Inefficient Automation

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Tax automation

Guerreiro et al 2017; Costinot-Werning 2018

(i) Govt. has preference for redistribution

(ii) Automation/reallocation are efficient

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

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This Paper

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

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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

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

Outline

Environment

Efficient Allocation

Decentralized Equilibrium

Failure of First Welfare Theorem

Optimal Policy

Quantitative Analysis

Environment

Continuous time $t \geq 0$

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Continuous time $t \geq 0$

Occupations

Workers

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(gross complements) ▸ Example

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Resource constraint

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

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

Reallocation frictions

- Reallocation of existing workers is **costly** (Kambourov-Manovskii, Violante, Costinot-Werning)

1. **Permanent cost**: productivity loss θ 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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  3. **Unemployment/retraining spells**: Enter when moving, and exit at rate κ

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- Arrival of new workers is **slow** (Rebelo et al., Adão et al.). Rate χ. Choose any occupation.

Outline

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^{FB} (No OLG case)

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where

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

is the IRF of Y to reallocation

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

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Decentralized Choices

Firms

Workers

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Workers not insured against automation risk

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Borrowing friction

$a_t(\mathbf{x}) \geq \underline{a}$ for some $\underline{a} \leq 0$

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$$\max_{\{\alpha,\boldsymbol{\mu}_t\}} \int_0^{+\infty} Q_t \Pi_t\left(\boldsymbol{\mu}_t;\alpha\right) dt$$

No arbitrage $\rightarrow$ $Q_t = \exp\left(-\int_0^t r_s ds\right)$

Equity priced by unconstrained workers

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Failure of the First Welfare Theorem

Proposition. (Failure of FWT)

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

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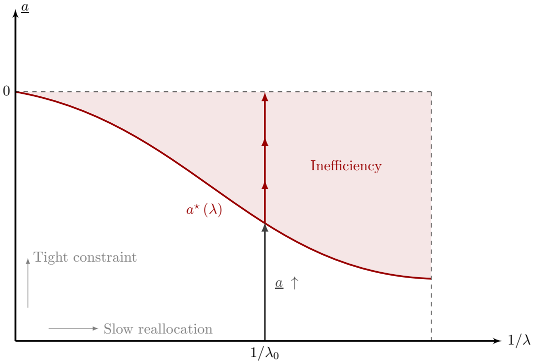
- **Interaction** between reallocation and borrowing frictions $\rightarrow$ inefficient automation

Failure of the First Welfare Theorem

Distortions at the laissez-faire



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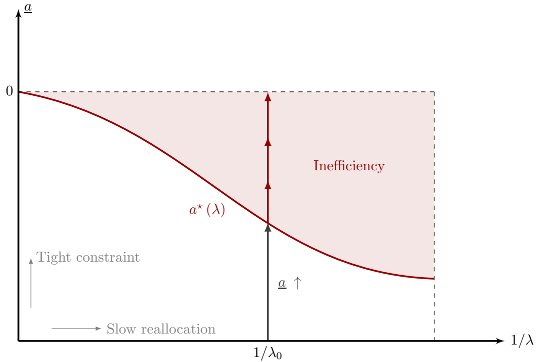

Efficient cases: instant realloc. (Costinot-Werning) or no borrowing frictions (Guerreiro et al)

Failure of the First Welfare Theorem

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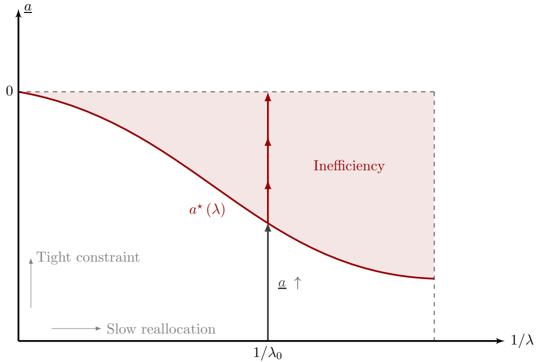
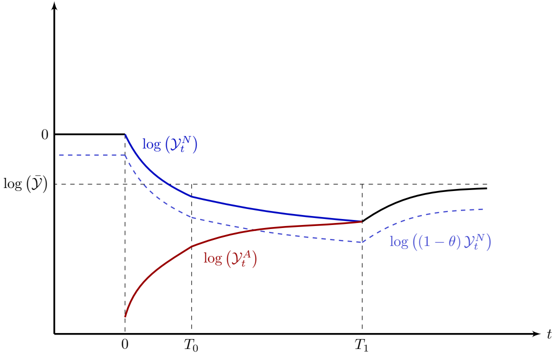


Average income



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

Why Is Automation Inefficient?

