On the Optimal Interplay of Early and Late Education Subsidies and Taxation

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Motivation

- Observation:
  - Progressive income tax codes
  - Education subsidies: primary, secondary & tertiary education
- Questions: Optimal...
  - progressivity?
  - size and timing of education subsidies?
  - mix?

Objective

- Quantitative characterization
- Interactions:
  - Progressive income taxes: (i) redistribute, (ii) provide insurance, (iii) distort
  - Education subsidies: (i) mitigate distortions, (ii) redistribute, (iii) relax borrowing constraints, (iv) increase tax base
  - Timing: complementarity btw. non-tertiary & tertiary education subsidies

Approach

- Quantitative OLG model in GE:
  - inter-generational links
  - idiosyncratic college completion and earnings risk
  - borrowing constraints
- Households:
  - Labor supply, savings & consumption
  - Parents: Human capital investments into children
  - Children: college attendance
- Ramsey government:
  - Instruments: Early & late education subsidies, progressive income taxes & debt
  - Maximize social welfare, incl. transition

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Preview of Results

- Three policy experiments:
  - Higher tertiary education subsidies: $>$ 100%
  - Higher non-tertiary education subsidies: ($>$) triple
  - Combination of both instruments enables more effective policies and analyzing them separately can lead to wrong conclusions

Contribution

- Three related strands of literature:
  1. Optimal progressive taxation in quantitative heterogeneous agent models
  2. Progressive taxation, education policies & human capital accumulation
  3. Life-cycle human capital accumulation & frictions

Outline

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Time Line I: From Childhood to Parenting

Birth

Draw:
$\mathbf{h_0} \sim \pi(\mathbf{h_0^p})$

College?

Given $\mathbf{h_{ja}}$ ($\mathbf{h_0}$, i^p, $\mathbf{i^g}$)
i) which determines college completion probability p($\mathbf{h_{ja}}$)
ii) parents make inter-vivo transfer
iii) then idiosyncr. shock η realizes

Agents choose: attend college?

Coll. Shock

3 types w.r.t. qualification (q):
Non-college (q=n)
$\Phi(n)=0$, draw γ
Graduates (q=c)
$\Phi(c)=1$, p($\mathbf{h_{ja}}$)
Dropouts (q=d)
$\Phi(d)=\phi$, 1−p($\mathbf{h_{ja}}$)

This determines:
borrow limit = $\Phi * \underline{A}$
c-fees = $\Phi(q)(1-\boldsymbol{\theta})\kappa w_c$

Coll. Ends

Full time working for wage $w_q \gamma\eta\varepsilon$ until ret.

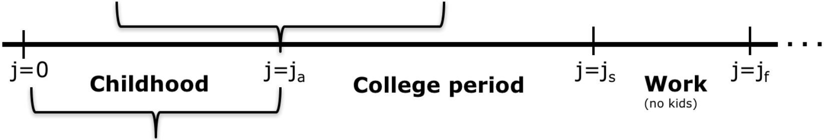
γ = fixed effect, drawn once with likelihood $p(\gamma^{high}|\mathbf{h_{ja}})$

ε = age and qualific. specific wage profile

η = idosyncr. shock, Markov

Have f Kids

Kids draw:
$h_0^c \sim \pi(h_0)$



Receive:
i^p and $\mathbf{i^g}$

Eat:
ξ

Given:
time reduction
$\Phi(q)\xi(\mathbf{h_{ja}})$ and wage

Choose:
c, l, a′, pay labor taxes **T(y)** and social security contributions

Time Line II: From Children Moving Out to Death

Kids become adults

HC process ends in:
$h_{ja}(h_0, i^p, i^g)$

Given kids h_{ja}^c and h_0^c parents decide over inter-vivos transfers

After that kids leave the, households and hence the utility function of parents

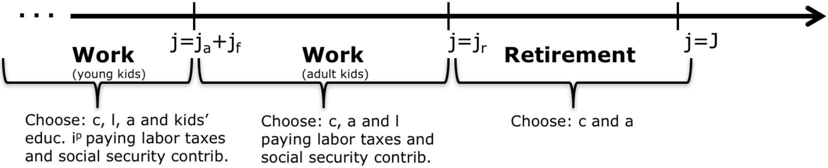
Retire

Leave workforce

Receive income from savings and pension benefits $p(y,q)$

Death

Death with certainty



Childhood: Human Capital Accumulation

- Parental & governmental investments:

