Questions for the next couple of weeks

1. To what extent does falling information processing equipment prices help explain:
   - ... in the relationship between education and income?
   - ... income for males vs. females?
2. What are the sources of these trends?
   - Institutional factors
     - Unionization
     - Minimum wage
   - Supply and demand factors
     - Trade and offshoring
     - Automation/computerization

Outline for the next couple of weeks

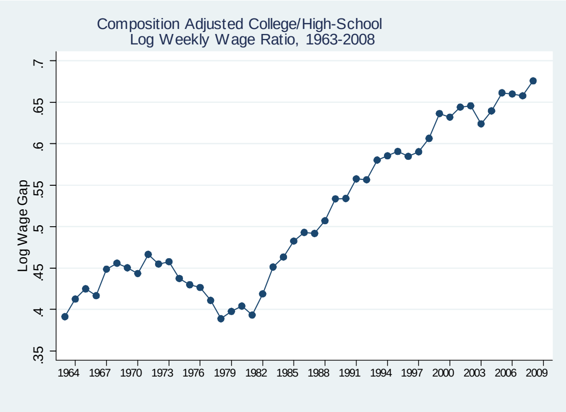
- Acemoglu and Autor; Autor, Levy, Murnane; Autor and Dorn:
  - "Canonical" model can help rationalize changes in the skill premium, but...
  - ... a task-based model of the labor market is necessary to match other trends in the wage distribution.

- Burstein, Morales, Vogel: Computerization explains much of the changes in "between-group" inequality.

- Statistical decompositions of the wage distribution

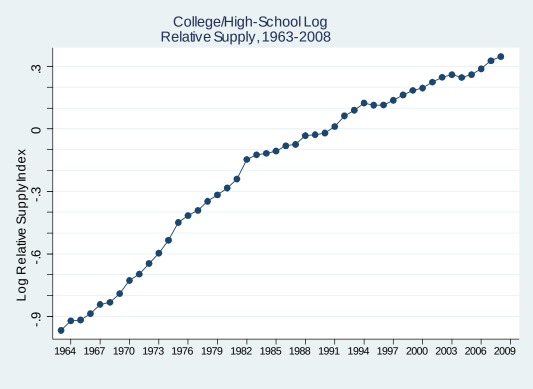
- Atalay, Phongthiengtham, Sotelo, Tannenbaum: Changes in tasks occurs mainly within occupations.

Acemoglu an Autor (2011; Figure 1)



- College premium increases from 50 percent (1963) to 60 percent (1973),
- ... decreases to 50 percent (1979), then up to 95 percent by 2010.

Acemoglu an Autor (2011; Figure 2)



- Fraction of hours worked by college workers increases continuously, decelerating in 1982

"Canonical Model"

- Designed to rationalize things like the last two figures.
- Workers, i, come in one of two skill types.
  - Let $L = \int_{i \in \mathcal{L}} l_i di$ refer to the aggregate supply of low-skilled workers
  - Let $H = \int_{i \in \mathcal{H}} h_i di$ refer to the aggregate supply of low-skilled workers
- Aggregate output is a combination of low-skilled, high-skilled-workers.

$$Y = \left[(A_H H)^{\frac{\sigma - 1}{\sigma}} + (A_L L)^{\frac{\sigma - 1}{\sigma}} \right]^{\frac{\sigma}{\sigma - 1}}$$

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- Factor markets are competitive:

$$w_L = \frac{\partial Y}{\partial L} = [A_L]^{\frac{\sigma-1}{\sigma}} \cdot L^{-\frac{1}{\sigma}} \left[(A_H H)^{\frac{\sigma-1}{\sigma}} + (A_L L)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{1}{\sigma-1}}$$

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"Canonical Model"

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- $\frac{H}{L}$ and $\frac{w_H}{w_L}$ have been increasing $\Rightarrow$ Either $\sigma > 1$ and $\frac{A_H}{A_L}$ is growing or $\sigma < 1$ and $\frac{A_H}{A_L}$ is shrinking.

"Canonical Model"

- From last slide, adding time subscripts:

$$\log \frac{w_{Ht}}{w_{Lt}} = \frac{\sigma - 1}{\sigma} \log \frac{A_{Ht}}{A_{Lt}} - \frac{1}{\sigma} \log \frac{H_t}{L_t}$$

- Suppose

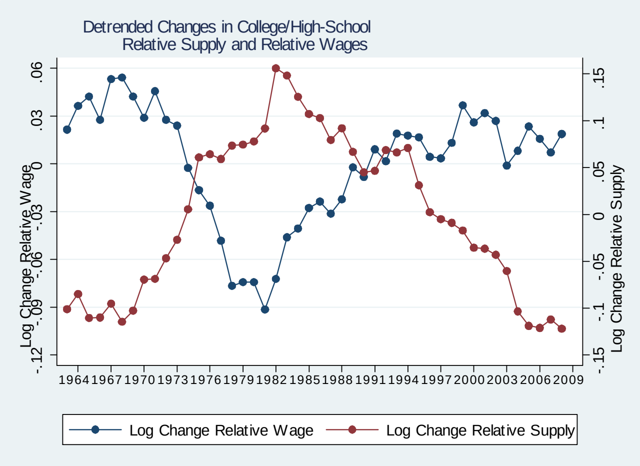
$$\log \frac{A_{Ht}}{A_{Lt}} = \gamma_0 + \gamma_1 t$$

- Then

$$\log \frac{w_{Ht}}{w_{Lt}} = \frac{\sigma - 1}{\sigma} \gamma_0 + \frac{\sigma - 1}{\sigma} \gamma_1 t - \frac{1}{\sigma} \log \frac{H_t}{L_t}$$

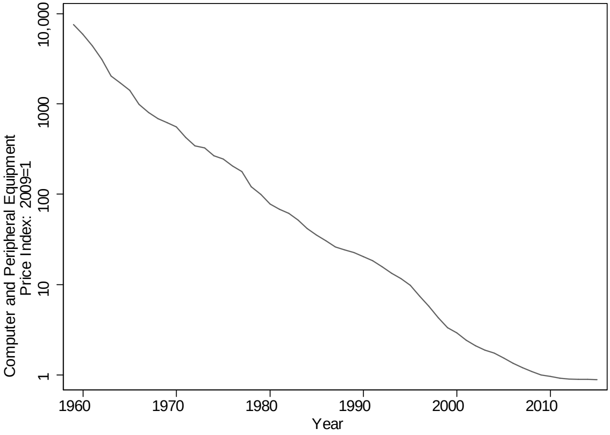
- An OLS regression, using data from 1963-87, of the past previous equation $\Rightarrow \sigma \approx 1.6$ and $\gamma_1 \approx 0.07$
- But what is the γ_1 term represent?

