# Inefficient Automation

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**Tax capital (long-run)**

Aiyagari 1995; Conesa et al. 2002

(i) Improve efficiency in economies with IM

(ii) Worker displacement/reallocation absent

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| Tax automation | Tax capital (long-run) |
|---|---|
| Guerreiro et al 2017; Costinot-Werning 2018 | Aiyagari 1995; Conesa et al. 2002 |

Take worker displacement seriously. **How should we respond to automation?**

# This Paper

1. Recognize that displaced workers face two important **frictions**:
   - (i) **Slow reallocation**: workers face mobility barriers and may go through unempl./retraining
     Davis-Haltiwanger, 1999; Jacobson et al, 2005; Lee-Wolpin, 2006; Alvarez-Shimer, 2011
   - (ii) **Imperfect credit markets**: workers have limited ability to borrow against future incomes
     Jappelli et al, 2010; Chetty, 2008; Landais-Spinnewijn, 2021

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4. **Quantitative**: gross flows + idiosync. risk → Optimal **speed** of automation + **welfare**

# Outline

# Firms

Continuous time $t \geq 0$

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where $\delta$ is the marginal cost of automation.

Preferences

$$U_0 = \int \exp\left(-\rho t\right) \frac{c_t^{1-\sigma}}{1-\sigma} dt$$

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   - Productivity loss $\theta$
2. Borrowing

$$a_t^h \geq \underline{a} \quad \text{for some} \quad \underline{a} \leq 0$$

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- All agents act competitively.

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Environment

Laissez-Faire

Optimal Policy

Quantitative Analysis

# Laissez-faire: Reallocation

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- Wages $w_t^A < w_t^N$ due to automation
- Reallocation from $h = A \rightsquigarrow h = N$
- Stop reallocating at $T^{\text{LF}}$

$$\int_{T^{\text{LF}}}^{+\infty} e^{-\rho t} u'\left(c_t^A\right) \Delta_t dt = 0$$

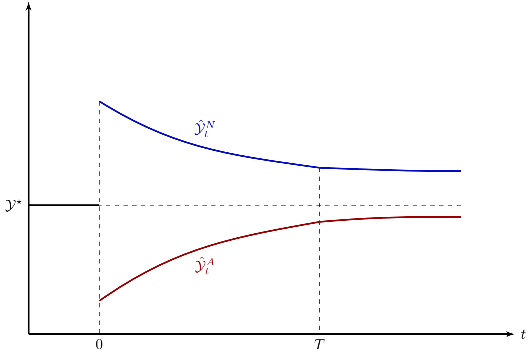
where

$$\Delta_t \equiv \underbrace{(1-\theta)\left(1 - e^{-\kappa\left(t - T^{LF}\right)}\right)}_{\text{Prod. loss + unemp}} \overbrace{w_t^N - w_t^A}^{\text{wage gap}}$$

denotes the output gains from reallocation

# Laissez-faire: Binding borrowing constraints

Average income



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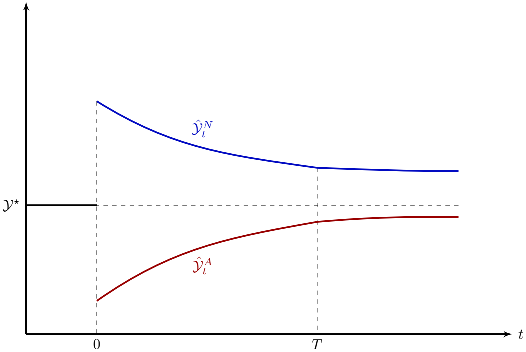


Workers expect income to improve as they reallocate → Motive for **borrowing**

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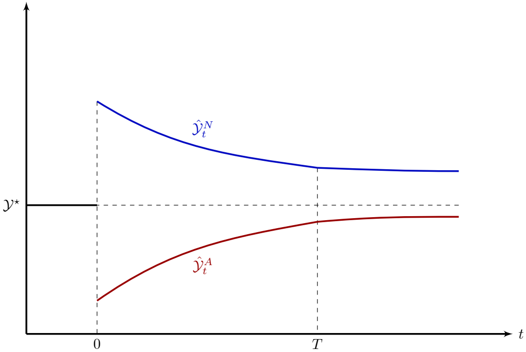
Labor incomes

