Inefficient Automation

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- Automation raises productivity but **displaces workers** and **lowers their earnings**

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Tax automation

Guerreiro et al 2017; Costinot-Werning 2018

(i) Govt. has preference for redistribution

(ii) Automation/reallocation are efficient

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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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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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   (i) Equilibrium is (generically) constrained inefficient and automation is **excessive**
   Conflict between how firms and displaced workers value the effects of automation $\rightarrow$ Pareto improv't

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   (ii) Optimal to **slown down automation** automation on efficiency grounds
4. **Quantitative**: gross flows + idiosync. risk → Optimal **speed** of automation + **welfare**

Outline

Firms

Continuous time $t \geq 0$

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Occupations

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$$G^{\star}\left(\mu^A, \mu^N; \alpha\right) \equiv G\left(\left\{y^h\right\}\right) - \mathcal{C}\left(\alpha\right)$$

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$\partial_A G^\star\left(\mu^A, \mu^N; \alpha\right) \downarrow$ in α (labor-displacing)

$G^\star\left(\mu^A, \mu^N; \alpha\right)$ concave in α (costly)

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$$\Pi_t\left(\alpha\right) \equiv \max_{\mu^A, \mu^N \geq 0} G^\star\left(\mu^A, \mu^N; \alpha\right) - \mu^A w_t^A - \mu^N w_t^N$$

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- Aggregate production function

$$G^\star\left(\mu^A, \mu^N; \alpha\right) = \left[\phi\left(\alpha + \mu^A\right)^{\frac{\nu-1}{\nu}} + (1-\phi)\left(\mu^N\right)^{\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{\nu-1}} - \delta\alpha,$$

where δ is the marginal cost of automation.

Workers

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

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   - Random opportunities arrive at rate λ
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2. Borrowing

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

Equilibrium

- Resource constraint:

$$\frac{1}{2}\sum_{h} c_t^h = G^\star\left(\mu_t^A, \mu_t^N; \alpha\right)$$

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- All agents act competitively.

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- Stop reallocating at T^{LF}

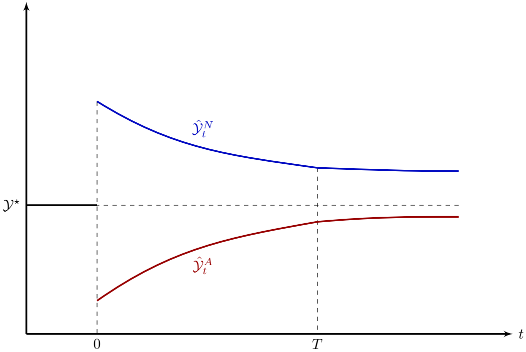
$$\int_{T^{\text{LF}}}^{+\infty} e^{-\rho t} u'\left(c_t^A\right) \Delta_t dt = 0$$

where

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

denotes the output gains from reallocation

Average income



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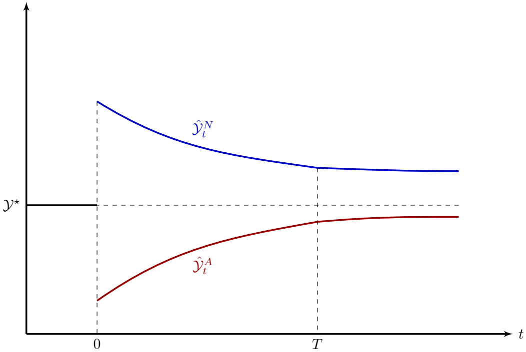
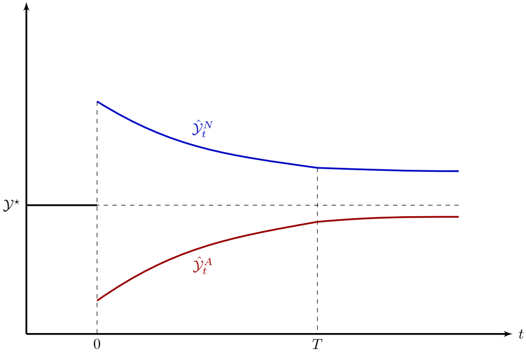