  perfect substitutes, $i_j = i_j^p + i_j^g$
- Human capital accumulation function:

$$h_{j+1} = (1-\delta)h_j + \left(\kappa_j h_j^{\phi_j} + (1-\kappa_j)\left(\psi i_j\right)^{\phi_j}\right)^{\frac{1}{\phi_j}}$$

- Properties (cf. Cunha & Heckman (2007))
  - Dynamic complementarity: $\frac{\partial^2 h_{j+1}}{\partial h_j \partial i_j} > 0$
  - Self productivity: $\frac{\partial h_{j+1}}{\partial h_j} > 0$:
- Notice: age dependency of ϕ_j, κ_j

Benefits of High Human Capital in our Model

- Higher human capital leads to
  - higher chances for college completion: $\pi_c(h_{j_a})$
  - lower time costs of college attendance: $\lambda(h_{j_a})$
  - higher wages in expectation: $\pi_\gamma(h_{j_a})$

College Decision & Completion Shock

- College decision: indicator $\mathbf{1}_c(j_a, A, h_0, h_{j_a}, \eta)$, where

$$\mathbf{1}_c(\cdot) = \begin{cases} 1 & \text{if } E\left[V_t\left(j_a, A, h_0, h, \neg n, \eta\right)\right] > E\left[V_t\left(j_a, A, h_0, h, n, \eta\right)\right] \\ 0 & \text{otherwise, with} \end{cases}$$

$$E\left[V_t\left(j_a, A, h_0, h, \neg n, \eta\right)\right] = \pi_c(h)\underbrace{V_t\left(j_a, A, h_0, h, c, \eta\right)}_{\text{college graduate}} + \dots$$

$$\dots + (1 - \pi_c(h))\underbrace{V_t\left(j_a, A, h_0, h, d, \eta\right)}_{\text{college dropout}},$$

$$E\left[V_t\left(j_a, A, h_0, h, n, \eta\right)\right] = \pi_\gamma(h)\underbrace{V_t\left(j_a, A, h_0, h, n, \gamma^h, \eta\right)}_{\text{non-college, high } \gamma} + \dots$$

$$\dots + (1 - \pi_\gamma(h))V_t\left(j_a, A, h_0, h, n, \gamma^l, \eta\right).$$

Dynamic Complementarity & Wages

- Expected wage premium after college completion:

$$
\begin{aligned}
E\left[\Delta w_t(h_{j_a})\right] &= E\left[w_t(h_{j_a}) - w_{t,n}\right] \\
&= \pi_c(h_{j_a})E\left[w_{t,c}\right] + (1-\pi_c(h_{j_a}))E\left[w_{t,n}\right] - E\left[w_{t,n}\right] \\
&= \pi_c(h_{j_a})E\left[\Delta w_t\right] \\
&\text{with } E\left[w_{t,q}\right] = \left(\pi_\gamma(h_{j_a})\gamma^h + (1-\pi_\gamma(h_{j_a}))\gamma^l\right) w_{t,q}
\end{aligned}
$$

- Higher parental investments:
  - higher probability of college completion
  - higher expected wages, conditional on completion

Government

- Endogenous:
  - Labor income taxes:

$$T_t(y_t) = \max\left\{0, \tau_{l,t}\left(y_t - d_t \frac{Y_t}{N_t}\right)\right\}$$

  - Non-tertiary government education subsidies / investments:

$$\begin{aligned} \textit{primary}: \ & i^g_{j,t} = \bar{i}^g_t \zeta^g_{p,t} \\ \textit{secondary}: \ & i^g_{j,t} = \bar{i}^g_t (1 - \zeta^g_{p,t}) \end{aligned}$$

  - College subsidies (tertiary): θ_t
    college costs: $\kappa w_{t,c}(1 - \theta_t - \theta_{pr})$
- Exogenous: consumption taxes, capital income taxes, PAYG pension system

