr}}{w_r L_r} = \left(\frac{w_{nr}}{w_r}\right)\left(\frac{L_{nr}}{L_r}\right) = (1 + \text{non-routine wage premium})\left(\frac{L_{nr}}{L_r}\right)$$

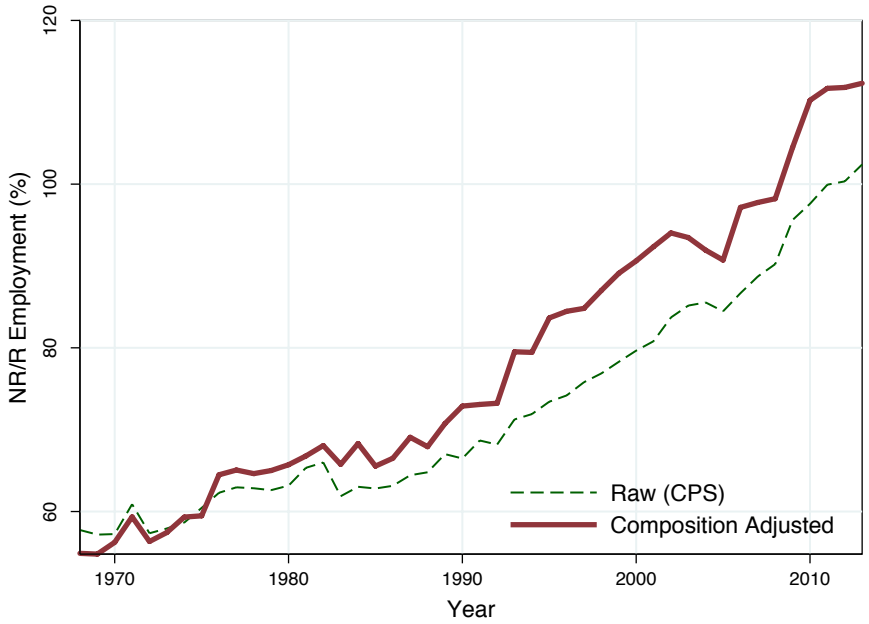


Data: CPS MARCH

Wage-Employment Decomposition

- Relative price **AND** quantity of NR increase
- Relative increase in the demand for NR labor
- Premium persists: unlikely due to frictions





Data: CPS MARCH & authors' calculations

Part 1: An Accounting Exercise

- **ICT** accounts for **about half** of the declining labor share

			Labor Share		Capital Share	
	Labor Share	Capital Share	Routine	Non-Routine	ICT	Non-ICT
1968	63.4	36.6	38.6	24.8	1.3	35.3
2013	57.1	42.9	23.6	33.6	4.1	38.8
Percentage Point Change since 1968						
1968-2013	-6.3	6.3	-15.0	8.7	2.8	3.5

Data: BEA, BLS, & authors' calculations

Part 2:

- Use trends in income shares to calibrate production structure
- Embed in neo-classical growth model
- Conduct counterfactual simulations
  - Take ICT price as exogenous
  - What if the ICT price had not fallen?

Production Structure

- CRS Production Structure (nested CES)

Output: $$y = k_n^{\alpha} x^{1-\alpha}$$

"Task" Inputs: $$x = (\eta x_r^{\theta} + (1-\eta) x_{nr}^{\theta})^{\frac{1}{\theta}}$$

R & NR Inputs: $$x_i = (\gamma_i k_{c,i}^{\sigma_i} + (1-\gamma_i) l_i^{\sigma_i})^{\frac{1}{\sigma_i}})$$

- Changes in the NICT income share are not interpreted as outcomes of automation

Production Structure

- Special Cases
  - Autor-Dorn (2013, AER)

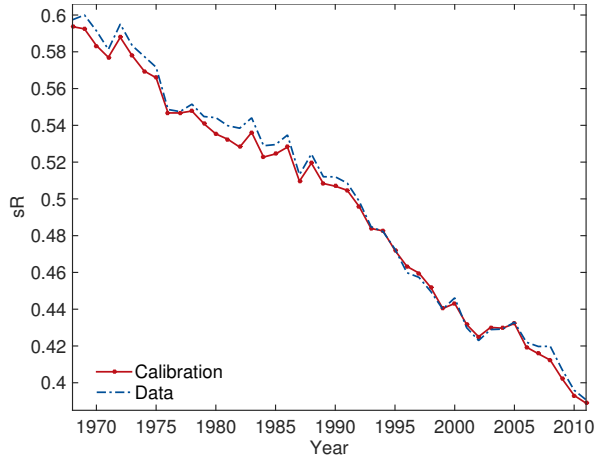
$$x = (\eta(\gamma_r k_c^{\sigma_r} + (1-\gamma_r) l_r^{\sigma_r})^{\frac{\theta}{\sigma_r}} + (1-\eta) l_{nr}^{\theta})^{\frac{1}{\theta}}$$

