Fiscal policy and human capital in the race against the machine

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Motivation

Automation (skill-biased technical change) is a major driver of:

1. economic growth
   - technological progress makes machines more productive
   - more productive machines substitute less productive workers
2. wage inequality
   - high-skilled workers are **complements** to machines
   - low-skilled workers are **substitutes** to machines

Government interventions

- transfers (US, 2019 - $461B)
  - reduce inequality but negative incentive effects
- education spending (US, 2019 - $1951B)
  - boosts growth
  - unclear effect on inequality

Research questions

1. What is the role of **human capital** and **public education spending** for the joint dynamics of automation-driven **economic growth** and **inequality**?

2. How do **tax policies** affect this interaction?
   (taking spending composition as given)

3. What is the **welfare-optimal** way to finance government spending on education and transfers?

In this paper

Rel. literature

- **Theoretical model**
  - endogenous R&D-driven growth with automation
  - endogenous education choice
  - endogenous human capital formation
  - fiscal policy: labor/robot tax, transfers/education spending
- **Tax policy (partial equilibrium)**
  a. redistribution channel $\Rightarrow$ inequality $\downarrow$
  b. human capital channel $\Rightarrow$ inequality $\uparrow$
- **Tax policy (general equilibrium)** (US, 2020)
  - tax policy effects on production and inequality
  - dynamic optimal tax policy
- **Private education spending** (US vs Germany)

Theoretical Model

2-period OLG

0. all agents acquire basic education
1. agents select into higher (tertiary) education, $j \in \{L, H\}$ and choose consumption/savings and labor supply, taxed at rate τ_W
2. agents retire and consume their savings (no pensions)

Education choice (extensive margin of human capital)

- heterogeneous agents in the ability to acquire high educ., a
- fixed time investment + ability dependent disutility
- college education if $\mathcal{U}_{H,t}(a) \geq \mathcal{U}_{L,t}(a) \iff a \geq a_t^*$

Production

$$Y_t = (\underbrace{h_{H,t}\ \tilde{H}_{Y,t}}_{\text{High skill}})^{1-\alpha}\left[(\underbrace{h_{L,t}\ \tilde{L}_t}_{\text{Low skill}})^{\alpha} + \underbrace{\sum_{i=1}^{A_t} x_{i,t}^{\alpha}}_{\text{Robots } (\tau_R)}\right]$$

- R&D (blueprints, technological frontier):

$$A_t = A_{t-1} + \underbrace{\bar{\delta}_t\ (\ \lambda_1,\ \ \lambda_2\ )}_{\text{spillover, congestion}} \cdot\ h_{H,t}\ \underbrace{\tilde{H}_{A,t}}_{\text{High skill}}$$

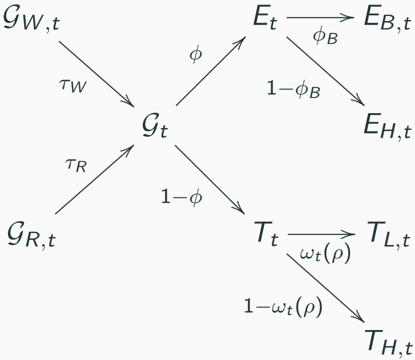
- Intensive margin of human capital (hierarchical education system):

$$h_{L,t} = h_{B,t} = B \cdot \left(\hat{E}_{B,t}\right)^{\mu_B}$$

$$h_{H,t} = B_H \cdot (h_{B,t})^{1-\mu_H} \cdot \left(\hat{E}_{H,t}\right)^{\mu_H}$$

- $\hat{E}_{B,t}$: per-capita basic (primary & sec.) education spending
- $\hat{E}_{H,t}$: per-capita higher (tertiary) education spending

Fiscal policy



- balanced budget

$$\underbrace{\mathcal{G}_{W,t} + \mathcal{G}_{R,t}}_{\text{total tax revenues}} = \underbrace{E_t + T_t}_{\text{total spending}}$$