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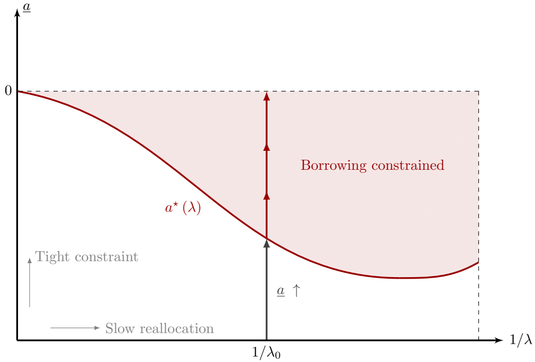


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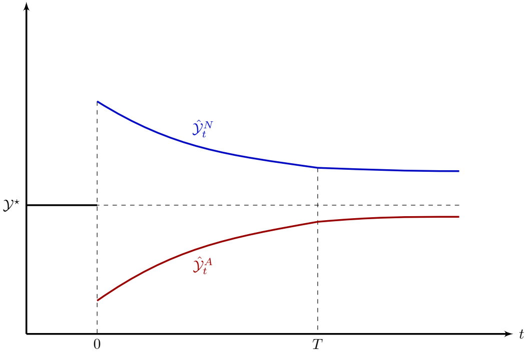


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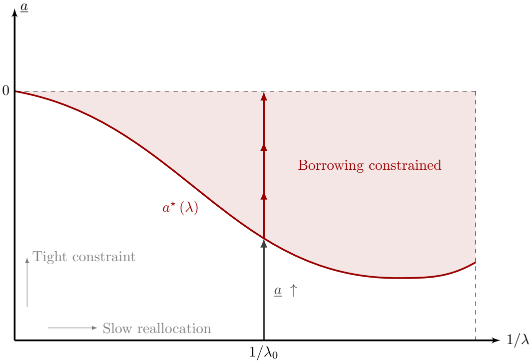


Two benchmarks: instant realloc. (Costinot-Werning) or no borrowing frictions (Guerreiro et al)

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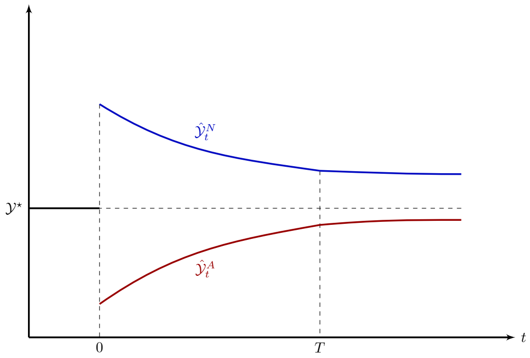


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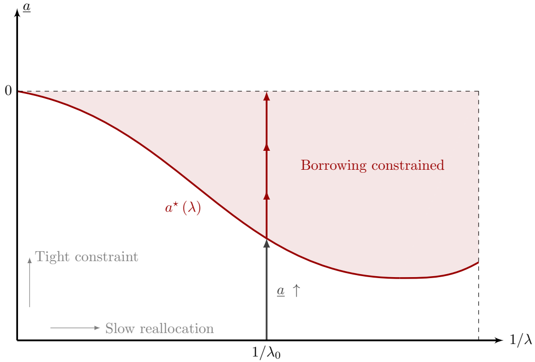


**Evidence:** Earnings losses (Jacobson et al, Braxton-Taska) + Imperf. cons. smoothing (Landais-Spinnewijn)

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- Firm automation choice $\alpha^{\text{LF}}$: trades off cost $\mathcal{C}(\alpha)$ with increase in output
- Optimality condition

$$\int_0^{+\infty} Q_t \Delta_t^{\star} dt = 0$$

where

$$\Delta_t^{\star} \equiv \frac{\partial}{\partial \alpha} G^{\star}\left(\mu_t^A, \mu_t^N; \alpha^{\text{LF}}\right)$$

denotes the output gains (net of cost) from automation, and

$$Q_t = \exp\left(-\int_0^t r_s ds\right) = \exp\left(-\rho t\right) \frac{u'\left(c_t^N\right)}{u'\left(c_0^N\right)}$$

since non-automated workers are unconstrained (savers).

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How should a government respond to automation?