  - KORV (2000, ECMA)

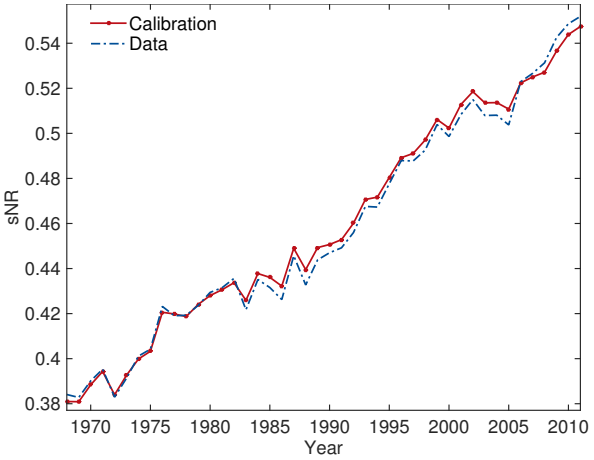
$$x = (\eta l_r^{\theta} + (1-\eta)(\gamma_{nr} k_c^{\sigma_{nr}} + (1-\gamma_{nr}) l_{nr}^{\sigma_{nr}})^{\frac{\theta}{\sigma_r}})^{\frac{1}{\theta}}$$

Calibration: Match Trend in Income Shares

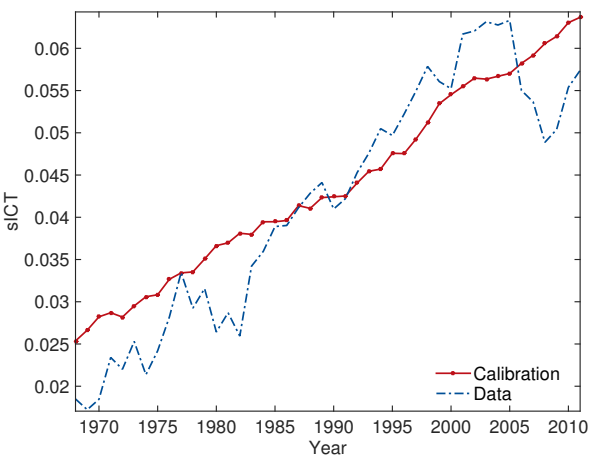
(A) Routine Share (% of x)



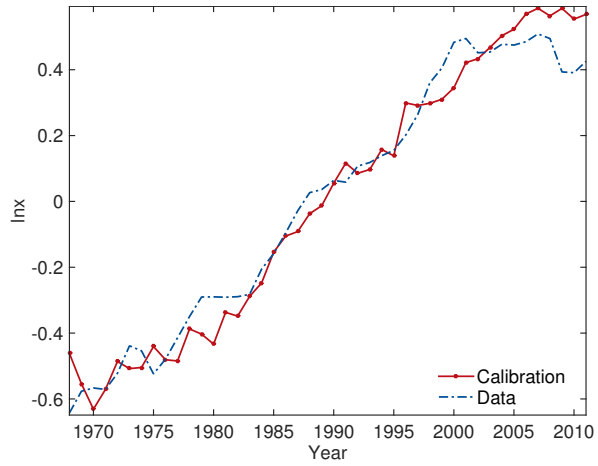
(B) Non-Routine Share (% of x)



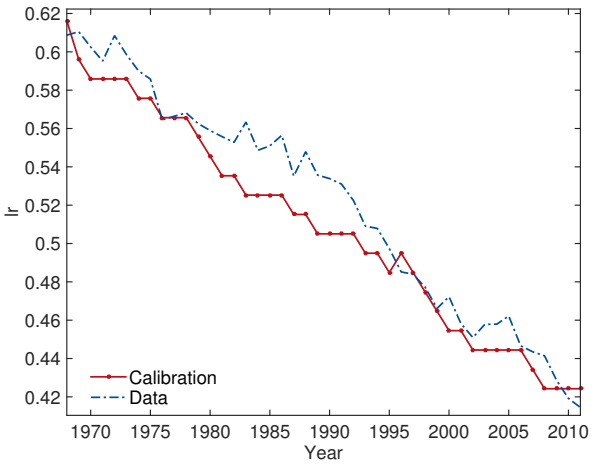
(C) ICT Share



(D) Log of x



(E) Routine Labor (l_r)