Policy parameters:

- τ_W: labor tax
- τ_R: robot tax
- ϕ: share to total education spending
- ϕ_B: share to basic education spending
- $\omega_t(\rho)$: low-skilled transfer share (dependent on progressivity ρ)

Focus on: **labor and robot tax** (spending parameters constant)

Tax Policy Analysis

Theoretical analysis (partial equilibrium (PE))

Fixed education & individual labor supply

Taxes affect inequality through:

a. REdistribution channel:

$$\uparrow \tau \;\Rightarrow \uparrow T \;\Rightarrow \;\downarrow \frac{c_H}{c_L} \quad \text{if } \underbrace{\omega > \hat{\omega} = w_L L/(w_L L + w_H(1-\eta)H)}_{\text{progressive system}}$$

- $\omega > \hat{\omega}$ necessary condition for τ_W
- $\omega > \hat{\omega}$ sufficient condion for τ_R

b. (intensive margin) Human Capital channel:

$$\uparrow \tau \;\Rightarrow \uparrow E \;\Rightarrow \uparrow \frac{h_H}{h_L} \;\Rightarrow \uparrow \frac{c_H}{c_L}$$

Propositions

1. τ_R more redistributive than τ_W
2. Higher taxation has an ambiguous effect on inequality

General equilibrium (GE)

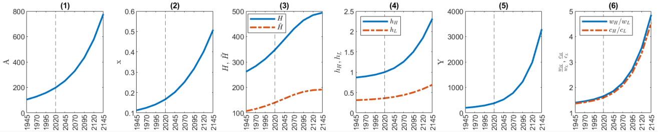
External Policy par.

Calibration (US, 2020): 11 external, 8 internal, 5 policy parameters

parameter	description	value
δ	R&D productivity	0.584
ψ_1	education cost (level)	0.479
ψ_2	education cost (slope)	17.09
B	productivity (basic)	1.720
B_H	productivity (higher)	6.236
μ_B	educ. spending elast. (basic)	0.354
μ_H	educ. spending elast. (higher)	0.223
A_0	(initial) technological frontier	87.30

target	data	model
R&D employment share	1.00%	1.69%
college share	34.7%	34.7%
skill premium	1.86	1.86
$h_{H,2020}$ (norm.)	1	1
TFP growth (annual)	0.91%	0.91%
elast. college att. wrt. w_L	1.2	1.2
elast. w_L wrt. $\hat{E}_B$	0.54	0.54

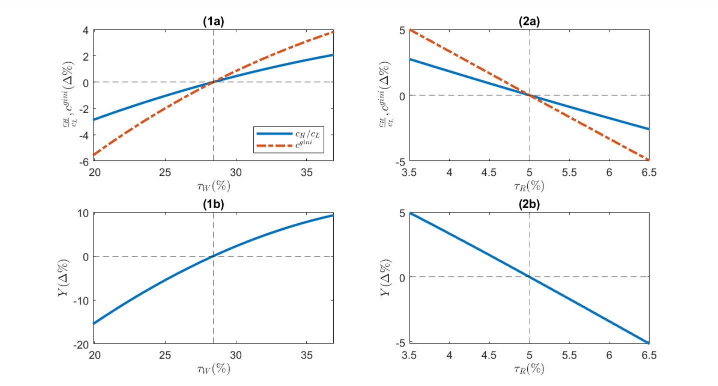
Dynamics



$$\uparrow A \Rightarrow \uparrow robots \Rightarrow \uparrow \frac{w_H}{w_L}, \frac{c_H}{c_L} \Rightarrow \uparrow \tilde{H} \Rightarrow \uparrow Y$$