"Canonical Model"

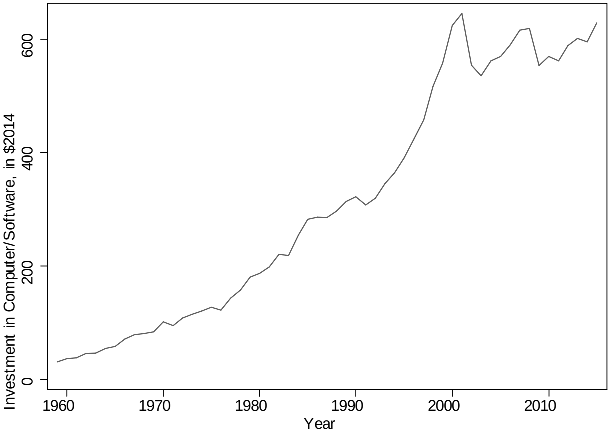


Notes on Krusell et al. (2000): "Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis"

Price of computers and peripheral equipment



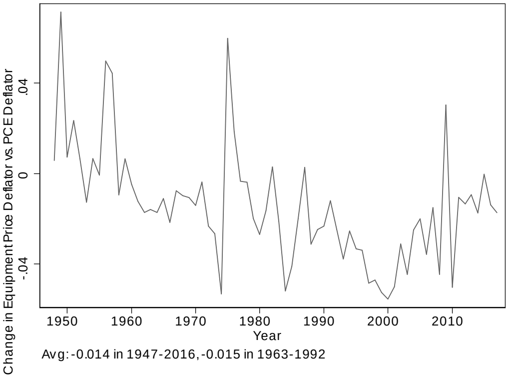
Investment in computers and software



Components of the argument

1. Equipment price declines are even more severe than what NIPA data indicate
2. High-skilled labor is complementary to equipment.
3. From (2), increase in equipment per worker $\Rightarrow \uparrow$ in skill premium

Nonresidential: Equipment: Implicit Price Deflators



Nonresidential: Equipment: Implicit Price Deflators

- As of 1990s: Criticism of standard (NIPA) measures of equipment price deflators for not fully incorporating quality improvements.
  - especially so for computers
- Gordon (1990) computes price of mainframe computers (1951-84), minicomputers (1965-84), personal computers(1982-87)
  - Mainframe price index declines by 22 percent per year.
- Gordon also computes quality adjustments for other type of equipment: industrial equipment, transportation, and other
- Krussel et al extrapolate Gordon's index to 1992

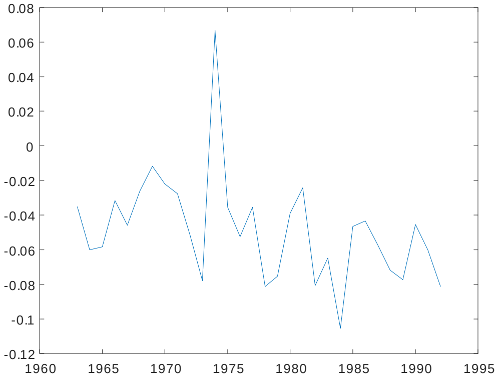
How the extrapolation works

- Estimate VAR for 1963 to 1984

$$\begin{pmatrix} P_{\text{Industrial Equipment,t}} \\ P_{\text{Transportation,t}} \\ P_{\text{Other Equipment,t}} \end{pmatrix} = \beta_0 + \beta_1 \begin{pmatrix} P_{\text{Industrial Equipment,t-1}} \\ P_{\text{Transportation,t-1}} \\ P_{\text{Other Equipment,t-1}} \end{pmatrix}$$
$$+ \beta_2 \cdot P_{\text{Equipment, NIPA,t-1}} + \epsilon_t$$

- Using observed NIPA prices, iteratively impute the three quality-adjusted equipment-prices to 1992.
- Main assumption: The degree to which NIPA understates equipment quality growth is the same in 1963 to 1984 as in 1984 to 1992
- For computers: Compile sources from a number of existing papers.

Nonresidential Equipment: Implicit Price Deflators



Average: -0.049.

Model

- Add structures, equipment to our "canonical model" production function

$$Y\left(K_{st}, K_{et}, H_t, L_t\right) = A_t \ \cdot K_{st}^{\alpha}\left[\mu L_t^{\sigma} + (1-\mu) \times \left(\lambda K_{et}^{\rho} + (1-\lambda) H_t^{\rho}\right)^{\frac{\sigma}{\rho}}\right]^{\frac{1-\alpha}{\sigma}}$$

  - K_{et} : equipment capital; K_{st} : structures
  - $[1-\rho]^{-1}$: elasticity of substitution between high-skilled labor and equipment.
  - $[1-\sigma]^{-1}$: elasticity of substitution between low-skilled labor and high-skilled-labor/equipment composite.
- Allow for $H_t = \tilde{H}_t \psi_{ht}$ to be a composite of hours worked by high-skilled workers and unobserved labor quality/utilization (similarly for low-skilled labor)

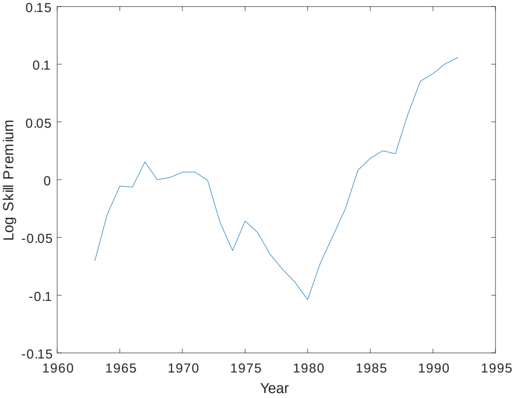
Skill-premium implied by the model.