Neoclassical Growth Model

$$\max_{c_t, k_{i,t+1}, l_{i,t}} \sum_{t=0}^{\infty} \beta^t u(c_t)$$

such that

$$l_{r,t} + l_{n,t} = 1$$

$$y_t = A k_n^{\alpha} x_t^{1-\alpha}$$

$$x = \left[\eta \ell_r^{\theta} + (1-\eta) x_{nr}^{\theta}\right]^{\frac{1}{\theta}}$$

$$x_{nr} = \left[\gamma k_c^{\sigma} + (1-\gamma)\ell_{nr}^{\sigma}\right]^{\frac{1}{\sigma}}$$

$$c_t + (1+\lambda_l)\sum_i p_{i,t} k_{i,t+1} = y_t + \sum_i p_{i,t}(1-\delta_{i,t}) k_{i,t}$$

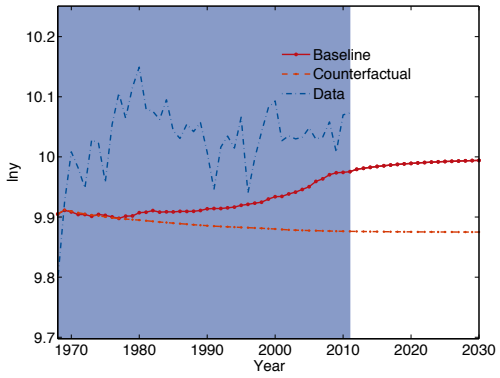
Units: per effective worker (1/AL)

Calibration

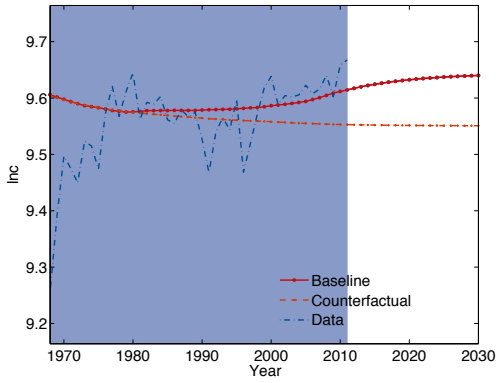
Parameter	Calibration	
γ_r	0	
γ_{nr}	0.0119	
σ_{nr}	0.2269	(EOS: 1.2276)
η	0.5494	
θ	0.847	(EOS: 5.6721)
λ_a	0	
Parameter	Calibration	
β	0.9747	
$u(c)$	$\ln(c)$	
δ_n	0.0594	
α	0.3476	
λ_l	0.028	
$p_{c,t}$	$\in [0.28, 1.62]$	(BEA data)
$\delta_{c,t}$	$\in [0.142, 0.208]$	(BEA data)

Counterfactual Simulation (Initial Year: 1968)

