

# INEFFICIENT AUTOMATION

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## Tax automation

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- ▶ Two **literatures** can justify taxing automation → **Reallocation** is **frictionless** or **absent**

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4. **Quantitative**: gross flows + idiosync. risk → **welfare gains** from slowing down autom.

Environment

Efficient Allocation

Decentralized Equilibrium

Failure of First Welfare Theorem

Optimal Policy

Quantitative Analysis

Continuous time  $t \geq 0$



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Occupations

Workers

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(gross complements)

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## Resource constraint

$$\int c_t(\mathbf{x}) d\Lambda = G^*(\mu^A, \mu^N; \alpha)$$

$$\phi^h \mu_t^h = \int \mathbf{1}_{\{h(x)=h\}} \xi d\pi_t$$

- ▶ Reallocation of existing workers is **costly** (Kambourov-Manovskii, Violante, Costinot-Werning)
  1. **Permanent cost**: productivity loss  $\theta$  due to skill-specificity

$$\xi_t = \begin{cases} \lim_{\tau \uparrow t} \xi_\tau & \text{if } h'_t(\mathbf{x}) = h \\ (1 - \theta) \times \lim_{\tau \uparrow t} \xi_\tau & \text{otherwise} \end{cases}$$

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  2. **Random opportunities**: Workers can move across occupations with intensity  $\lambda$
  3. **Unemployment/retraining spells**: Enter when moving, and exit at rate  $\kappa$
- ▶ Arrival of new workers is **slow** (Rebelo et al., Adão et al.). Rate  $\chi$ . Choose any occupation.

Environment

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# FIRST BEST PROBLEM

Ex post problem

Ex ante problem

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- ▶ Reallocate labor and distribute output
- ▶ Close MPLs gap. Stop reallocation at  $T_0^{\text{FB}}$   
(No OLG case)

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$$\int_{T_0^{\text{FB}}}^{+\infty} e^{-\rho t} u'(c_t^N) \Delta_t dt = 0$$

where

$$\Delta_t \equiv \underbrace{(1 - \theta) \left( 1 - e^{-\kappa(t - T_0^{\text{FB}})} \right)}_{\text{Cost} = \text{Skill loss} + \text{unemp}} \overbrace{\mathcal{Y}_t^N - \mathcal{Y}_t^A}^{\text{MPL gap}}$$

is the IRF of Y to reallocation

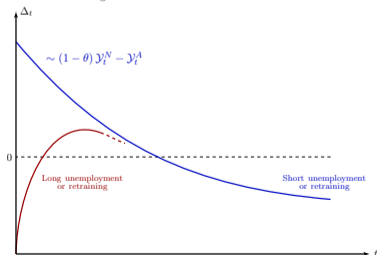
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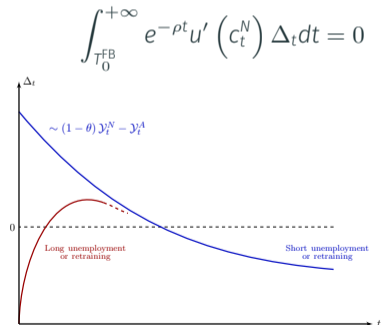


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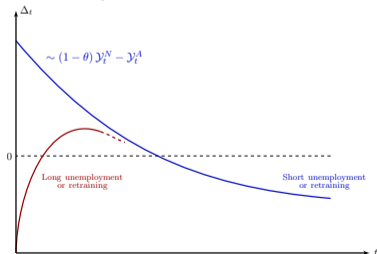
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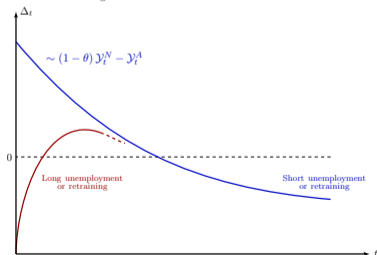
is the IRF of  $Y$  to automation (net of cost)