# Constrained Ramsey problem

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- Depends on the **tools** available
- **First best tools**: **lump sum transfers** (directed, UBI)

  Info requirements? Fiscal cost? (Guerreiro et al., 2017; Costinot-Werning, 2018, Guner et al., 2021)

# Constrained Ramsey problem

How should a government respond to automation?

- Depends on the tools available
- Second best tools: tax automation + active labor market interventions

  E.g., South Korea's reduction in automation tax credit in manuf; Geneva's tax on automated cashiers.

  Severance or higher payroll tax after layoffs from automation, as for other qualifying layoffs in the US?

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- **Primal problem:** The government maximizes the social welfare function

$$\mathcal{U} \equiv \sum_h \eta^h \int_0^{+\infty} \exp\left(-\rho t\right) u\left(c_t^h\right) dt$$

by choosing $\{\alpha, T, \mu_t^A, \mu_t^N, c_t^A, c_t^N\}$ subject to workers choosing consumption optimally, the law of motion of labor, firms choosing labor optimally, and market clearing.

- Consider a perturbation $\delta\alpha$ starting from the laissez-faire. Welfare change

$$\frac{\delta \mathcal{U}}{\delta \alpha} = \eta^N u'\left(c_0^N\right) \times \int_0^{+\infty} \underbrace{\exp\left(-\rho t\right) \frac{u'\left(c_t^N\right)}{u'\left(c_0^N\right)}}_{=\exp\left(-\int_0^t r_s ds\right)} \times \left(\hat{c}_t^{N,\star} + \bar{c}^{N,\star}\right) dt$$

$$+ \eta^A u'\left(c_0^A\right) \times \int_0^{+\infty} \underbrace{\exp\left(-\rho t\right) \frac{u'\left(c_t^A\right)}{u'\left(c_0^A\right)}}_{\text{How automated workers value flows}} \times \left(\hat{c}_t^{A,\star} + \bar{c}^{A,\star}\right) dt$$

where $\hat{c}_t^{h,\star}$ are **time-varying** terms (zero PDV) and $\bar{c}^{A,\star} + \bar{c}^{N,\star} = 0$ are **distributional**.

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- No borrowing constraints $\rightarrow \frac{u'(c_t^N)}{u'(c_0^N)} = \frac{u'(c_t^A)}{u'(c_0^A)} \rightarrow$ **Efficiency** (only distributional terms)

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where $\hat{c}_t^{h,\star}$ are **time-varying** terms (zero PDV) and $\bar{c}^{A,\star} + \bar{c}^{N,\star} = 0$ are **distributional**.

- No borrowing constraints $\rightarrow \frac{u'(c_t^N)}{u'(c_0^N)} = \frac{u'(c_t^A)}{u'(c_0^A)} \rightarrow$ **Efficiency** (only distributional terms)
- There is still an **equity** rationale since $u'\left(c_t^N\right) < u'\left(c_t^A\right)$, e.g., utilitarian weights.

# Aggregate vs. Distributional Effects

- Consider a perturbation $\delta\alpha$ starting from the laissez-faire. Welfare change

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Firms do not fully internalize how automation affects incomes. Source of ineff. if firms (or $N$ workers) and $A$ workers disagree on how they value income over time.

# Constrained Inefficiency (for any Pareto weights)

**Proposition.** (Constrained inefficiency)

Generically, there exists $\{\delta\alpha, \delta T\}$ such that $\delta U^A > 0$ and $\delta U^N = 0$. This requires $\delta\alpha < 0$.

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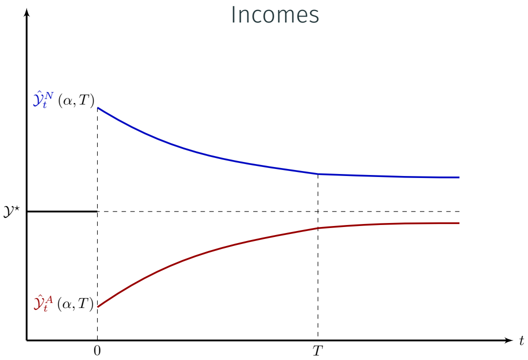