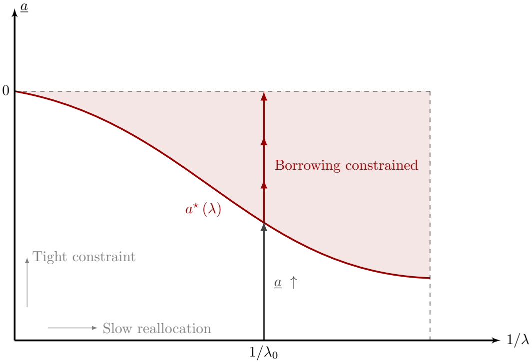
Workers expect income to improve as they reallocate → Motive for **borrowing**

LAISSEZ-FAIRE: BINDING BORROWING CONSTRAINTS

Labor incomes



Borrowing constraints



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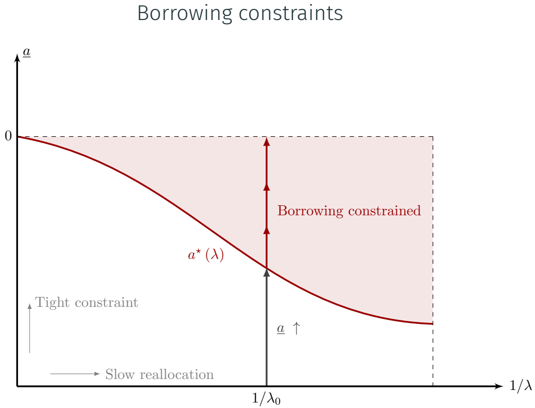
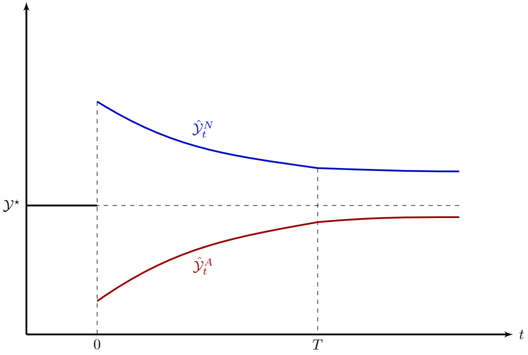


Two benchmarks: instant realloc. (Costinot-Werning) or no borrowing frictions (Guerreiro et al)

Laissez-faire: Binding borrowing constraints

Labor incomes



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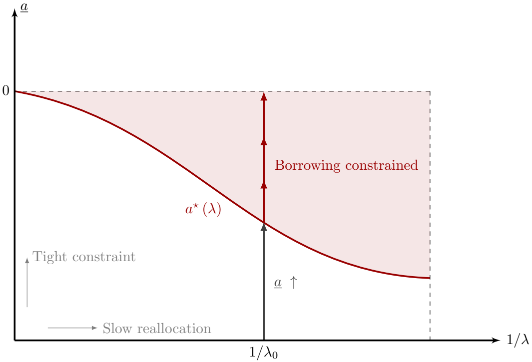

Evidence: Earnings partially recover (Jacobson et al) + Imperfect cons. smoothing (Landais-Spinnewijn)

Laissez-faire: Automation

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

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- Optimality condition

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

where

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

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).

Outline

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- Depends on the **tools** available

Constrained Ramsey problem

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- **First best tools**: **lump sum transfers** (directed, UBI)

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

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- **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.

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

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

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.

Aggregate vs. Distributional Effects

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

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

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

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- Still rationale for redistribution since $u'\left(c_t^N\right) < u'\left(c_t^A\right)$, e.g., utilitarian weights

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- Borrowing constraints $\rightarrow \frac{u'(c_t^N)}{u'(c_0^N)} > \frac{u'(c_t^A)}{u'(c_0^A)} \rightarrow$ **Inefficiency**

Aggregate vs. Distributional Effects

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

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

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

where $\Delta_t^\star$ is aggregate term and $\Sigma_t^{A,\star} + \Sigma_t^{N,\star} = 0$ are distributional terms.

- Borrowing constraints $\rightarrow \frac{u'(c_t^N)}{u'(c_0^N)} > \frac{u'(c_t^A)}{u'(c_0^A)} \rightarrow$ **Inefficiency**

There is a **conflict** between how the firm and displaced workers value the **effects of automation over time**. This creates room for **Pareto improvements**.

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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3. Set $\delta\alpha < 0$, and $\delta T < 0$ to compensate non-auto. workers (akin to future transfer)

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Taxing automation increases **aggregate consumption** and **redistributes** early on during the transition, precisely when **displaced workers** value it more.

