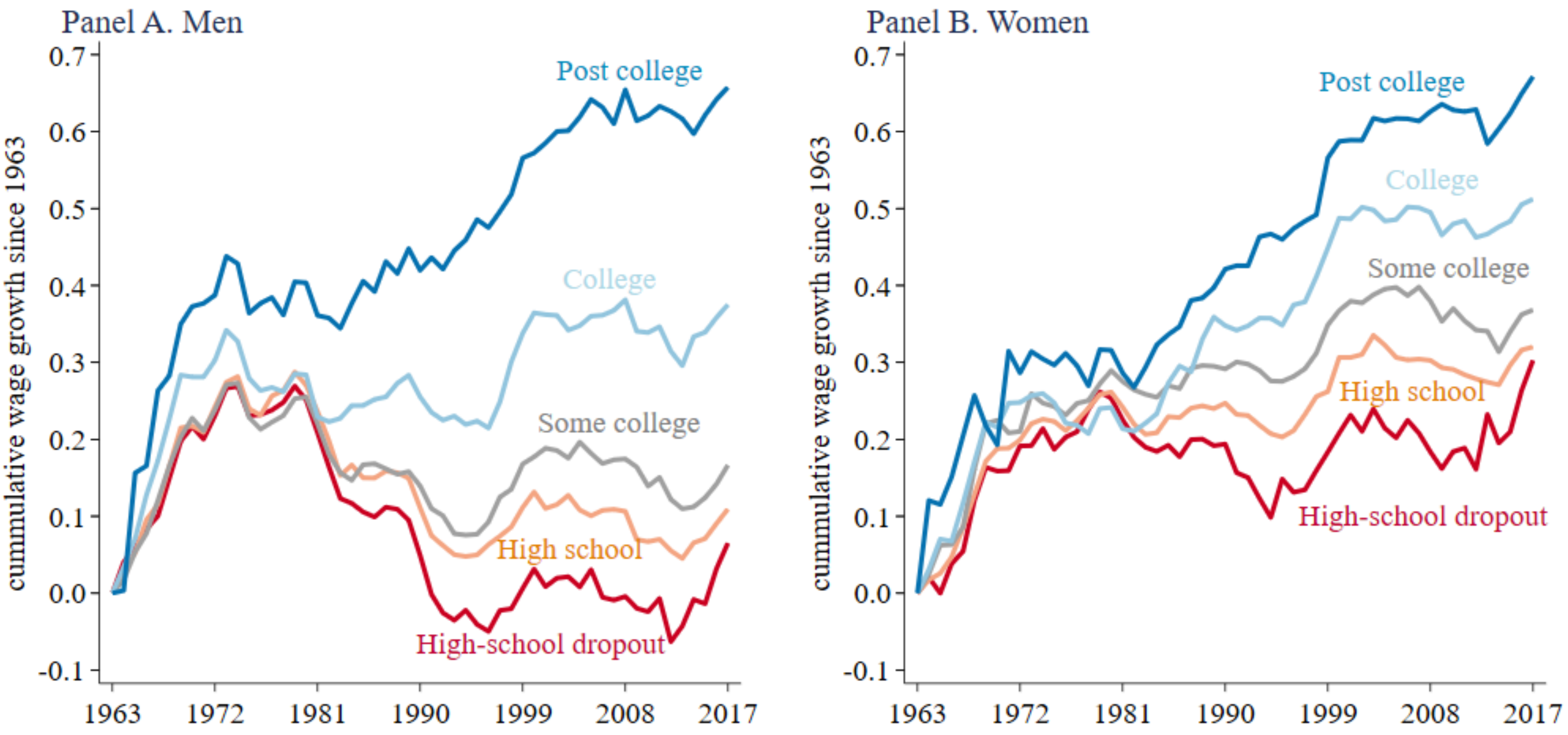
DARON ACEMOGLU (MIT) & PASCUAL RESTREPO (BOSTON UNIVERSITY)

AUTOMATION AND RENT DISSIPATION

NBER Growth Meeting, July 2023

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 $\Rightarrow$ 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 $$y = \left(\frac{1}{M} \cdot \int_{x \in \mathcal{T}} (M \cdot y_x)^{\frac{\lambda - 1}{\lambda}} \cdot dx \right)^{\frac{\lambda}{\lambda - 1}}$$

Task production $$y_x = \psi_{k,x} \cdot k_x + \sum_g \psi_{g,x} \cdot \ell_{g,x}$$

Labor market g $$\ell_g = \int_{x \in \mathcal{T}} \ell_{g,x} \cdot dx$$

Resource constraint $$c = y - k, \quad k = \int_{x \in \mathcal{T}} (k_x / q_x) \cdot dx$$

Unit costs for task x $$\frac{1}{q_x \cdot \psi_{k,x}}$$ if produced with k_x, $$\frac{w_g \cdot \mu_{g,x}}{\psi_{g,x}}$$ 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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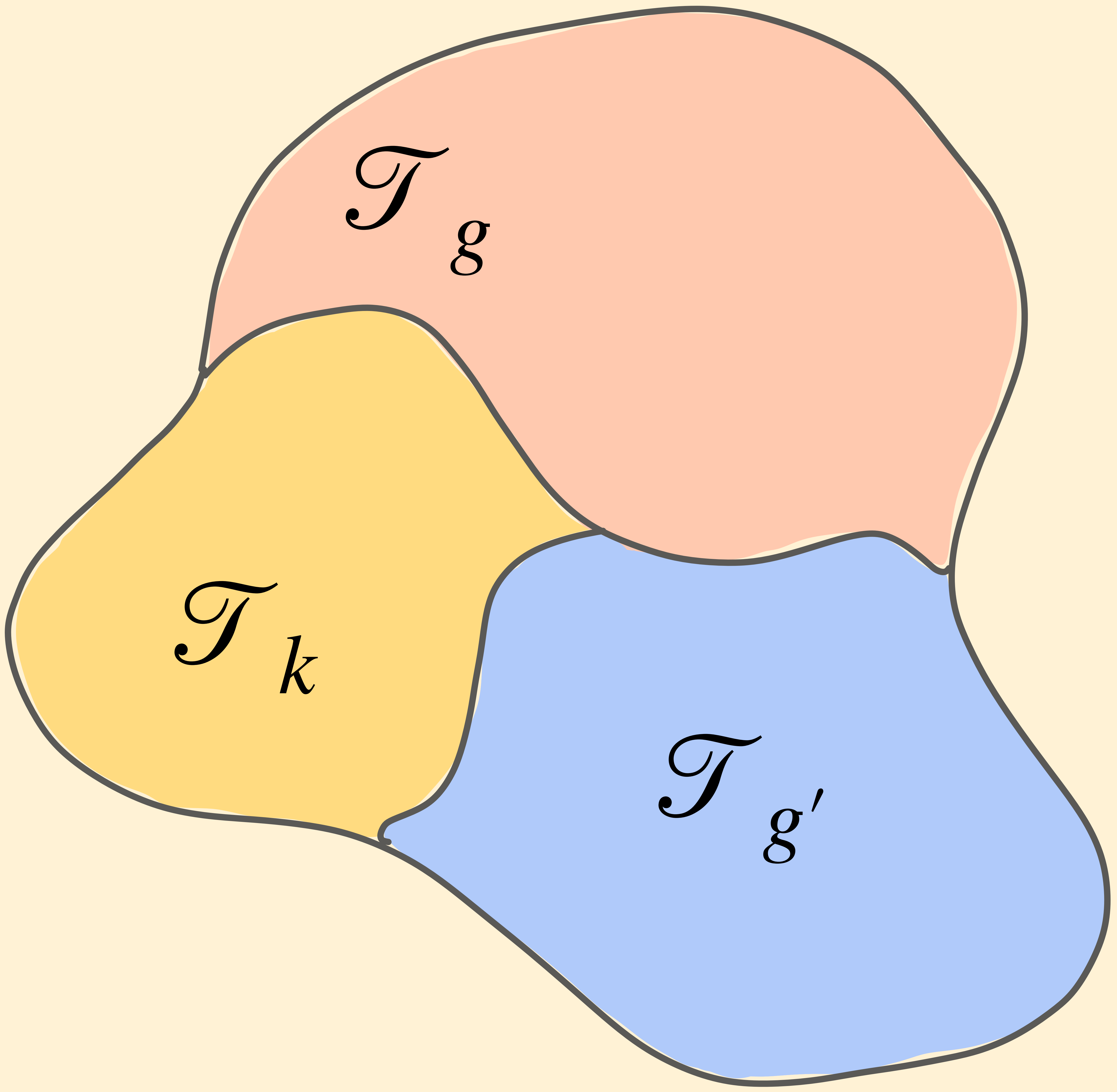
Rents modeled as exogenous labor wedge $\mu_{g,x} \geq 1$ above w_g
$\Rightarrow$ wage dispersion and misallocation.

EQUILIBRIUM ALLOCATION AND ADVANCES IN AUTOMATION



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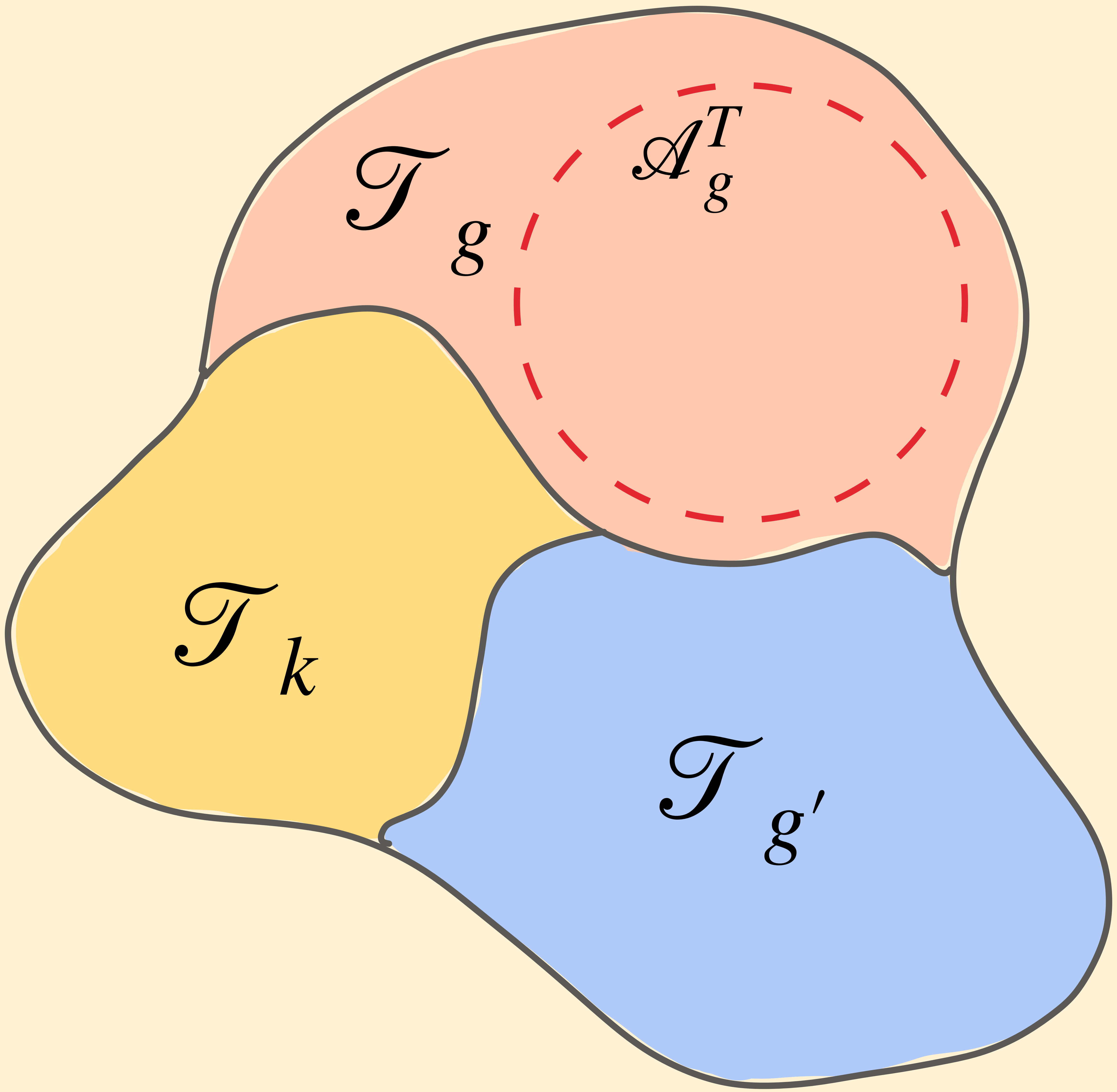