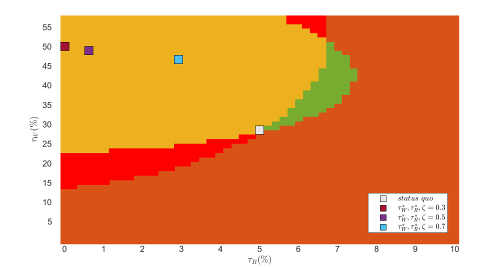
Model validation (US, 1970-2020)

Effect of a change in τ_W or τ_R



- PE analysis: RE reduces, but HC increases inequality
- GE (calibrated) setting:
  - $\tau_W \uparrow$: higher inequality, i.e., HC>RE, higher growth
  - $\tau_R \uparrow$: lower inequality, i.e., RE>HC, lower growth

Effect of a <u>combined</u> change in τ_W and τ_R



Relative to status quo:

green: $\uparrow$ production, $\downarrow$ inequality

red: $\downarrow$ production, $\uparrow$ inequality

yellow: $\uparrow$ production, $\uparrow$ inequality

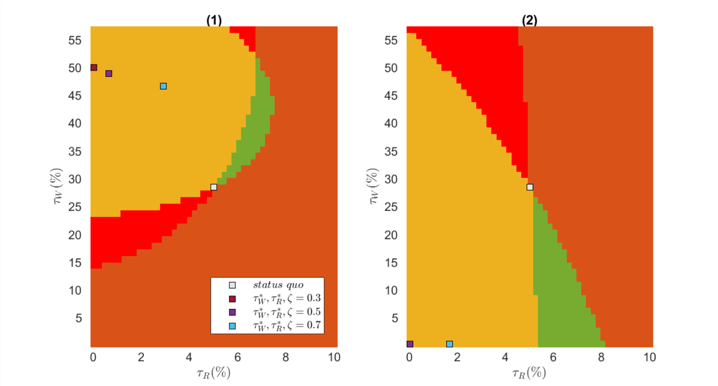
orange: $\downarrow$ production, $\downarrow$ inequality

Green region $(\uparrow \tau_w, \uparrow \tau_R)$ is welfare-improving. Welfare-optimizing?

$$\Omega_t = \zeta \cdot L_t \cdot \mathcal{U}_{L,t} + (1-\zeta) \cdot H_t \cdot \mathcal{U}_{H,t}$$

Welfare optimum $(\zeta = 0.5)$: $\uparrow \tau_w, \downarrow \tau_R$

Relevance of HC channel

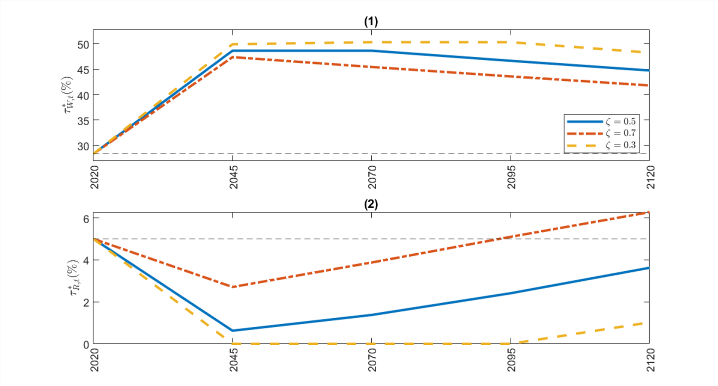


- with HC: welfare optimality requires positive taxation
- with no HC: optimality requires no taxation
  - no productivity-enhancing tax effect through HC
  - transfers distort education decisions

⇒ abstracting from HC leads to **misleading policy recommendations**

Optimal tax policy

Decomposition



- relative to status quo: increase τ_W^* and decrease τ_R^* (**boost growth**)
- over time: decrease τ_W^* and increase τ_R^* (**redistribute**)
- τ_R^* increasing in preference for equality, ζ

Private education spending

Does private educ. spend. affect the results?