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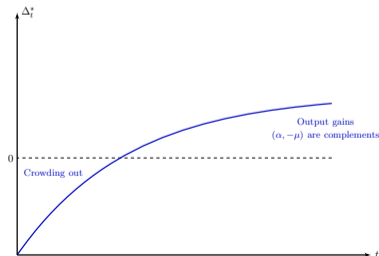
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# DECENTRALIZED CHOICES

Firms

Workers

Firms

Choose automation  $\alpha$  + labor demand  $\mu_t$

$$\max_{\{\alpha, \mu_t\}} \int_0^{+\infty} Q_t \Pi_t(\mu_t; \alpha) dt$$

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**Assets:** bonds, incomplete markets

Workers not insured against automation risk

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**Borrowing friction**

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$Q_t$  : equity priced by unconst. workers

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## Proposition. (Failure of FWT)

1. The laissez-faire equilibrium is inefficient if and only if **reallocation frictions**  $(\lambda, \kappa)$  and **borrowing frictions**  $(\underline{a})$  are such that  $a^*(\lambda, \kappa) < \underline{a} \leq 0$  for threshold  $a^*(\cdot)$ .

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2. The threshold  $a^*(\lambda, \kappa) < 0$  if and only if reallocation is slow ( $1/\lambda$  or  $1/\kappa > 0$ ).

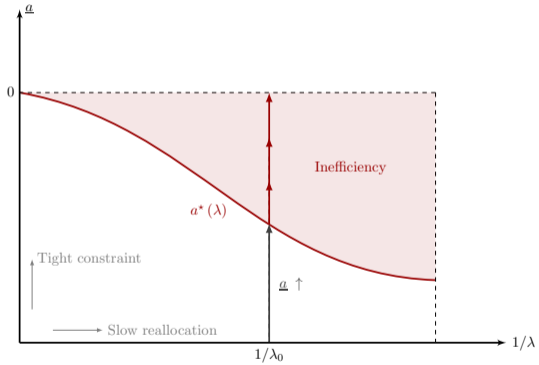
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2. The threshold  $a^*(\lambda, \kappa) < 0$  if and only if reallocation is slow ( $1/\lambda$  or  $1/\kappa > 0$ ).

- ▶ **Interaction** between reallocation and borrowing frictions is key
- ▶ Efficient cases: instant realloc. (Costinot-Werning) or no borrowing frictions (Guerreiro et al)

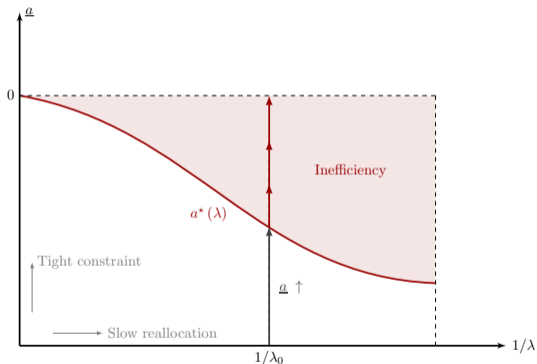
# NATURE OF THE INEFFICIENCY

Distortions at the laissez-faire

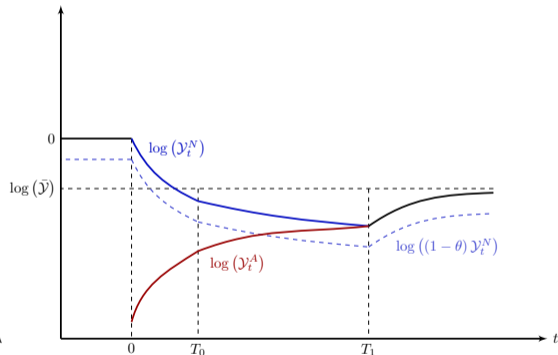


# NATURE OF THE INEFFICIENCY

Distortions at the laissez-faire



Average income



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

## WHY IS AUTOMATION INEFFICIENT?

- **Automation.** Compare the optimality conditions  
(first best)

$$\int_0^{+\infty} e^{-\rho t} \frac{u'(c_{0,t}^A)}{u'(c_{0,0}^A)} \Delta_t^* dt = 0$$

(laissez-faire)

$$\int_0^{+\infty} e^{-\rho t} \frac{u'(c_{0,t}^N)}{u'(c_{0,0}^N)} \Delta_t^* dt = 0$$

where  $\Delta_t^*$  is the IRF of  $Y$  to automation.