Optimal Policy Intervention

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

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$$\underbrace{d\alpha_t = (x_t - \delta\alpha_t)\,dt;}_{\text{Law of motion}} \qquad \underbrace{Y_t = G^*\left(\boldsymbol{\mu}_t; \alpha_t\right) - q_t x_t}_{\text{Output net of investment cost}}$$

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- **Workers have identical MRS and MU** in the long-run $\Longrightarrow \alpha_t^{\text{LF}}/\alpha_t^{\text{FB}} \rightarrow 1$ 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: $q_t = q^{\text{fin}} + \exp(-\psi t)\left(q^{\text{init}} - q^{\text{fin}}\right)$

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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

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

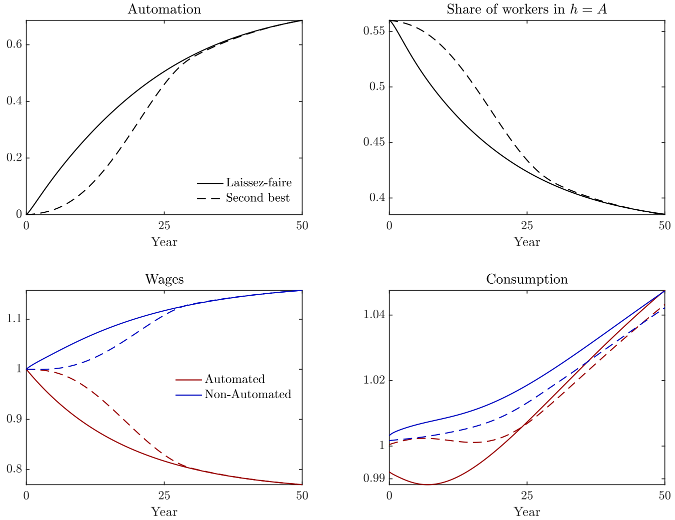
Calibration

- 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
ρ	Discount rate	0.04	2% real interest rate
λ	Mobility hazard	0.364	Gross mobility 1980 (10%)
γ	Fréchet parameter	0.036	Elasticity of labor supply (1)
A^A, A^N	Productivities	$0.719, 1.710$	$Y_0 = 1$, symm. wages
ϕ	Share of automated occupations	0.537	Routine empl. share 1980 (55%)
q^{fin}	Final cost of autom.	5.621	Log wage gap (0.45) in Cortes et al (2016)
ψ	Cost convergence rate	0.054	Half-life of wage gap $(15$ yrs$)$ in Cortes et al (2016)

Allocations



Half-life of automation: 15 years at LF v. 20 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).

▸ Optimal taxes

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Wage supplements: In PDV, second best is *as if* the gov't gave $19,126 to the avg. automated worker, and would tax $4,622 from the avg. non-automated worker

Takeaways

- Two **novel results** in economies where automation **displaces workers**, and these workers face reallocation and borrowing **frictions**

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

     Conflict between how firms and displaced workers value the effects of automation over time

  2. Optimal to **slow down automation** while workers reallocate, but not tax it in the long-run

     Raises agg. consumption and redistributes early on, precisely when displaced workers value it more

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       Raises agg. consumption and redistributes early on, precisely when displaced workers value it more

- Quantitatively: important **welfare gains** from slowing down automation

Extension: No Active Labor Market Intervention

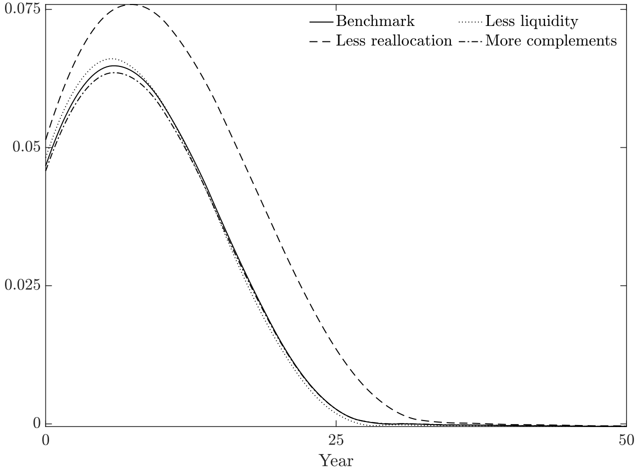
- Active labor market interventions might not be available (Heckman et al., Card et al.)
- Gov't now internalizes indirect effect of automation due to reallocation $T'(\alpha) > 0$

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

- 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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