

Revisiting U.S. Wage Inequality at the Bottom 50%

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Inequality Trends at the Bottom 50%

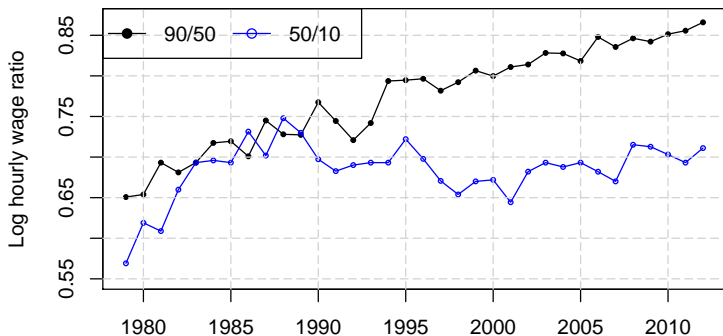


Figure: 90/50 and 50/10 Log Hourly Wage Ratio

Quantiles are calculated for all workers with positive earnings at the hours level, using sample weights multiplied by hours worked. Source: CPS Outgoing Rotation Groups

Leading Hypotheses

In the early 1980s, inequality is rising in both parts of the distribution

- Skill-Biased Technological Change (Katz & Murphy, 1992)

In late 1980s - 1990s inequality decreases at the bottom

- “Wage Polarization” - decline in middle wages [▶ Figure](#)
- Routine-Biased Technological Change (Autor, Katz & Kearney, 2006)
- Decrease in demand for workers performing routine tasks
- Key support: job/employment polarization (Goos et al., 2014)

Key Challenges to RBTC

- 1 **Why should middle wages relatively decline?**
 - Routine workers are dispersed almost equally at bottom 50%
 - [▶ Figure](#)
- 2 **Why did middle wages stopped declining around 2000?**
 - Employment polarization continues long after
- 3 **Why can't we capture this with decompositions?**
 - RBTC cannot explain the full trend in wages
 - Autor, Katz & Kearney (2005) and Firpo, Fortin & Lemieux (2013)

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This Paper: A new theory for the trends in the bottom 50% of the income distribution that addresses these challenges

This Paper

① Theory

- Small (but important) modification to RBTC
- Skill-Replacing RBTC
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② Empirically Test the Model's Predictions

- Decline in return to skill in routine occupations
- Reallocation of low-skill workers into routine occupations
- Interactive-Fixed-Effect-Model

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③ Decomposition

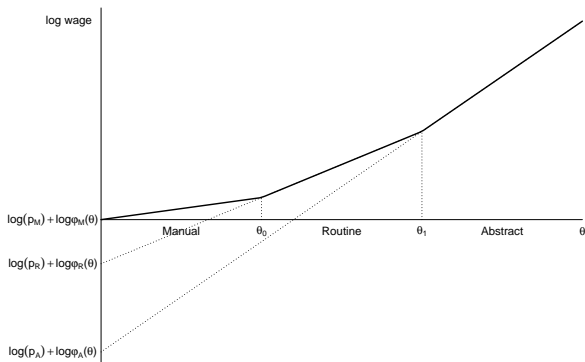
- 93% of wage polarization can be attributed to SR-RBTC
- Skewness Decomposition

Theoretical Framework

Assumptions

Building on Jung and Mercenier (2014) and Cortes (2016)

- Workers have one-dimensional skill θ ;
- Three occupations: Manual, Routine, Abstract
- **Key Assumption:** Comparative advantage



Skill Replacing RBTC

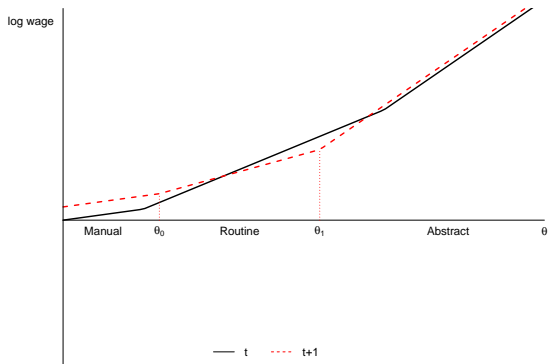
New technology in the routine occupations

- Does not replace the workers
- Instead - replaces their skill
- Decrease in the return to skill in routine occupations [▶ Details](#)