Invention: q_x (investment productivity) up from zero to $q_x' > 0$ in $\mathcal{A}_g^T$

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

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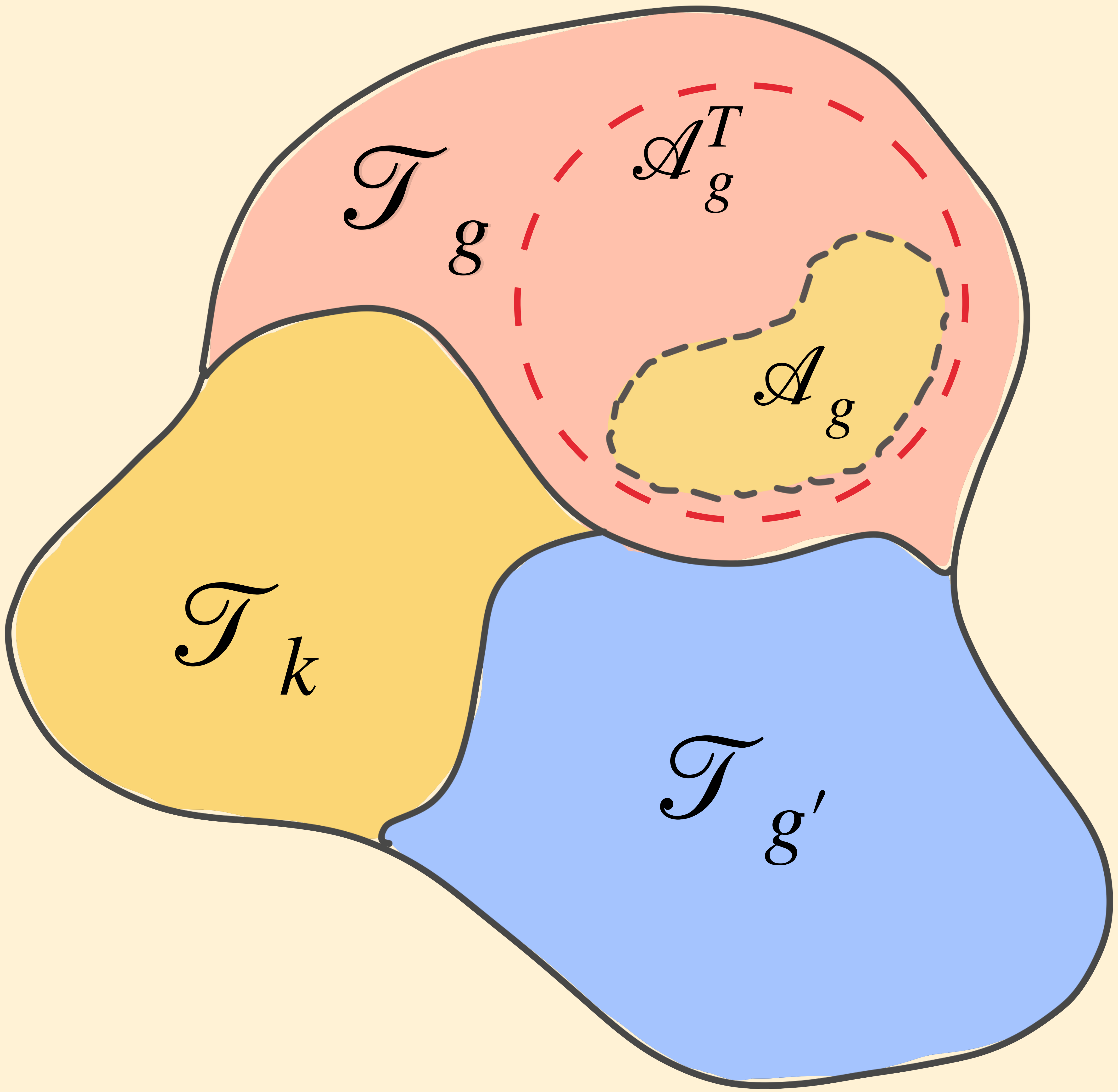

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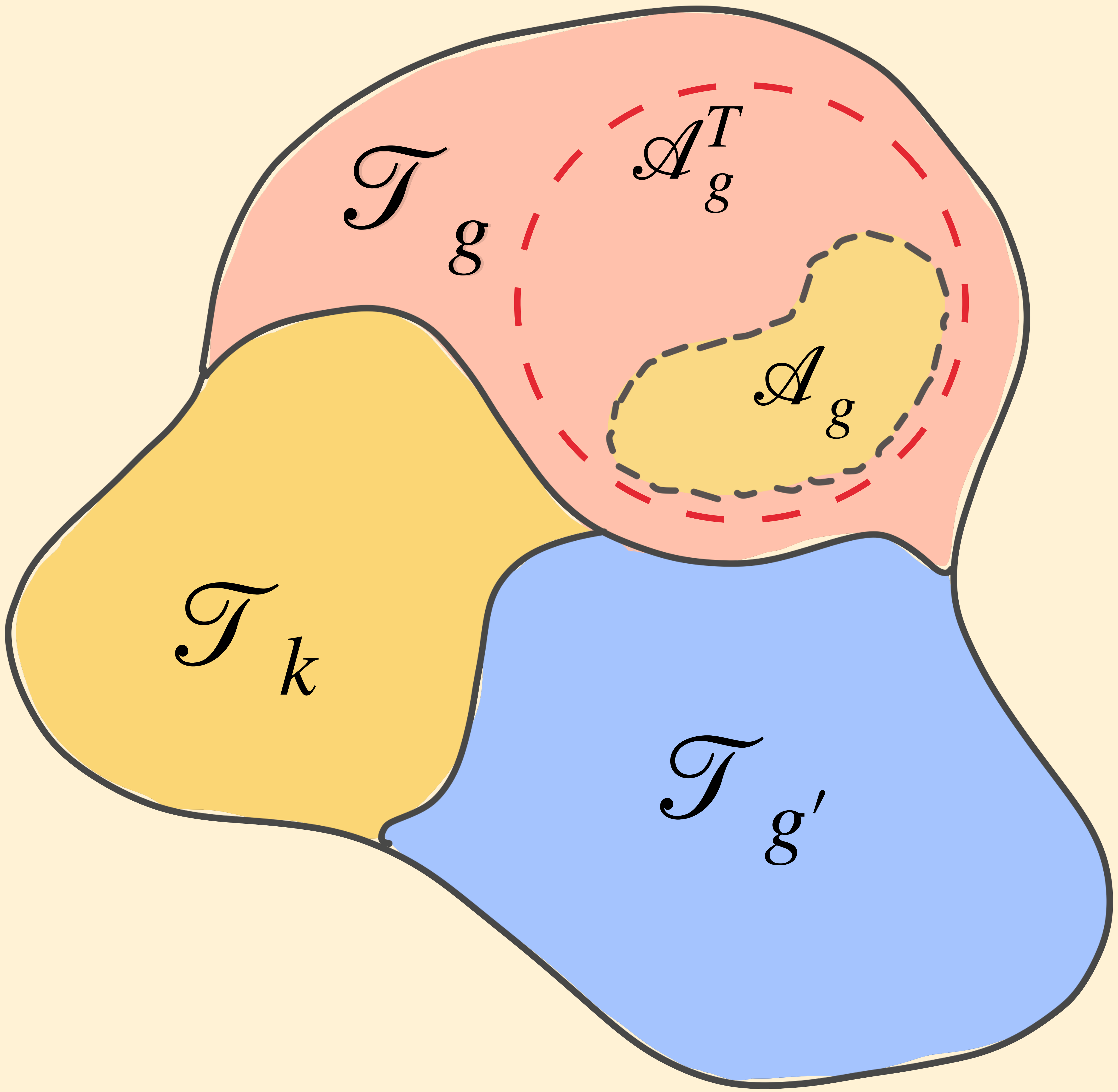

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Adoption: automate tasks in $\mathscr{A}_g \subseteq \mathscr{A}_g^T$

Questions:

- Which tasks in $\mathscr{A}_g^T$ are automated?
- Implications for wages and TFP?

AUTOMATION TARGETS HIGH RENT TASKS OR JOBS

Proposition

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

1) adoption targets higher-rents tasks, $\mu_{\mathscr{A}g} > \mu_g$.

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

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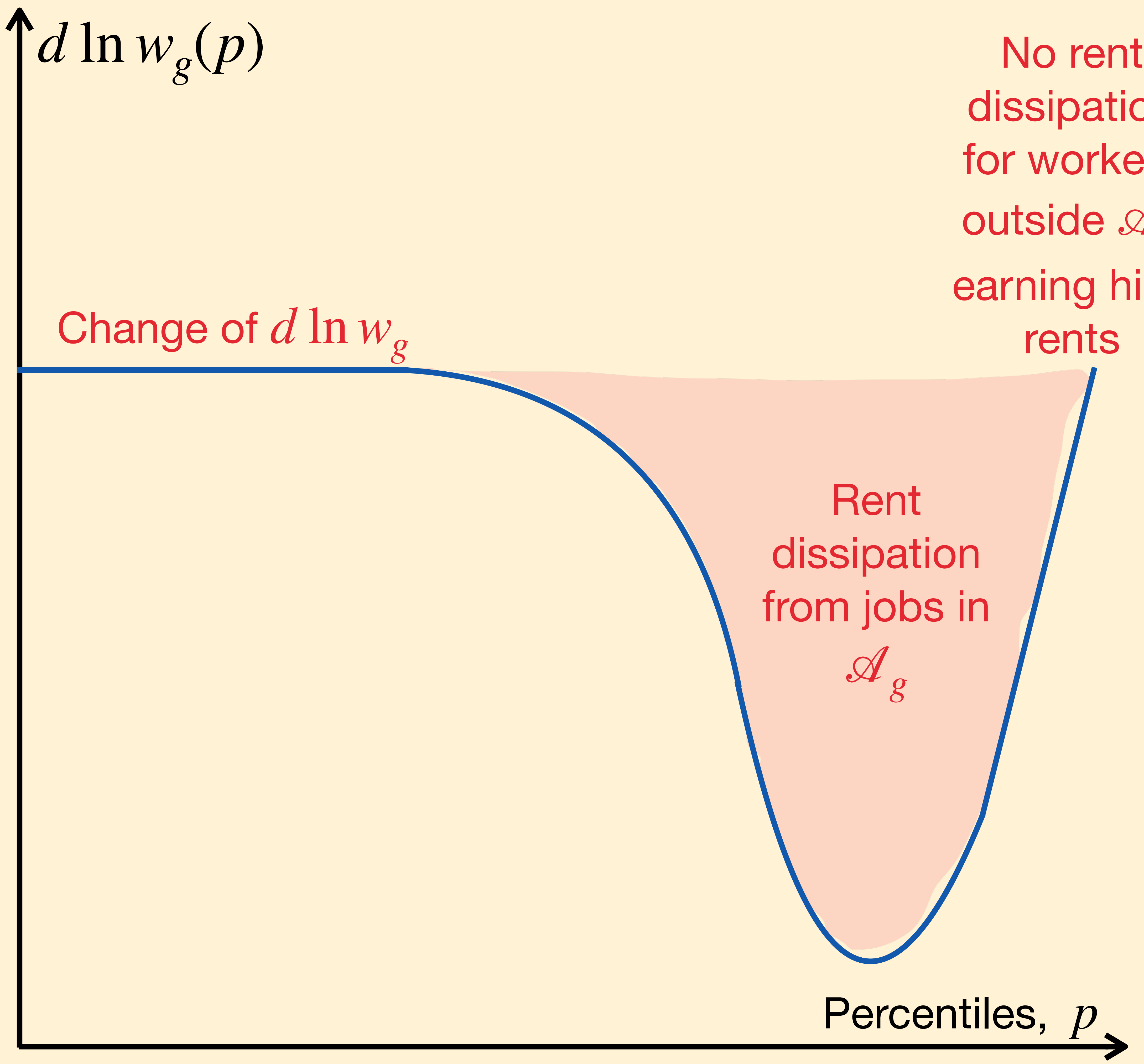
Change in wage quantiles for group g