- Compare two optimality conditions for automation

(Firm at laissez-faire)

$$\int_0^{+\infty} e^{-\rho t} \underbrace{\frac{u'(c^N_{0,t})}{u'(c^N_{0,0})}}_{\exp\left(-\int_0^t r_s ds\right)} \Delta^\star_t dt = 0$$

(Valuing like displaced workers would)

$$\int_0^{+\infty} e^{-\rho t} \frac{u'(c^A_{0,t})}{u'(c^A_{0,0})} \Delta^\star_t dt = 0$$

where $\Delta^\star_t$ is the IRF of Y to automation.

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- No borrowing constraints $\to \frac{u'(c^N_{0,t})}{u'(c^N_{0,0})} = \frac{u'(c^A_{0,t})}{u'(c^A_{0,0})} \to$ First best = Laissez-faire

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

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- Wedge between first best and laissez-faire optimality condition

$$\tau^{\alpha} = \int_0^{+\infty} e^{-\rho t} \left(\frac{u'(c^N_{0,t})}{u'(c^N_{0,0})} - \frac{u'(c^A_{0,t})}{u'(c^A_{0,0})} \right) \Delta^{\star}_t \, dt$$

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$$\tau^{\alpha} = \int_0^{+\infty} e^{-\rho t} \left(\frac{u'(c^N_{0,t})}{u'(c^N_{0,0})} - \frac{u'(c^A_{0,t})}{u'(c^A_{0,0})} \right) \Delta^{\star}_t dt$$

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

Optimal policy

How should a government respond to automation? Depends on the **tools** available

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1. **Worker/time-specific lump sum transfers** → implement any **first best** (SWT holds)

   Info requirements? Take-up? Political? (Piketty-Saez, 2013; Guerreiro et al., 2017; Costinot-Werning, 2018)

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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)

Constrained Ramsey problem

- **Second best tools**: **tax automation** (*ex ante*) + **labor market interventions** (*ex post*)

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- Tractability: hand-to-mouth workers ($\underline{a} \to 0$), no OLG ($\chi = 0$)
- **Primal problem:** control automation α and reallocation T_0

$$\max_{\{\alpha, T_0, \boldsymbol{\mu}_t, \mathbf{c}_t\}} \sum_h \phi^h \eta^h \int_0^{+\infty} \exp\left(-\rho t\right) u\left(c_t^h\right) dt$$

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

Constrained inefficiency (regardless of Pareto weights)

- Government's optimality conditions to **automate** (α) and **reallocate** (T_0)

$$\underbrace{\int_0^{+\infty} \exp(-\rho t) \frac{u'\left(c_{0,t}^N\right)}{u'\left(c_{0,0}^N\right)} \Delta_t^\star dt = \int_{T_0^{\text{SB}}}^{+\infty} \exp(-\rho t) \frac{u'\left(c_{0,t}^A\right)}{u'\left(c_{0,0}^A\right)} \Delta_t dt}_{\text{laissez-faire}} = \underbrace{-\Phi^\star\left(\alpha^{\text{SB}}, T_0^{\text{SB}}; \boldsymbol{\eta}\right) = -\Phi\left(\alpha^{\text{SB}}, T_0^{\text{SB}}; \boldsymbol{\eta}\right)}_{\textbf{pecuniary externalities}}$$

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Proposition. (Constrained inefficiency)

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

Taxing automation on efficiency grounds

- **No pref. for redistribution**: weights η^{effic} so that distributional terms cancel out

  Government does not distort an efficient alloc. to improve redistribution

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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: Gradual automation

- Tax capital in the long-run $\rightarrow$ improve **insurance** or prevent **dynamic inefficiency**
  (Aiyagari, 1995; Chamley, 2001; Conesa et al., 2009; Dávila et al., 2021; Aguiar et al.; 2021)