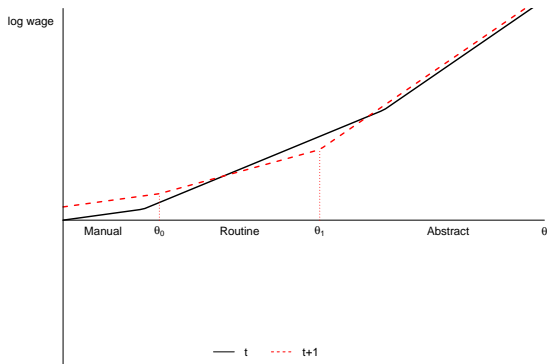
Examples

- Arithmetic skills are replaced with calculators
- Memory skills are replaced with computers
- Physical strength is replaced with machinery

First Stage: Wage Polarization



First Stage: Wage Polarization

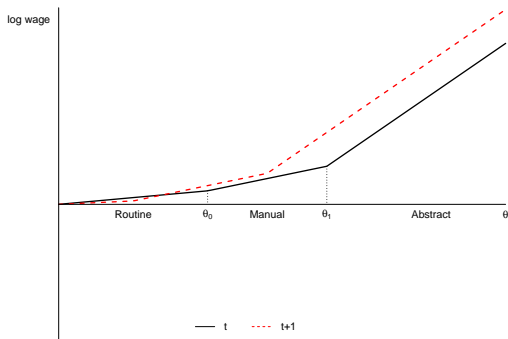


1. Why should middle wages relatively decline?

A: Because these are the highest skill routine workers

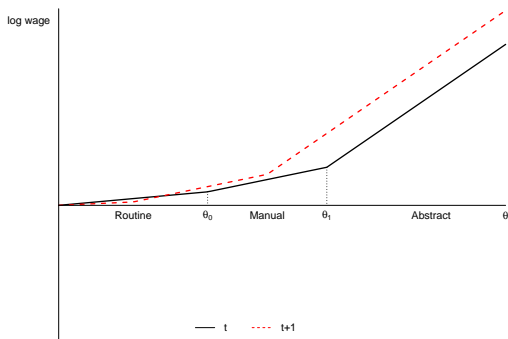
Second Stage: Bottom 50% Inequality Rises

When SR-RBTC is large enough comparative advantage would flip:



Second Stage: Bottom 50% Inequality Rises

When SR-RBTC is large enough comparative advantage would flip:



- Why did middle wages stopped declining around 2000?**
A: Middle-wage workers are no longer in the routine occupation
 - bottom 50% inequality could increase

List of New Predictions

- ① Decline in return to skill in routine occupations
- ② Routine workers gradually become less skilled
- ③ Routine workers become more concentrated at lower wages
- ④ Eventually, routine workers have less skill than manual

Empirical Results

IFEM

Skill is not directly observed

- I use panel data, assume that skill is constant over time

Use Interactive Fixed Effect Model (**IFEM**) ▶ Why?

$$\log w_{ijt} = \beta_{jt}X_{it} + \lambda_{jt} + \alpha_{jt}\theta_i + \varepsilon_{ijt}$$

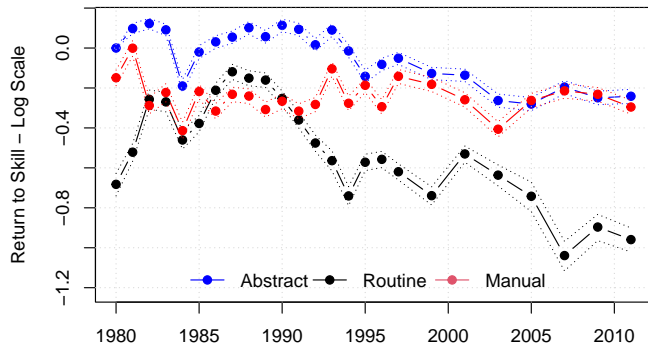
i - worker, j - occupation category, t - year and X_{it} experience².

We are interested in:

- 1 How $\alpha_{routine,t}$ changes with time
- 2 How average routine skill $\frac{1}{N_R} \sum_{i \in R} \hat{\theta}_i$ change