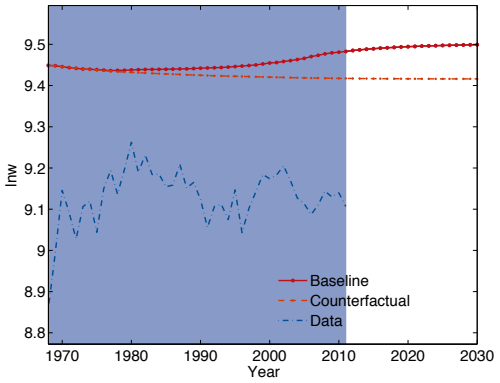
(A.1) Output



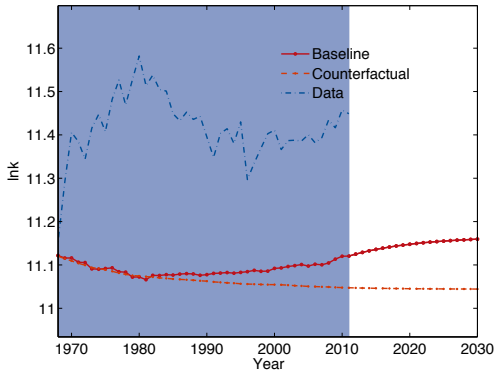
(A.2) Consumption



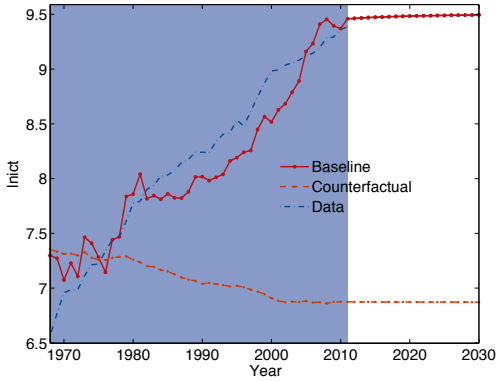
(A.3) Wages



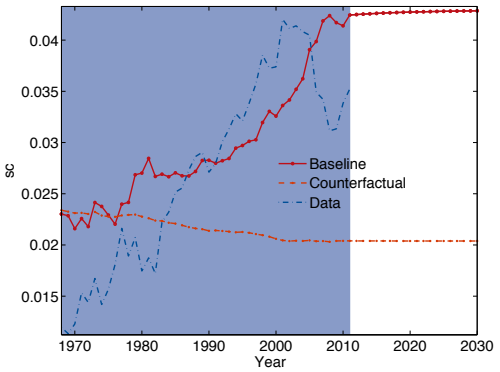
(B.1) NICT Capital



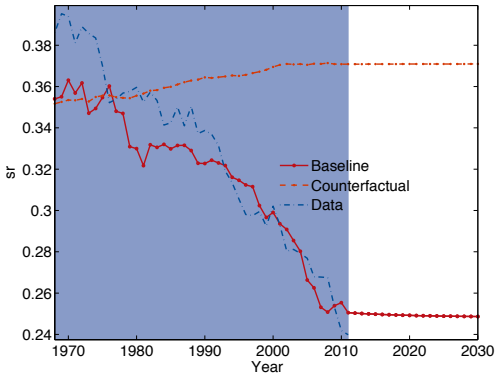
(B.2) ICT Capital



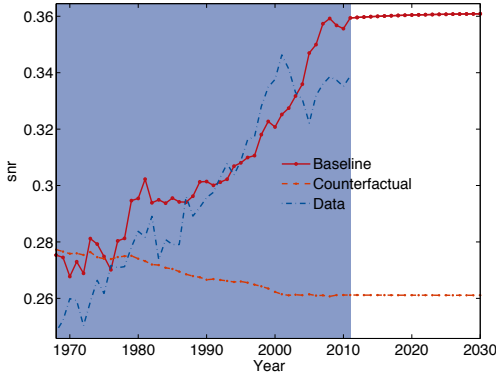
(B.3) ICT Share



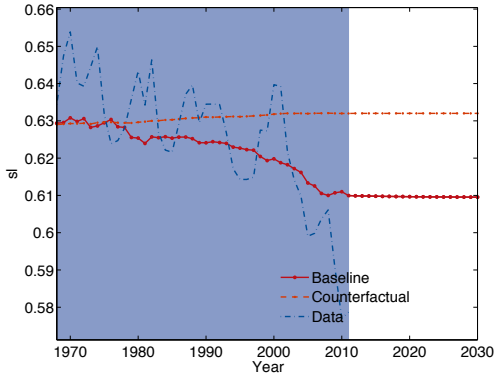
