Job Polarization, Skill Mismatch, and the Great Recession

Riccardo Zago
New York University

6 December 2018
ECB/CEPR Labour Market Workshop
Job Polarization

![Graph showing job polarization trends from 1990 to 2015]

- **ΔEmp. Rate Abstract**
- **ΔEmp. Rate Routine**
- **ΔEmp. Rate Manual**
Vertical Downgrade & the Great Recession

Pr(Downgrade)

Before  Recession  Recovery  After

Details  High-Skilled vs. Low-Skilled

Riccardo Zago (NYU)
This paper is the first to show that

- the decline of routine employment
- the change in skill-demand across jobs

explain together

- deterioration of skills-to-job match quality $\rightarrow$ “Skill Mismatch”
- longer unemployment spells
- sluggish labor mobility
Theoretical Mechanism

- A model with endogenous mapping of skills to jobs
  - skill-heterogeneous workers
  - job-specific technologies and endogenous skill-requirements
  - skill-dependent job opportunities and multiple jobs search

- Asymmetric technology shocks and labor market frictions affect
  - workers’ job opportunities and mobility
  - the process of sorting skills with jobs

\[ \downarrow \]

Skills-to-Job Mismatch

- Routine Biased Technical Change drives Job Polarization
- Estimation to **match only employment dynamics** between 2005 and 2015

- The model accounts well for the **reallocation patterns** of
  - high-skilled workers
  - low-skilled workers

- The **aggregate predictions** of the model are also **true within local-labor markets**
Main Results

1. job polarization accounts for the rise in skill mismatch

2. skill mismatch dynamics differ across workers when the market polarizes

3. higher skills attenuate the wage loss from mismatch

4. changes in skill-demand across jobs and frictions explain 38% of the shift-out of the Beveridge Curve
**Policy Relevance**

- **Inefficiency** in labor factor allocations due to frictions
  - longer unemployment spells for the low-skilled
  - welfare loss due to job polarization

- **The central planner**
  - reduces low-skilled unemployment
  - attenuates job-polarization
  - reduces skill mismatch by 1/3
Outline

1. **THE MODEL**
   - Technologies and Jobs
   - Workers and Job-Search
   - Equilibria

2. **QUANTITATIVE ASSESSMENT**
   - Estimation to match occupational dynamics between 2005 and 2015
   - Comparison of the implied allocation patterns of HS and LS with the data
   - Model implications for welfare, matching efficiency and wages
The Model
RBTC and Temporary Shocks

- Assume abstract and manual technology to follow this

\[ z_{a,t} = \bar{z}_a + \sigma_a \epsilon_t \; ; \; \; z_{m,t} = \bar{z}_m + \sigma_m \epsilon_t \]

- Assume routine technology to follow this

\[ z_{r,t} = \begin{cases} 
    z_{r,0}(1 + g_{z_r})^t + \sigma_r \epsilon_t & \text{for } t \in [0, T] \\
    z_{r,T} + \sigma_r \epsilon_t & \text{for } t > T 
\end{cases} \]

- The technological shock \( \epsilon \) follows an AR(1) process:

\[ \epsilon_{t+1} = \rho \epsilon_t + \nu_{t+1} \]

and \( \nu \) being a random shock out of a standard-normal distribution.

- \( \sigma_j \) governs the the job-specific intensity of the shock (similar to Lilien ’82)
Production and Skill Requirements

- Workers differ in their skill-level $x$
- Technology $z_j$ and skills $x$ are mixed as follows:

  \[ y(x; z_a) = z_a x^{\lambda_a} ; \quad y(x; z_r) = z_r x^{\lambda_r} ; \quad y(x; z_m) = z_m \]

- The value of production is

  \[ J(x; z_j) = y(x; z_j) - w(x; z_j) + \beta \mathbb{E} \left\{ s_j'(x)(1-\delta)J(x; z_j') + [1-s_j'(x)(1-\delta)]V(z_j') \right\} \]

  with

  \[ s_j'(x) = s(x, e_j') = Pr(x \geq e_j') \]

- Firms choose the minimum requirement $e_j$ to ensure a non-negative $J$:

  \[ J(e_j; z_j) = 0 \]

- **Countercyclical Skill Requirements:** if $z_j \downarrow \Rightarrow e_j \uparrow
Vacancy Posting

- Firms posts vacancies \( v_j \) for \( j = \{a, r, m\} \) following this rule

\[
V(z_j) = -c_j + \beta \mathbb{E}\left\{ p(\theta_j)J(x, z'_j) + [1 - p(\theta_j)]V(z'_j) \right\}
\]

with

\[
p(\theta_j) = \psi_j \theta_j^{-\alpha}
\]

and

\[
\theta_j = \frac{v_j}{u_j} = \frac{\text{n. of vacancies for market } j}{\text{n. of qualified unemp. workers for market } j}
\]