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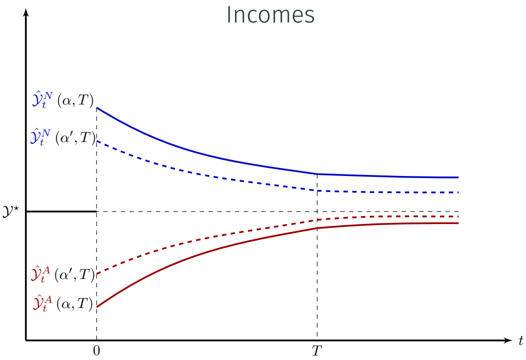


Taxing automation $\delta\alpha < 0$ benefits *A* but hurts *N* workers

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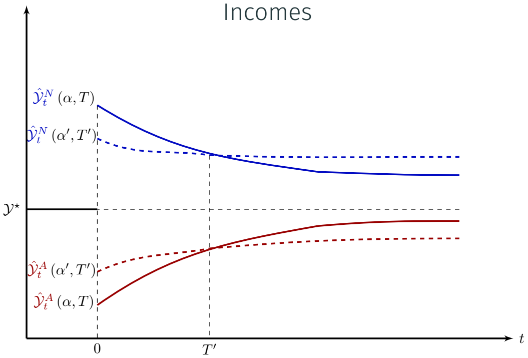


Can compensate $N$ workers ($\delta U^N = 0$) with $\delta T < 0$

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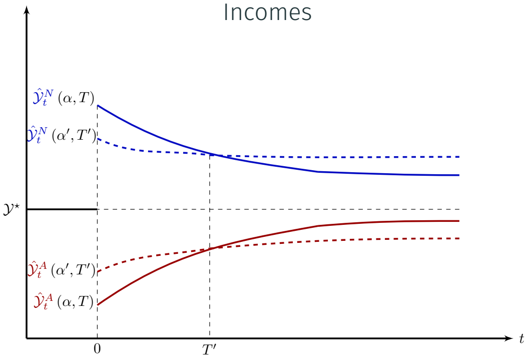


*A* workers are hurt more by losses early on. Policy alleviates those ($\delta U^A > 0$)

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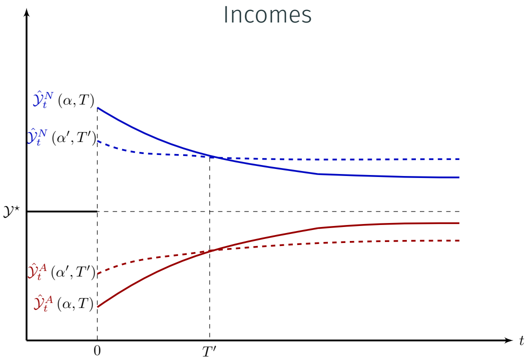


Taxing automation raises income of displaced worker early on during the transition precisely when they value it more.

## Optimal Policy Intervention

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- **Pref. for equity**: Government taxes even more with utilitarian weights

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- Tax capital $\rightarrow$ might improve **insurance** or prevent **capital overaccumulation**
  (Aiyagari, 1995; Conesa et al., 2009; Dávila et al., 2021)

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- **Workers have identical MRS and MU** in the long-run $\Longrightarrow \alpha_t^{LF}/\alpha_t^{FB} \rightarrow 1$ as $t \rightarrow +\infty$
  No efficiency nor equity rationale for intervention

▸ Extension: Third best

# Outline

## Firm

Production – Acemoglu-Restrepo

$$y_t^A = A^A \left(\alpha + \mu^A\right)^{1-\eta} \quad \text{and} \quad y_t^N = A^N \left(\mu^N\right)^{1-\eta}$$

$$Y = \left[\phi \left(y_t^A\right)^{\frac{\nu-1}{\nu}} + (1-\phi)\left(y_t^N\right)^{\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{\nu-1}}$$

Investment – Guerreiro et al

Law of motion: $d\alpha_t = (x_t - \delta\alpha_t)\, dt;\ \ \alpha_0 = 0$

Cost p/unit: $q_t = q^{\text{fin}} + \exp(-\psi t)\left(q^{\text{init}} - q^{\text{fin}}\right)$