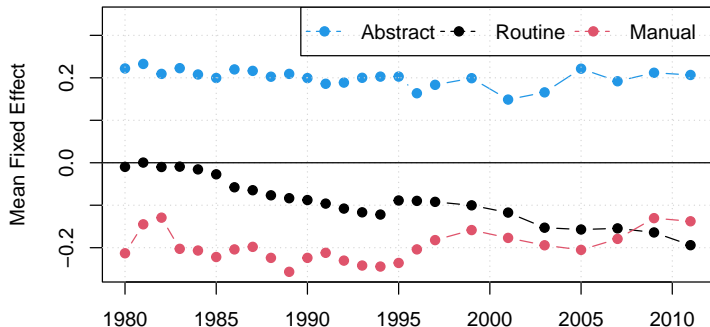
▶ Estimation

Long Term Trend of α_{jt}



► 1-Digit Occupational Category

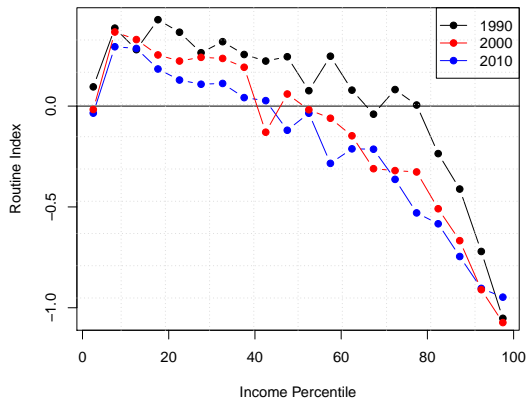
Decline in Skill in Routine Occupations



▶ 1-Digit Occupational Category

Routine by Income Percentile

Routine task intensity measured by occupation with O*NET



Quantifying the Role of SR-RBTC Using Skewness Decomposition

Why Decompose?

SR-RBTC is consistent with the data

- But is it large enough to explain the full wage trend?
- Or maybe other explanations also play a role

This is the motivation for decomposition exercise

- Which share of the overall trend can be attributed to different hypotheses
- Focus in the period of “wage polarization”
- Inequality at the bottom is relatively stable afterwards

Skewness

Just like we measure inequality with Variance (2nd moment), we can measure polarization with skewness (3rd moment)

$$\mu_3(Y) = E \left[\frac{Y - \mu}{\sigma} \right]^3$$

Then we can use a similar decomposition

$$\mu_3(Y) = \underbrace{E[\mu_3(Y|X)]}_{\text{Within}} + \underbrace{\mu_3(E[Y|X])}_{\text{Between}} + \underbrace{3\text{COV}(E[Y|X], V[Y|X])}_{\text{Correlation}}$$

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Set X to be occupation

- Within component - non-occupation explanations
- Between component - standard RBTC: decrease in routine wages
- Correlation component - SR-RBTC: decrease in inequality within routine occupations

Skewness Decomposition by Occupation

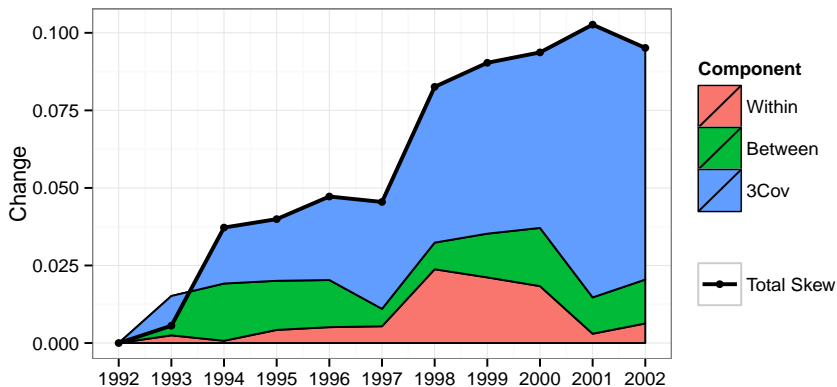


Figure: Skewness Decomposition Changes 1992-2002

Skewness Decomposition by Occupation

- The within component is “residual” and it is small.
 - 7% of overall trend
 - Suggests that 93% of the trend is related to occupations.
- The between component is negligible.
 - Should be main change in Acemoglu & Autor (2011)
- Most of the increase is in correlation between Expectation and Variance
 - High paying occupations have larger inequality.
 - Low paying occupations have smaller inequality. ▶ Robustness

3. Why couldn't we capture SR-RBTC with decompositions?

A: Did not quantify wage changes within routine occupations

Conclusion

Key Takeaways

- ① SR-RBTC model can explain the puzzles with RBTC
 - Why middle wage decline in 1990s
 - Why inequality at the bottom fluctuates
 - Why previous decomposition methods did not work
- ② Predictions of the model are verified in the data
 - Return to skill in routine occupations falls below manual
 - Reallocation of workers
 - 93% can be attributed to occupational trends
- ③ Skewness Decomposition
 - Can be useful in other cases where skewness matters:
 - Superstar models; return to patents; wealth distribution etc.
 - R-package available at CRAN

Thank You!