- With appropriate (competitive) assumptions, this setup leads to the following equation:

$$\log\left(\frac{w_{Ht}}{w_{Lt}}\right) = \lambda\left[\frac{\sigma-\rho}{\rho}\right]\left(\frac{K_{et}}{\psi_{ht}\cdot\tilde{H}_t}\right)^{\rho} + (\sigma-1)\cdot\log\left(\frac{\tilde{H}_t}{\tilde{L}_t}\right) + \sigma\log\left(\frac{\psi_{ht}}{\psi_{lt}}\right)$$

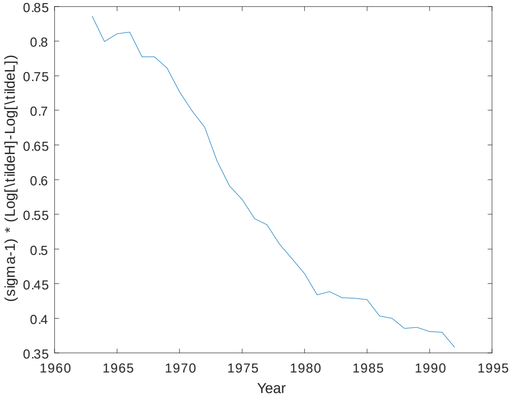
- Key to Krusell et al.: $\sigma > \rho$:
  - If high-skilled labor and equipment are relatively complementary, then lower prices of equipment push up the demand for skilled labor.
  - In their benchmark specification, assume that $\frac{\psi_{ht}}{\psi_{lt}}$ is constant.
- Estimate that $\sigma = 0.401$; $\rho = -0.495 \Rightarrow \frac{1}{1-\sigma} = 1.67$; $\frac{1}{1-\rho} = 0.67$

Skill-premium: Data



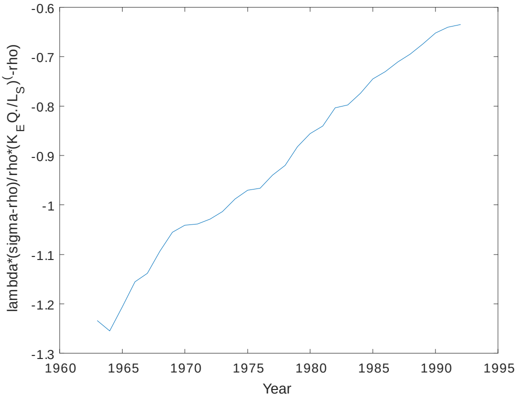
$$\log\left(\frac{w_{Ht}}{w_{Lt}}\right) = \lambda\left[\frac{\sigma-\rho}{\rho}\right]\left(\frac{K_{et}}{\psi_{ht}\cdot\tilde{H}_t}\right)^{\rho} + (\sigma-1)\cdot\log\left(\frac{\tilde{H}_t}{\tilde{L}_t}\right)$$

Skill-premium: Labor Supply



$$\log\left(\frac{w_{Ht}}{w_{Lt}}\right) = \lambda\left[\frac{\sigma-\rho}{\rho}\right]\left(\frac{K_{et}}{\psi_{ht}\cdot\tilde{H}_t}\right)^{\rho} + (\sigma-1)\cdot\log\left(\frac{\tilde{H}_t}{\tilde{L}_t}\right)$$

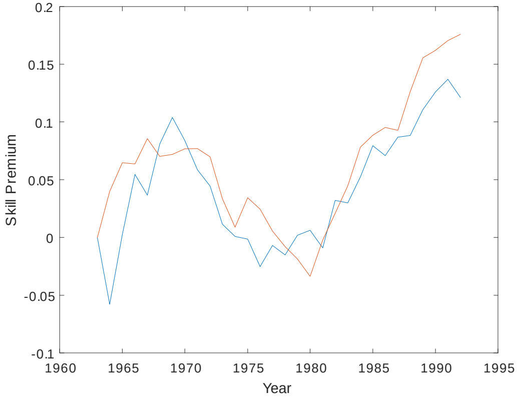
Skill-premium: Equipment per skilled worker



$$\log\left(\frac{w_{Ht}}{w_{Lt}}\right) = \lambda\left[\frac{\sigma-\rho}{\rho}\right]\left(\frac{K_{et}}{\psi_{ht}\cdot\tilde{H}_t}\right)^{\rho} + (\sigma-1)\cdot\log\left(\frac{\tilde{H}_t}{\tilde{L}_t}\right)$$

My best estimation: $\lambda \cdot \psi_{ht}^{-\rho} \approx 5.15$

Skill-premium: Comparison



$$\log\left(\frac{w_{Ht}}{w_{Lt}}\right) = \lambda\left[\frac{\sigma-\rho}{\rho}\right]\left(\frac{K_{et}}{\psi_{ht}\cdot\tilde{H}_t}\right)^{\rho} + (\sigma-1)\cdot\log\left(\frac{\tilde{H}_t}{\tilde{L}_t}\right)$$

Notes on Autor, Levy, Murnane (2003): "The Skill Content of Recent Technological Change: An Empirical Exploration"

Goal of the paper

Existing papers — like Krusell et al. (2000) —skill-biased technical change:

- high-skilled workers both use computers more and are paid more than low-skilled workers
- decrease in price of computers (increase in computers per worker) $\Rightarrow$ increase in skill-premium

Goal of this paper: Explain "what it is that computers do — or what it is that people do with computers — that causes educated workers to be relatively more in demand."
Main hypotheses:

- Computers and low-to-middle skilled workers perform "routine" tasks.
- High-skilled workers preform "nonroutine" analytic and interactive tasks.
  $\Rightarrow$Decline in the price of computers reduces demand for worker-performed routine tasks.

Examples of Routine and Nonroutine Tasks

Routine	Nonroutine
Analytic and Interactive Tasks	
Record Keeping	Testing hypothesis
Calculations	Medical diagnosis
Repetitive customer service	Persuading/selling
	Managing others
Manual Tasks	
Picking or sorting	Janitorial services
Assembly work	Truck driving

A Motivating Model

- Industries/occupation j produces with computers, routine labor, and nonroutine labor

$$U = \left[\sum Q_j^{\frac{\sigma - 1}{\sigma}} \right]^{\sigma/(\sigma - 1)}$$

$$Q_j = \left(\frac{L_{R_j} + C_j}{1 - \beta_j} \right)^{1 - \beta_j} \cdot \left(\frac{L_{N_j}}{\beta_j} \right)^{\beta_j}$$

- Industries/occupations can rent computers at price $\rho \Rightarrow w_R = \rho$.