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- ▶ No borrowing constraints  $\rightarrow \frac{u'(c_{0,t}^A)}{u'(c_{0,0}^A)} = \frac{u'(c_{0,t}^N)}{u'(c_{0,0}^N)} \rightarrow$  Laissez-faire = First best

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- ▶ Automation  $\rightarrow u'(c_{0,t}^A) > u'(c_{0,t}^N) \rightarrow$  Rationale for redistribution
- ▶ Borrowing constraints  $\rightarrow \frac{u'(c_{0,t}^A)}{u'(c_{0,0}^A)} < \frac{u'(c_{0,t}^N)}{u'(c_{0,0}^N)} \rightarrow$  Laissez-faire  $\neq$  First best

## WHY IS AUTOMATION INEFFICIENT?

- ▶ **Automation.** Compare the optimality conditions  
(first best)

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Firms fail to internalize that displaced workers have a limited ability to smooth consumption while they reallocate.

# OUTLINE

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When is  $\tau^\alpha = 0$ ? **Redistributive tools**  $\rightarrow$  alleviate borrowing cons. and close MRS gap

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1. **Worker/time-specific lump sum transfers** → implement any **first best** (SWT holds)  
Info req's? Take-up? Unint. conseq's? (Piketty-Saez, 2013; Schochet, 2002; Crépon and van der Berg, 2016)

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2. **Symmetric lump sum transf.** (UBI) → govt. borrows for workers → restore **efficiency**  
Fiscal cost? Distortions? Tighten constraints? (Guner et al., 2021, Aiyagari-Mcgrattan, 1998)

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3. **Non-linear income taxes or unemp. insurance** → help but **do not restore efficiency**  
Heterogeneity **within** occupations swamps heterogeneity **between** occupations (as in quantitative model)

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# CONSTRAINED RAMSEY PROBLEM

- ▶ **Second best tools:** tax automation (*ex ante*) + labor market interventions (*ex post*)  
No social insurance for now, reintroduced in quantitative model
- ▶ Tractability: hand-to-mouth workers ( $\underline{a} \rightarrow 0$ ), no OLG ( $\chi = 0$ )
- ▶ **Primal problem:** control automation  $\alpha$  and reallocation  $T_0$

$$\max_{\{\alpha, T_0, \mu_t, c_t\}} \sum_h \phi^h \eta^h \int_0^{+\infty} \exp(-\rho t) u(c_t^h) dt$$

subject to workers' budget constraints, the law of motion of labor, firms choosing labor optimally, and market clearing.

- ▶ Government's optimality conditions to automate ( $\alpha$ ) and reallocate ( $T_0$ )

$$\int_0^{+\infty} \exp(-\rho t) u'(c_{0,t}^N) \Delta_t^* dt = -\Phi^*(\alpha^{SB}, T_0^{SB}; \eta)$$

$$\underbrace{\int_{T_0^{SB}}^{+\infty} \exp(-\rho t) u'(c_{0,t}^A) \Delta_t dt}_{\text{laissez-faire}} = \underbrace{-\Phi(\alpha^{SB}, T_0^{SB}; \eta)}_{\text{pecuniary externalities}}$$

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## Proposition. (Constrained inefficiency)

Fix weights  $\eta$ . Then, there is always a small perturbation of the technology  $G^*(\cdot)$  such that either  $\Phi^*(\cdot) \neq 0$  or  $\Phi(\cdot) \neq 0$  — i.e., the equilibrium is *generically* constrained inefficient.

## TAXING AUTOMATION ON EFFICIENCY GROUNDS

- ▶ **No pref. for redistribution:** weights  $\eta^{\text{effic}}$  so that distributional terms cancel out  
Guarantee that the government would not distort an efficient allocation for redistributive reasons

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Firms (partly) overlook that the gains from automation take time to materialize.

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→ Optimal to tax automation on efficiency grounds

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The optimal **tax on automation** improves aggregate efficiency. It raises consumption early on in the transition, precisely when displaced workers value it more.