AUTOMATION AND ITS EFFECT ON AGGREGATES

Average group wages:

$$\bar{w}_g = \left(\frac{y}{\ell_g}\right)^{\frac{1}{\lambda}} \cdot \Gamma_g^{\frac{1}{\lambda}} \cdot \mu_g, \qquad \Gamma_g := \frac{1}{M} \cdot \int_{x \in \mathcal{T}_g} \psi_{g,x}^{\lambda-1} \cdot \mu_{g,x}^{-\lambda} \cdot dx$$

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

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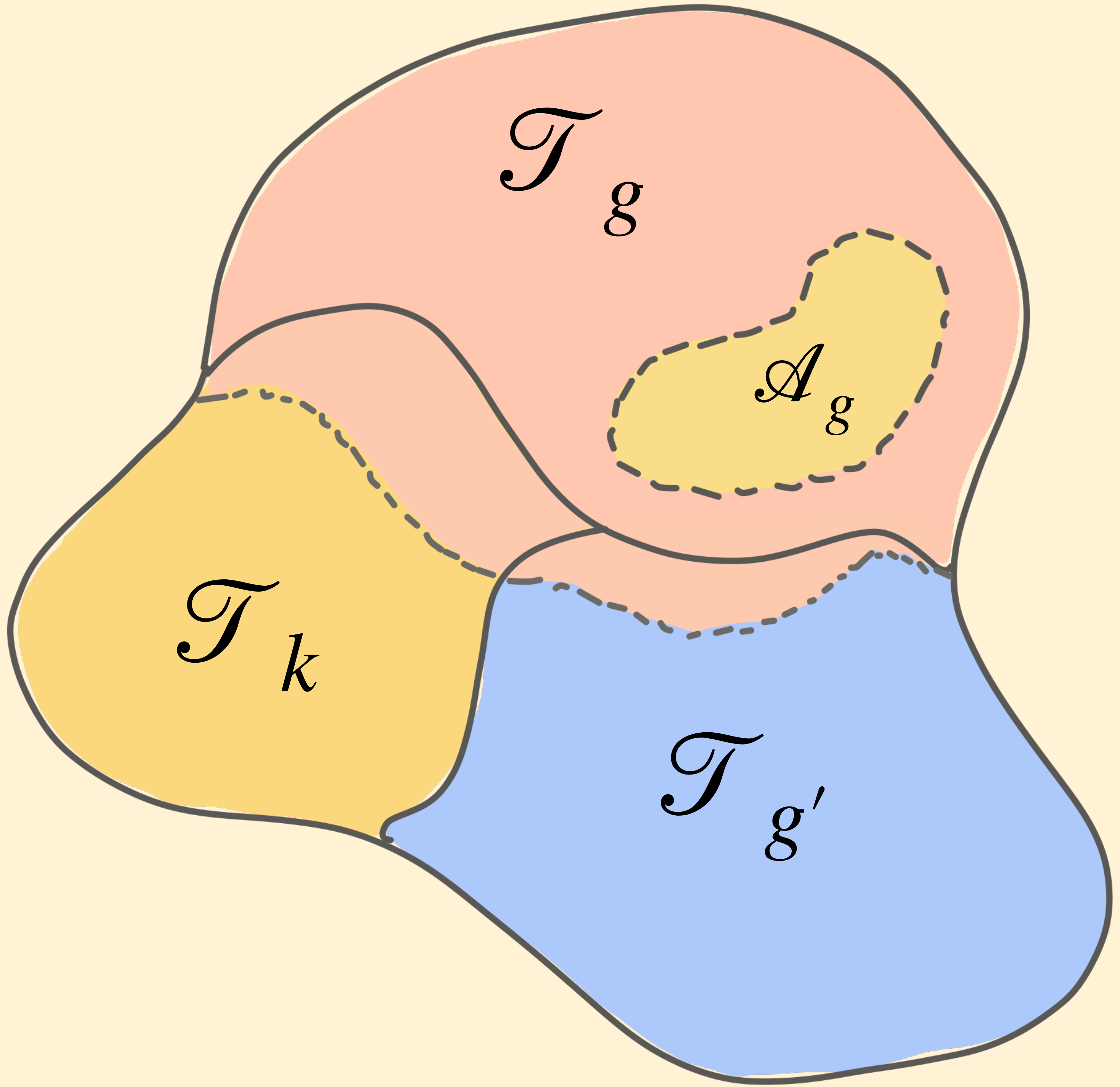

Automation affects **group average wages** by:

1) Increasing output

2) Reducing their task share by removing $\mathcal{A}_g$

3) Pushing workers to lower-rent jobs

4) Ripple effects

EFFECTS OF AUTOMATION ON GROUP WAGES

Proposition

Let $d\ln\Gamma_g^d$ = reduction in Γ_g due to the automation of tasks in $\mathscr{A}_g$ and π_g = average cost-reduction in automated tasks. With <u>no ripples</u>, the effects of automation on wages and TFP are

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

$$d\ln tfp = \sum_g s_g\cdot\frac{\mu_{\mathscr{A}g}}{\mu_g}\cdot d\ln\Gamma_g^d\cdot\pi_g - \sum_g s_g\cdot\left(\frac{\mu_{\mathscr{A}g}}{\mu_g} - 1\right)\cdot d\ln\Gamma_g^d$$

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(1) Hulten's theorem ($\pi_g \geq 0$)

(2) Changes in allocative efficiency (a-la Baqaee-Farhi)

EFFECTS ACCOUNTING FOR RIPPLES

Proposition

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

$$d \ln \bar{w}_g = \frac{1}{\lambda} \cdot (\Theta_g + \mathscr{M}_g) \cdot \text{stack}(d \ln y - d \ln \Gamma_j^d) - \left(\mu_{\mathscr{A}g}/\mu_g - 1\right) \cdot d \ln \Gamma_g^d$$

$$d \ln tfp = \sum_g s_g \cdot \frac{\mu_{\mathscr{A}g}}{\mu_g} \cdot d \ln \Gamma_g^d \cdot \pi_g$$

$$+ \sum_g s_g \cdot (\frac{1}{\lambda} \cdot \mathscr{M}_g \cdot \text{stack}(d \ln y - d \ln \Gamma_j^d) - \left(\mu_{\mathscr{A}g}/\mu_g - 1\right) \cdot d \ln \Gamma_g^d)$$

Column vector of all "shocks"

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⇒Formulas to compute effects of automation shock $\{d \ln \Gamma_g^d, \mu_{\mathscr{A}g}/\mu_g, \pi_g\}_g$

EMPIRICS: OUR APPROACH

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

- **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 $\mu_{\mathscr{A}g}/\mu_g$
- **Step 3:** estimate propagation matrices $\{\Theta, \mathscr{M}\}$ (in paper)
- **Step 4:** combine with estimates of π_g to compute effects of automation

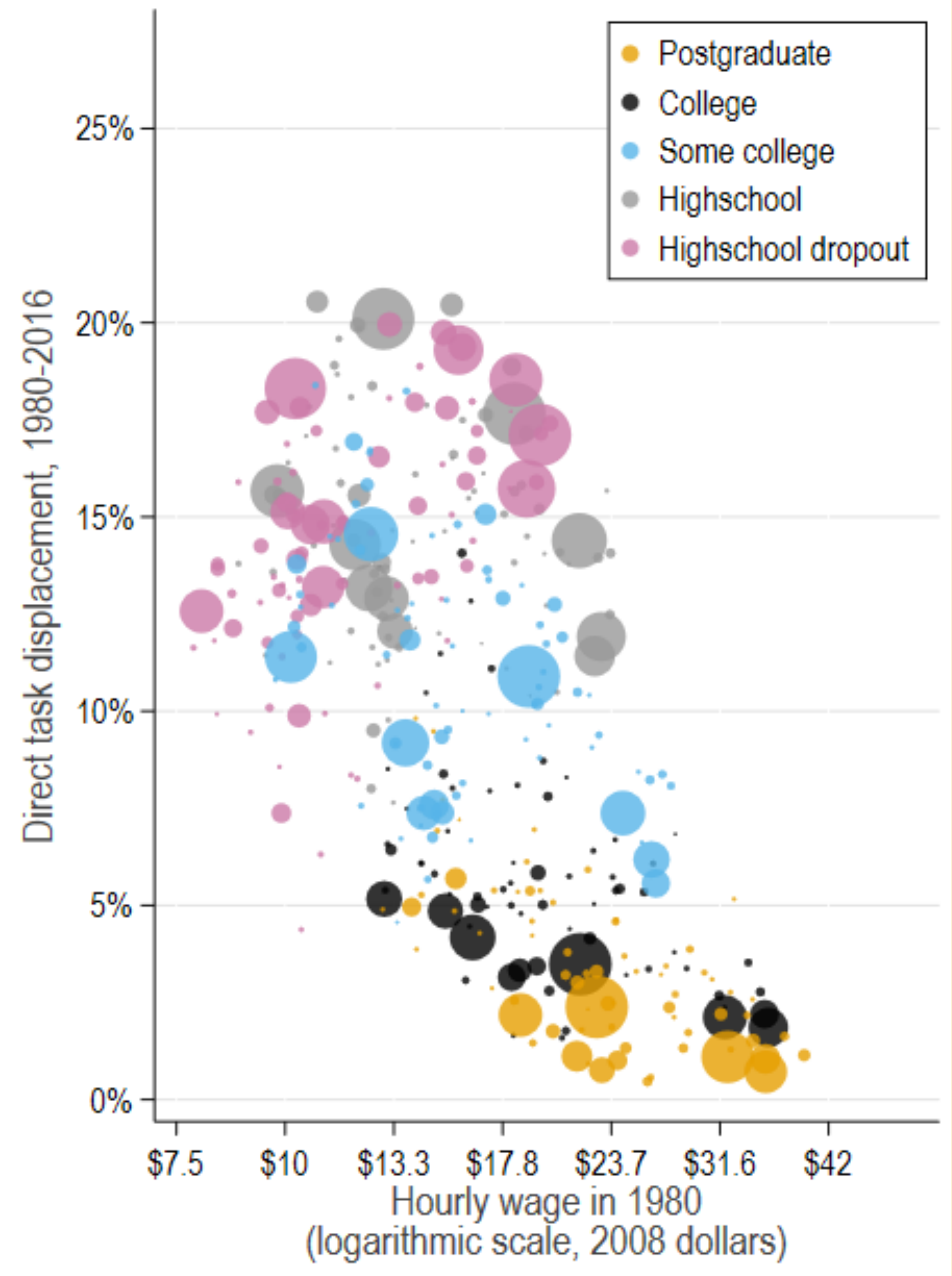
MEASURING DIRECT TASK DISPLACEMENT

Direct task displacement experienced by g ("share tasks" lost to automation):