General Equilibrium

- Non-college workers & college dropouts: perfect substitutes, $L_{t,nd} \equiv L_{t,n} + L_{t,d}$
- Aggregate production:

$$Y_t = F(K_t, L_t) = K_t^{\alpha} \left[\left(L_{t,nd}^{\rho} + L_{t,c}^{\rho} \right)^{\frac{1}{\rho}} \right]^{1-\alpha}$$

- Aggregate component of college wage premium:

$$\frac{w_{t,c}}{w_{t,nd}} = \left(\frac{L_{t,nd}}{L_{t,c}} \right)^{1-\rho}$$

- Krueger and Ludwig (2016): importance of redistribution through Stiglitz (1985) GE effect

Outline

Calibration: Overview

- Today:
  - Fully calibrated to match all relevant moments
  - Government budget and pension system cleared
  - Partial equilibrium: exogenous wages and interest rates

First Stage Parameters: Government

Parameter	Interpretation	Value
θ	Public Tertiary Education Subsidy	38.8%
ζ_p	Weight on Primary Education Subsidies	50%
d	Tax Deduction Rate	27.1%
τ_c	Consumption Tax Rate	5.0%
τ_k	Capital Income Tax Rate	28.3%
τ_{ss}	Social Security Payroll Tax	12.4%
b	Debt to GDP Ratio	60%
gy	Government Consumption to GDP Ratio	17%

First stage parameters (selection)

Baseline Economy: Second Stage Parameters

- Government budget clears at $\tau_l = 0.45$

Target	Data	Model	Parameter	Value
Fraction non-college	0.56	0.56	time costs college	1.64
Dropout rate	0.50	0.50	curv. coll. success	1.12
College wage premium	1.80	1.81	wage of graduates	1.79
Capital output ratio	3.00	3.01	time discount rate	0.97
Non-tertiary / tertiary edu	2.62	2.63	invest. level / wage	0.048

Second stage parameters

Government Budget and Pension System

- Government budget: $\left\|\tau_l^* - \frac{T_t^* - \tau_c C_t - \tau_k r_t K_t}{Y_t^d}\right\| = 0$
- Pension budget: $\left\|\rho_{ss}^* - \frac{\tau_{ss} \sum_q w_{t,q} L_{t,q}}{\sum_{j=jr}^{J} N_{t,j} \int \gamma w_{t,q} d\Phi_{t,j}}\right\| = 0$
- Tax progressivity: $\left\|z^* - d\frac{Y_t}{N_t}\right\| = 0$

For all parameters $p \in (\tau_l, \rho_{ss}, z)$ the benchmark model fits respective targets satisfying $f(p) = \|p^* - p\| < 0.001\ \forall p$.

Selected Parameters

- Four year periods: childhood for $j = 0, \ldots, j_a - 1 = 0, \ldots, 3$
- Recall: Human capital accumulation function

$$h_{j+1} = (1-\delta)h_j + \left(\kappa_j h_j^{\phi_j} + (1-\kappa_j)\left(\psi i_j\right)^{\phi_j}\right)^{\frac{1}{\phi_j}},\ \sigma_j = \frac{1}{1-\phi_j}$$

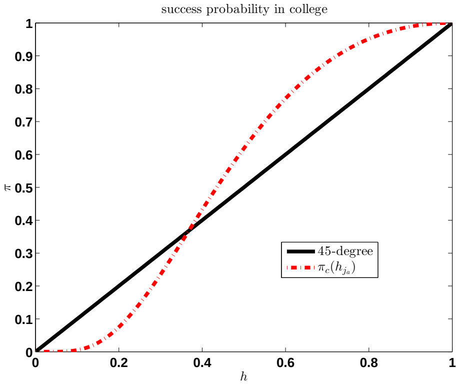
- Calibration based on Cunha et al. (2010):

$$\begin{aligned} &\delta = 1 && \\ &\kappa_0 = \kappa_1 = 0.75, && \kappa_2 = \kappa_3 = 0.95 \\ &\sigma_0 = \sigma_1 = 1.5, && \sigma_2 = \sigma_3 = 0.5. \end{aligned}$$

- Altruism: $\nu = 0.5$
- Annual interest rate: $r = 3.5\%$

Success Probability

- Recall success probability in college: $\pi_c(h_{j_a})$



- Convex region: approximation to thresholds
- Concave region: decreasing marginal success probability
- Note: generally, calibration ensures that maximum reasonable $h^c_{j_a}$ is equal to 1.