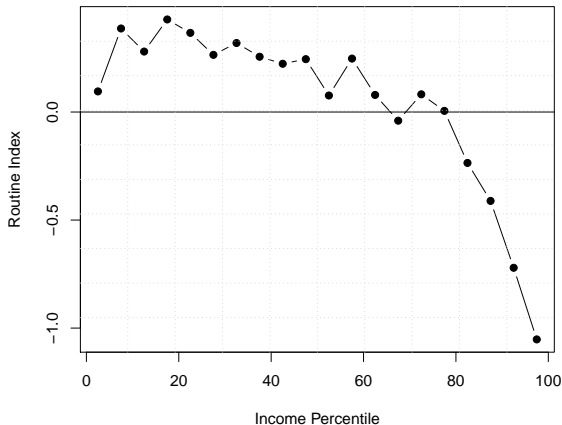
Appendix

Wage Growth by 5% Bins



Routine Level by Income Percentile

Replication of Figure in Autor & Dorn (2013, Fig 4)



Routine index is defined using O*NET data

[Details](#)

[Return](#)

Routine Index O*NET

Following Acemoglu-Autor (2011) use O*NET to take the average of

- Pace determined by speed of equipment
- Controlling machines and processes
- Spend time making repetitive motions.
- Importance of repeating the same tasks
- Importance of being exact or accurate
- Structured v. Unstructured work (reverse)

Proposition 1

Proposition: Let $w_a < w_b$ denote wages of two routine workers. The effect of RBTC ($\tau \uparrow$) on the wage ratio $\frac{w_b}{w_a}$ depends on

$$\text{sign} \left(\frac{\partial \frac{w_b}{w_a}}{\partial \tau} \right) = \text{sign}(1 - \sigma)$$

Focus only on effect on the routine occupation. RBTC is $\tau \uparrow$

$$\varphi_R(\theta_i; \tau) = \left(\theta_i^{\frac{\sigma-1}{\sigma}} + \tau^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

- $\sigma = 1$ skill neutral similar to Acemoglu & Autor (2011)
- $\sigma < 1$ skill enhancing
- $\sigma > 1$ **skill replacing**
- [▶ Return](#)

General Equilibrium

Total amount produced from each intermediate good

$$M = \int_{\theta_{min}}^{\theta_0} \varphi_M(\theta) d\theta \quad R = \int_{\theta_0}^{\theta_1} \varphi_R(\theta) d\theta \quad A = \int_{\theta_1}^{\theta_{max}} \varphi_A(\theta) d\theta$$

General Equilibrium

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The final good is the output of a CES function with $\rho < 0$

$$Y = (M^\rho + R^\rho + A^\rho)^{\frac{1}{\rho}}$$

Manual and abstract workers become more productive through complementarities

- [▶ Theorem](#)

SR-RBTC

I will focus on the case of Skill-Replacing RBTC

- Increase in τ when $\sigma > 1$

As technology advances ($\tau \uparrow$) the routine occupation see a decline in:

- Price of routine goods (p_R)
- Employment

SR-RBTC

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As technology advances ($\tau \uparrow$) the routine occupation see a decline in:

- Price of routine goods (p_R)
- Employment

- Mean skill level ($E[\theta_i|R]$)
- Inequality within the routine occupation

SR-RBTC: First Stage

Impact on bottom 50% inequality changes with time

- Divide it into two stages

In the first stage, τ is still “small”

- Comparative advantage still holds
- Returns to skill are higher in R than M

During the first stage, overall wage trend would be U-Shaped

- [▶ Theorems](#)

GE Theorem

Theorem

Assume $\rho < 0$, so $\tau \uparrow$ implies decrease in p_R and the income share of routine workers

- Does not depend on σ
- Empirically shown by Cortes (2016), Eden & Gaggl (2018)

▶ Return

Weaker Assumptions

Theorem

Assuming a skill replacing technology ($\sigma > 1$). An RBTC (increase in τ) would generate:

- 1 A decline in gaps between routine workers who do not switch occupations*
- 2 The most skilled routine workers would leave the routine occupation ($\frac{\partial \theta_1}{\partial \tau} < 0$)*
- 3 Wages for the highest skill routine worker (θ_1) would fall relative to any other worker.*

Stronger Assumptions

Assume $0 < \frac{d\theta_0}{d\tau} < \left| \frac{d\theta_1}{d\tau} \right|$ as seen in the data.