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

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▸ Extensions

Outline

Quantitative Model

Firm

task-based framework – Acemoglu-Autor

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

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

$$d\alpha_t^A = \left(x_t - \delta \alpha_t^A\right) dt \qquad \alpha_t^N = 0$$

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gross flows – Kambourov-Manovskii

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

uninsured risk – Huggett-Aiyagari

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

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

▸ Incomes and Government

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Incomes and Government | Parameters

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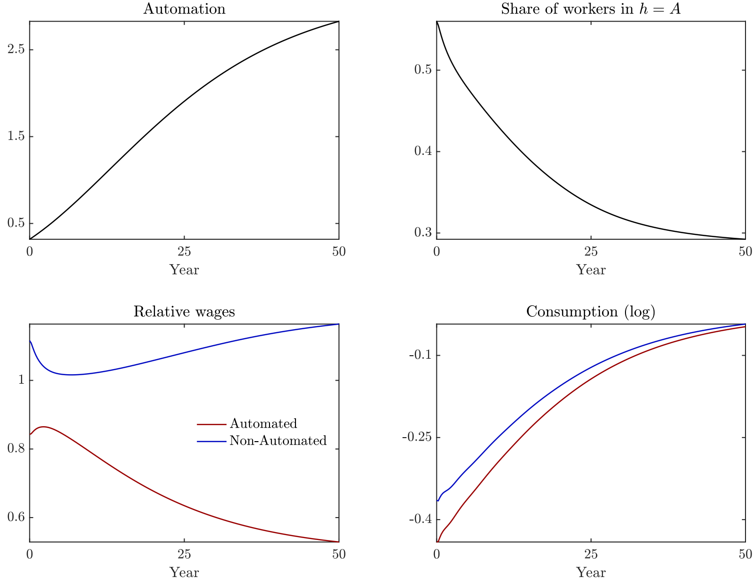
▸ Incomes and Government ▸ Parameters ▸ Example

Automation, Reallocation and Inequality



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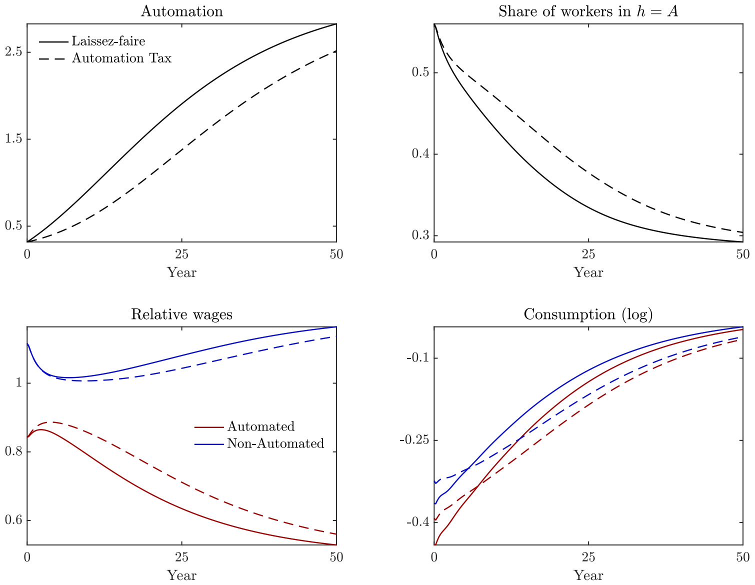

Second Best Policies and Welfare

- **Objective**: The government maximizes

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

- **Second best**: Choose $\{\tau_t^x\}$ on investment, rebated to firm owners.
- **Numerically**: Iterate on $\{\tau_t^x\}$ (parametrically) to find the second best.

Welfare Gains Form Slowing Down Automation

Table: Welfare Gains at Second Best Intervention

		Alternative calibrations		Alternative policies	
	Benchmark	Long unempl.	High liquid.	Transfers	Joint
Efficiency	3.8%				
Utilitarian	5.9%				

Note: 'Long unempl.' and 'High liquid.' are alternative calibrations with $1/\kappa = 2$ and $-B/Y = 1.4$. 'Transfers' denotes $\$10$k to automated workers. 'Joint' denotes optimal tax on automation and transfers.

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- Half-life of automation: 20 years at LF and 47 years at SB in our benchmark

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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

     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

     Improve aggregate efficiency by raising consumption when displaced workers are constrained

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

     Improve aggregate efficiency by raising consumption when displaced workers are constrained

- Quantitatively: substantial **efficiency** and **welfare gains** from slowing down autom.