Details

Model modification:

- private education spending decision, θ_t
- private spending substitutes public spending (tertiary):

$$h_{H,t} = B_H \cdot (h_{B,t})^{1-\mu_H} \cdot \left(\epsilon \cdot (\theta_t)^{\frac{\nu-1}{\nu}} + (1-\epsilon) \cdot \left(\hat{E}_{H,t} \right)^{\frac{\nu-1}{\nu}} \right)^{\mu_H \cdot \frac{\nu}{\nu-1}}$$

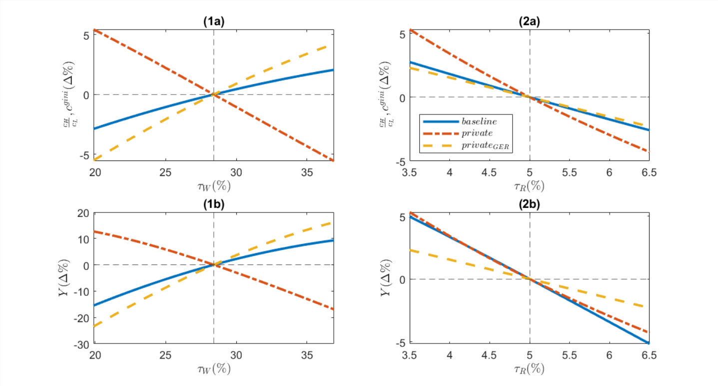
Two scenarios considered:

- US case: **high** private-to-public tertiary educ. spending (1.54)
- GER case: **low** private-to-public tertiary educ. spending (0.28)

Calib. internal Calib. targets

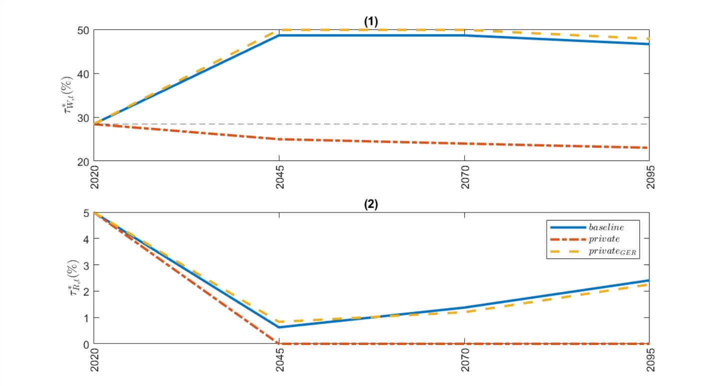
Private education spending – Exogenous tax policy

Details



- τ_W: US case, dominance reverses (RE>HC): inequality ↓, growth ↓
  - strong substitution effect (publ. crowds out priv. educ. spend.)
  - DE case, similar to baseline
- τ_R: similar to baseline

Private education spending – Optimal tax policy



- τ^*_W: US case, lower and directly declining
  - reversed dominance (RE>HC, negative effect of tax on growth)
- τ^*_R: US case, drops to zero
  - both redistrib. taxes (RE>HC), rely on less distortionary tax
- GER case, similar to baseline

Conclusion

1. tax policies affect the economy through **human capital**
    - neglecting HC leads to misleading policies
2. mixed tax policies can **break the growth-equality trade-off**
3. **welfare optimality** requires an initial reduction and then a gradual increase in the robot tax (non-zero robot tax result)
4. optimal robot tax under **public vs. private** higher education
    - private: individuals benefiting from higher education pay already the price, no necessity to tax them with a robot tax
    - public: use robot tax to finance tertiary education

Thank you!