Theorem

SR-RBTC generates

- 1 *Decline in: employment, within occupation inequality and mean skill level in the routine occupation.*
- 2 *Overall wage trend would be U-shaped (“wage polarization”)*

▶ Return

Theorem

Theorem

There exists $\tilde{\tau}$, such that for every $\tau \geq \tilde{\tau}$

$$\frac{\partial \log \varphi_R(\theta; \tau)}{\partial \theta} < \frac{\partial \log \varphi_M(\theta)}{\partial \theta}$$

and routine workers would earn the lowest wages.

Any additional SR-RBTC ($\tau \uparrow$) would (still)

- Decrease employment in the routine occupation ($\frac{d\theta_0}{d\tau} < 0$)
- Decrease gaps between routine workers who do not switch occupation

▶ Return

Testing Decline in Return to Skill

The key prediction of the model is that inequality is declining within routine occupations

- But this is only for “stayers” - those who do not switch occupations
- Overall inequality in routine occupations is affected by compositional changes

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- Overall inequality in routine occupations is affected by compositional changes

There are several challenges in measuring inequality for stayers

- 1 Regression to mean
- 2 Selected sample (especially over long time periods)
- 3 Can be confused with income volatility

▶ Return

Estimation

θ_i is a nuisance parameter. Can only get some estimate of it $\hat{\theta}_i$ based on a small number of observations. [▶ Details](#)

Problem: $\hat{\theta}_i$ is noisy, so least squares will suffer from attenuation bias because

$$E \left[\hat{\theta}_i \varepsilon_{ijt} \right] \neq 0$$

Therefore we need additional moments.

- Holtz-Eakin et al. (1988), Ahn et al. (2001)

- [▶ Details](#)

Years of Schooling

I use years of schooling S_i as an instrument and estimate

$$E[S_i \varepsilon_{ijt}] = 0$$

Exclusion Restriction: Years of schooling S_i only affects wages through its impact on θ_i

$$\log w_{ijt} \perp S_i | \theta_i, X_{ijt}, j, t$$

This would be violated if skills are multi-dimensional and different skill have different returns

- I.e., the fundamental assumption of the model is wrong
- Results with three skills [▶ Details](#)

- Holtz-Eakin et al. (1988) use lagged variables
 - Violated (for instance) is ε are serially correlated
- Ahn et al. (2001) add assumption on covariance structure of $V(\varepsilon_{ijt})$
 - For instance - constant variance for ε
 - Rules out changes in volatility

▶ Return

$\hat{\theta}$

Define

$$\nu_{ijt} = \frac{1}{\alpha_{jt}} (y_{ijt} - \beta_{jt} X_{ijt} - \lambda_{jt}) = \theta_i + \frac{\varepsilon_{ijt}}{\alpha_{jt}}$$

For every $\sum_t w_{ijt} = 1$ can define

$$\hat{\theta}(y_i, X_i, \alpha, \beta, \lambda) = \sum_t w_{ijt} \overline{\nu_{ijt}} = \theta_i + \tilde{\varepsilon}_i \quad (1)$$

such that

$$y_{ijt} - \beta_{jt} X_{it} - \lambda_{jt} - \alpha_{jt} \hat{\theta}_i = \varepsilon_{ijt} - \alpha_{jt} \tilde{\varepsilon}_i = \epsilon_{ijt}$$

I choose $w_{ijt} = \frac{\alpha_{jt}^2}{\sum_{j't'} \alpha_{j't'}^2}$ which minimizes the mean squared error $\overline{\epsilon_{ijt}^2}$ [▶ Return](#)