  Even when the government can implement generous transfers

Contributions to the Literature

Taxation of automation. Naito (1999), Guerreiro et al. (2017), Thuemmel (2018), Rebelo et al. (2018), Costinot-Werning (2020), Jaimovich et al. (2020); Acemoglu et al. (2020); Korinek-Stiglitz (2021)

- ⋆ Policy interventions on **efficiency grounds**

Labor reallocation. Lucas-Prescott (1974), Alvarez-Veracierto (1999, 2001), Alvarez-Shimer (2011); Keane-Wolpin (1997), Lee-Wolpin (2006); Davis-Haltiwanger (1999), Kambourov-Manovskii (2009)

- ⋆ Normative analysis with **incomplete markets**

Optimal policy in HA economies. Aiyagari (1995), Golosov-Tsyvinski (2006), Conesa-Krueger (2006), Conesa et al. (2009), Davila et al. (2012), Heathcote et al. (2017), Aguiar et al. (2021)

- ⋆ Focus on **taxation of automation** with **labor reallocation** frictions

Technology

- **Example.** A task-based technology (Acemoglu-Restrepo, 2018):

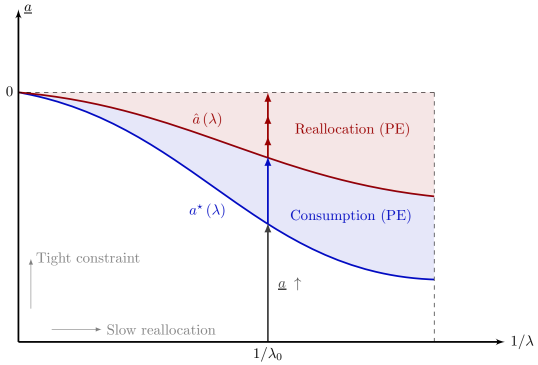
$$G\left(\mu^A, \mu^N; \alpha\right) = \exp\left(\int_0^{\phi} \log\left(\varphi\alpha + \mu^A\right) + \int_{1-\phi}^{1} \log\left(\mu^N\right)\right)$$
$$= \left(\varphi\alpha + \mu^A\right)^{\phi}\left(\mu^N\right)^{1-\phi}$$

- Automation and labor are perfect substitutes *within* occupations.
- They can still be complements *across* occupations.
- **Quantitative model.** Specification above with gross complements across occup.

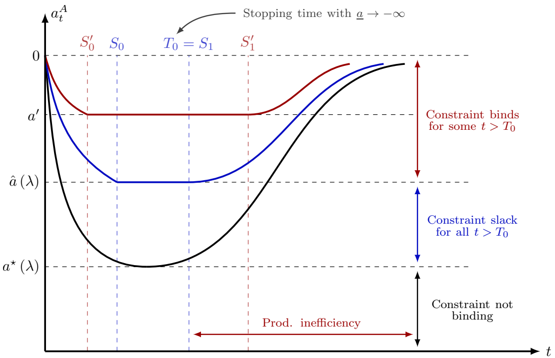
Back 1 Back 2

Borrowing

Distortions at the laissez-faire



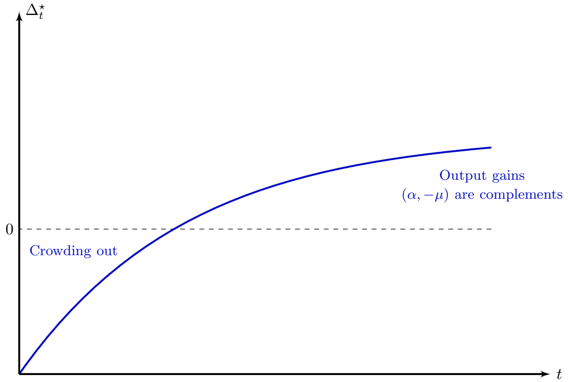
Distributional effects



Back

Automation returns $\Delta_t^\star$ are back-loaded

- **Assumption** (complementarity). $\partial_\alpha G^\star(\mu, 1-\mu; \alpha)$ has increasing differences in $(\alpha, -\mu)$



Back

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- Active labor market interventions might not be available (Heckman et al., Card et al.)