(C.1) Routine Share



(C.2) Non-Routine Share



(C.3) Labor Share



Aggregate Effects: SS comparison (1968)

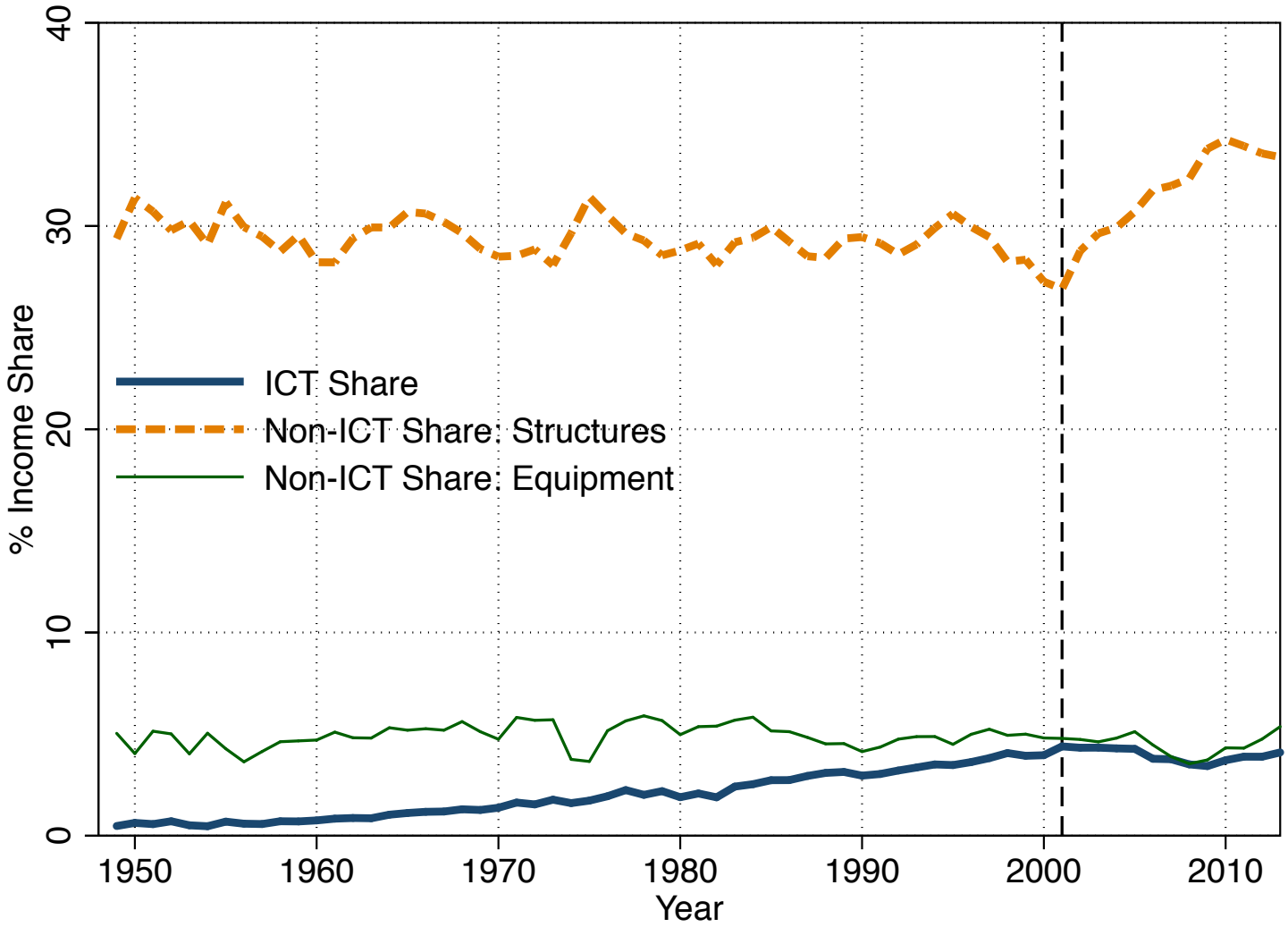
Variable	Change in SS relative to counterfactual
Quantities	
Output	+12%
Consumption	+9.4%
non-ICT Capital	+12%
ICT Capital	+263%
Real Wage	+8.5%
Income Shares	
Labor Share	-2.26%
Routine Share	-12.26%
Non-routine Share	+10%
ICT Share	+2.26%
Welfare Gain	+3.6%