Labor market clearing

- Each worker i has skills in performing routine or nonroutine tasks r_i, n_i.
- Workers choose which task to perform based on their skills and the price of the two tasks. Perform routine tasks if

$$w_R \cdot r_i > w_N \cdot n_i \Rightarrow$$
$$\eta_i \equiv \frac{n_i}{r_i} < \frac{w_R}{w_N}$$

Define:

$$g(\eta) = \sum r_i \cdot I\left[\eta_i < \frac{w_R}{w_N}\right] \text{ and } h(\eta) = \sum n_i \cdot I\left[\eta_i > \frac{w_R}{w_N}\right]$$

FOC for industries

$$\frac{\partial Q_j}{\partial \left(L_{R_j} + C_j\right)} = \frac{\rho}{P_j};\ \frac{\partial Q_j}{\partial L_{N_j}} = \frac{w_N}{P_j}$$

Demand for routine tasks:

$$\begin{aligned} L_{R_j} + C_j &= \frac{1}{\rho} \cdot Q_j \cdot P_j = \frac{1}{\rho} \cdot (P_j)^{1-\sigma} \\ &= \frac{1}{\rho} \cdot \left(w_N^{\beta_j} \cdot \rho^{1-\beta_j}\right)^{1-\sigma} \end{aligned}$$

Demand for nonroutine tasks:

$$L_{N_j} = \frac{1}{w_N} \cdot \left(w_N^{\beta_j} \cdot \rho^{1-\beta_j}\right)^{1-\sigma}$$

Comparative statics:

From last slide:

$$\log\left(L_{R_j}+C_j\right) = \beta_j \log w_N + \left(-\beta_j - \sigma + \beta_j\sigma\right)\log\rho$$
$$\log L_{N_j} = \left(\beta_j - \beta_j\sigma - 1\right)\log w_N + \left(1-\beta_j\right)\left(1-\sigma\right)\log\rho$$

So

$$\frac{\partial \log\left(L_{R_j}+C_j\right)}{\partial\left(-\log\rho\right)} = \left(\beta_j + \sigma - \beta_j\sigma\right) > 0;\ \frac{\partial^2 \log\left(L_{R_j}+C_j\right)}{\partial\left(-\log\rho\right)\partial\beta_j} = 1-\sigma < 0$$
$$\frac{\partial \log L_{N_j}}{\partial\left(-\log\rho\right)} = \left(1-\beta_j\right)\left(\sigma-1\right) > 0\ ;\ \frac{\partial^2 \log L_{N_j}}{\partial\left(-\log\rho\right)\partial\beta_j} = 1-\sigma > 0$$

- Lower computer prices leads to more routine tasks (performed by the combination of computers and workers), more nonroutine tasks.
- These effects are stronger in low β_j industries .

Results of the model

1. Across industries/occupations: A decline in worker-performed routine tasks; an increase in worker-performed nonroutine tasks.
2. Within industries/occupations:
   - Industries which were rich in routine tasks (β_j is low) in the pre-computer era is small adopt computers more intensely.
     - We should see a correlation across industries in changes in routine task growth and computer usage growth.
   - Industries which increase their computer usage most have the largest changes in nonroutine task growth.

Measures of Occupational Content

Dictionary of Occupational Titles

- Updated periodically (first version in 1939, last version in 1991)
  - see http://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/8942 for the 1977 version.
- For each occupation multiple measures, including:
  1. Direction, Control, and Planning of activities (Nonroutine interactive)
  2. Mathematical ability (Nonroutine analytic)
  3. Ability to Set limits, Tolerances, or Standards (Routine cognitive)
  4. Finger Dexterity (Routine manual)
  5. Eye Hand Coordination.(Nonroutine manual)
- In Autor and Dorn, the routineness measure equals the difference between 3, 4 and 1, 2, 5

Measures of Occupational Content

Dictionary of Occupational Titles

- Alternatively: Michaels, Rauch, Redding (2016) use text from the descriptions of each occupation.
- Description of an economist:

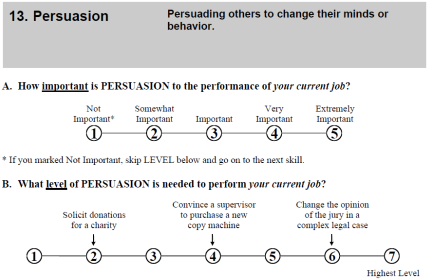
  Plans, designs, and conducts research to aid in interpretation of economic relationships and in solution of problems arising from production and distribution of goods and services: Studies economic and statistical data in area of specialization, such as finance, labor, or agriculture. Devises methods and procedures for collecting and processing data, utilizing knowledge of available sources of data and various econometric and sampling techniques....

- Groups verbs (e.g., "plans", "design", "studies," "devises") according to the type of task (analytical? interpersonal?)

Measures of Occupational Content

O*NET

- First version in 1998, updated periodically. Based on interviews of workers (plus expert opinion) across a much broader set of work elements:



13. Persuasion — **Persuading others to change their minds or behavior.**

A. How <u>important</u> is PERSUASION to the performance of *your current job*?

Not Important*	Somewhat Important	Important	Very Important	Extremely Important
1	2	3	4	5

* If you marked Not Important, skip LEVEL below and go on to the next skill.

B. What <u>level</u> of PERSUASION is needed to perform *your current job*?

1	2	3	4	5	6	7
	Solicit donations for a charity		Convince a supervisor to purchase a new copy machine		Change the opinion of the jury in a complex legal case	Highest Level

- Top occupations (importance/level): 1) Sales Engineers, 2) Sales Representatives, 3) Chief Executives/ 1) Chief Executives, 2) Arbitrators, 3) Lawyers.
- 68 questions like this on skills/requirements, 98 questions on work activities/contexts.

Measures of Occupational Content

O*NET

A common approach is to take certain questionnaire items as measures of routineness, manual vs. cognitive, etc...

- Routine manual:
  - Pace determined by speed of equipment
  - Controlling machines and processes
  - Spend time making repetitive motions
- Non-routine cognitive: Analytical
  - Analyzing data/information
  - Thinking creatively
  - Interpreting information for others
- Non-routine cognitive: Interpersonal
  - Establishing and maintaining personal relationships
  - Guiding, directing and motivating subordinates
  - Coaching/developing others

Aggregate trends

- For each cell, define a task score, based on the occupations of workers in that cell:
  - Top/bottom cells for GED Math Score:
  - Engineer/College/Male: 7.62
  - Medical/College/Male: 7.46
  - Pharmacy/College/Male: 7.46
  - Fishing/<HS/Female: 0.33
  - Fishing/<HS/Male: 0.92
  - Tobacco Manufacturing/<HS/Female: 1.08
- Compute the rank of each cell (accounting for the size as of 1960)
- Compute the weighted average of the ranks, allowing the sizes of the cells to change.