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- The government uses automation (α) as a *proxy* for reallocation (T_0)

$$\int_0^{+\infty} e^{-\rho t} \sum_h \phi^h \eta^h \frac{u'\left(c_{0,t}^h\right)}{u'\left(c_{0,0}^h\right)} \left(\Delta_t^\star + T_0'\left(\alpha^{\mathrm{SB}}\right)\Delta_t\right) dt = 0$$

so that

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

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

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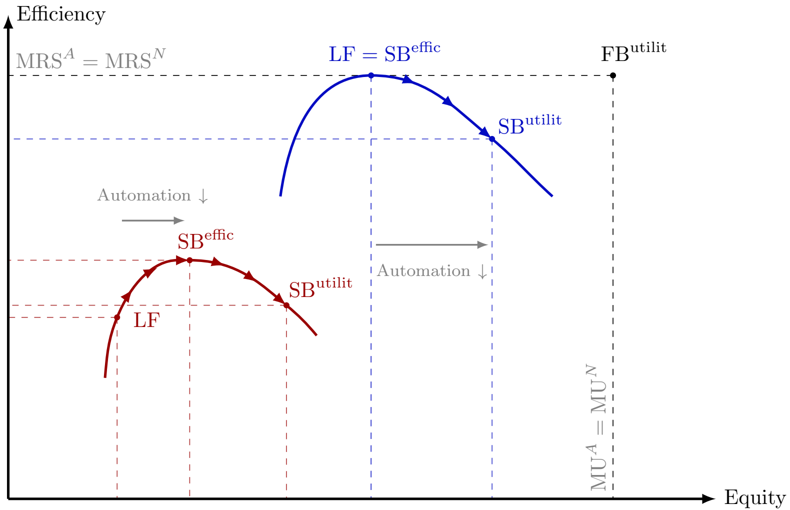
Short unempl/retraining spells $(1/\kappa$ low$)$ $\rightarrow$ **tax α more**

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

- We play with the duration of these spells $(1/\kappa)$ in our quantitative model.

Back

Extension II: Equity concerns



Back

Competitive Equilibrium

- **Incomes**:

$$\mathcal{Y}_t^\star(\mathbf{x}) = \Pi_t + (1-\tau_t) \times \begin{cases} \xi \exp(z)\, w_t^h & \text{if } e = E \\ b\xi \exp(z)\, w_t^{-h} & \text{if } e = U \end{cases}$$

where b is replacement rate during unemployment.

- **Assets**:

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

- **Fiscal policy**:

  Constant debt / GDP, adjusts distorsionary tax $\{\tau_t\}$

- **Resource constraint**:

$$\int c_t(\mathbf{x})\, d\pi_t + x_t + \omega \left(\frac{x_t}{\alpha_t}\right)^2 \alpha_t = G^*\left(\left\{\frac{\int \mathbf{1}_{\{h(\mathbf{x})=h\}} \xi\, d\pi_t}{\phi^h}\right\}\right) + b \int \mathbf{1}_{\{e=U\}} \tilde{\mathcal{Y}}(\mathbf{x})\, d\pi_t,$$

Back

Calibration

- **Parameters**: External calibration (14) and internal calibration (7)

Table 1: Internal Calibration

Parameter	Description	Calibration	Target / Source
ρ	Discount rate	0.10	2% real interest rate
A^A, A^N	Productivities	0.94, 1.16	Initial output (1)
ω	Adjustment cost	4	Routine empl. share 2015
ϕ	Fraction of automated occupations	0.55	Routine empl. share 1970
λ	Mobility hazard	0.312	Occupational mobility 1970
γ	Fréchet parameter	0.052	Elasticity of labor supply

Back

Calibration

Table 2: External Calibration

Parameter	Description	Calibration	Target / Source
σ	EIS (inverse)	2	-
χ	Death rate	$1/50$	Average working life of 50 years
$1-\eta$	Initial labor share	0.64	1970 labor share (BLS)
δ	Depreciation rate	0.1	Graetz-Michaels (2018)
ν	Elasticity of substitution across occs.	0.75	Buera-Kaboski (2011)
$1/\kappa$	Average unemployment duration	$1/3.2$	Alvarez-Shimer (2011)
θ	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)
ρ_z, σ_z, b	Income	$0.023, 0.102, 0.4$	Floden-Lindé (2001), Shimer (2005)

Back