## EXTENSION I: NO LABOR MARKET INTERVENTION

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- ▶ The **government** uses automation ( $\alpha$ ) as a *proxy* for **reallocation** ( $T_0$ )

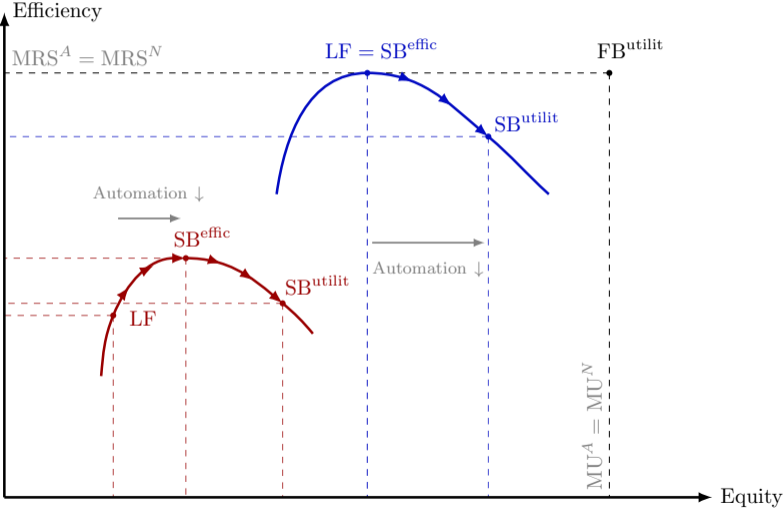
$$\int_0^{+\infty} e^{-\rho t} \sum_h \phi^h \eta^h \frac{u'(c_{0,t}^h)}{u'(c_{0,0}^h)} (\Delta_t^* + T_0'(\alpha^{SB}) \phi^A \lambda \exp(-\lambda T_0(\alpha^{SB})) \mathbf{1}_{\{t > T_0(\alpha^{SB})\}} \Delta_t) dt = 0$$

so that

Short unempl/retraining spells ( $1/\kappa$  low)  $\rightarrow$  tax  $\alpha$  more

Long unempl/retraining spells ( $1/\kappa$  high)  $\rightarrow$  tax  $\alpha$  less

# EXTENSION II: EQUITY CONCERNS



## EXTENSION III: SLOWING DOWN AUTOMATION

- ▶ Tax capital in the long-run → improve **insurance** or prevent **capital overaccumulation**  
(Aiyagari, 1995; Conesa et al., 2009; Dávila et al., 2012)

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- ▶ To clarify 2., extend model so that automation takes place **gradually**

$$\underbrace{d\alpha_t = (x_t - \delta\alpha_t) dt;}_{\text{Law of motion}}$$

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- ▶ Workers are unconstrained in the long-run  $\implies \alpha_t^{\text{LF}}/\alpha_t^{\text{FB}} \rightarrow 1$  as  $t \rightarrow +\infty$

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## Firm

task-based framework – Acemoglu-Autor

$$y_t^h = F(\mu_t^h; \alpha_t^h) = A^h (\varphi^h \alpha_t^h + \mu_t^h)^{1-\eta}$$

quadratic adjustment costs –  $\omega (x_t/\alpha_t)^2 \alpha_t$

$$d\alpha_t^A = (x_t - \delta\alpha_t^A) dt \quad \alpha_t^N = 0$$

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## Workers

gross flows – Kambourov-Manovskii

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

uninsured risk – Huggett-Aiyagari

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

$$z_t^P = (1 - \theta) z_{t,-}^P \text{ when moving}$$

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## Calibration

internal (7) and external (14)

