THE CHANGING US WAGE STRUCTURE

Cumulative real wage growth for men (left) and women (right) 1963-2017 (from Autor, 2019)
EFFECTS OF AUTOMATION ON WAGE STRUCTURE

- **This paper:** effects of automation with distorted labor markets and worker rents.

- Automation targets higher-rent jobs ⇒ **rent dissipation mechanism**
  - reduces within-group wage differentials
  - more adverse effect on wages of exposed groups of workers than in CLM
  - pushes workers to low MRP jobs, smaller TFP gains than in CLM

- **Today:** task model and empirical application to US
  - automation accounts for 60% of changes in wage structure with 16% due to rent dissipation
A TASK MODEL WITH WORKER RENTS

Output

\[ y = \left( \frac{1}{M} \cdot \int_{x \in \mathcal{F}} (M \cdot y_x)^{\frac{\lambda - 1}{\lambda}} \cdot dx \right)^{\frac{\lambda}{\lambda - 1}} \]

Task production

\[ y_x = \psi_{k,x} \cdot k_x + \sum_{g} \psi_{g,x} \cdot \ell_{g,x} \]

Labor market \( g \)

\[ \ell_g = \int_{x \in \mathcal{F}} \ell_{g,x} \cdot dx \]

Resource constraint

\[ c = y - k, \quad k = \int_{x \in \mathcal{F}} \left( \frac{k_x}{q_x} \right) \cdot dx \]

Unit costs for task \( x \)

1. \( \frac{1}{q_x \cdot \psi_{k,x}} \) if produced with \( k_x \),
2. \( \frac{w_g \cdot \mu_{g,x}}{\psi_{g,x}} \) if produced with \( \ell_{g,x} \).
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Here \( q_x = 0 \) for tasks that are not technologically automatable
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Rents modeled as exogenous labor wedge \( \mu_{g,x} \geq 1 \) above \( w_g \)

\( \Rightarrow \) wage dispersion and misallocation.
**Invention:** $q_x$ (investment productivity) up from zero to $q'_x > 0$ in $A^T_g$

**Adoption:** automate tasks in $A_g \subseteq A^T_g$
**Invention:** $q_x$ (investment productivity) up from zero to $q'_x > 0$ in $\mathcal{A}^T_g$

**Adoption:** automate tasks in $\mathcal{A}_g \subseteq \mathcal{A}^T_g$
EQUILIBRIUM ALLOCATION AND ADVANCES IN AUTOMATION

Invention: $q_x$ (investment productivity) up from zero to $q_x' > 0$ in $\mathcal{A}_g^T$

Adoption: automate tasks in $\mathcal{A}_g \subseteq \mathcal{A}_g^T$

Questions:
- Which tasks in $\mathcal{A}_g^T$ are automated?
- Implications for wages and TFP?
AUTOMATION TARGETS HIGH RENT TASKS OR JOBS

Proposition

If (i) not all tasks in $\mathcal{A}_g^T$ automated and (ii) advances in automation orthogonal to rents:

1) adoption targets higher-rents tasks,
   \[ \mu_{\mathcal{A}_g} > \mu_g. \]

2) displacement of workers from $\mathcal{A}_g$ brings more pronounced decline at top quantiles of within-group wage distribution.
**Proposition**

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2) displacement of workers from $A_g$ brings more pronounced decline at top quantiles of within-group wage distribution.
AUTOMATION AND ITS EFFECT ON AGGREGATES

Average group wages:

\[ \bar{w}_g = \left( \frac{y}{\ell_g} \right)^{\frac{1}{\lambda}} \cdot \Gamma_g^{\frac{1}{\lambda}} \cdot \mu_g, \]

\[ \Gamma_g := \frac{1}{M} \cdot \int_{x \in \mathcal{T}_g} \psi_{g,x}^{\lambda-1} \cdot \mu_{g,x}^{-\lambda} \cdot dx \]