# Quantitative Model

## Firm

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## Workers

gross flows – Kambourov-Manovskii

$$\mathcal{S}_t(\mathbf{x}) = \frac{(1-\phi)\exp\left(\frac{V_t^N(\mathbf{x}'(N;\mathbf{x}))}{\gamma}\right)}{\sum_{h'} \phi^{h'} \exp\left(\frac{V_t^{h'}(\mathbf{x}'(h';\mathbf{x}))}{\gamma}\right)}$$

uninsured risk – Huggett-Aiyagari

$$\mathcal{Y}_t^{\text{labor}}(\mathbf{x}) = \xi \exp(z)\, w_t^h$$

$$dz_t = -\rho_z z_t dt + \sigma_z dW_t$$

$\xi_t = (1-\theta)\,\xi_{t,-}$ if move; Replacement rate $b$

$$\mathcal{Y}_t^{\text{net}}(\mathbf{x}) = \mathcal{T}\left(\mathcal{Y}_t^{\text{labor}}(\mathbf{x}) + \exp(z)\,\Pi_t^{\text{div}}\right)$$

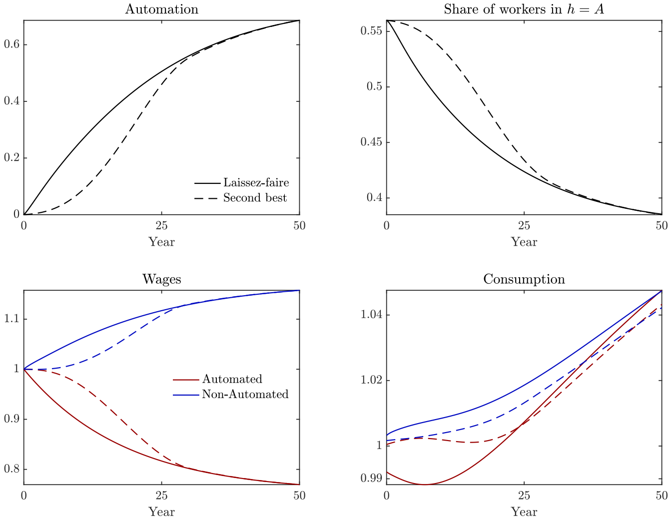
# Calibration

- Initial stationary eq (no automation) = year 1980. $A$ occupations = Routine-intensive
- Mix of external (15 param.) and internal (8 param.) calibration

**Table 1:** Internal Calibration

| Parameter | Description | Calibration | Target / Source |
|---|---|---|---|
| $\rho$ | Discount rate | $0.04$ | $2\%$ real interest rate |
| $\lambda$ | Mobility hazard | $0.364$ | Gross mobility 1980 $(10\%)$ |
| $\gamma$ | Fréchet parameter | $0.036$ | Elasticity of labor supply $(1)$ |
| $A^A, A^N$ | Productivities | $0.719, 1.710$ | $Y_0 = 1$, symm. wages |
| $\phi$ | Share of automated occupations | $0.537$ | Routine empl. share 1980 $(55\%)$ |
| $q^{\text{fin}}$ | Final cost of autom. | $5.621$ | Log wage gap $(0.45)$ in Cortes et al (2016) |
| $\psi$ | Cost convergence rate | $0.054$ | Half-life of wage gap $(15$ yrs$)$ in Cortes et al (2016) |

# Allocations




**Half-life of automation**: 16 years at LF v. 22 years at SB

# Welfare Gains From Slowing Down Automation

| | Benchmark | Less liquidity | Less reallocation | More complements |
|---|---|---|---|---|
| Automated | $0.80\%$ | $0.91\%$ | $0.93\%$ | $0.78\%$ |
| Non-autom. | $-0.19\%$ | $-0.22\%$ | $-0.35\%$ | $-0.21\%$ |
| New gener. | $-0.08\%$ | $-0.11\%$ | $-0.10\%$ | $-0.08\%$ |
| Total | $0.20\%$ | $0.24\%$ | $0.20\%$ | $0.19\%$ |

Note: 'Less liquidity' and 'Less reallocation' denote alternative calibrations where we target a ratio of liquidity to GDP of $0.35$ (instead of $0.5$) and a separation rate of $7.2\%$ (instead of $10\%$), respectively. 'More complements' denotes an alternative calibration where the elasticity of substitution across occupations is $0.76$ (instead of $0.9$).

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**Wage supplements:** Second best is *as if* the gov't gave \$19,126 to each $A$ worker, and taxed \$4,622 each $N$ worker in PDV. Total fiscal cost: 1.1 trn.