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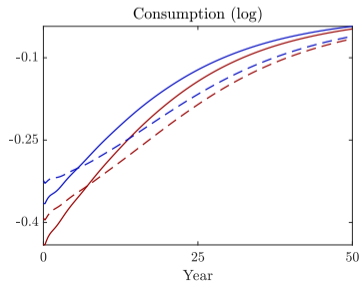
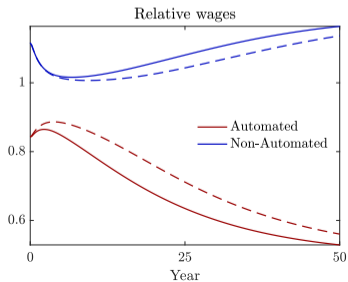
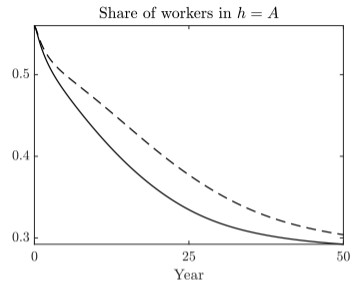
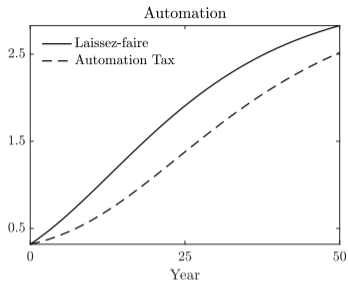
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► Incomes and Government

► Parameters

# AUTOMATION, REALLOCATION AND INEQUALITY



- ▶ Objective: The government maximizes

$$\mathcal{W}(\eta) \equiv \int_{-\infty}^{+\infty} \int \eta_t(\mathbf{x}) V_t^{\text{birth}}(\mathbf{x}) d\pi_t(\mathbf{x}) dt$$

- ▶ Second best: Choose  $\{\tau_t^x\}$  on investment, rebated to firm owners.

**Table 1:** Welfare Gains  $\Delta W$  from Second Best Interventions

	Benchmark	Alternative calibrations		Alternative policies	
		Long unempl.	High liquid.	Transfers	Joint
Efficiency	3.8%	3.5%	0.6%	0.3%	3.9%
Utilitarian	5.9%	5.8%	2.3%	3.0%	8.7%

Note: 'Long unempl.' and 'High liquid.' are calibrations with  $1/\kappa = 2$  and  $-B/Y = 1.4$ . 'Transfers' gives \$10k to automated workers at time  $t = 0$  financed with government debt.

- ▶ Two **novel results** in economies where automated workers face reallocation and borrowing **frictions**
  1. Automation is **inefficient** when frictions are sufficiently severe  
Firms fail to internalize that automated workers have a limited ability to smooth consumption
  2. Optimal to **slow down automation** while workers reallocate, but not tax it in the long-run

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  1. Automation is **inefficient** when frictions are sufficiently severe
    - Firms fail to internalize that automated workers have a limited ability to smooth consumption
  2. Optimal to **slow down automation** while workers reallocate, but not tax it in the long-run
- ▶ **Quantitatively**, slowing down automation achieves substantial **efficiency and welfare gains**, even when the government can implement generous transfers

► **Competitive equilibrium.** Set of

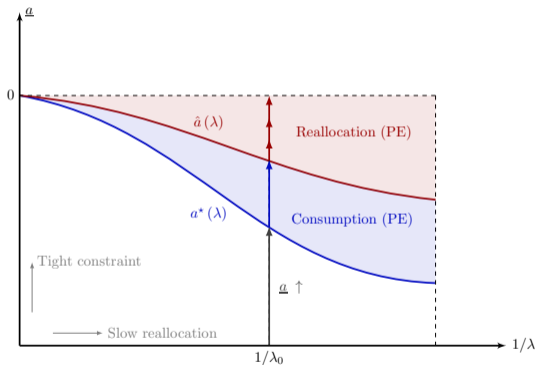
1. Allocation for consumption  $\{c_t\}$  and labor supplies  $\{\mu_t, \Theta_t\}$ , and automation  $\alpha$
2. Interest rate  $\{r_t\}$ , wages  $\{w_t^A, w_t^N\}$  and profits  $\{\Pi_t\}$

such that

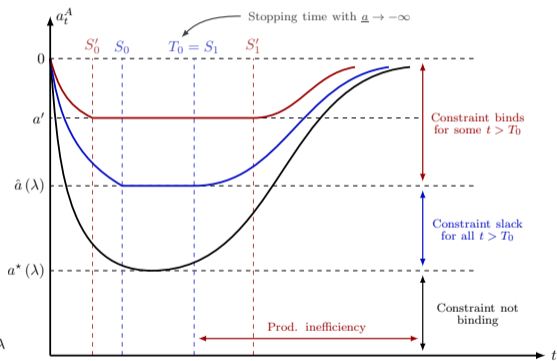
1. Workers consume, save and move optimally given prices
2. Representative firm chooses automation and hires labor optimally given prices
3. Labor markets clear and resource constraint holds