Conclusions

- ICT accounts for **half** of the **decline in the labor share** (2 pp)
- **Reallocates** labor from routine to non-routine (10 pp)
- **Policy implications:**
  - In the short run: focus on redistribution of labor income rather than redistribution from capital to labor
  - In the long run: develop non-routine skills, and welcome automation!

THANK YOU !!

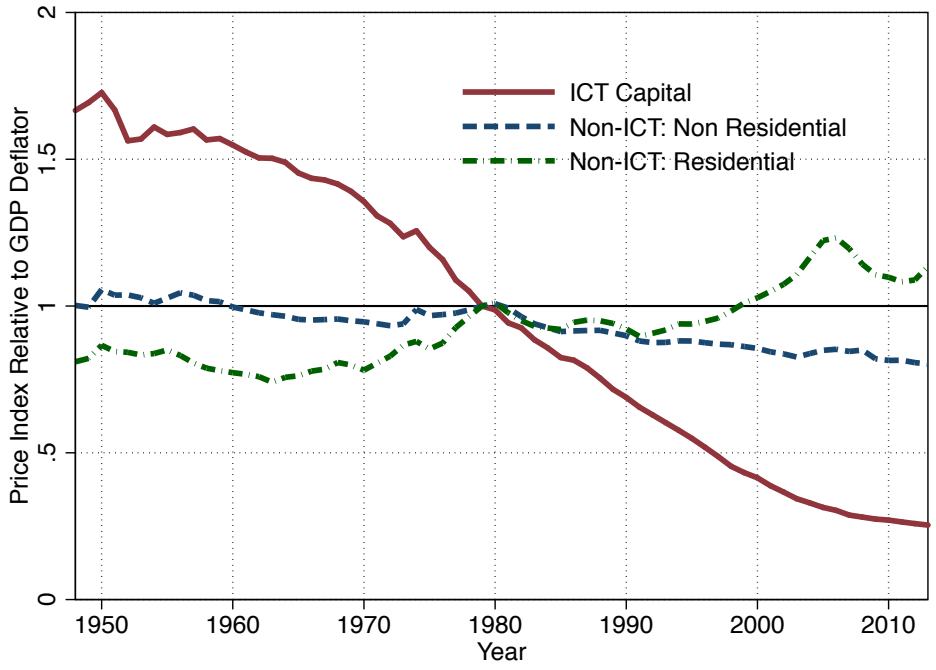
Capital Income Share

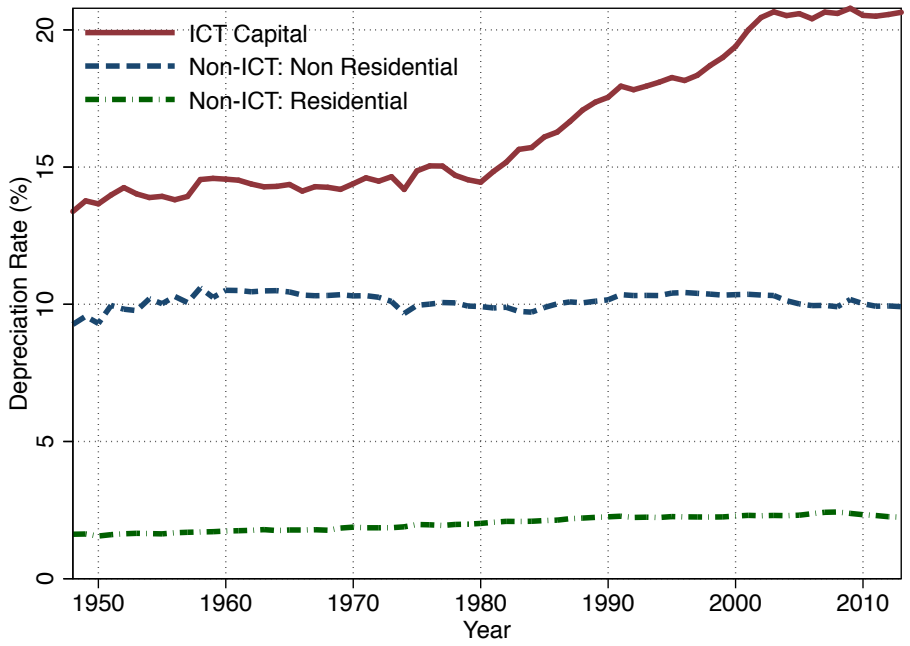


Data: BEA detailed asset accounts & author's computations