Education and Occupation in 1960

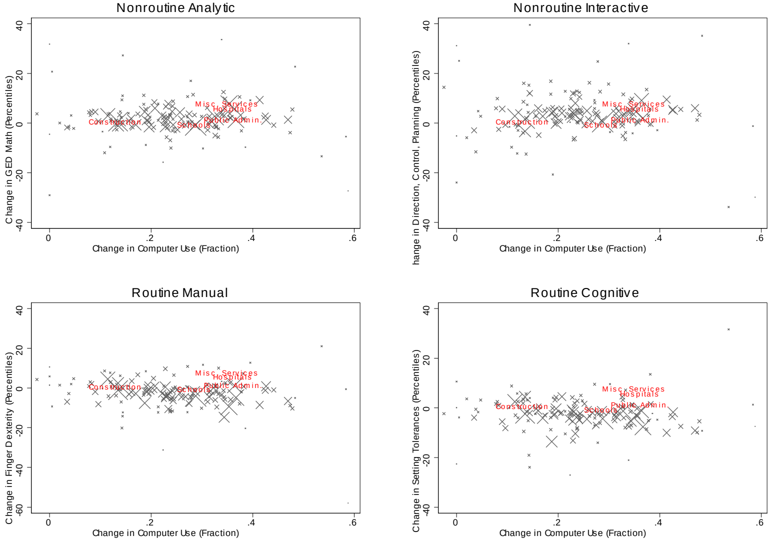
	Routine			Nonroutine		
	Cog.	Man.	All	Ana.	Int.	Man.
$<$HS	51.2	46.8	53.2	34.5	40.6	61.8
HS	55.9	58.0	56.9	52.9	49.6	42.7
Some Col.	50.6	54.5	46.5	74.0	65.8	36.3
$\geq$College	32.8	43.7	24.5	91.4	80.7	34.1

Aggregate Trends

	Routine		Nonroutine		
	Cognitive	Manual	Analytic	Interactive	Manual
1960	50.0	50.0	50.0	50.0	50.0
1970	53.1	53.5	51.9	50.7	46.2
1980.	51.8	55.1	53.2	53.3	44.0
1990	48.3	52.3	56.2	58.6	41.8
1998	44.4	49.2	58.7	62.2	41.3

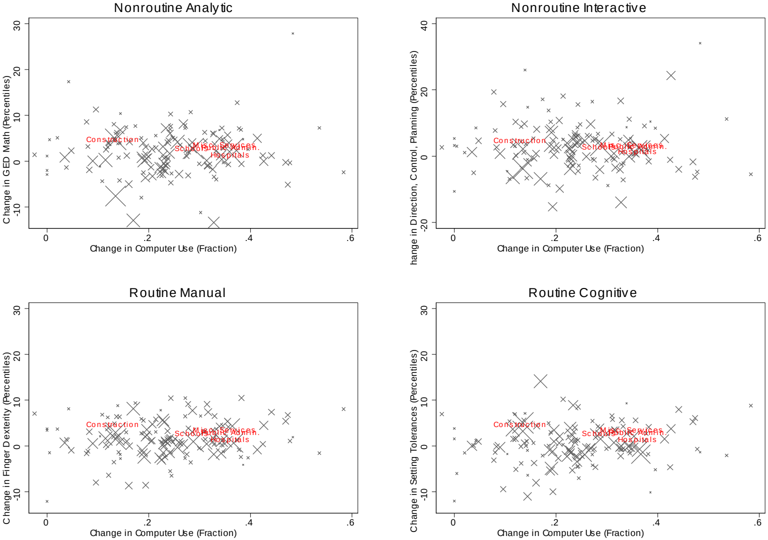
- Increase in nonroutine cells, decrease in nonroutine cells (with the exception of nonroutine manual).

Computer Use 1984-97 Changes and 1990s Task Changes



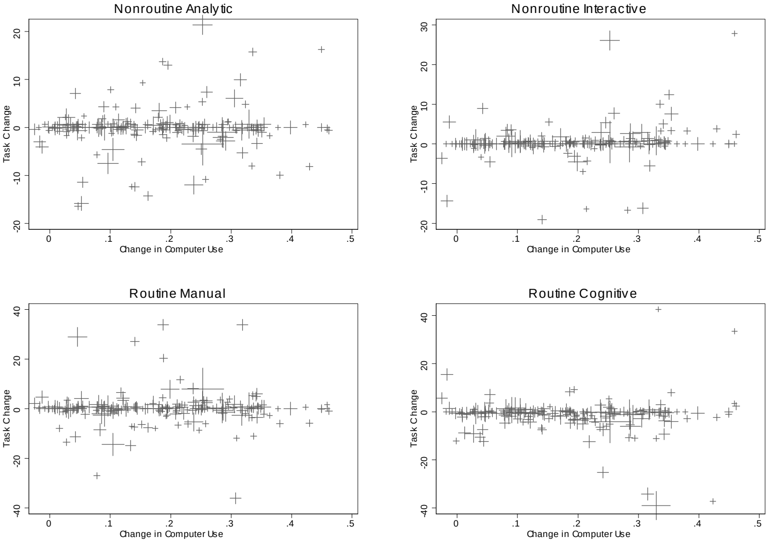
Correlations: 0.22, 0.21, -0.34, -0.26 (all significant)

Computer Use 1984-97 Changes and 1960s Task Changes



Correlations: 0.12, 0.09, 0.11, -0.07 (none significant)

Computer '84-97 Change & Within-Occ. 77-91 Task Change



Correlations: 0.08, 0.14*, 0.03, -0.25* (* significant)

Summary

1. Industry-sex-education cells who...
   - tend to work in nonroutine occupations grew from 1960 to 1998
   - tend to work in routine occupations shrank from 1960 to 1998.
2. Industries which had an increase in computer usage between 84 and 97...
   - shifted towards "nonroutine" sex-education combinations in the 80s and 90s
   - shifted away from "routine" sex-education combinations in the 80s and 90s
   - no such changes in the 1960s
3. Occupations which had an increase in computer usage between 84 and 97...
   - shifted towards nonroutine interactive tasks, away from cognitive routine tasks
   - not shown: similar results when including controls for education/gender in the occupation

Summary

In the rest of the paper: how much of the increase in the demand for skilled workers was due to:

- changes in tasks.
- changes in tasks which were due to computerization?