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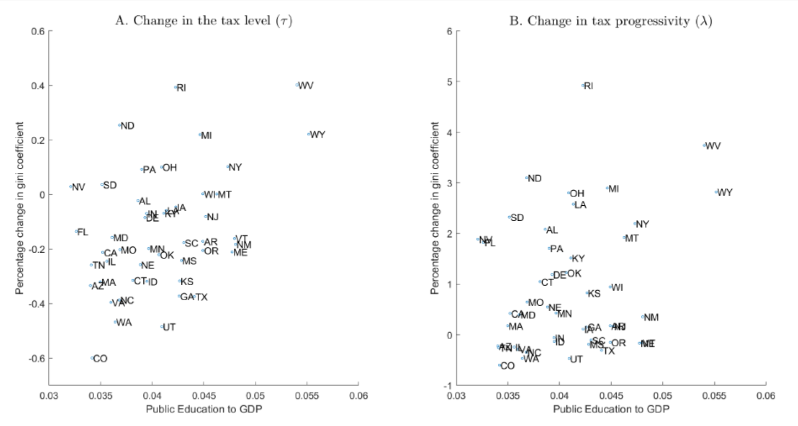
Appendix

Education and inequality



Percentage change in (pre-tax) Gini coefficient following a one percentage point increase in public education expenditures to GDP. Source: Artige and Cavenaile (2023).

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Related literature

- **Automation on Growth & Inequality**

  Krusell et al. (2000), Goldin and Katz (2010), Brynjolfsson and McAfee (2011), Acemoglu et al. (2012), Frey and Osborne (2017), Graetz and Michaels (2018), Goldin et al. (2020), Acemoglu and Restrepo (2020)

  this paper: human capital (extensive and intensive margins)

- **Tax policies on Growth & Inequality**

  Restuccia and Urrutia (2004), Blankenau (2005), Guvenen et al. (2013), Krueger and Ludwig (2016), Jacobs and Thuemmel (2020), Prettner and Strulik (2020), Artige and Cavenaile (2023)

  this paper: interaction with the hierarchical education system

- **Optimal Capital (Robot) Tax**

  Slavik and Yazici (2014), Jacobs and Thuemmel (2020), Guerreiro et al. (2022), Thuemmel (2022)

  this paper: positive and increasing robot tax

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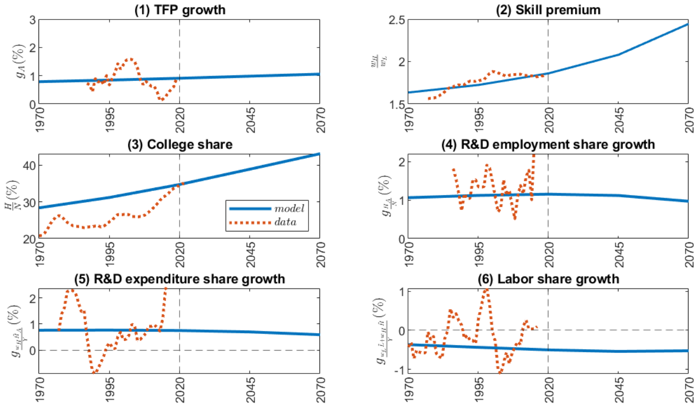
Model validation (US, 1970-2020)



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Optimal tax policy – Decomposition

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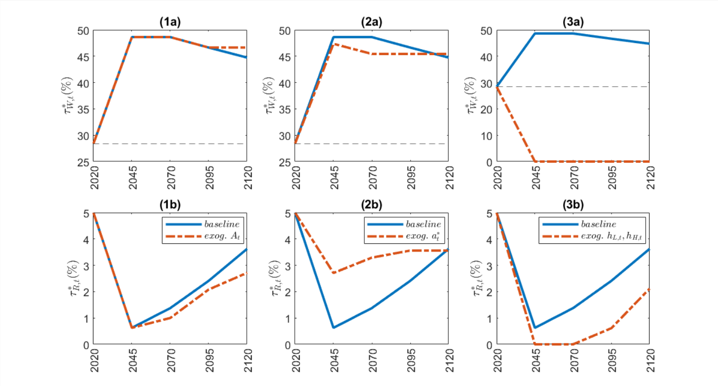
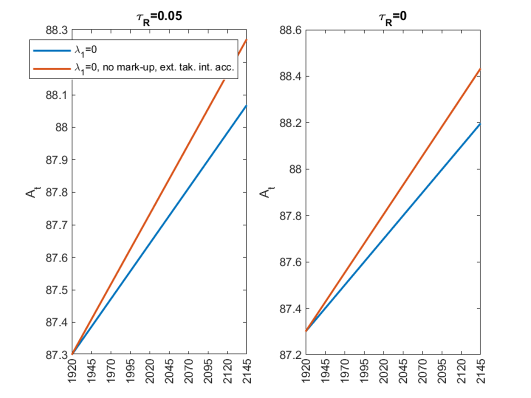