Task share of group g (importance of tasks assigned to g)
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Task share of group g (importance of tasks assigned to g)

Automation affects \textbf{group average wages} by:

1) Increasing output
2) Reducing their task share by removing \( A_g \)
3) Pushing workers to lower-rent jobs
4) Ripple effects
Proposition

Let $d \ln \Gamma_g^d = \text{reduction in } \Gamma_g$ due to the automation of tasks in $\mathcal{A}_g$ and $\pi_g = \text{average cost-reduction in automated tasks}$. With no ripples, the effects of automation on wages and TFP are

$$d \ln \tilde{w}_g = \frac{1}{\lambda} \cdot d \ln y - \frac{1}{\lambda} \cdot d \ln \Gamma_g^d - \left( \frac{\mu_{\mathcal{A}g}}{\mu_g} - 1 \right) \cdot d \ln \Gamma_g^d$$

$$d \ln \text{tfp} = \sum_g s_g \cdot \frac{\mu_{\mathcal{A}g}}{\mu_g} \cdot d \ln \Gamma_g^d \cdot \pi_g - \sum_g s_g \cdot \left( \frac{\mu_{\mathcal{A}g}}{\mu_g} - 1 \right) \cdot d \ln \Gamma_g^d$$
EFFECTS OF AUTOMATION ON GROUP WAGES

Proposition

Let $d \ln \Gamma^d_g$ = reduction in $\Gamma_g$ due to the automation of tasks in $A_g$ and $\pi_g = \text{average cost-reduction in automated tasks.}$ With no ripples, the effects of automation on wages and TFP are

\[
d \ln \bar{w}_g = \frac{1}{\lambda} \cdot d \ln y - \frac{1}{\lambda} \cdot d \ln \Gamma^d_g - \left( \frac{\mu_{A_g}}{\mu_g} - 1 \right) \cdot d \ln \Gamma^d_g
\]

(1) Prod effect  (2) Direct task displacement  (3) Rent dissipation

\[
d \ln tfp = \sum_g s_g \cdot \frac{\mu_{A_g}}{\mu_g} \cdot d \ln \Gamma^d_g \cdot \pi_g - \sum_g s_g \cdot \left( \frac{\mu_{A_g}}{\mu_g} - 1 \right) \cdot d \ln \Gamma^d_g
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EFFECTS OF AUTOMATION ON GROUP WAGES

Proposition

Let \( d \ln \Gamma_g^d \) = reduction in \( \Gamma_g \) due to the automation of tasks in \( \mathcal{A}_g \) and \( \pi_g = \) average cost-reduction in automated tasks. With no ripples, the effects of automation on wages and TFP are

\[
\begin{align*}
  d \ln \bar{w}_g &= \frac{1}{\lambda} \cdot d \ln y - \frac{1}{\lambda} \cdot d \ln \Gamma_g^d - \left( \frac{\mu_{\mathcal{A}_g}}{\mu_g} - 1 \right) \cdot d \ln \Gamma_g^d \\
  d \ln tfp &= \sum_{g} s_g \cdot \frac{\mu_{\mathcal{A}_g}}{\mu_g} \cdot d \ln \Gamma_g^d \cdot \pi_g - \sum_{g} s_g \cdot \left( \frac{\mu_{\mathcal{A}_g}}{\mu_g} - 1 \right) \cdot d \ln \Gamma_g^d
\end{align*}
\]

(1) Prod effect  (2) Direct task displacement  (3) Rent dissipation

(1) Hulten's theorem  (2) Changes in allocative efficiency (a-la Baqee-Farhi)