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

- Measured from 1980-2016 for 500 worker groups (education, gender, age, race, US born).
- 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

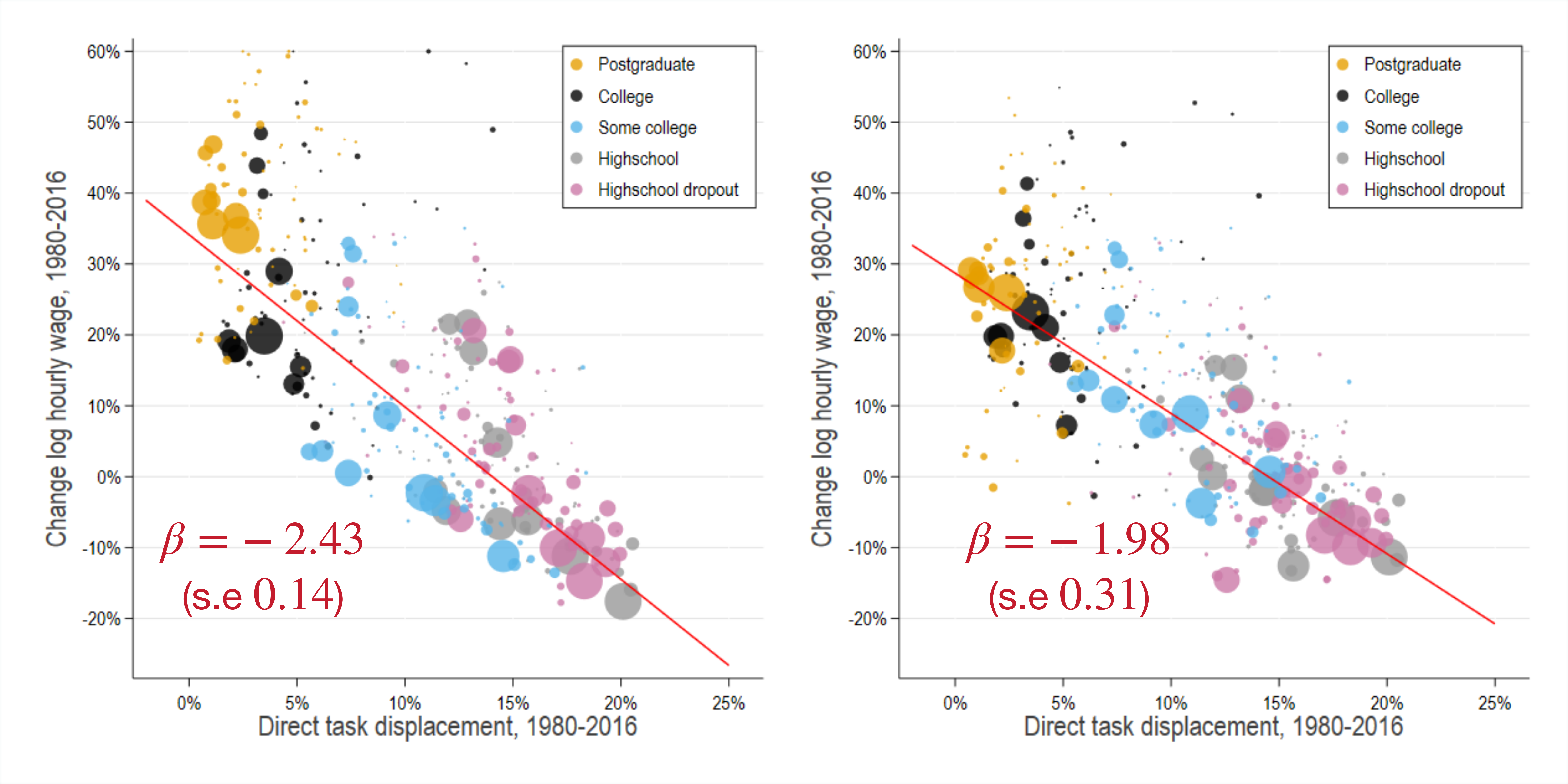
Note: a_i is an extra adjustment term given in paper