- **(1) technological progress:** lower robot tax; boost in automation less pronounced, less need for redistribution
- **(2) ext. marg. of HC:** higher robot tax, lower labor tax; education decision is not responding, more low-skilled workers in the economy, more need for redistribution
- **(3) int. marg. of HC:** labor tax drops to zero, lower robot tax; no motive for education spending, role of the government only redistribution

Sources of inefficiency

Does the decentralized equilibrium entail too little or too much R&D?

- (i) monopoly markup $\frac{1}{\alpha}$; (ii) intertemporal spillover λ_1; (iii) congestion externality λ_2
- consider $\lambda_1 = 0$ and compare decentralized equilibrium to planner solution (no markup, congestion externality internalized)



Decentralized equilibrium always delivers too little R&D, so no built-in efficiency rationale for τ_R.

Model appendix

Households – Utility functional forms

Diamond model, 2-period OLG

0. all agents start with basic education, but heterogeneous abilities a
1. agents choose consumption, savings, labor supply and select into higher (college) education, $j \in \{L, H\}$

$$\mathcal{U}_{j,t}(a) = \log(c_{j,t}) + \beta \cdot \log(\bar{R} \cdot s_{j,t}) + \gamma \cdot \log(z_{j,t}) - \mathbb{1}_{[j=H]}\ v(a)$$

$$\text{s.t.} \qquad (1 - \tau_W) \cdot (1 - \eta_j - z_{j,t}) \cdot w_{j,t} + \hat{T}_{j,t} = c_{j,t} + s_{j,t}$$

2. agents retire and consume their savings (no pensions)

$$c_{j,t+1} = \bar{R} \cdot s_{j,t}$$

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Households – Disutility from higher education investment

$$v(a) = \begin{cases} \psi_1 \cdot \log(\frac{\psi_2}{a-\underline{a}}), \ \ if \ \ a \geq \underline{a} \\ +\infty, \ \ if \ \ a < \underline{a} \end{cases}$$

- ψ_1: level of higher education costs
- ψ_2: slope of higher education costs
- $\underline{a}$: minimum ability level to be able to obtain a higher (tertiary) education degree

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Households – Ability threshold

- ability threshold in detail

$$a_t^* = \psi_2 \left(\frac{c_{H,t}}{c_{L,t}} \right)^{-\frac{1+\beta+\gamma}{\psi_1}} \left(\frac{w_{H,t}}{w_{L,t}} \right)^{\frac{\gamma}{\psi_1}} + \underline{a}$$

- number of high-skilled workers

$$H_t = (1 - \mathcal{F}(a_t^*)) \cdot N$$

- number of low-skilled workers

$$L_t = \mathcal{F}(a_t^*) \cdot N$$

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Production – Details

- factor demand

$$
\begin{aligned}
w_{H,t} &= (1-\alpha)\left(h_{H,t}\tilde{H}_{Y,t}\right)^{-\alpha} h_{H,t}\left((h_{L,t}\tilde{L}_t)^{\alpha} + \sum_{i=1}^{A_t} x_{i,t}^{\alpha}\right) \\
w_{L,t} &= \alpha\left(\frac{h_{H,t}\tilde{H}_{Y,t}}{h_{L,t}\tilde{L}_t}\right)^{1-\alpha} h_{L,t} \\
(1+\tau_R)p_{i,t} &= \alpha\left(\frac{h_{H,t}\tilde{H}_{Y,t}}{x_{i,t}}\right)^{1-\alpha}
\end{aligned}
$$