\((\pi_g \geq 0)\)
EFFECTS ACCOUNTING FOR RIPPLES

Proposition

Let $\Theta = \left( I - \frac{1}{\lambda} \frac{\partial \ln \Gamma}{\partial \ln w} \right)^{-1}$ and $\mathcal{M} = \frac{\partial \ln \mu}{\partial \ln w} \cdot \left( I - \frac{1}{\lambda} \frac{\partial \ln \Gamma}{\partial \ln w} \right)^{-1}$. With ripples, the effects of automation on wages and TFP are

$$d \ln \bar{w}_g = \frac{1}{\lambda} \cdot (\Theta_g + \mathcal{M}_g) \cdot \text{stack}(d \ln y - d \ln \Gamma^d_j) - \left( \frac{\mu \mathcal{A}_g}{\mu_g} - 1 \right) \cdot d \ln \Gamma^d_g$$

$$d \ln tfp = \sum_g s_g \cdot \frac{\mu \mathcal{A}_g}{\mu_g} \cdot d \ln \Gamma^d_g \cdot \pi_g$$

$$+ \sum_g s_g \cdot \left( \frac{1}{\lambda} \cdot \mathcal{M}_g \cdot \text{stack}(d \ln y - d \ln \Gamma^d_j) - \left( \frac{\mu \mathcal{A}_g}{\mu_g} - 1 \right) \cdot d \ln \Gamma^d_g \right)$$

Column vector of all "shocks"
**EFFECTS ACCOUNTING FOR RIPPLES**

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\[
+ \sum_g s_g \cdot \frac{1}{\lambda} \cdot \mathcal{M}_g \cdot \text{stack}(d \ln y - d \ln \Gamma^d_j) - \left( \frac{\mu_{\mathcal{A}g}}{\mu_g} - 1 \right) \cdot d \ln \Gamma^d_g
\]

⇒ Formulas to compute effects of automation shock $\{d \ln \Gamma^d_g, \frac{\mu_{\mathcal{A}g}}{\mu_g}, \pi_g\}_g$
EMPIRICS: OUR APPROACH

Automation shock described by \( \{d \ln \Gamma_g^d, \mu_{\mathcal{A}g}/\mu_g, \pi_g\}_g \):

- **Step 1:** create measures of direct task displacement \( d \ln \Gamma_g^d \) for different groups of US workers over 1980–2016 (Acemoglu-Restrepo 2022)

- **Step 2:** provide reduced form evidence on effects of automation on groups directly exposed to it, both for wages and rents, which gives \( \mu_{\mathcal{A}g}/\mu_g \)

- **Step 3:** estimate propagation matrices \( \{\Theta, \mathcal{M}\} \) (in paper)

- **Step 4:** combine with estimates of \( \pi_g \) to compute effects of automation
MEASURING DIRECT TASK DISPLACEMENT

Direct task displacement experienced by $g$ (“share tasks” lost to automation):

$$d \ln \Gamma_g^d = \sum_i \omega_{gi} \cdot RCA_{g,i}^{rout} \cdot \frac{1}{a_i} \cdot \text{automation-driven declines in } \frac{d \ln s_{\ell i}}{}$$

- Employment and wages by industry and in routine jobs from 1980 US Census
- $d \ln s_{\ell i}^d$ from cross-industry regression of labor share changes on automation proxies

Note: $\omega_{gi}$ is an extra adjustment term given in paper.
Regression for average wage changes in group $g$

$$d \ln \bar{w}_g = \beta \cdot \text{task displacement}^d_g + \text{covariates}_g + u_g$$

- **Left panel:** raw data
- **Right panel:** controls for industry shifts, education, gender, manufacturing exposure
- 10 pp $\uparrow$ in task displacement reduces mean wage by 20%

\[ \beta = -2.43 \quad (\text{s.e 0.14}) \]

\[ \beta = -1.98 \quad (\text{s.e 0.31}) \]
How much of the relative wage decline is due to rent dissipation?