How to do this:

1. Regress using data from 1977 DOT, matched with 1984 CPS

$$\text{College share}_j = \alpha + \pi_{\text{NR-Aanalytic}} \cdot T_j^{\text{NR-Analytic}} + \pi_{\text{NR-Inter}} \cdot T_j^{\text{NR-Inter}} \pi_{\text{R-Cog}} \cdot T_j^{\text{R-Cog}} + \pi_{\text{R-Man}} \cdot T_j^{\text{R-Man}}$$

2. Predict changes

$$\tilde{\Delta}\text{Col. Sh.}_{1970-1998} = \pi_{\text{NR-Aanalytic}} \cdot \Delta T_{1970-1998}^{\text{NR-Analytic}} + \pi_{\text{NR-Inter}} \cdot \Delta T_{1970-1998}^{\text{NR-Inter}} + \pi_{\text{R-Cog}} \cdot \Delta T_{1970-1998}^{\text{R-Cog}} + \pi_{\text{R-Man}} \cdot \Delta T_{1970-1998}^{\text{R-Man}}$$

Notes on Autor and Dorn (2013): "The Growth of Low-Skill Service Jobs and the Polarization of the US Labor Market"

"Canonical Model"

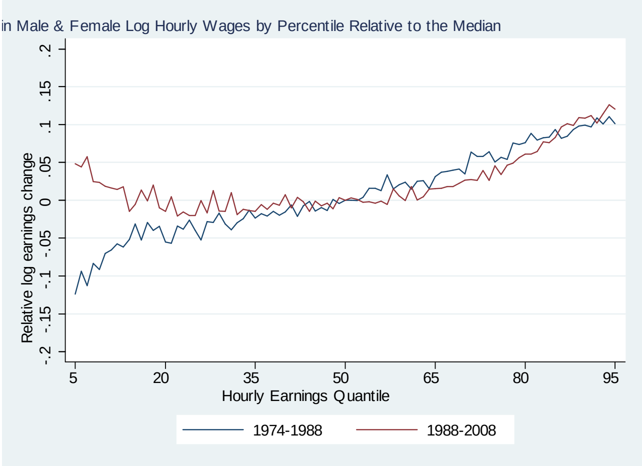
Summary

1. Changes in the skill premium are due to changes in factor-augmenting technology and to the supply of workers of different skilled types.
2. Fits well the decrease in the skill premium of the 70s, increase in the 60s and 80s. (Overpredicts the skill premium increase of the 90s and 00s)

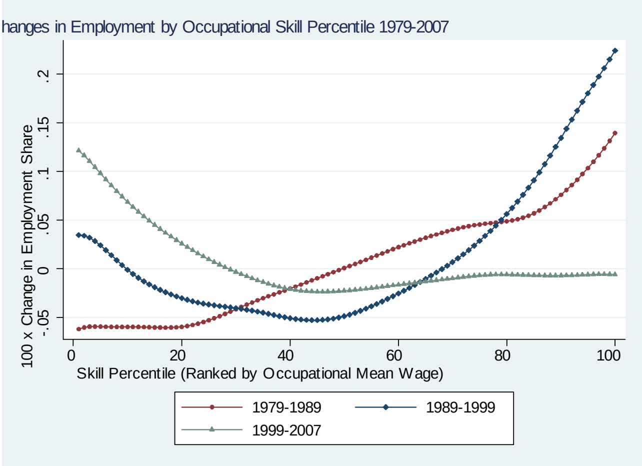
Areas where it has trouble fitting the data

1. Has trouble explaining why wages would decline for some types of workers.
2. Cannot speak to wage polarization, or occupational polarization, which seems to have been prevalent in the 90s and/or 00s.

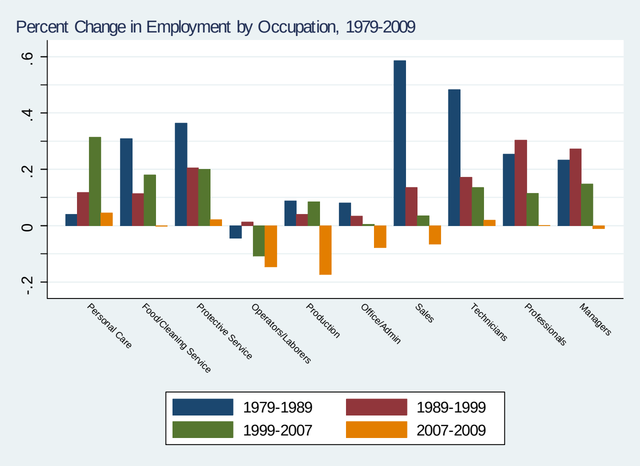
Wage polarization



Occupational polarization



Occupational polarization



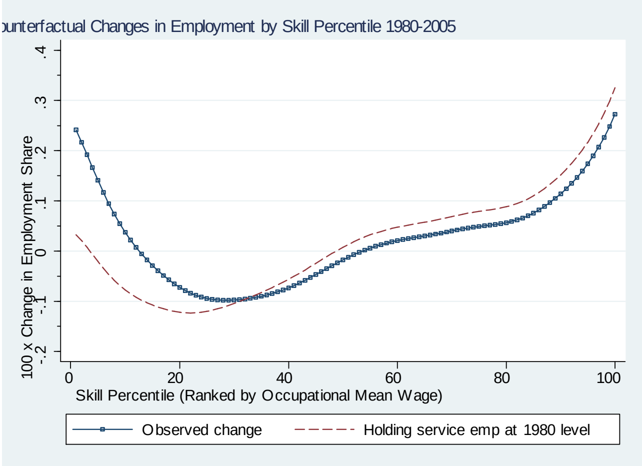
Overview

- Research question: To what extent is job polarization due to a decline in the demand for routine tasks?
  - Underlying driving force: Decline in the price of computers (substitutable with labor in the production of routine tasks)

Two types of evidence and a model.

- National evidence:
  - Growth in the bottom of the distribution is increasingly in service occupations. Without this growth, statistically, there would be no wage polarization.
  - Routine occupations are in the 2nd quintile.
- Cross-sectional evidence:
  - Areas with higher initial routine-occupation shares have larger service occupation growth rates, more polarization.

Without the growth of services, job polarization looks much less pronounced



Reweighting procedure

- Due originally to DiNardo, Firpo, Lemieux (1996)
- Designed to answer things like: What would a counterfactual employment distribution look like if the distribution of service occupations vs. other occupations stayed as in 1980?
- Mechanics: Pool sample of (many) workers in 1980 and 2005.
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  - Weight 2005 observations $w_i = \frac{p_i}{1-p_i} \cdot \frac{1-\pi}{\pi}$.
  - Weight 1980 observations $w_i = 1$
- Since $\beta_1 < 0$: for i in a service occupation $p_i < \pi \Rightarrow w_i < 1$

Reweighting procedure

Where does this procedure come from?