- **Free entry condition:** \( V(z_j) = 0, \forall t \)
- Skills $x$ are drawn from a $U_{[0,1]}$ pdf

- For given $e_a$ and $e_r$, a worker with skill $x$ knows his job-opportunity set
  $\Omega(x) = \{j : e_j \leq x\}$

- The value of unemployment is

$$U(x; z) = b + \beta \mathbb{E} \left\{ \sum_{j \in \Omega(x)} q(\theta_j) N(x; z'_j) + \left[ 1 - \sum_{j \in \Omega(x)} q(\theta_j) \right] U(x; z') \right\}$$

with $z = [z_a, z_r, z_m]$, a vector of all technologies currently available in the job-opportunity set
Employment Value and Dynamics

- The value of employment is

\[ N(x; z_j) = w(x; z_j) + \beta \mathbb{E} \left\{ s_j'(x)[(1-\delta)N(x; z_j') + \delta U(x; z')] + [1-s_j'(x)]U(x; z') \right\} \]

- The dynamic for the stock of employment in job \( j \) is

\[ n'_j = s_j(1-\delta)n_j + u_j q(\theta_j) \]

- For an increase in requirements in \( j \), the factor \( s_j(1-\delta) \) falls such that it
  
  - amplifies job destruction dynamics
  - exposes also highly-ranked worker to displacement (differently from Mortensen and Pissarides '94)
  - increases individual employment uncertainty (as in Ravn and Sterk '15...but here endogenously)
- Under Nash Bargaining:

\[ w(x; z_j) = (1 - \eta)b + \eta y(x; z_j) + \eta \left\{ \sum_{j \in \Omega(x)} c_j \theta_j \right\} \]

with the value of the out-side option that varies over time and across workers due to:

- changes in \( \theta_j \)
- changes in \( |\Omega(x)| \)
- changes in both \( \theta_j \) and \( |\Omega(x)| \)
Two Alternative Equilibria

Skill-Separating Equilibrium: PAM of Skills and Technology

\[ m(\theta_a) \]

Abstract Production

\[ m(\theta_r) \]

Routine Production

\[ m(\theta_m) \]

Manual Production

\[ x=1 \]

\[ e_a \]

\[ x=0 \]

\[ e_r \]
Two Alternative Equilibria

Skill-Pooling Equilibrium: Skill Mismatch

Riccardo Zago (NYU)

6 December 2018
Skill-Pooling Equilibrium

Definition

Contingent to technology, a skill-pooling equilibrium is a vector \( \{\theta_j, n_j, w(x, z_j), e_j, u_j\}_{t=0}^{\infty} \) for any \( j = \{a, r, m\} \) and \( x \in [0, 1] \) satisfying simultaneously the job creation condition, the minimum requirement condition, the wage equation, employment and unemployment dynamics.

Existence Condition

A skill-pooling equilibrium exists in the routine submarket iff the surplus from the match \( S(x, z_r) \geq 0 \) for all \( x \in [e_a, 1] \); a skill-pooling equilibrium exists in the manual submarket iff \( S(x, z_m) \geq 0 \) for all \( x \in [e_r, 1] \).
Quantitative Assessment
Bringing the Model to the Data

- Use CPS classification of educational attainments as a sufficient statistics for the distribution of skills

- Define two major skill groups (ILO)
  
  ▶ **High Skilled (HS):** bachelor, master, phd
  
  ▶ **Low Skilled (LS):** 11th Grade, high-school diploma, 2 years of college, vocational degree

- Build (quarterly) series for HS and LS employment in each occupation (only full time, non-self employed workers; codes for farming, fishing, forestry and military occupations excluded)

- **GOAL:** estimate the model to match occupational employment dynamics from 2005 to 2015 and check reallocation patterns for HS and LS workers
Structural Estimation via SMM

- Preset Parameters: $\beta$, $b$, $\delta$, $\eta$, $\alpha$, $z_{r,0}$, $g_{LS}$

Two Step Estimation

1st Step: characterize the economy at an initial point (2005q1)
- use $n_{a,2005}$, $n_{r,2005}$, $n_{m,2005}$, $Share^HS_{a,2005}$, $Share^HS_{r,2005}$, $Share^HS_{m,2005}$, $Share^HS_{u,2005}$,
  $w^HS_{r,2005}$, $w^HS_{m,2005}$, $w^LS_{r,2005}$, $w^LS_{m,2005}$
- back-up $z_a$, $z_m$, $c_j$, $\psi_j$, $\lambda_a$, $\lambda_r$, $\gamma$