Two strategies:

- Proxy rents as wage premia by industry and occupation (Katz-Summers 89)
- Estimate group-quantile regression, building on theory
Estimate changes in (unconditional) wage quantiles within exposed groups:

\[ d \ln w_g(p) = \beta(p) \cdot \text{task displacement}^d_g + \text{covariates}_g + u_g \]

- Wage decline in exposed group more pronounced above its 30th percentile
- Decline in rents inferred from within-group wage compression
- Implies \( \mu_{\mathcal{A}}_g / \mu_g = 1.5 \implies 50\% \text{ rent in automated jobs} \)
Estimate changes in (unconditional) wage quantiles within exposed groups:

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- Wage decline in exposed group more pronounced above its 30th percentile
- Decline in rents inferred from within-group wage compression
- Implies \( \mu_{\mathcal{A}_g}/\mu_g = 1.5 \Rightarrow 50\% \text{ rent in automated jobs} \)
Sets $\pi_g = 30\%$

Note: automation also affects wages by shifting industry composition. This effect is small and pooled in Panel B. These results assume $\lambda = 0.5$
## QUANTITATIVE FINDINGS, 1980–2016

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<th>Model (ignoring rent dissipation, CLM)</th>
<th>Model (with rent dissipation)</th>
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<td>Share group wage changes explained</td>
<td>44%</td>
<td>60%</td>
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<td>-10.4%</td>
<td>-6.5%</td>
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<td>Average wages (comp adjusted)</td>
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<td>3%</td>
<td>-0.7%</td>
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<tr>
<td>Welfare (aggregate consumption)</td>
<td>4.5%</td>
<td>-1%</td>
<td>60%</td>
</tr>
</tbody>
</table>
CONCLUDING REMARKS

• In non-competitive labor markets, automation creates rent dissipation

• Reduced-form results:
  - rent dissipation accounts for 25% of negative wage effects of automation on exposed worker groups from 1980-2016
  - and creates within group wage compression

• Quantitative results:
  - automation accounts for 60% of changes in wage structure since 1980s (16 pp due to rent dissipation)
  - rent dissipation has large effect on allocative efficiency. “Zero” net effects on TFP and utilitarian social welfare
  - Automation has been an important force shaping the wage structure and inequality, but not aggregate consumption or TFP growth
Regression for **wage compression** in group \( g \)

\[
d \ln \bar{w}_g - d \ln w_{g}^{30th} = \beta \cdot td_g^d + \text{covariates}_g + e_g
\]

- **Left panel:** raw data
- **Right panel:** controls
- 10 pp ↑ in task displacement **reduces rents by 4%**
- Suggests \( \mu_{A_g}/\mu_g = 1.4 \) (rises to 1.5 when controlling for ripples)

\[
\beta = -0.38 \quad \text{(s.e 0.06)} \\
\beta = -0.4 \quad \text{(s.e 0.11)}
\]
Regression for **proxy for rent changes** in group $g$

$$d \ln \mu_{g, \text{proxy}} = \beta \cdot t d_{g}^d + \text{covariates}_g + e_g$$

- **Alternative rent proxy:**
  Change in group employment at high-wage jobs in 1980 (industry $\times$ occupation) from Mincer equation
- **Suggests** $\mu_{A_g}/\mu_g = 40\%$
EXTRA: MORE EVIDENCE CONSISTENT WITH RENT DISSIPATION

- **Kogan et al.**: exposure to technological advances in an occupation reduces wages the most for highest-paid workers.

- **Acemoglu et al.**: high-wage firms more likely to adopt automation technologies (conditional on size, age, and industry).

- **Braxton-Taska**: workers displaced from job for technological reasons experience a 30% drop in earnings (compared to 5% for others)

- **Winkler**: loss of firm rents accounts for 70% of wage losses of workers exposed to import competition
**EXTRA: ESTIMATE PROPAGATION AND RENT IMPACT MATRICES**

- Take $\lambda = 0.5$ (Humlum, 22) and estimate

\[
d \ln w_g = \frac{1}{\lambda} \cdot \Theta_g(\beta) \cdot \text{stack}(d \ln y - d \ln \Gamma^d_j + Z_j + u_j)
\]

\[
d \ln \mu_g = - (\mu_{\mathcal{A}g}/\mu_g - 1) \cdot d \ln \Gamma^d_g + \frac{1}{\lambda} \cdot \mathcal{M}_g(\beta) \cdot (d \ln y - d \ln \Gamma^d_j + Z_j + u_j) + Z^\mu_g + e_g
\]