Outline

Policy Experiment

- Three experiments:

1. **College Subsidies** θ, $\kappa w_c(1-\theta-\theta_{pr})$:

   Five scenarios from 0.0% to 100%

2. **Non-tertiary education subsidies** $\bar{i}^g/w_c$:

   Five scenarios from 1.7% to $\approx$ 14.0%

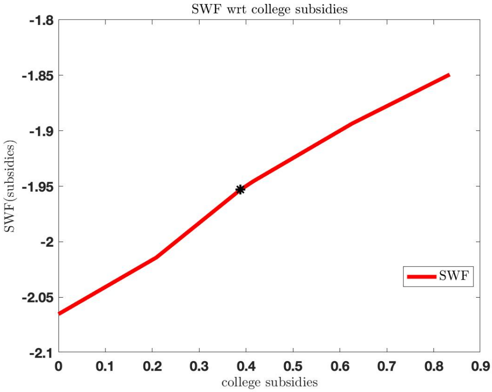
3. **College and non-tertiary education** subsidies combined:

   All 25 scenarios combined

Government budget is cleared by τ_l.

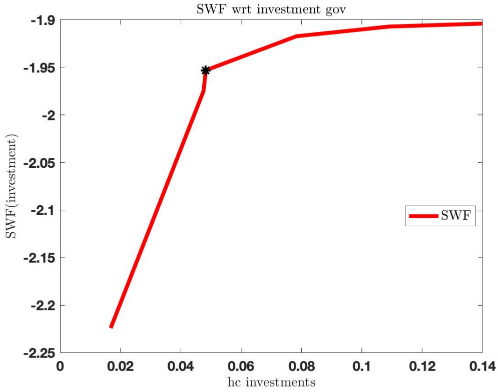
College Subsidies (BM: $\theta = 0.388$)

θ	0.000	0.209	0.417	0.625	0.834
ϕ_{nc}	0.847	0.731	0.644	0.490	0.374
SWF	-2.065	-2.014	-1.945	-1.894	-1.849
τ_l	0.454	0.453	0.457	0.460	0.466
Av. hc	0.362	0.364	0.377	0.398	0.411

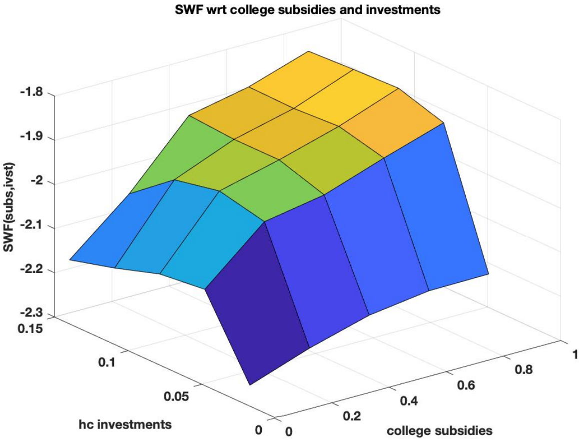


Investments Non-Tertiary Education (BM: $\bar{i}^g = 0.048$)

ivstL	0.017	0.048	0.078	0.109	0.140
ϕ_{nc}	0.811	0.643	0.533	0.439	0.344
SWFun	-2.224	-1.975	-1.917	-1.907	-1.904
τ_l	0.440	0.453	0.474	0.493	0.508
Av.hc	0.172	0.377	0.457	0.522	0.588