# BORROWING

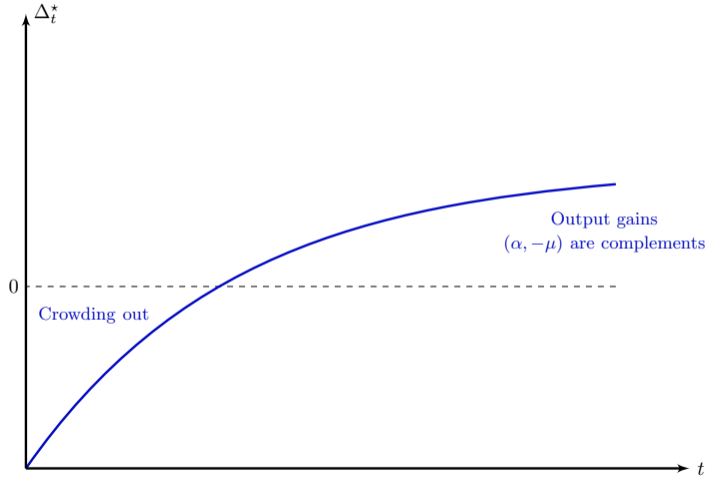
## Distortions at the laissez-faire



## Distributional effects



# RESPONSE OF OUTPUT TO AUTOMATION



# COMPETITIVE EQUILIBRIUM

► Incomes:

$$\mathcal{Y}_t(\mathbf{x}) = \mathcal{T}_t \left( \xi \exp(z) w_t^h + \exp(z) \Pi_t \right)$$

where  $\mathcal{T}_t(y) = y - \psi_{0,t} y^{1-\psi_1}$  captures the non-linear tax schedule.

► Assets:

Workers trade riskless bonds, and annuities (Blanchard-Yaari)

► Fiscal policy:

Constant government spending and debt to GDP, adjusts taxes

► Resource constraint:

$$\int a_t(\mathbf{x}) d\pi_t = -B_t,$$

**Table 2:** External Calibration

Parameter	Description	Calibration	Target / Source
$\sigma$	EIS (inverse)	2	-
$\chi$	Death rate	1/50	Average working life of 50 years
$1 - \eta$	Initial labor share	0.64	1970 labor share (BLS)
$\delta$	Depreciation rate	0.1	Graetz-Michaels (2018)
$\nu$	Elasticity of substitution across occs.	0.75	Buera-Kaboski (2011)
$1/\kappa$	Average unemployment duration	1/3.2	Alvarez-Shimer (2011)
$\theta$	Productivity loss from relocation	0.18	Kambourov-Manovskii (2009)
$\underline{a}$	Borrowing limit	0	Auclert et al (2018)
$\phi_0, \phi_1, -B/Y$	Government	0.35, 0.18, 0.26	Heathcote et al (2017), Kaplan et al (2018)
$\rho_z, \sigma_z, b$	Income	0.023, 0.102, 0.4	Floden-Lindé (2001), Shimer (2005)

**Table 3:** Internal Calibration

Parameter	Description	Calibration	Target / Source
$\rho$	Discount rate	0.148	2% real interest rate
$A^A, A^N$	Productivities	0.89, 1.23	Initial output (1)
$\omega$	Adjustment cost	2	Half-life of automation
$\phi$	Fraction of automated occupations	0.53	Routine occs. share 1970
$\lambda$	Mobility hazard	0.42	Occupational mobility 1970
$\gamma$	Fréchet parameter	0.053	Elasticity of labor supply