- Suppose we observe (Y, X) from two periods (or from two groups).
- The marginal cdf of Y in period 1 is

$$F_{Y_1}(y) = \int F_{Y_1|X}(y|x)\, dF_{X_1}(x)$$

  (integrate over the covariates that are observed in period 1).
- Similarly for period 2:

$$F_{Y_2}(y) = \int F_{Y_2|X}(y|x)\, dF_{X_2}(x)$$

Reweighting procedure

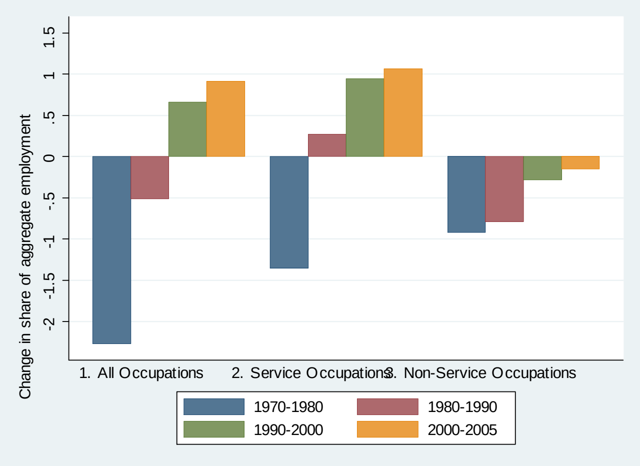
Where does this procedure come from?

- Our ("holding services constant") exercise was doing something like:

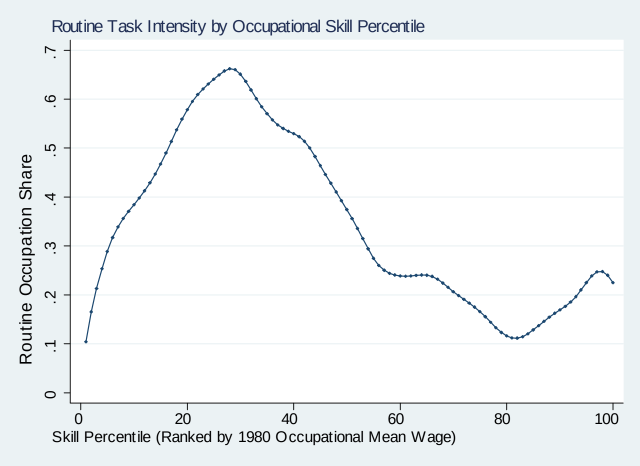
$$F_{Y_2^C}(y) = \int F_{Y_2|X}(y|x)\, dF_{X_1}(x)$$
$$= \int F_{Y_2|X}(y|x) \cdot \frac{dF_{X_1}(x)}{dF_{X_2}(x)} \cdot dF_{X_2}(x)$$

- $\frac{dF_{X_1}(x)}{dF_{X_2}(x)}$ was the weighting factor that we computed in the last slide.

Beginning in the 1980s, service occupation (unlike other low-type occupations) tend to grow.



Routine tasks are concentrated in the second quintile of the "skill" distribution



Task-based model

1. Workers have different abilities to perform different tasks, sort into different tasks based on their comparative advantage.
2. Model can be consistent with job/wage polarization, technology growth $\Rightarrow$ declines in wages for some workers.
3. Generalization of the "canonical" model from earlier.
4. We'll work out a closed-economy model, but consider different values of β

Key elements of the task-based model

- High-skilled, H (produce abstract/analytic tasks).
- Low-skilled workers, U (produce either routine or manual tasks).
  - have heterogeneous ability η to produce routine tasks, pdf $f(\eta) = e^{-\eta}$
- Two sectors:
  - Goods

$$Y_g = \Big(\underbrace{L_a}_{\text{"abstract tasks"}}\Big)^{1-\beta} \cdot \underbrace{\left[(\alpha_r L_r)^{\mu} + (\alpha_k K)^{\mu}\right]}_{\text{"routine tasks"}}^{\frac{\beta}{\mu}}$$

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  - Elasticity of substitution between computers and routine workers in producing routine tasks is $\frac{1}{1-\mu}$
  - Over time, price of capital is declining at rate δ

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- Services (everything that is not a goods occupation)

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  - Goods are used either as consumption or to produce capital: $c_g + e^{-\delta t}\theta K = Y_g$
- Utility over goods and services is CES with elasticity σ

Allocation of low-skilled workers

- Suppose η_i is the cutoff unskilled worker, where $1 - L_m$ workers are to the right of η_i.
  - $\eta_i = -\log(1 - L_m)$
- The effective labor of routine tasks equals the integral to the right of η_i

$$
\begin{aligned}
L_r &= \int_{\eta_i}^{\infty} \eta e^{-\eta} \cdot d\eta \\
&= \int_{-\log(1-L_m)}^{\infty} \eta e^{-\eta} \cdot d\eta \\
&= (1 - L_m)(1 - \log[1 - L_m])
\end{aligned}
$$

Planner's problem

$$\max_{K,L_m} \left[(c_s)^{\frac{\sigma-1}{\sigma}} + (c_g)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

$$= \max_{K,L_m} \left[L_m^{\frac{\sigma-1}{\sigma}} + (Y_g - p_k K)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

$$= \max_{K,L_m} \left[L_m^{\frac{\sigma-1}{\sigma}} + \left(L_a^{1-\beta} \left[(\alpha_r L_r)^{\mu} + (\alpha_k K)^{\mu} \right]^{\frac{\beta}{\mu}} - p_k K \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

Use

$$L_r = (1 - L_m)(1 - \log[1 - L_m])$$

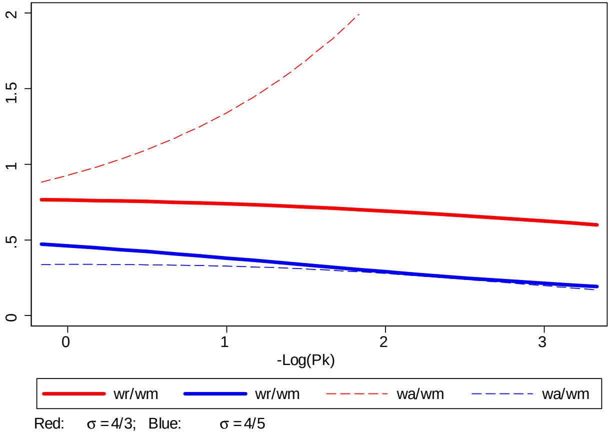
from the last slide

Use this model to ask: What happens to $\frac{L_r}{L_m}$, $\frac{w_r}{w_m}$, $\frac{w_a}{w_m}$ as $p_k \to 0$? How does this depend on σ, β, μ?