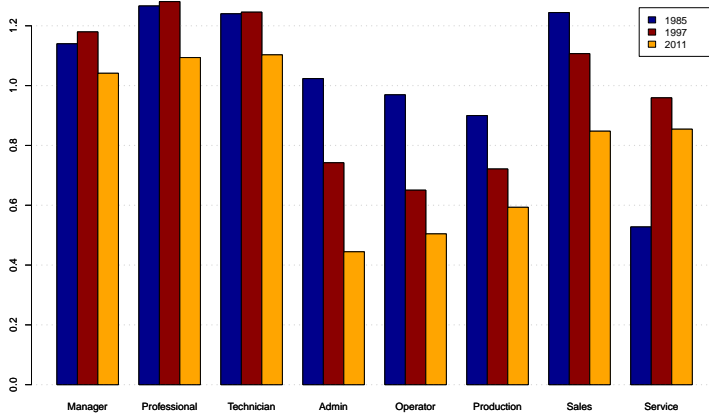
Three Skills

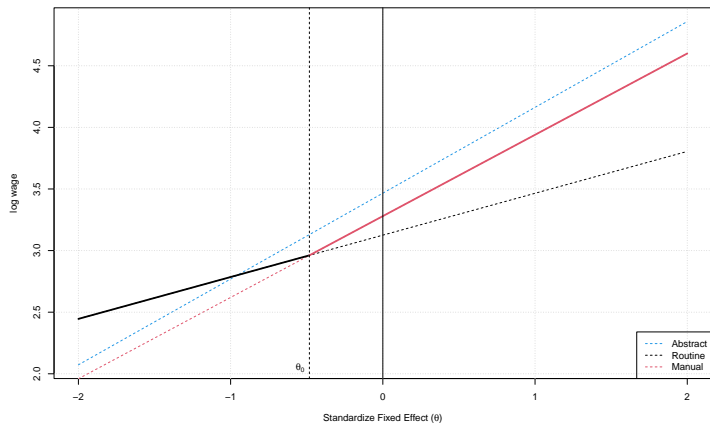
Estimate IFEM with

$$\log w_{ijt} = \beta_{ijt} X_{it} + \lambda_{jt} + \alpha_{jt} \theta_{ij} + \varepsilon_{ijt}$$

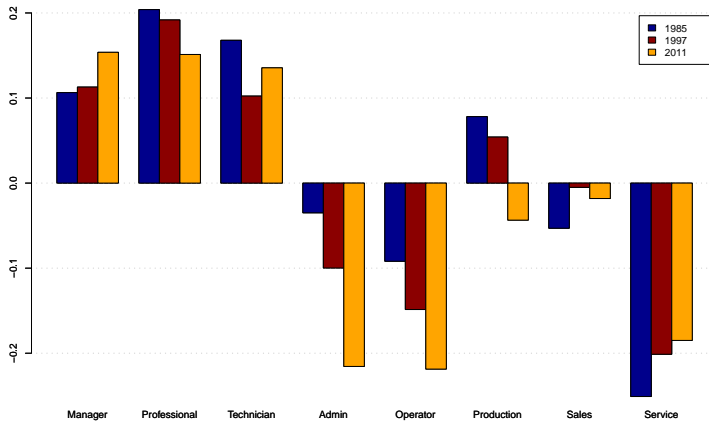
	Abstract	Routine	Manual
Abstract	1		
Routine	.74	1	
Manual	.83	.69	1

α_{jt} by 1-Digit



[▶ Return](#)

Decline in Skill in Routine: 1-Digit



Robustness

Looking by other categories yields large residual component

- [▶ 3 digit Industry](#)
- [▶ Years of School](#)

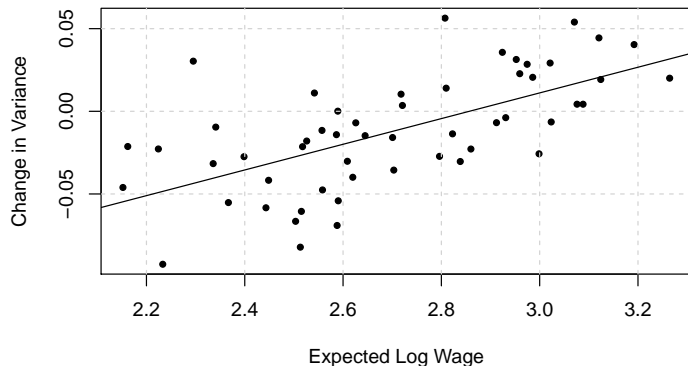
Decomposing jointly shows occupations explain the large increase

- [▶ Details](#)
- [▶ 3 digit Industry](#)
- [▶ Years of School](#)

Longer time period [▶ Details](#)

Using imputed wages [▶ Details](#)

Changes in Variance 1992-2002



Documented before by Firpo et al. (2013)

- Explains full increase in covariance component [▶ Decompose](#)