TASK DISPLACEMENT, WAGES, AND RENTS

Regression for **average wage changes** in group g

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



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

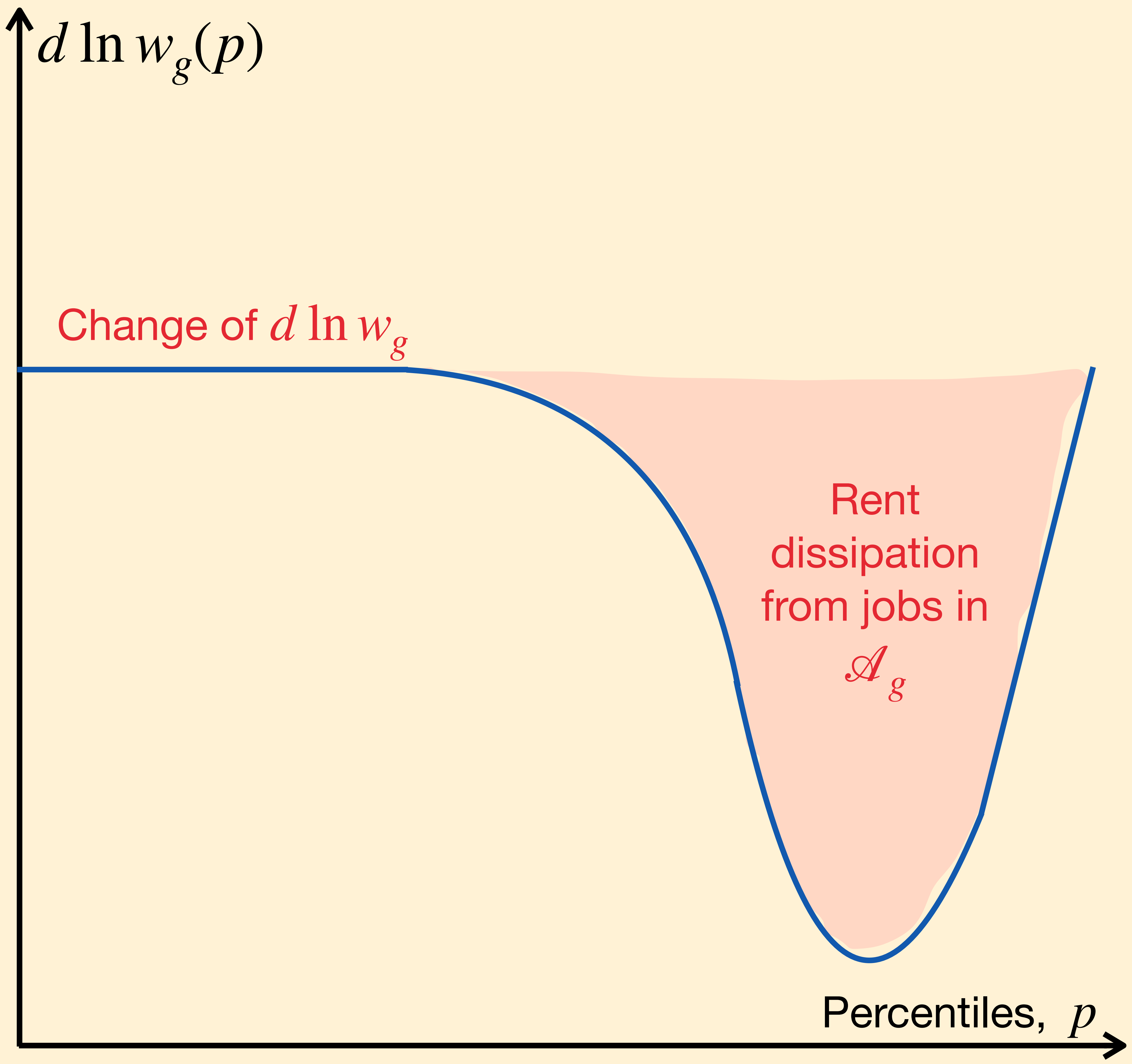
TASK DISPLACEMENT, WAGES, AND RENTS

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

Change in wage quantiles for group g

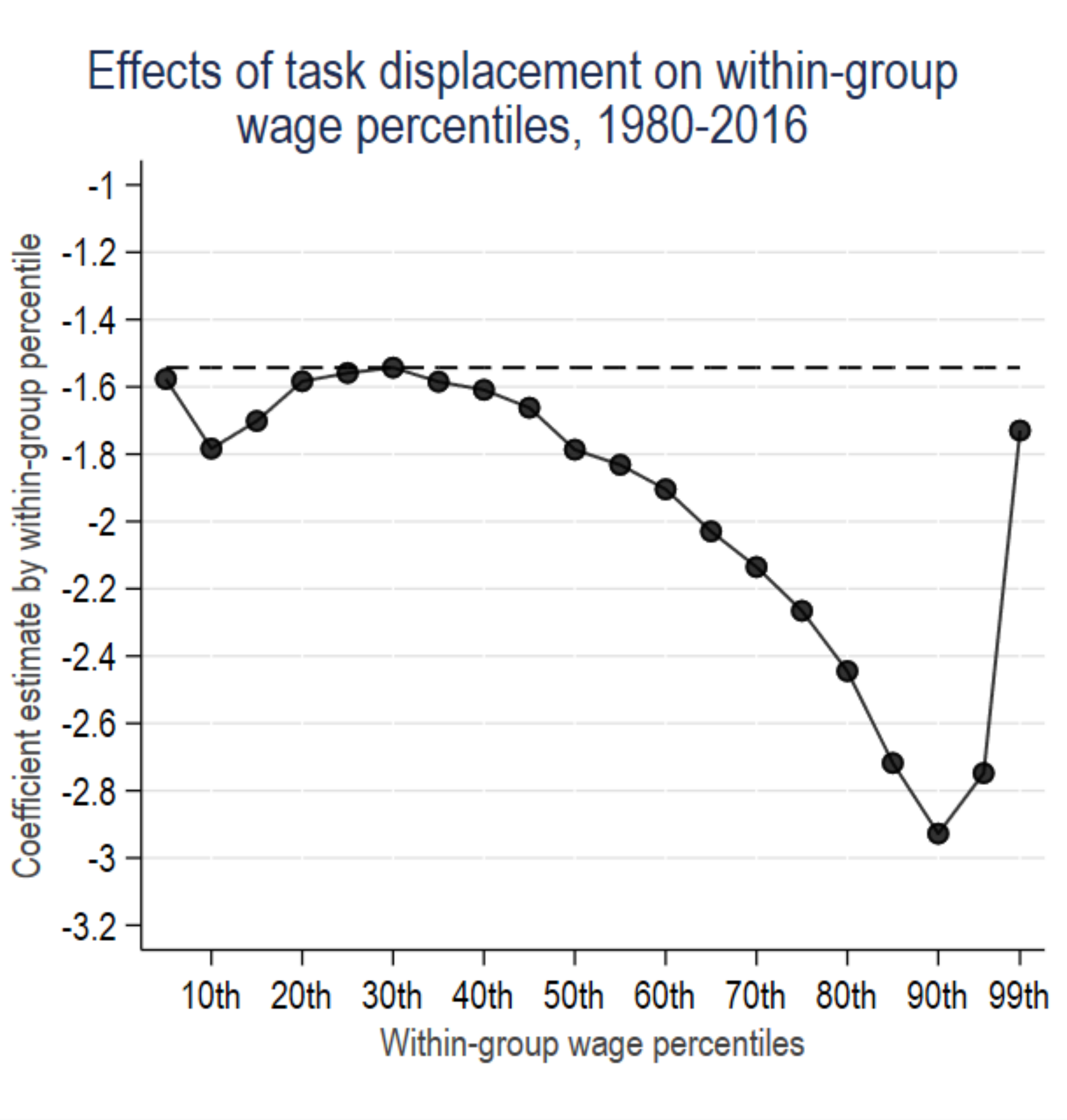


TASK DISPLACEMENT, WAGES, AND RENTS

Estimate changes in (unconditional) wage quantiles **within exposed groups:**

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

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



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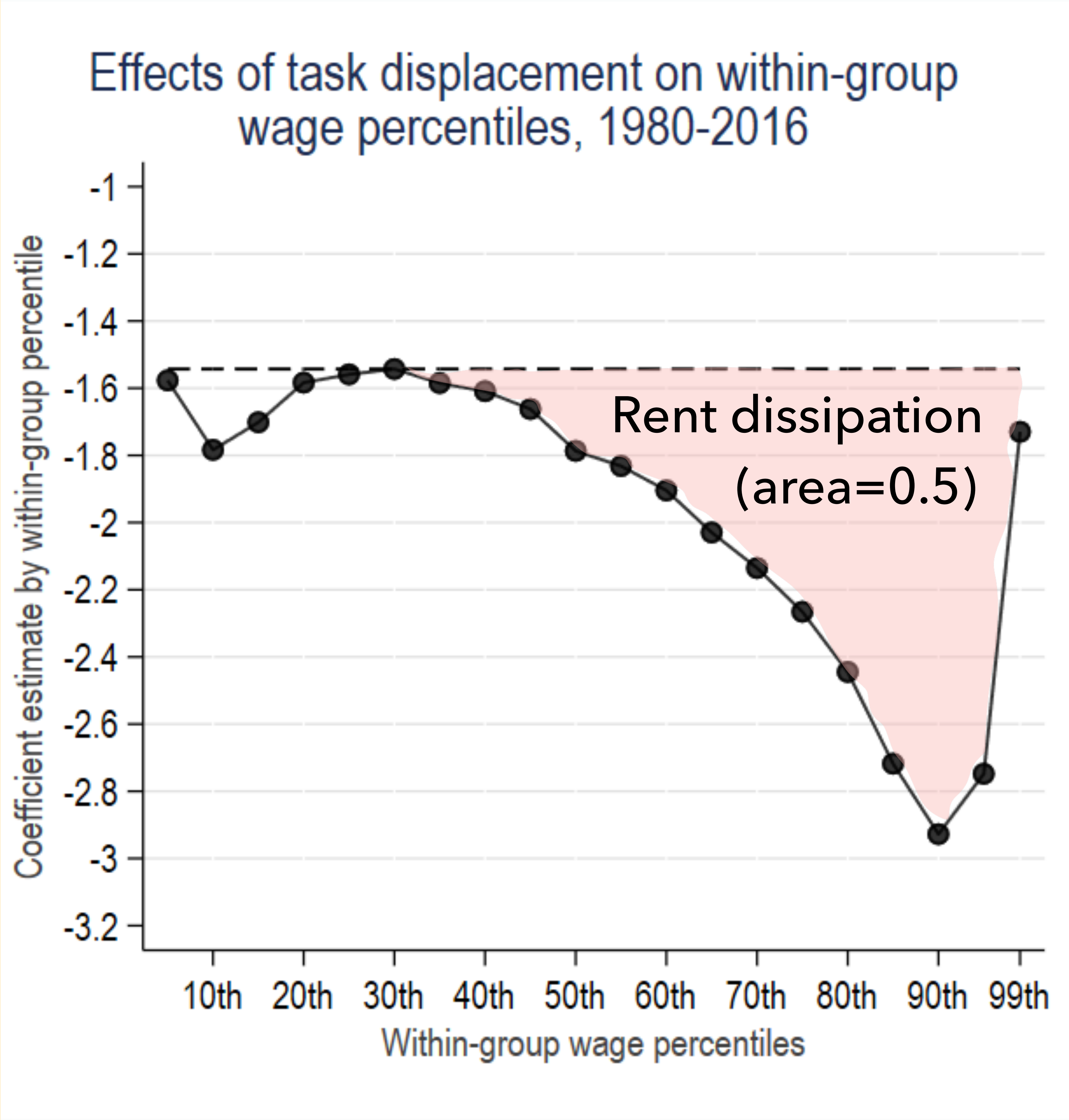
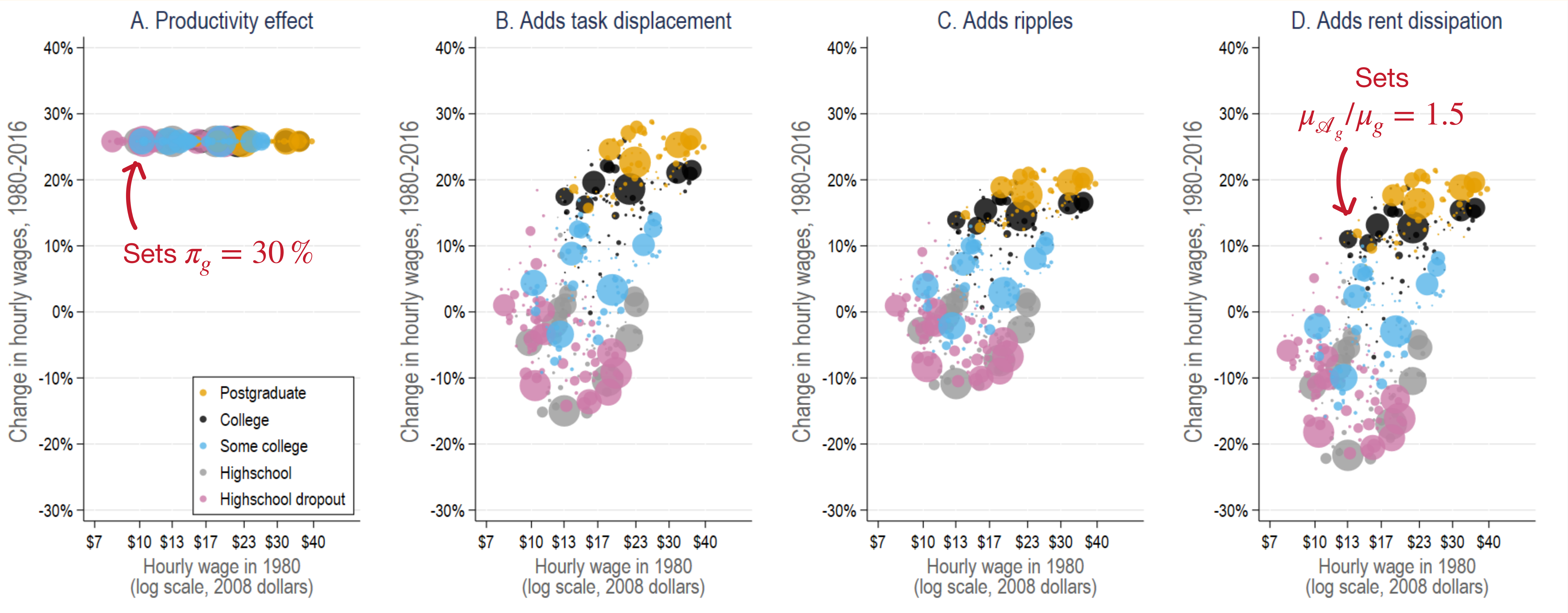


QUANTITATIVE FINDINGS



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

	Model (ignoring rent dissipation, CLM)	Model (with rent dissipation)	Data (1980–2016)
Share group wage changes explained	44%	60%	.
Wages for men with no college	-2.5%	-10.4%	-6.5%
Average wages (comp adjusted)	4.5%	-1%	9%
TFP	3%	-0.7%	30%
Welfare (aggregate consumption)	4.5%	-1%	60%

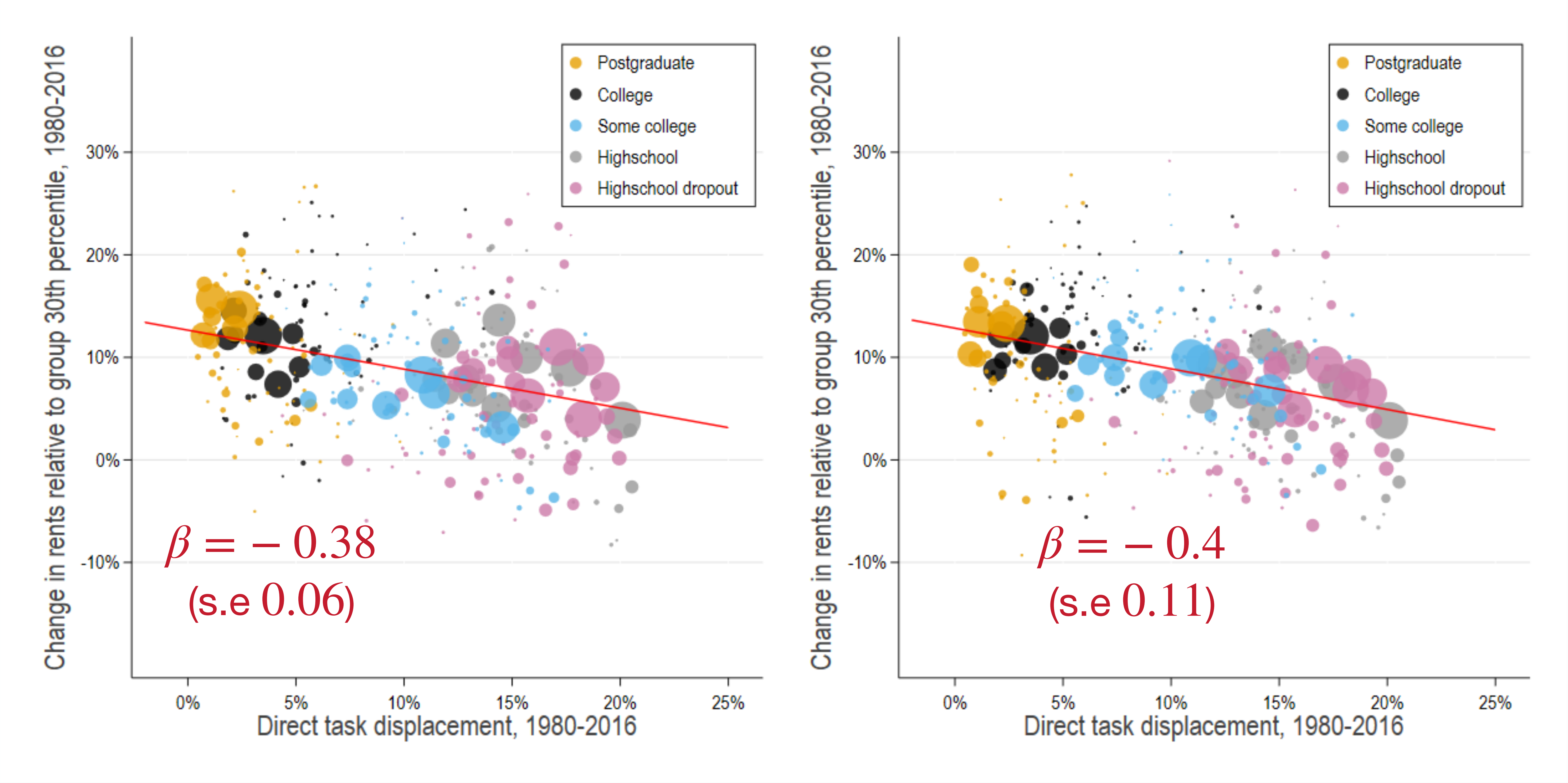
CONCLUDING REMARKS

- 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

EXTRA: TASK DISPLACEMENT AND RENTS I

Regression for **wage compression** in group g

$$d\ln \bar{w}_g - d\ln w_g^{30th} = \beta \cdot \text{td}_g^d + \text{covariates}_g + e_g$$