2nd Step: let the economy move on the RBTC trend and shock it to generate the dynamics observed from the Great Recession (2005q1 to 2015q4)
- use long-run $g_{n_r}$, $\Delta n_{a,GR}$, $\Delta n_{r,GR}$, $\Delta n_{m,GR}$, $Corr(u_t, u_{t-1})$
- back-up $g_{z_r}$, $\sigma_j$, $\rho$
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$z_a$</td>
<td>Tech. in abstract jobs</td>
<td>1.09</td>
</tr>
<tr>
<td>$z_m$</td>
<td>Tech. in manual jobs</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>Labor Market</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$c_a$</td>
<td>Vacancy posting cost in abstract</td>
<td>0.02</td>
</tr>
<tr>
<td>$c_r$</td>
<td>Vacancy posting cost in routine</td>
<td>0.04</td>
</tr>
<tr>
<td>$c_m$</td>
<td>Vacancy posting cost in manual</td>
<td>0.05</td>
</tr>
<tr>
<td>$\psi_a$</td>
<td>Matching efficiency in abstract</td>
<td>0.79</td>
</tr>
<tr>
<td>$\psi_r$</td>
<td>Matching efficiency in routine</td>
<td>0.68</td>
</tr>
<tr>
<td>$\psi_m$</td>
<td>Matching efficiency in manual</td>
<td>0.46</td>
</tr>
<tr>
<td><strong>Skills</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\lambda_a$</td>
<td>Return to skills in abstract</td>
<td>1.02</td>
</tr>
<tr>
<td>$\lambda_r$</td>
<td>Return to skills in routine</td>
<td>0.49</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Lowest skill for HS workers</td>
<td>0.71</td>
</tr>
<tr>
<td><strong>Dynamics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$g_r$</td>
<td>Growth of routine tech.</td>
<td>$-9.81 \times 10^{-5}$</td>
</tr>
<tr>
<td>$\sigma_a$</td>
<td>Std. for tech. shock in a</td>
<td>0.040</td>
</tr>
<tr>
<td>$\sigma_r$</td>
<td>Std. for tech. shock in r</td>
<td>0.051</td>
</tr>
<tr>
<td>$\sigma_m$</td>
<td>Std. for tech. shock in m</td>
<td>0.017</td>
</tr>
<tr>
<td>$\rho$</td>
<td>Persistency of the shock</td>
<td>0.91</td>
</tr>
</tbody>
</table>
Job Polarization and Jobless Recovery

- The model generates too high unemployment in the long-run. Why?
  Rise in non-participation rate after the Great Recession

Change $\sigma$ (employment)  
Change $gr_z$
Employment Dynamics by Skill Group

- Temporary reversal in emp. shares for HS workers
- Permanent change in emp. shares for LS workers

Change $\sigma$ (sorting)  Data (state-level)  $E \rightarrow U$ (aggregate)  Other Dynamics

Riccardo Zago (NYU)  Model’s Prediction  6 December 2018  25
**Social Planner**

Following Bhattacharya and Bunzel ’03, assume a social planner maximizes total expected output and total value of “leisure” at the net vacancy costs:

\[
\max_{\theta_j, e_j, n_j'} \mathbb{E} \sum_{t=0}^{\infty} \beta^t \{ \tilde{y}_a n_a + \tilde{y}_r n_r + y_m n_m + b(1 - n_a - n_r - n_m) - \sum_j c_j \theta_j u_j \}
\]

s.t. \[n_j' = s(1 - \delta) n_j + u_j q(\theta_j)\]

\[\tilde{y}_j = \int_{e_j}^{1} y(x; z_j) U_{[x \geq e_j]} \, dx \Rightarrow \text{average output in } j\]
The Shift of the Beveridge Curve

Beveridge Curve (Model)

Beveridge Curve (Data)

Job Opening Rate (Model)

Job Opening Rate (JOLTS)

Unemployment

Riccardo Zago (NYU)

6 December 2018
Wage loss is bounded for HS workers when moving down the ladder.
Conclusion

- The change in the occupational structure and in skill-demand across jobs explain the rise in skill mismatch:
  - mismatch dynamics differ across skill-groups
  - the wage-loss from mismatch is bounded for high-skilled

- Job polarization is associated with specific reallocation patterns

- A central planner reduces skill mismatch and the process of polarization

- Changes in skill-demand across jobs and frictions explain the deterioration of aggregate matching efficiency
Job Polarization