What is the importance of σ?

- σ measures the substitutability between goods (where H workers work, and where some U workers work) and services (where U workers work).
- If U skilled workers end up working in manual occupations (we will give conditions for this in a second), what happens to $\frac{w_a}{w_m}$ when $p_k \to 0$?
  - When $p_k \to 0$, if $\sigma > 1$: consumers are relatively happy to substitute to the increasingly cheaper goods $\Rightarrow$ labor demand for H workers increases relative to that for U workers $\Rightarrow$ $\frac{w_a}{w_m}$ increases.
  - Opposite result for $\frac{w_a}{w_m}$ when $\sigma < 1$.

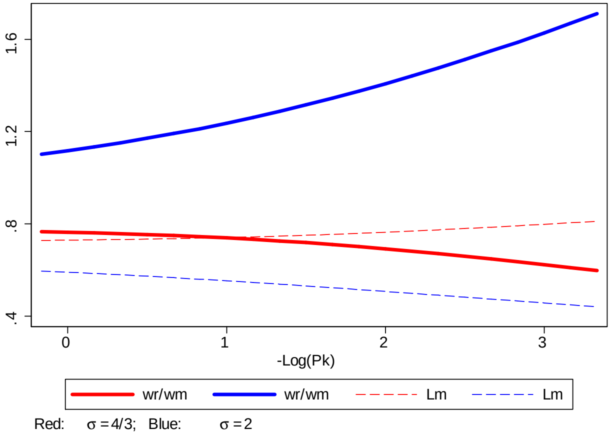
When σ is >1, $\frac{w_a}{w_m}$ increases as $p_k \to 0$.



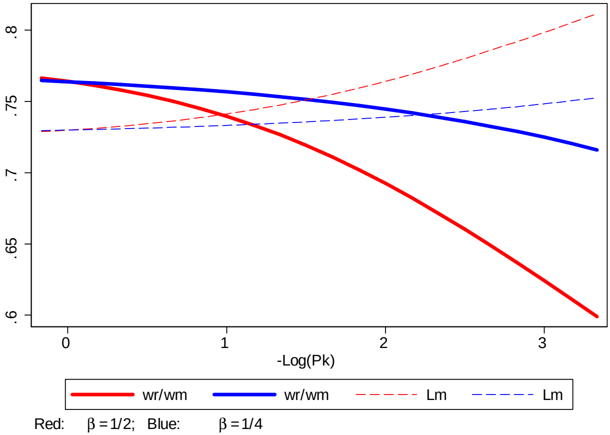
What is the importance of σ, β , μ?

- If μ is large, computers and workers are substitutable in producing routine tasks. For a given decline in p_k, labor demand (for producing routine tasks) falls more
- If σ is large, consumers are happy to substitute between goods and services. Declining price of computers (and hence goods) means that the demand for workers producing goods (either routine workers or high-skilled "a" workers) increases more.
- Long-run ($p_k \to 0$) allocation of workers and $\frac{w_r}{w_m}$ follows
  - If $\frac{1}{\sigma} > 1 - \frac{\mu}{\beta}$ then $L_m \to 1$ and $\frac{w_r}{w_m} \to 0$.
  - If $\frac{1}{\sigma} < 1 - \frac{\mu}{\beta}$ then $L_m \to 0$ and $\frac{w_r}{w_m} \to \infty$.

Path of $\frac{w_r}{w_m}$ depends on $\frac{1}{\sigma}$ compared to $\frac{\beta-\mu}{\beta}$



"Polarization" is more pronounced when β is large



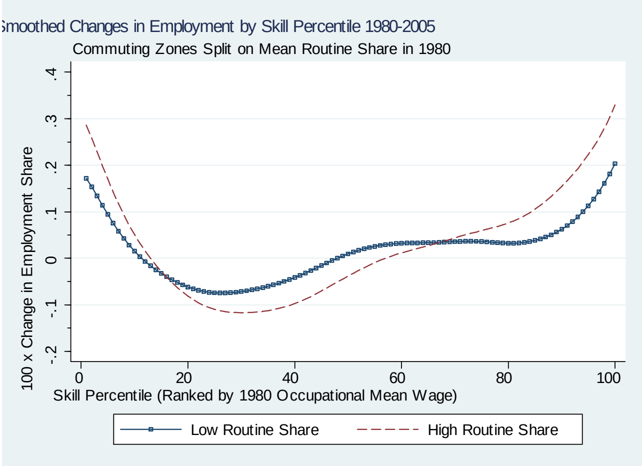
Summarizing the model predictions

Cross-sectional implications:

- Regions differ according to β_j.

1. IT adoption coincides with replacement of labor from routine tasks, into service occupations
2. With greater IT adoption (which happens in high routine-labor-share areas), greater shifts of low-skilled labor into service occupations.

Areas with a greater share of routine-intensive occupations in 1980 had "more polarization"



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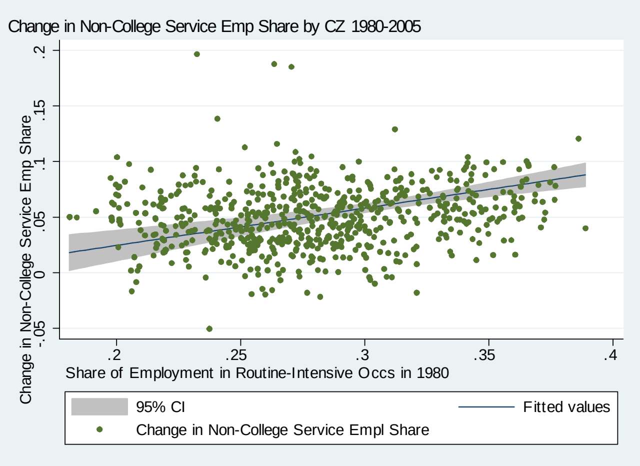

Summary

Open question so far: How much of the observed change in the service occupation share comes because of lower computer prices? From other sources?

- How informative is the cross-regional variation from the previous slide?