Relative Price of ICT & Depreciation

- Implicit Price Deflators for capital
- BEA's estimate of depreciation

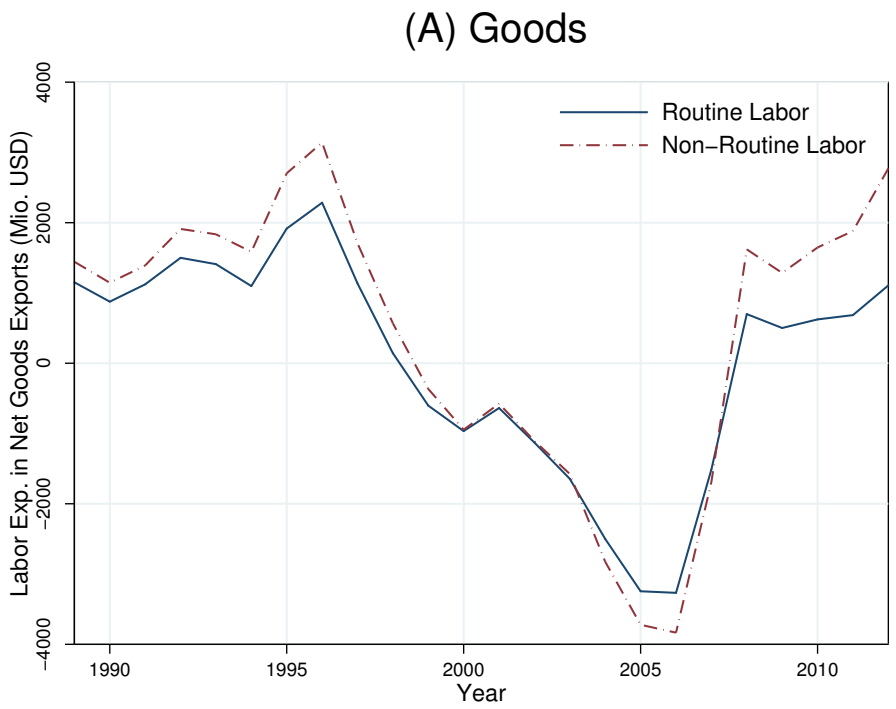


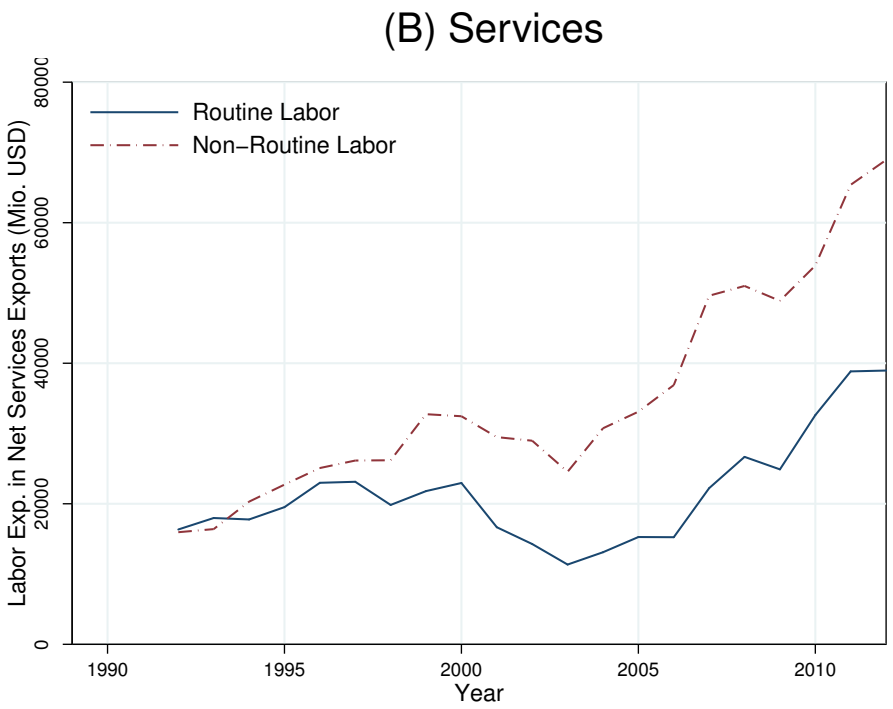


Data: BEA detailed fixed asset accounts & author's computations

Alternative Structure: R/NR Labor in Net Exports

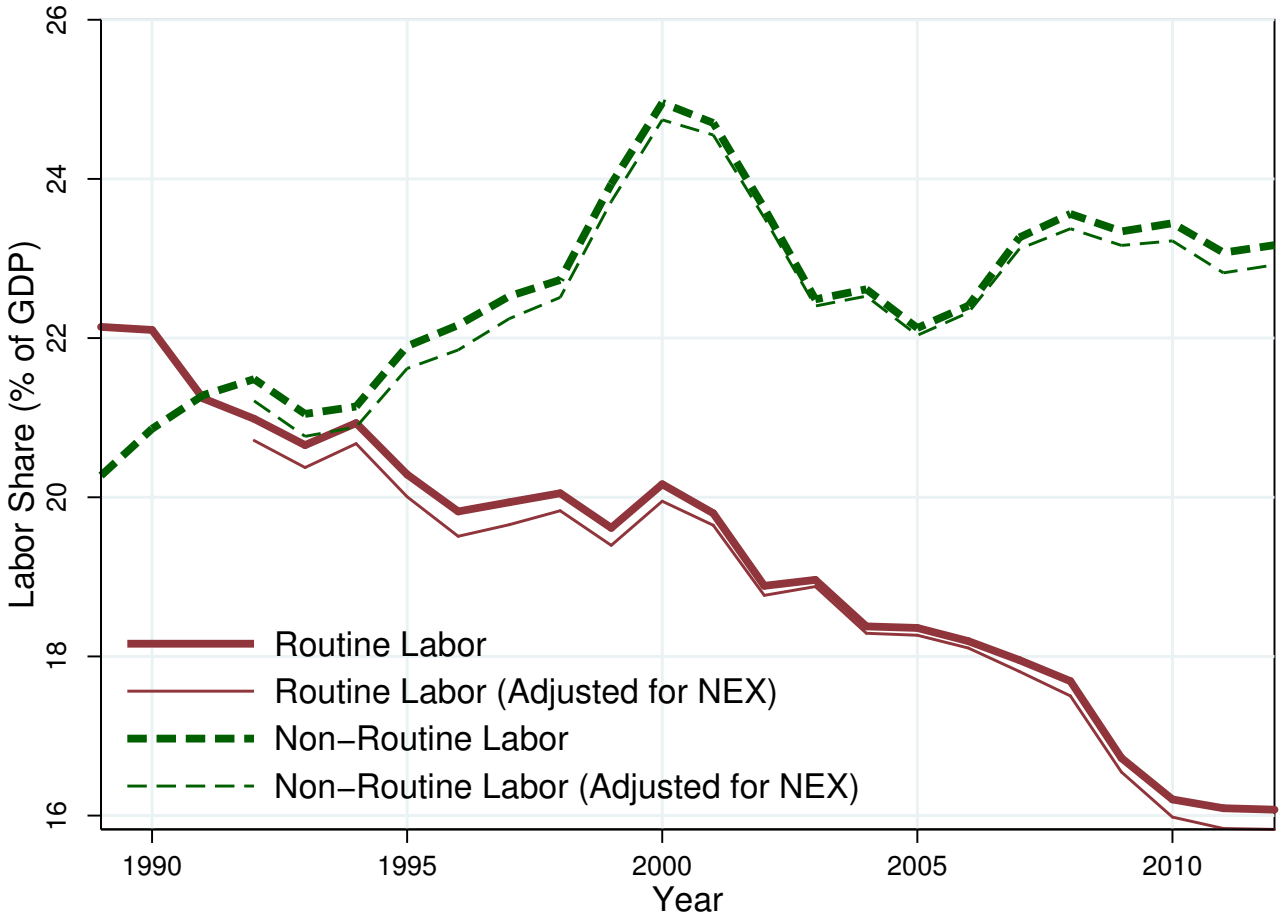
- Net Exports of R/NR labor services: $\sum_{i \in I} s_{\ell,i,t} \cdot NX_{i,t}$
  - Industry Specific R/NR exp. share
  - Industry Specific Net Exports