- Since the 80s, **routine employment** is falling along with wages

- Jobs grouped by task (Acemoglu and Autor '11):
  
  - **abstract**: Management, Professionals, and Related jobs
  - **routine**: Production and Clerical jobs
  - **manual**: Food prep and service, personal/child care, recreation and hospitality jobs

- Job Polarization is driven by:
  
  - **Routine Biased Technical Change (RBTC)**: robotics, IT innovations, etc.
  - **International Trade**: imports of "routine" products (e.g. cloths from China), offshoring, etc.
Vertical Downgrade & the Great Recession

**High-Skilled**

- Before: 1.5
- Recession: 2.5
- Recovery: 3
- After: 2

**Low-Skilled**

- Before: 1
- Recession: 2
- Recovery: 3
- After: 1.5
Flows from Unemp. to Emp.

- Model

Appendix

6 December 2018
Job-Finding and Skill-Requirements

Job-Finding Ratio in A (HS v. LS)

Job-Finding Ratio in R (HS v. LS)

Job-Finding Ratio in M (HS v. LS)

Requirements in A ($e^a$)

Requirements in R ($e^r$)

Requirements in M ($e^m$)

Up-skilling (data)  Model

Riccardo Zago (NYU)
From Unemployment to Abstract Jobs

Transition Probability from Unemp. to Abstract Jobs

$Pr(U \rightarrow A)$

Below | High School | Some College | Bachelor | Msc/Phd

Before | Recession | Recovery

Riccardo Zago (NYU)
From Unemployment to Routine Jobs

Transition Probability from Unemp. to Routine Jobs

Pr(U→R)

Below High School Some College Bachelor Msc/Phd

Before Recession Recovery
From Unemployment to Manual Jobs

Transition Probability from Unemp. to Manual Jobs

Pr(U->M)

Below | High School | Some College | Bachelor | Msc/Phd

Before | Recession | Recovery

Riccardo Zago (NYU)
Returns to Education over the Cycle

Schooling and Wages in Abstract Jobs

Schooling and Wages in Routine Jobs

Schooling and Wages in Manual Jobs

Beefore
Recession
Recovery
After

Riccardo Zago (NYU)
The long-run decline in routine employment

\[ \log(\text{Routine Emp.})_t = \beta \times \text{time} + \epsilon_t \]
Structural Estimation

- \( \gamma \) is the skill level in the interval \([0, 1]\) that splits the skill distribution in two subgroups: high-skilled \((\forall x \geq \gamma)\), low-skilled \((\forall x < \gamma)\)
- The share of low-skilled population decline at a rate \( g_{LS} = -0.1\% \).
Job-specific Surplus over time

Surplus in A

Surplus in R

Surplus in M
### Table: Preset Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>Discount factor (quarterly)</td>
<td>0.95</td>
</tr>
<tr>
<td>$b$</td>
<td>Value of leisure</td>
<td>0.40</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Separation rate</td>
<td>0.10</td>
</tr>
<tr>
<td>$\eta$</td>
<td>Employer bargaining power</td>
<td>0.50</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Matching elasticity</td>
<td>0.50</td>
</tr>
<tr>
<td>$g_{LS}$</td>
<td>Growth of LS pop. Share</td>
<td>$-1.1 \times 10^{-3}$</td>
</tr>
<tr>
<td>$z_{r,0}$</td>
<td>Technology in routine jobs</td>
<td>1</td>
</tr>
</tbody>
</table>
### Table: Targeted moments and model moments

<table>
<thead>
<tr>
<th>Moment</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n_a$ in 2005</td>
<td>0.285</td>
<td>0.286</td>
</tr>
<tr>
<td>$n_r$ in 2005</td>
<td>0.512</td>
<td>0.510</td>
</tr>
<tr>
<td>$n_m$ in 2005</td>
<td>0.152</td>
<td>0.153</td>
</tr>
<tr>
<td>HS Share of $n_a$ in 2005</td>
<td>0.660</td>
<td>0.675</td>
</tr>
<tr>
<td>HS Share of $n_r$ in 2005</td>
<td>0.154</td>
<td>0.152</td>
</tr>
<tr>
<td>HS Share of $n_m$ in 2005</td>
<td>0.102</td>
<td>0.105</td>
</tr>
<tr>
<td>HS Share of $u$ in 2005</td>
<td>0.12</td>
<td>0.11</td>
</tr>
<tr>
<td>$\frac{w_r, HS}{w_a, HS}$ in 2005</td>
<td>0.683</td>
<td>0.689</td>
</tr>
<tr>
<td>$\frac{w_m, HS}{w_a, HS}$ in 2005</td>
<td>0.572</td>
<td>0.590</td>
</tr>
<tr>
<td>$\frac{w_r, LS}{w_a, LS}$ in 2005</td>
<td>0.810</td>
<td>0.795</td>
</tr>
<tr>
<td>$\frac{w_m, LS}{w_a, LS}$ in 2005</td>
<td>0.603</td>
<td>0.590</td>
</tr>
<tr>
<td>$n_r$ long-run growth rate</td>
<td>$-1.5 \times 10^{-3}$</td>
<td>$-1.6 \times 10^{-3}$</td>
</tr>
<tr>
<td>$%\Delta n_a$ during GR</td>
<td>-0.68%</td>
<td>-0.67%</td>
</tr>
<tr>
<td>$%\Delta n_r$ during GR</td>
<td>-4.00%</td>
<td>-4.01%</td>
</tr>
<tr>
<td>$%\Delta n_m$ during GR</td>
<td>-0.24%</td>
<td>-0.22%</td>
</tr>
<tr>
<td>$\text{Corr}(u_t, u_{t-1})$ during GR</td>
<td>0.900</td>
<td>0.899</td>
</tr>
</tbody>
</table>
Vertical Downgrade over the Cycle