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  1. Automation is **inefficient** when frictions are sufficiently severe

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     Raise income of displaced workers when they value it more

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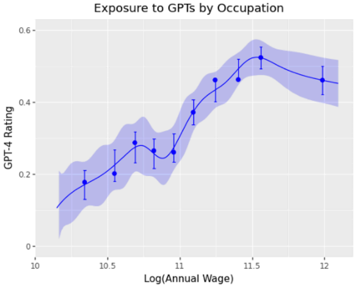
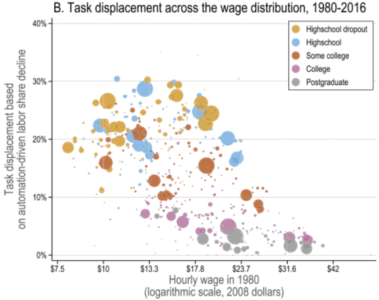
- Quant: Meaningful **efficiency** and **welfare gains** from slowing down automation

# Are the rationales for slowing down AI as strong as they were for Robots?

- Equity rationale seems much **weaker for AI** than it was for robots
  - Robots automate routine, low-to-middle-wage jobs (car manuf)
  - AI (likely) automates cognitive, middle-to high-wage jobs (lawyers, journos, soft devs)




Eloundou et al (2023)

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# AI (generative, LLMs) ≠ Robots

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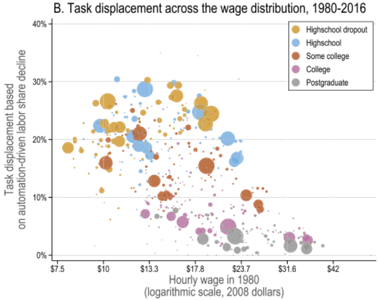


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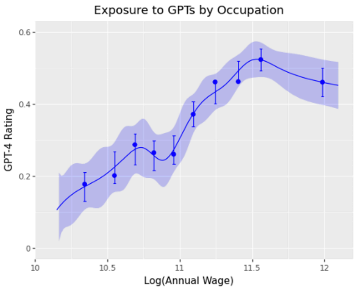
- Weaker rationale for **slowing down AI** due to job automation. AI **alignment** concerns?

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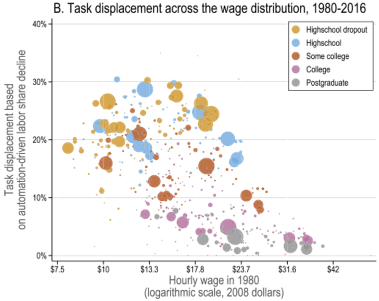


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# Extension: No Active Labor Market Intervention

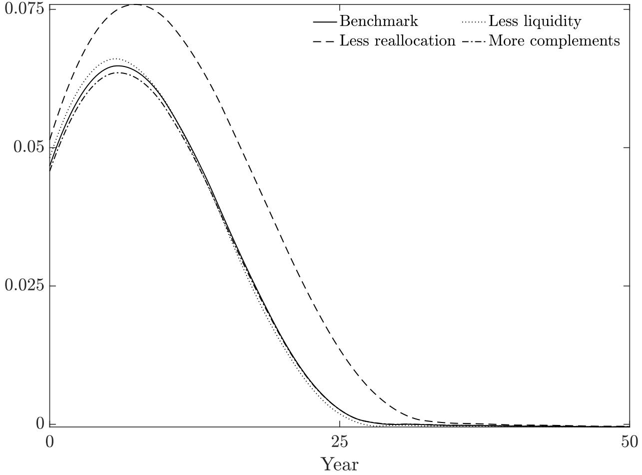
- Active labor market interventions might not be available (Heckman et al., Card et al.)
- Gov't now internalizes indirect effect of automation due to reallocation $T'(\alpha) > 0$

$$T'(\alpha) \times \frac{1}{2}\lambda \exp(-\lambda T) \times \int_{T(\alpha)}^{+\infty} \exp(-\rho t) \left\{\eta^N u'\left(c_t^N\right) - \eta^A u'\left(c_t^A\right)\right\} \times \partial_T c_t^N dt$$

- Can reinforce or dampen incentives to tax automation, depending on Pareto weights.
- Utilitarian $\rightarrow$ tax less. Efficiency weights $\rightarrow$ tax more.

Back

# Optimal taxes

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