- labor supply

$$
\begin{aligned}
\tilde{H}_{Y,t} &= (1-\eta_H - z_{H,t}) \cdot H_{Y,t} \\
\tilde{L}_t &= (1 - z_{L,t}) \cdot L_t
\end{aligned}
$$

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R&D – Details

- R&D productivity (Jones, 1995)

$$\bar{\delta}_t \equiv \delta \cdot \frac{(A_{t-1})^{\lambda_1}}{\left(h_{H,t}\tilde{H}_{A,t}\right)^{1-\lambda_2}}$$

  - δ: productivity parameter
  - λ_1: intertemporal knowledge spillovers
  - λ_2: congestion externalities, "stepping-on-the-toes"

- factor demand

$$w_{A,t} = p_{A,t} \cdot \bar{\delta}_t \cdot h_{H,t}$$

- labor supply

$$\tilde{H}_{A,t} = (1 - \eta_H - z_{H,t}) \cdot H_{A,t}$$

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Intermediate goods sector

Machine production:

- linear production function: $x_i = k$
- full machine depreciation after one period (around 25 years)
- R&D patents last one period

Two types of machines:

1. **older-vintage**, only requiring capital ($\bar{R}$) to be produced (zero profit) $\Rightarrow$

$$R_{\text{older}} = \bar{R}$$

2. **latest-vintage**, also require blueprints from R&D (profits equal to the cost of blueprints, p_A) $\Rightarrow$

$$R_{\text{latest}} > \bar{R}$$

Competitive equilibrium

For a given balanced-budget fiscal policy $\{\tau_W, \tau_R, \phi, \phi_B, \omega_t(\rho)\}$, a **competitive equilibrium** is given by an allocation and prices, s.t.

(i) households maximize utility (education, leisure, consumption),

(ii) final good, R&D, intermediate sector firms maximize profits,

(iii) no-arbitrage condition for high-skilled holds ($w_{H,Y} = w_{H,A}$),

(iv) low-skilled and high-skilled labor markets clear,

(v) patent and final good markets clear

Calibration appendix

Calibration – External parameters

parameter	description	value
β	discount factor	0.55
γ	preference weight	1.44
α	output elasticity wrt. automated eff. labor	0.80
$\underline{a}$	lower bound ability level	100
μ_a	mean ability level	100
σ_a	variance in ability level	15
η	time spent in higher education	0.11
N	population size (norm.)	1000
λ_1	intertemporal knowledge spillover	0.67
λ_2	congestion externality	0.44
$\bar{R}$	interest rate	2.32

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Calibration – Policy parameters

parameter	description	value
τ_W	labor tax (%)	28.4
τ_R	robot tax (%)	5
ϕ	share of tot. to education spending (%)	26.9
ϕ_B	share of tot. to basic education spending (%)	78.3
ρ	progressivity of tax and transfer system	0.18

- ω calibrated to match progressivity of tax and transfer system of $\rho = 0.18$ (Heathcote et al., 2017)

$$\frac{\Delta \tilde{y}_{i,t}}{\Delta y_{i,t}} \frac{y_{i,t}}{\tilde{y}_{i,t}} = \frac{(1-\tau_{W,t})[w_{H,t}\tilde{h}_t - w_{L,t}\tilde{l}_t] + [\hat{T}_{H,t} - \hat{T}_{L,t}]}{[w_{H,t}\tilde{h}_t - w_{L,t}\tilde{l}_t]} \frac{w_{L,t}\tilde{l}_t}{(1-\tau_{W,t})w_{L,t}\tilde{l}_t + \hat{T}_{L,t}} = 1 - \rho = 0.82$$