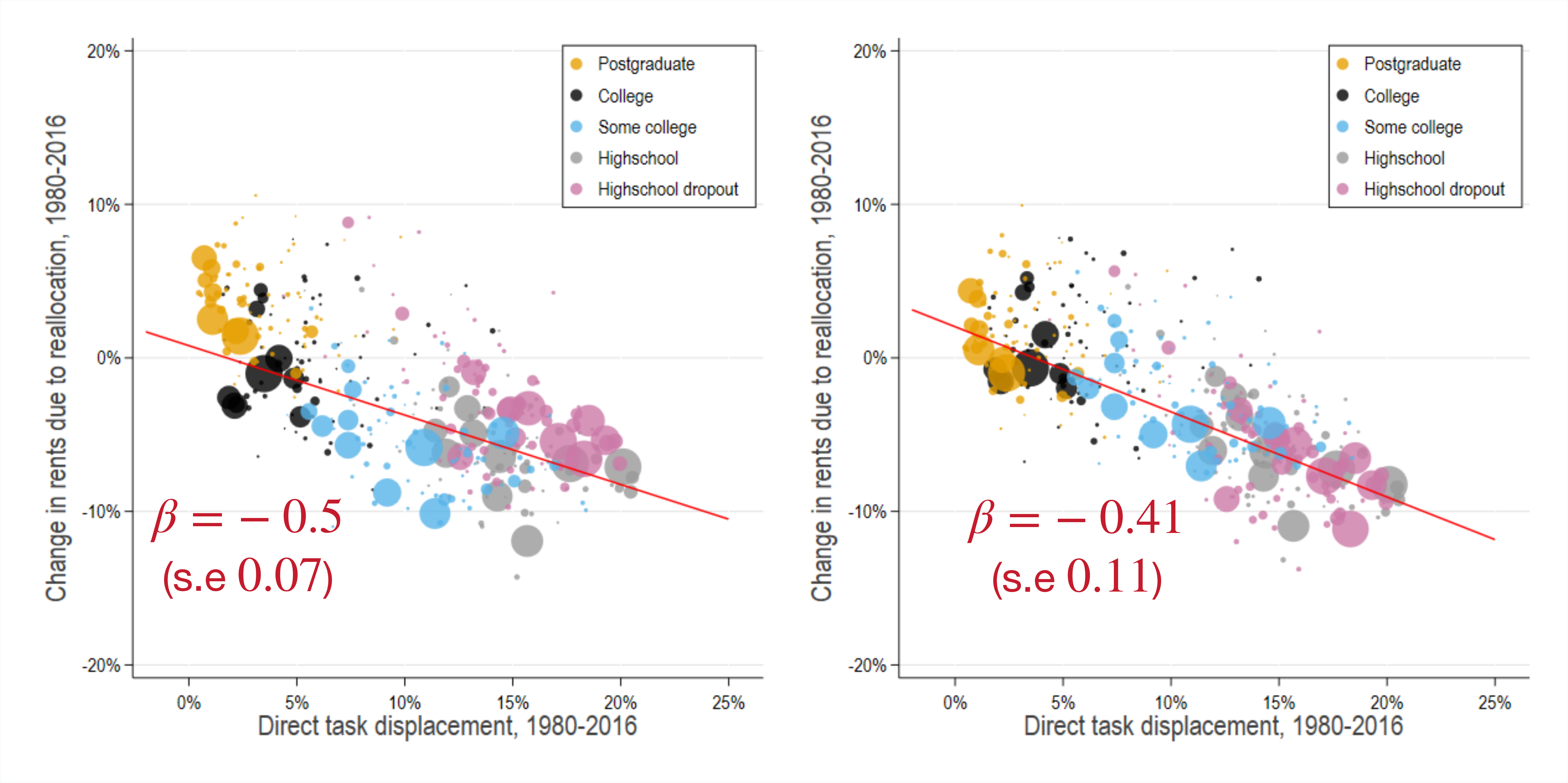


- **Left panel:** raw data
- **Right panel:** controls
- 10 pp ↑ in task displacement **reduces rents by 4%**
- Suggests $\mu_{\mathcal{A}g}/\mu_g = 1.4$ (rises to 1.5 when controlling for ripples)

EXTRA: TASK DISPLACEMENT AND RENTS II

Regression for **proxy for rent changes** in group g

$$d \ln \mu_g^{\text{proxy}} = \beta \cdot \text{td}_g^d + \text{covariates}_g + e_g$$



- **Alternative rent proxy:** Change in group employment at high-wage jobs in 1980 (industry × occupation) from Mincer equation
- Suggests $\mu_{\mathcal{A}g}/\mu_g = 40\,\%$

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

$$d \ln w_g = \frac{1}{\lambda} \cdot \Theta_g(\beta) \cdot \text{stack}(d \ln y - d \ln \Gamma_j^d + Z_j + u_j)$$

$$d \ln \mu_g = -(\mu_{\mathscr{A}g}/\mu_g - 1) \cdot d \ln \Gamma_g^d + \frac{1}{\lambda} \cdot \mathscr{M}_g(\beta) \cdot (d \ln y - d \ln \Gamma_j^d + Z_j + u_j) + Z_g^\mu + e_g$$

- **Identification:** $d \ln \Gamma_j^d, Z_j, Z_j^\mu \perp u_g, e_g$ for all g, j and different shocks $\{Z_g, Z_g^\mu\}$
- **Restrictions:** Matrices parametrized in terms of employment similarity across groups and overlap at high-wage jobs

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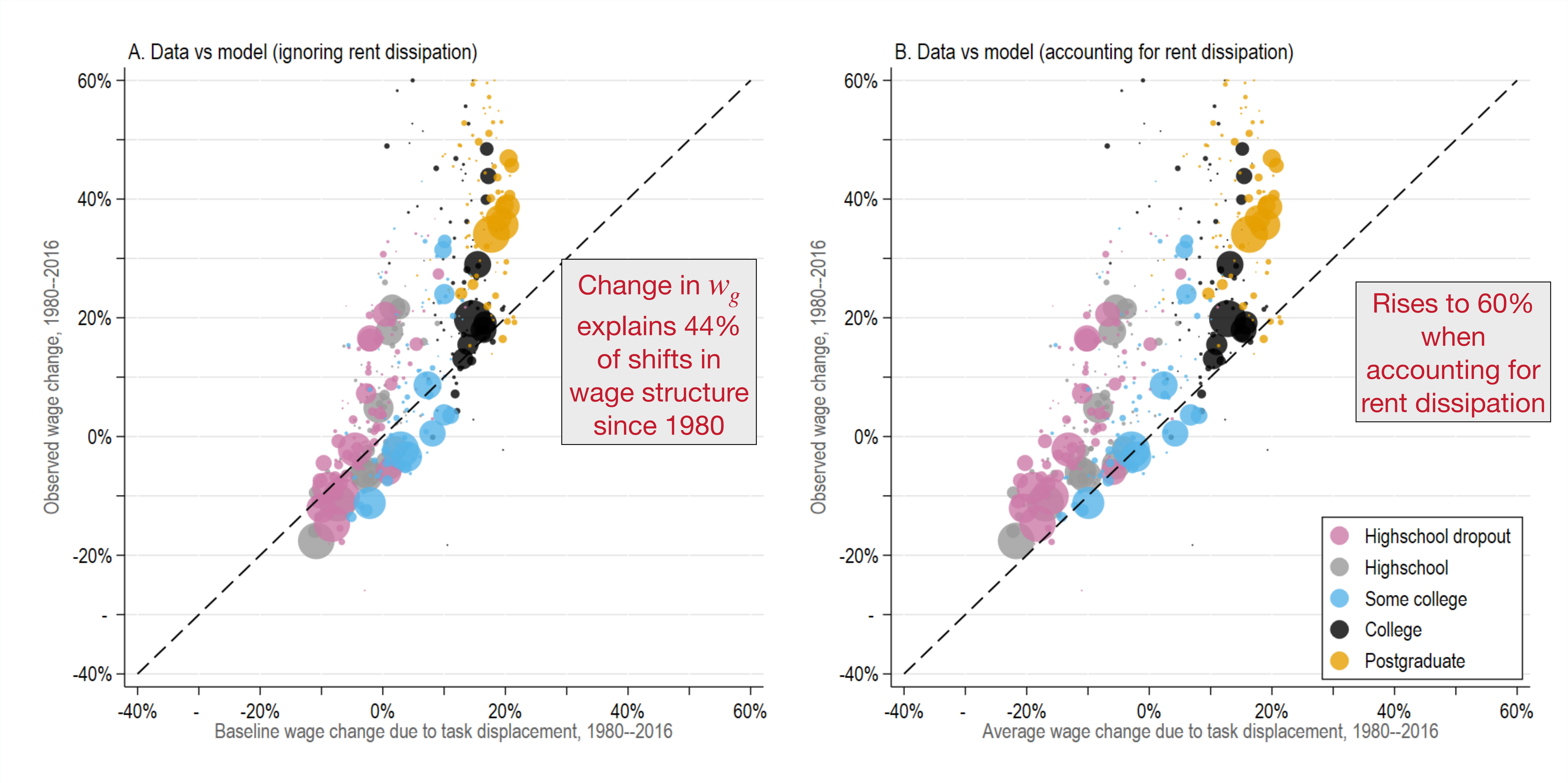
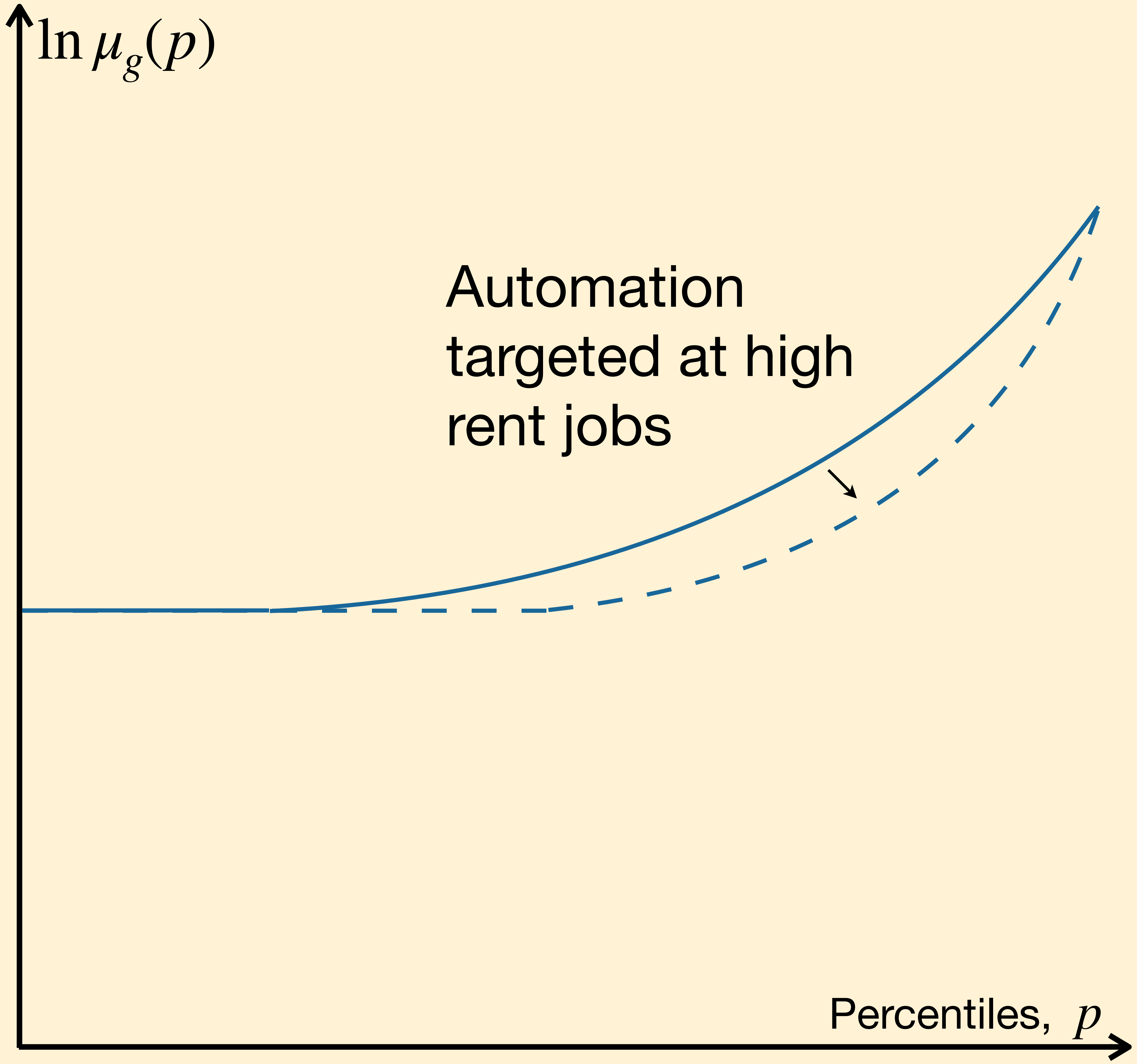
- **Restrictions:** Matrices parametrized in terms of employment similarity across groups and overlap at high-wage jobs
  - Propagation matrix has diagonal term 1.4 and off-diagonal terms sum of 0.4
  - Rent impact matrix has small entries; average rent dissipation $\mu_{\mathscr{A},g}/\mu_g = 1.5$