- **Identification:** $d \ln \Gamma^d_j, Z_j, Z^\mu_j \perp u_g, e_g$ for all $g,j$ and different shocks $\{Z_g, Z^\mu_g\}$

- **Restrictions:** Matrices parametrized in terms of employment similarity across groups and overlap at high-wage jobs
EXTRA: ESTIMATE PROPAGATION AND RENT IMPACT MATRICES

- Take $\lambda = 0.5$ (Humlum, 22) and estimate

\[
\frac{d \ln w_g}{\lambda} = \Theta_g(\beta) \cdot \text{stack}(d \ln y - d \ln \Gamma^d_j + Z_j + u_j)
\]

\[
\frac{d \ln \mu_g}{\lambda} = -\left(\frac{\mu_{\mathcal{A}g}/\mu_g - 1}{\lambda}\right) \cdot d \ln \Gamma^d_g + \frac{1}{\lambda} \cdot \mathcal{M}_g(\beta) \cdot (d \ln y - d \ln \Gamma^d_j + Z_j + u_j) + Z^\mu_g + e_g
\]

- **Identification:** $d \ln \Gamma^d_j, Z_j, Z^\mu_j \perp u_g, e_g$ for all $g, j$ and different shocks $\{Z_g, Z^\mu_g\}$

- **Restrictions:** Matrices parametrized in terms of employment similarity across groups and overlap at high-wage jobs
  - Propagation matrix has diagonal term 1.4 and off-diagonal terms sum of 0.4
  - Rent impact matrix has small entries; average rent dissipation $\mu_{\mathcal{A},g}/\mu_g = 1.5$
Change in $w_g$ explains 44% of shifts in wage structure since 1980.

Rises to 60% when accounting for rent dissipation.
Rent quantiles for group $g$

$$\ln \mu_g(p)$$

Automation targeted at high rent jobs

Change in wage quantiles for group $g$

$$d \ln w_g(p)$$

Change of $d \ln w_g$ for jobs that pay no rents

Loss of high-rent jobs within $\mathcal{A}_g$

No rent dissipation for workers outside $\mathcal{A}_T$ earning high rents
Rent quantiles for group $g$

$\ln \mu_g(p)$

Change in wage quantiles for group $g$

$d \ln w_g(p)$

Automation targeted at low rent jobs and not all low rent jobs eliminated

Middle-waged workers pushed up
Rent quantiles for group $g$

$$\ln \mu_g(p)$$

Change in wage quantiles for group $g$

$$d \ln w_g(p)$$

Automation targeted at low rent jobs and all low rent jobs eliminated

Middle-waged workers pushed up
Two tasks performed by \( g \): welding and delivery

- Welding pays a rent \( \mu_{\text{welding}} = 1.2 \) and delivery pays no rent \( \mu_{\text{delivery}} = 1 \)
- MRPL at welding exceeds MRPL at delivery by 20%
- Imagine that firm given chance to automate welding job at cost \( \kappa \) per worker
- Firm benefits \( \pi = \mu_{\text{welding}} \cdot w - \kappa \)
- Social benefit \( \pi_{\text{social}} = \pi - 0.2 \cdot w = w - \kappa \)
- Automation reduces social welfare if \( \pi > 0 > w - \kappa \)
Capping of cans done by specialized tinmiths with high bargaining power.

Development of mechanical capper by James Cox motivated by this issue.

Mechanical capper operated by unorganized workers earning no rents.

After its development, mechanical capper substituted for some of the specialized tinmiths, even though it was not as productive.

Wasteful from a social point of view: specialized tinmith might have a lower opportunity cost than combo of mechanical capper plus operator.

Following introduction around 1870, subsequent compression of wage structure in canneries (from bimodal to unimodal).