Variance Trends in Other Decades

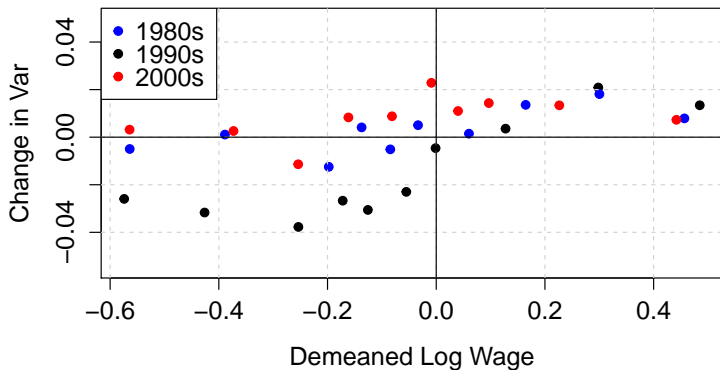


Figure: Change in $V[\ln w|occ]$ by $E[\ln w|occ]$ - Binned Scatter Plot

Variance Trend in Routine/Non-routine Occupations

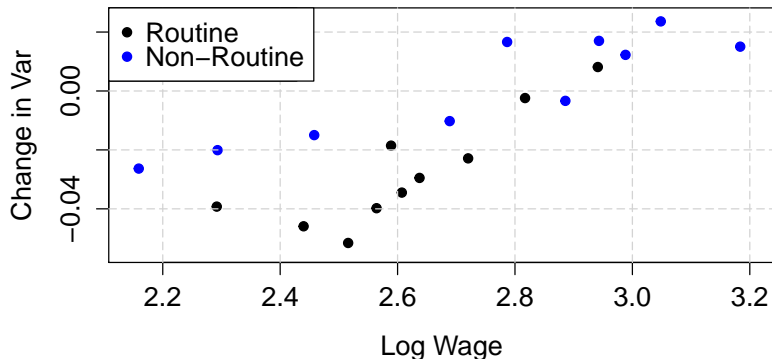


Figure: Change in $V[\ln w|occ]$ by $E[\ln w|occ]$ 1992-2002

Data resource: CPS-ORG. Routine occupations are administrators, producers and operators. Categories are divided same as in Acemoglu & Autor (2011)

Counterfactual Covariance

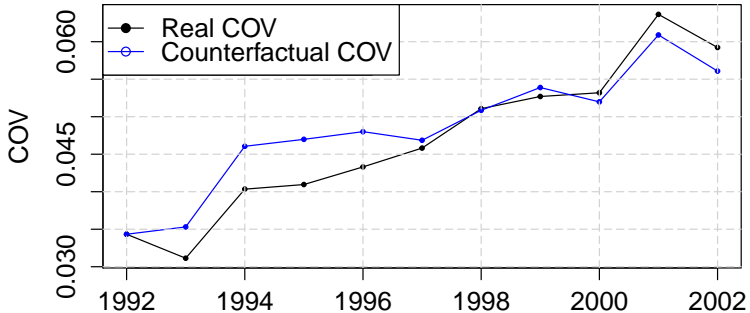
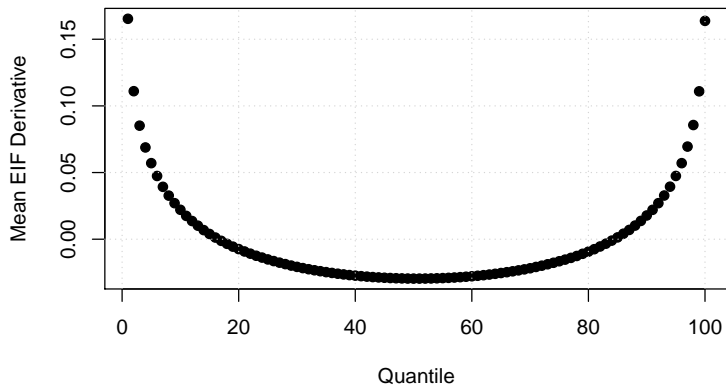


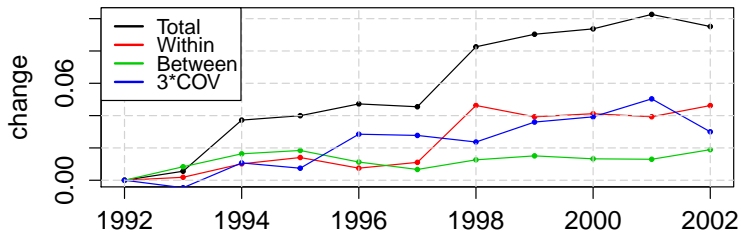
Figure: Covariance of Expectation and Variance of Log-Wage

Influence Function



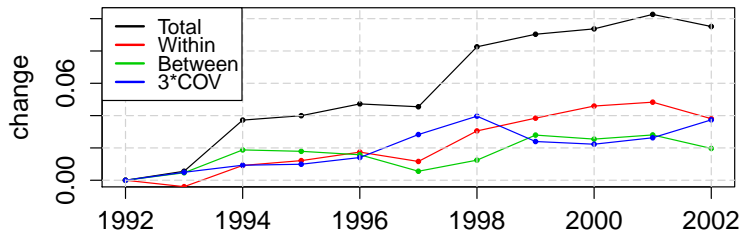
▶ Return

Decomposing by Industry



Return

Decomposing by Education and Experience



▶ Return

Linear Skewness Decomposition

If $Y = \sum_i X_i$ can write

$$\mu_3(Y) = \sum_i \mu_3(X_i) + \sum_i \sum_{j \neq i} \text{COV}(X_i^2, X_j) + \sum_i \sum_{j \neq i} \sum_{k \neq i, j} E[X_i X_j X_k] \quad (2)$$

and decompose into several components. The simple skins decomposition is for $Y = E[Y|X] + \varepsilon$