EXTRA: QUANTITATIVE FINDINGS

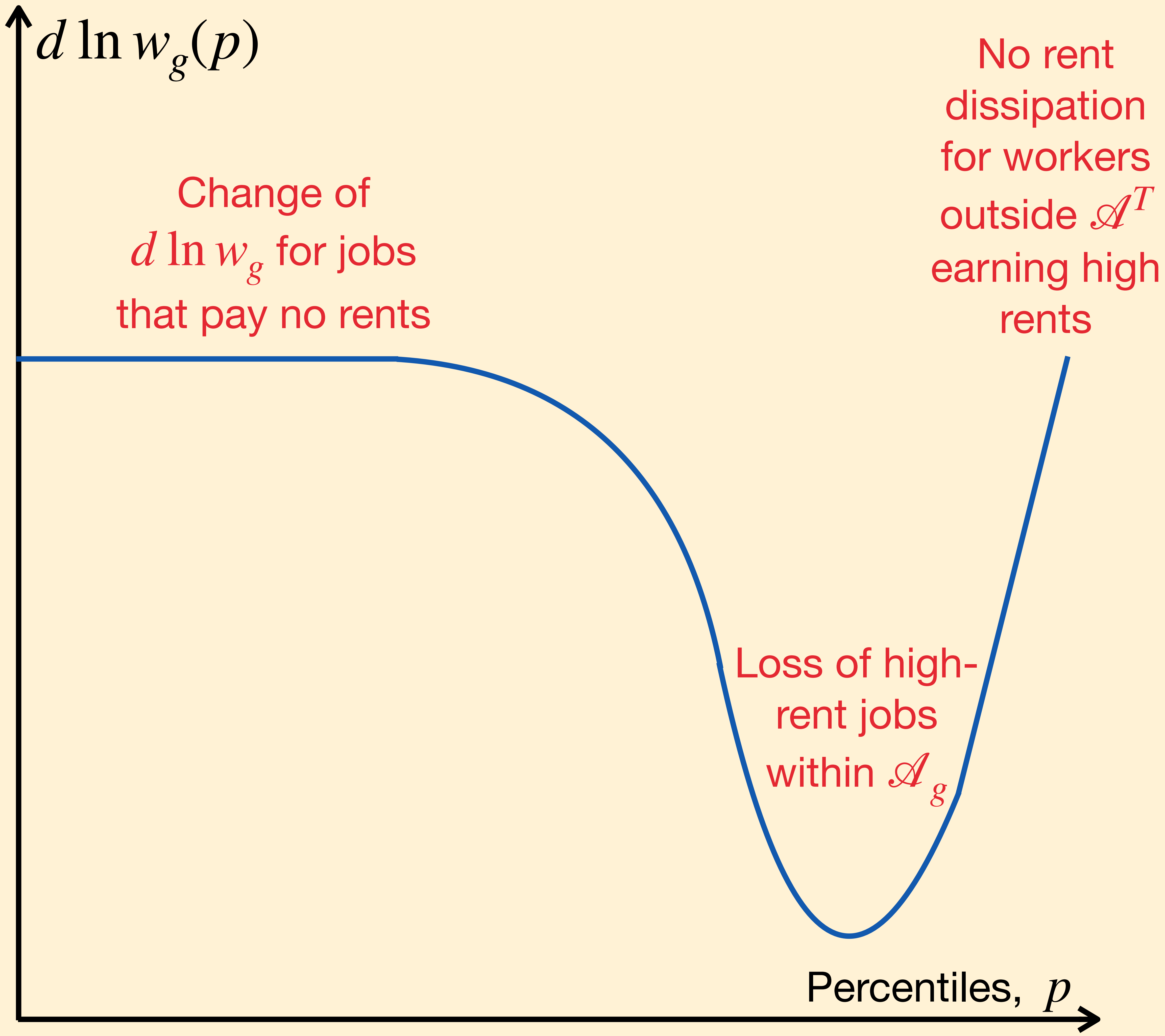


EXTRA: WAGE QUANTILE FUNCTIONS I

Rent quantiles for group g

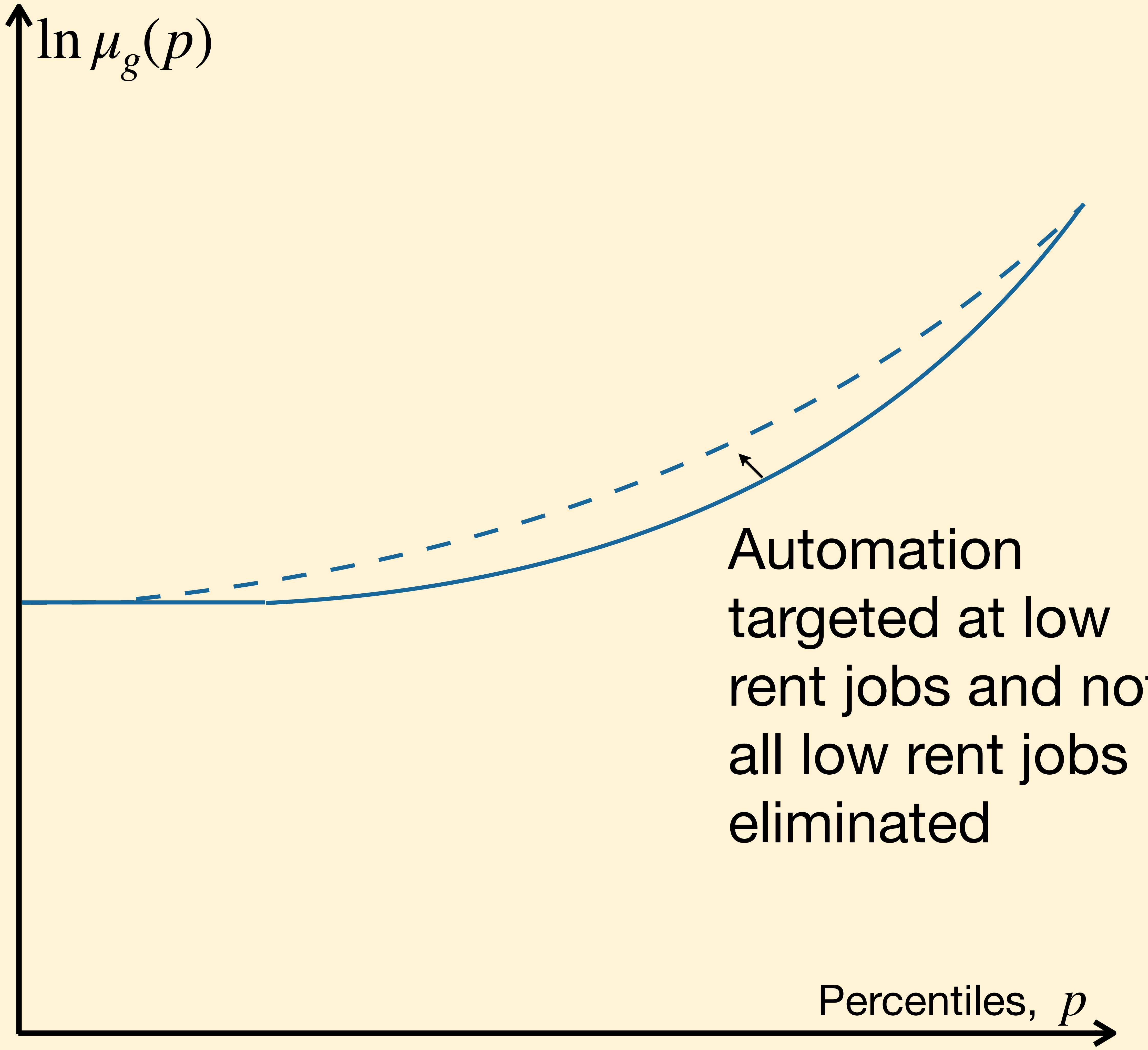


Change in wage quantiles for group g



EXTRA: WAGE QUANTILE FUNCTIONS II

Rent quantiles for group g



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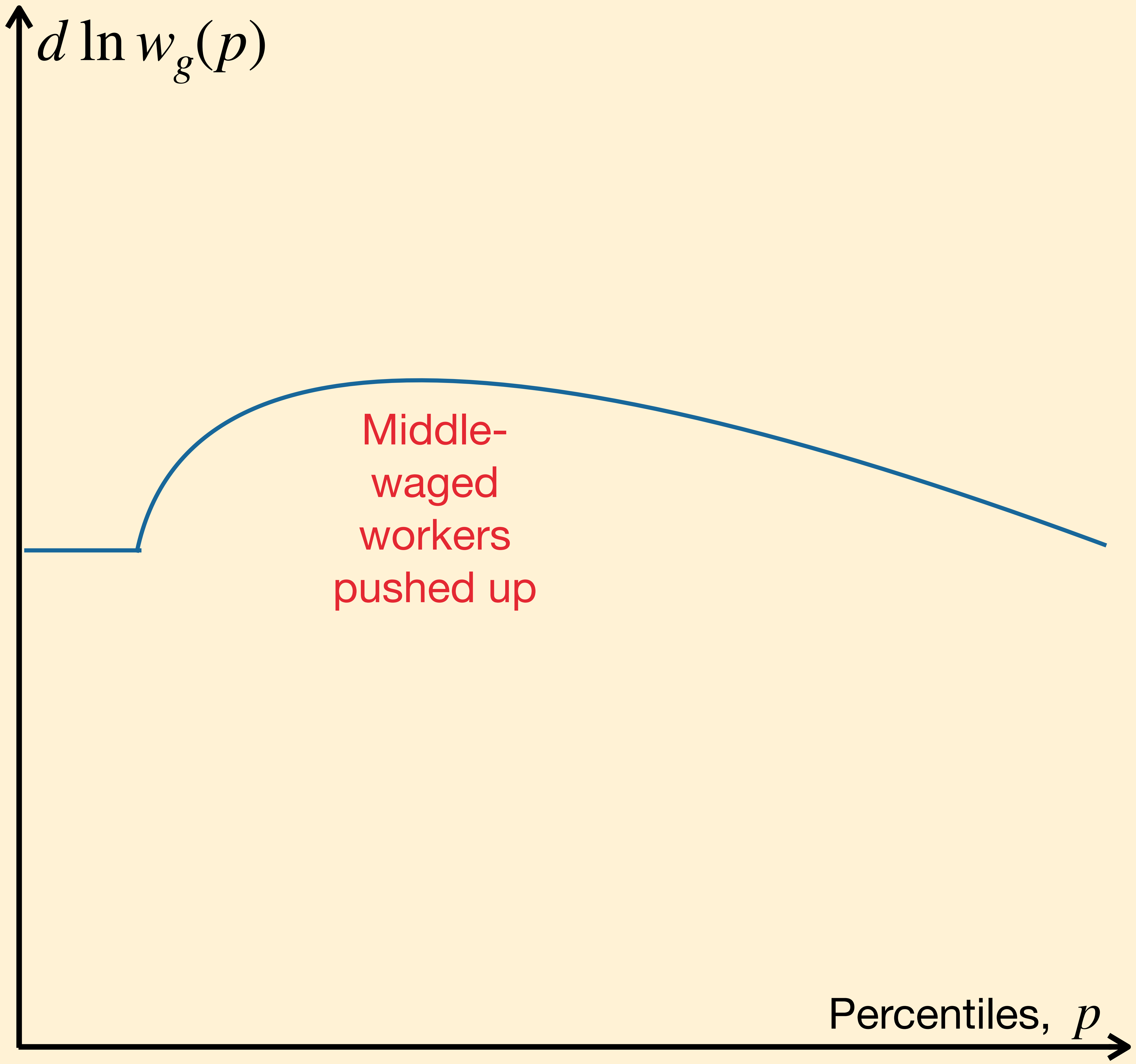
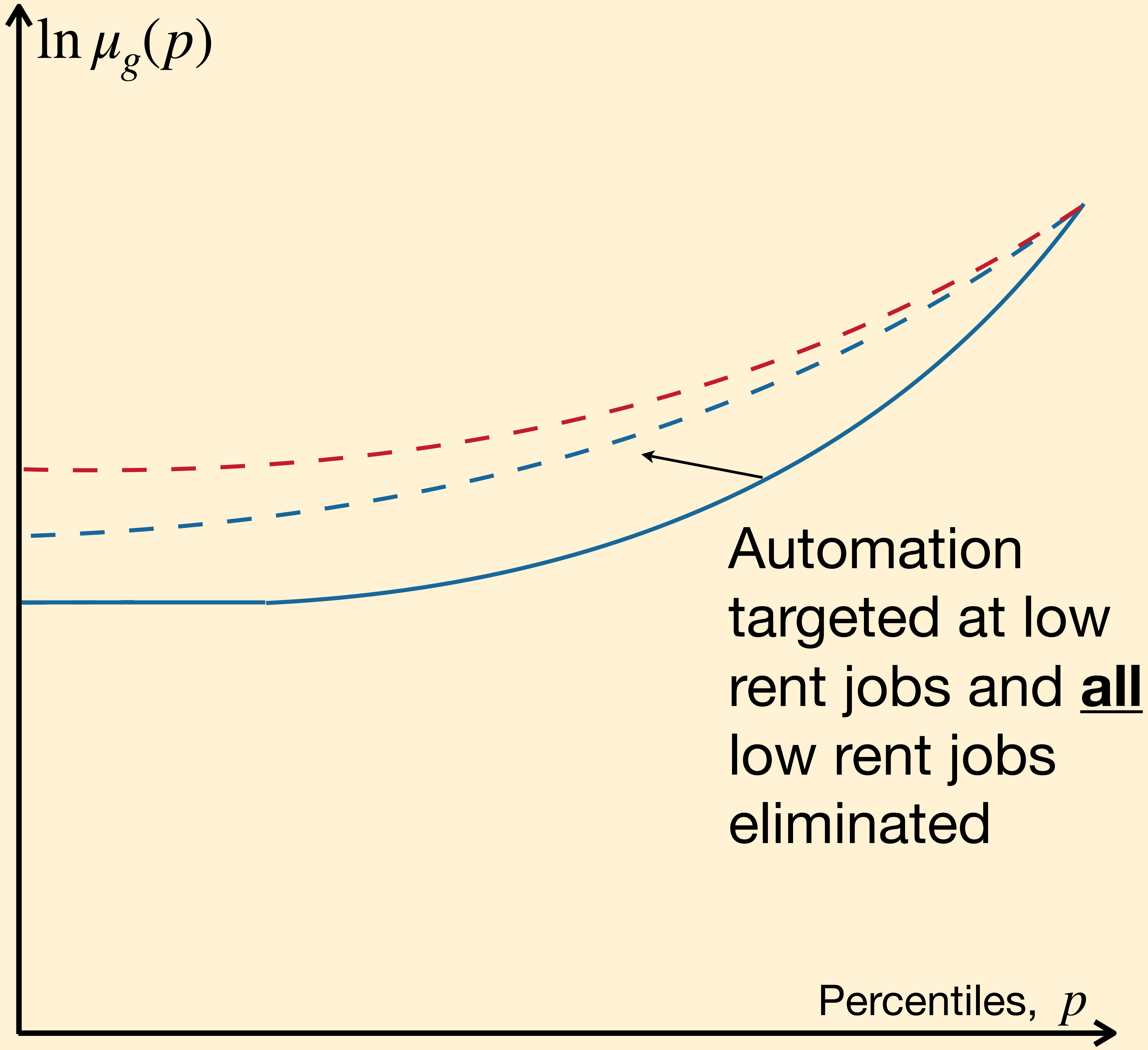
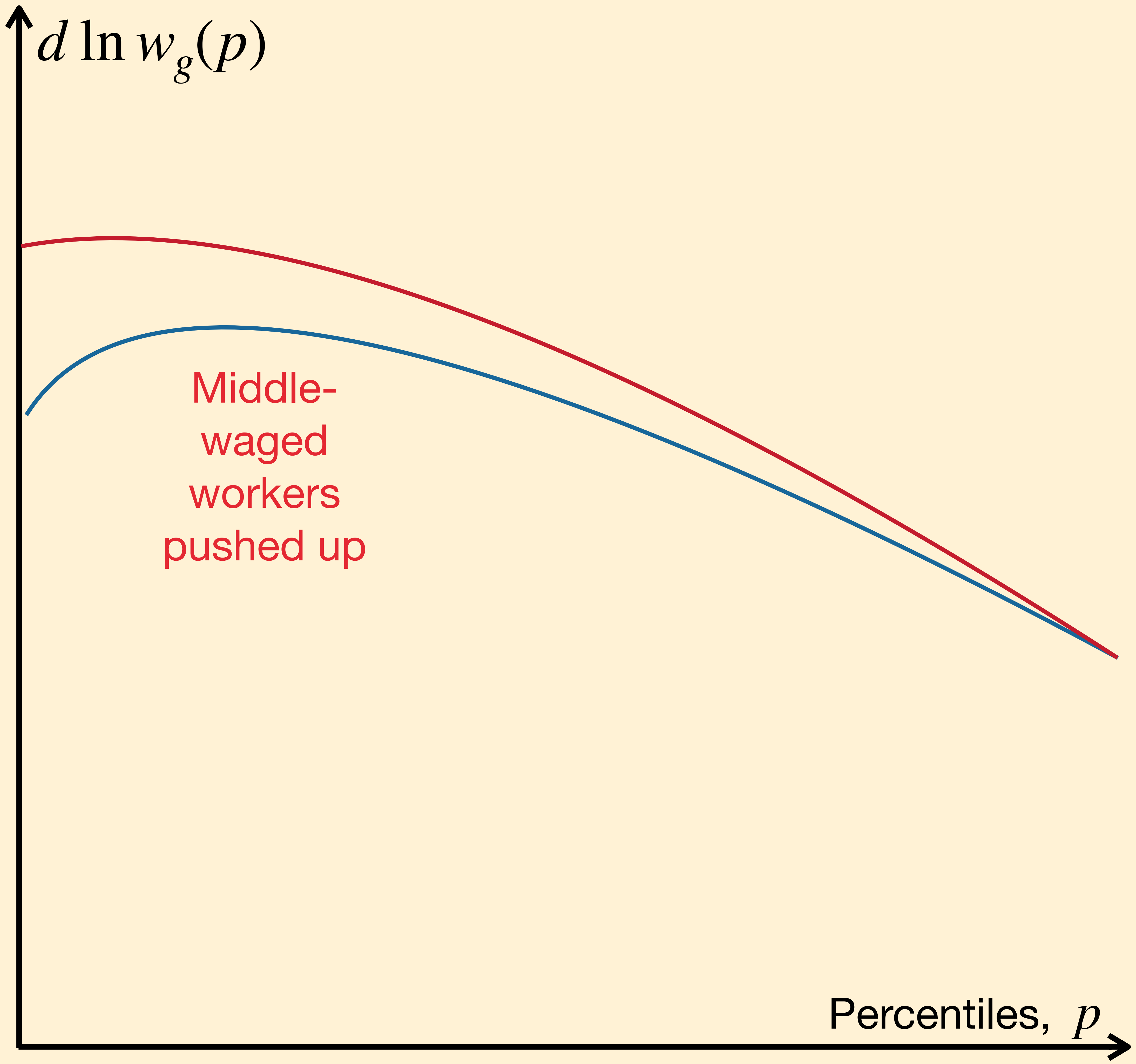


EXTRA: WAGE QUANTILE FUNCTIONS III

Rent quantiles for group g



Change in wage quantiles for group g



EXTRA: EXAMPLE I

- Two tasks performed by g: welding and delivery
- Welding pays a rent $\mu_{welding} = 1.2$ and delivery pays no rent $\mu_{delivery} = 1$
- MRPL at welding exceeds MRPL at delivery by 20%
- Imagine that firm given chance to automate welding job at cost κ per worker
- Firm benefits $\pi = \mu_{welding} \cdot w - \kappa$
- Social benefit $\pi_{social} = \pi - 0.2 \cdot w = w - \kappa$
- Automation reduces social welfare if $\pi > 0 > w - \kappa$

EXAMPLE II: COX'S CAPPER VS. CRAFT LABOR (BOWLES 87)

- Capping of cans done by specialized tinsmiths 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 tinsmiths, even though it was not as productive.
- Wasteful from a social point of view: specialized tinsmith 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)