- Say your company shuts down. What is your next job going to be over the cycle?

- Use Displaced Worker Supplement (DWS) to identify workers that had been fired for “exogenous” reasons (plant closing, abolished jobs,...)

- For worker $i$ consider:

\[
Pr(\text{Downgrade}_i \neq 0 | X_i) = \Phi(\delta'_s\beta + X'_i\gamma)
\]

where

- $\delta_s$ is a vector of mutually exclusive dummy variables for state-specific expansion, recession and recovery periods

- $X$ controls for sex, age, education, experience, marital status, number of children.
The role of $\sigma$

**Routine Employment**

- $n^\text{Data}_R$
- $n^\text{Model}_R, \sigma_j = 0.03, \forall j = \{a, r, m\}$
- $n^\text{Model}_R, \sigma_j = 0.05, \forall j = \{a, r, m\}$
- $n^\text{Model}_R, \sigma_r = 0.05, \sigma_{a,m} = 0$

**Unemployment**

- $u^\text{Data}$
- $u^\text{Model}_u, \sigma_j = 0.03, \forall j = \{a, r, m\}$
- $u^\text{Model}_u, \sigma_j = 0.05, \forall j = \{a, r, m\}$
- $u^\text{Model}_u, \sigma_r = 0.05, \sigma_{a,m} = 0$
The role of $\sigma$
The role of $g_{zr}$
Employment Dynamics across States' Cycles

\[ \Delta \text{Emp. Share}_{s,t} = \beta \text{year}_s + X'_{s,t} \gamma + \epsilon_{s,t} \]

- Model

Riccardo Zago (NYU)
Job Polarization (Planner)

Routine Employment

Unemployment

Emp. Mismatch  Policy Relevance
The role of $\psi$ and the Social Planner

Emp. Mismatch

Riccardo Zago (NYU)
## Frictions vs. Shocks

<table>
<thead>
<tr>
<th></th>
<th>Search Frictions</th>
<th>Shock Asymmetry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up-Skilling</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Shift-out BC</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Job Polarization</td>
<td>✓ +</td>
<td>✓</td>
</tr>
<tr>
<td>LS Mismatch</td>
<td>✓ +</td>
<td>✓</td>
</tr>
<tr>
<td>HS Mismatch</td>
<td>✓</td>
<td>✓ +</td>
</tr>
</tbody>
</table>
1. **Job Polarization and Technical Change**
   - over the cycle: Jaimovich and Siu '13, Foote and Ryan '15, Restrepo '15
   - in the long-run: Acemoglu and Autor '11, Autor '07, Autor and Dorn '13

2. **Skill Mismatch and Inefficiency in Labor Allocation**
   - cyclical reallocation of skills and efficiency: McLaughlin and Bils '01, Altiwanger et al. '15, Carillo-Tudela and Visschers '13
   - vertical displacement and wage loss: Huckfeldt '16, Krolikowsky '17, Jarosch '14
   - fall in aggregate matching efficiency: Sahin et al. '14, Barnichon and Figure '11

2. **Skill-pooling and Up-skilling**
   - skill-pooling and requirements: Albrecht and Vroman '02
   - counter-cyclical skill requirements: Modestino et al. 15
Validation of the Skill-Pooling Equilibrium

Under Nash Bargaining, the value of production is a share of the surplus

\[ J(x; z_j) = (1 - \eta)S(x; z_j) \]

Under the estimated parameters, the condition for existence of a skill-pooling equilibrium holds.