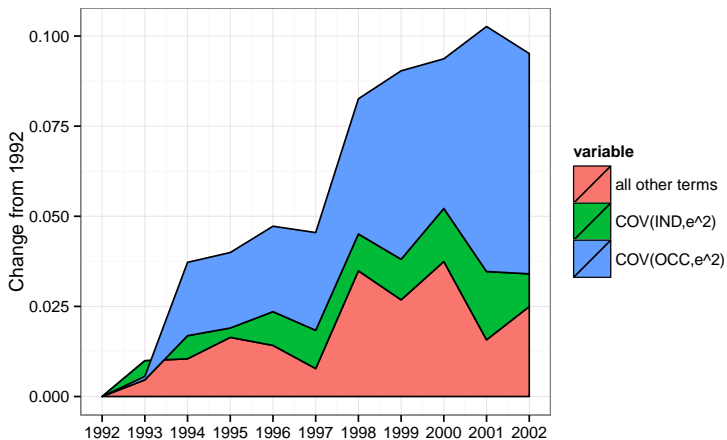
Can first run a regression such as

$$\ln w_i = occ_i + ind_i + \varepsilon_i$$

and decompose by each component.

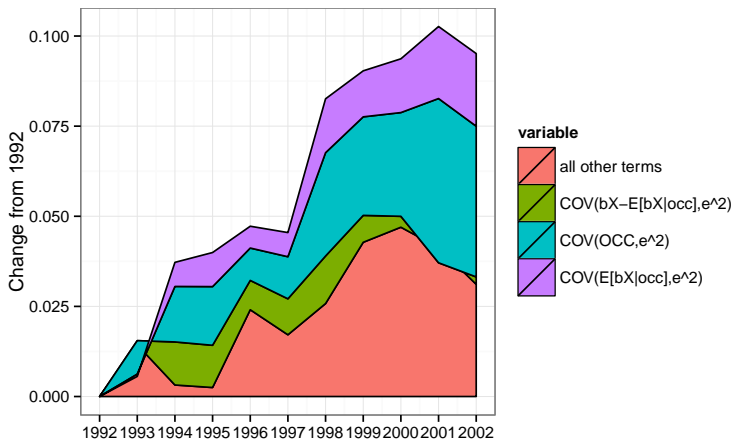
[▶ Return](#)

Joint Occupation-Industry Decomposition



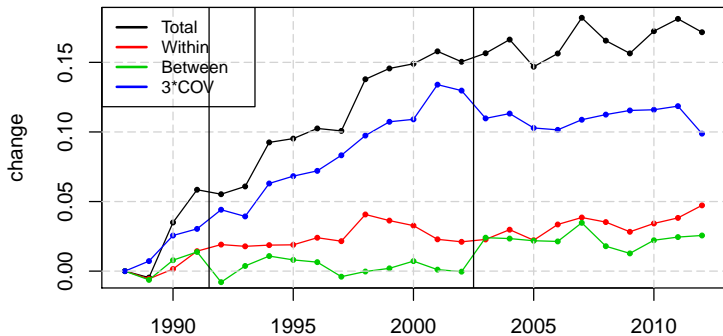
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Joint Occupation-School-Experience Decomposition

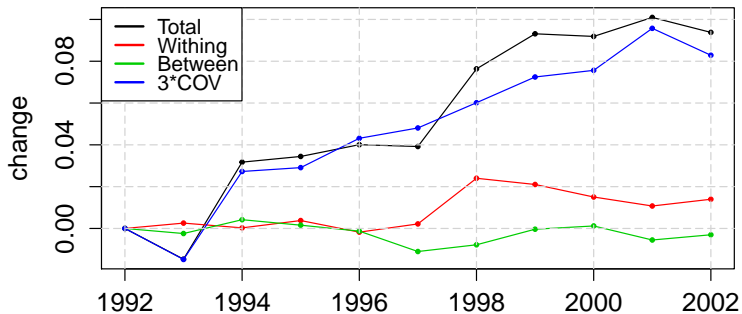


▶ Return

Decomposition with Imputed Wages



Decomposition with Imputed Wages



▶ Return