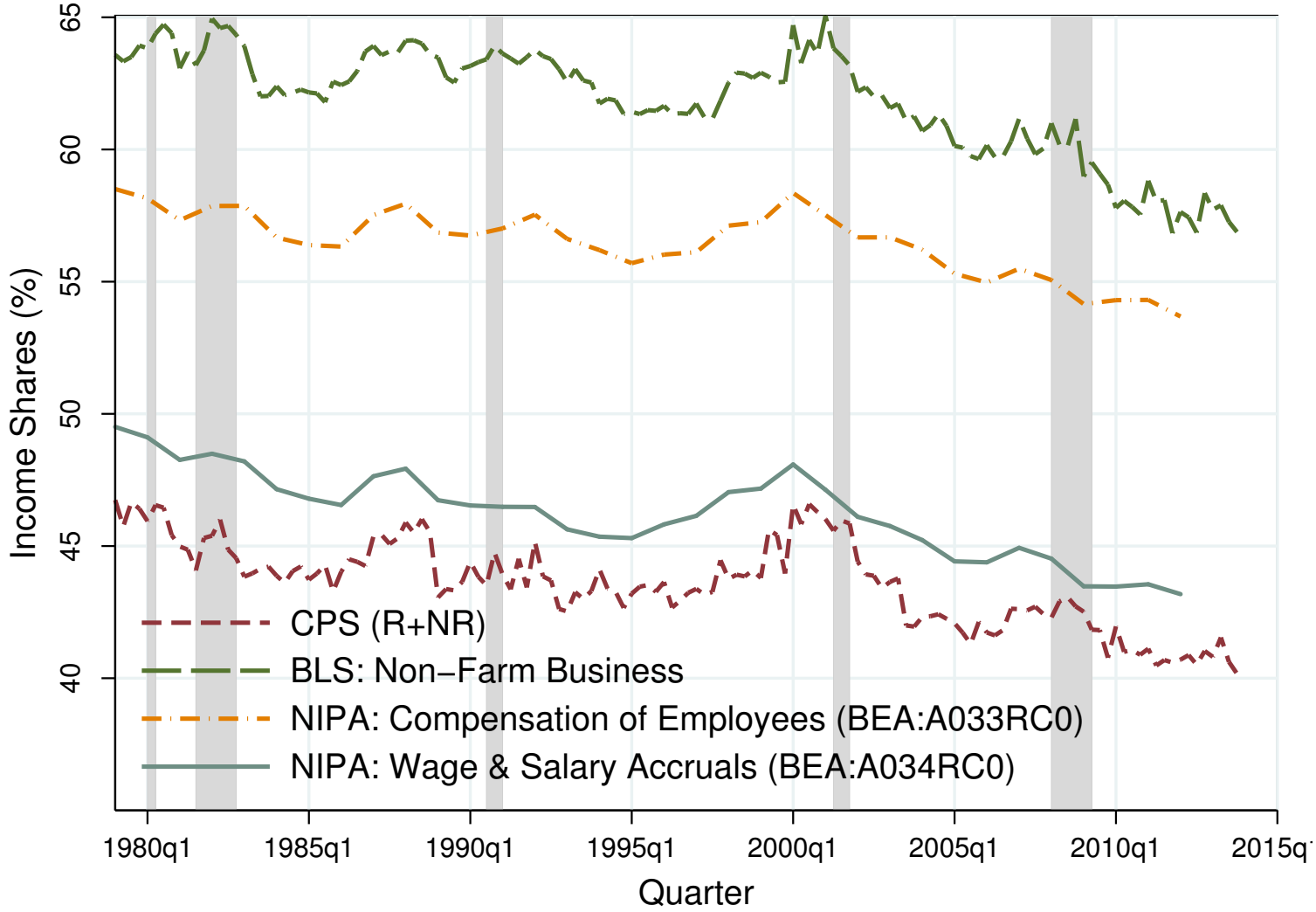


Alternative Structure: R/NR Labor in Net Exports

$$s_{NX,\ell,t} = \frac{\sum_{i \in I} s_{\ell,i,t} \cdot NX_{i,t}}{GDP_t}$$



Labor's Income Share



Data: CPS MORG (1979-2013) & authors' computations