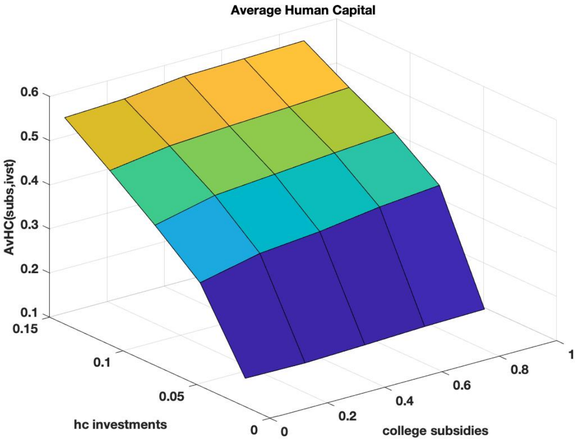


Subsidies and Investment Level: SWF



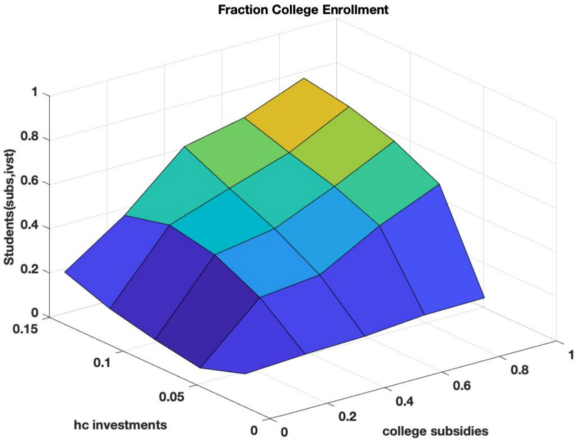
- upward triangle, (0;0), threshold

Subsidies and Investment Level: Human Capital



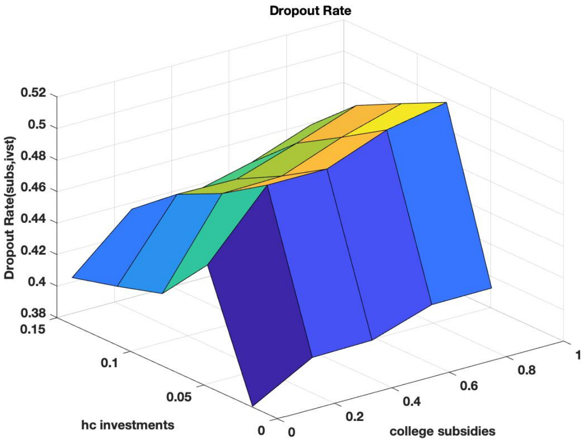
- seedtime

Subsidies and Investment Level: Enrollment



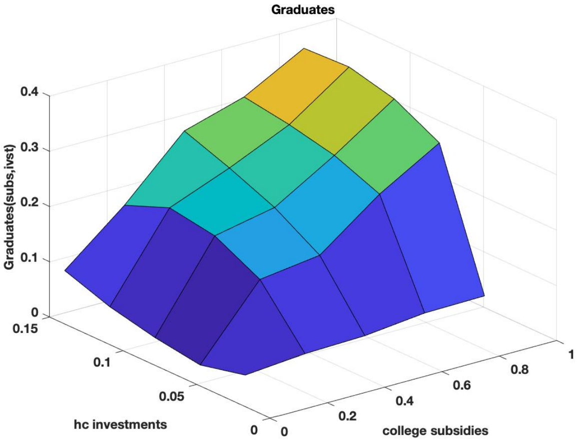
- harvest (if you can)

Subsidies and Investment Level: Dropout Rate



- no one tries, no one fails

Subsidies and Investment Level: Graduates



- graduates = f(attendance, skill)

Summary: Policy Experiments

1. Higher college subsidies
   - Crowding-in of parents' investments & human capital
2. Higher non-tertiary education subsidies:
   - Crowding-out of parental investments
   - Human capital increased, educational inequality decreased
3. Subsidies are reinforcing each other:
   - The effectiveness of a subsidy depends on the level of the other subsidy
   - This *"upward triangle"* fits the general finding of the human capital literature: Early investment has to be followed up by late investment, or its effect is lessened

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Conclusion

- Partial equilibrium: higher tertiary & non-tertiary education subsidies
- Interplay of policy instruments matters
- Next steps:
  - Optimal mix
  - General equilibrium