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Calibration – Internal parameters

parameter	baseline	private	$private_{GER}$
δ	0.584	0.605	0.566
ψ_1	0.479	0.457	0.381
ψ_2	17.09	17.92	19.77
μ_B	0.354	0.352	0.357
μ_H	0.223	0.515	0.477
B	1.720	1.760	1.648
B_H	6.236	13.79	18.27
ν	-	$\rightarrow 1^*$	$\rightarrow 1^*$
ϵ	-	0.928	0.139
A_0	87.3	87.3	87.3

- *it follows:

$$h_{H,t} = B_H \cdot \left(h_{B,t}\right)^{1-\mu_H} \cdot \left((\theta_t)^{\epsilon} \cdot \left(\hat{E}_{H,t}\right)^{1-\epsilon}\right)^{\mu_H}$$

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Calibration – Targets

target	value	baseline	private	$private_{GER}$
R&D employment	1.00%	1.69%	0.90%	0.86%
college share	34.7%	34.7%	30.7%	35.9%
wage premium	1.86	1.86	1.86	1.86
$h_{H,2020}$ (norm.)	1	1	1	1
TFP growth (annual)	0.91%	0.91%	0.91%	0.91%
elast. college att. wrt. w_L	1.2	1.2	1.2	1.2
elast. w_L wrt. $\hat{E}_B$	0.54	0.54	0.59	0.55
priv. to publ. high. education, US	1.54	-	1.54	-
priv. to publ. high. education, GER	0.28	-	-	0.28

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Private education spending appendix

Private education spending

- (young-age) budget constraint

$$(1-\tau_{W,t})\cdot(1-\eta_j-z_{j,t})\cdot w_{j,t}+\hat{T}_{j,t}-\mathbb{1}_{[j=H]}\,\theta_t=c_{j,t}+s_{j,t}$$

- optimality for high-skilled worker, $j=H$

$$1=(1-\tau_{W,t})\cdot(1-\eta-z_{H,t})\cdot\frac{\partial w_{H,t}}{\partial\theta_t}$$

- with

$$\frac{\partial w_{H,t}}{\partial\theta_t}=(1-\alpha)^2\cdot\frac{\left((h_{L,t}\tilde{L}_t)^\alpha+\tilde{A}_t x_t^\alpha\right)}{\left(h_{H,t}\tilde{H}_{Y,t}\right)^\alpha}\cdot\frac{\partial h_{H,t}}{\partial\theta_t}$$

- and

$$\frac{\partial h_{H,t}}{\partial\theta_t}=B_H\cdot(h_{B,t})^{1-\mu_H}\cdot\mu_H\cdot\epsilon\cdot(\theta_t)^{-\frac{1}{\nu}}\cdot\left(\epsilon\cdot(\theta_t)^{\frac{\nu-1}{\nu}}+(1-\epsilon)\cdot\left(\hat{E}_{H,t}\right)^{\frac{\nu-1}{\nu}}\right)^{\frac{\nu}{\nu-1}\cdot\mu_H-1}$$

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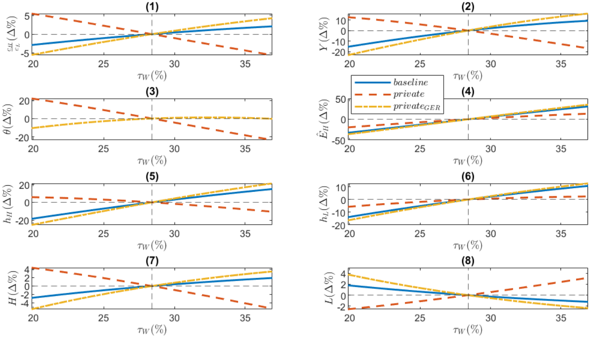
Private education spending – Tax policy



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