University Research and the Market for Higher Education

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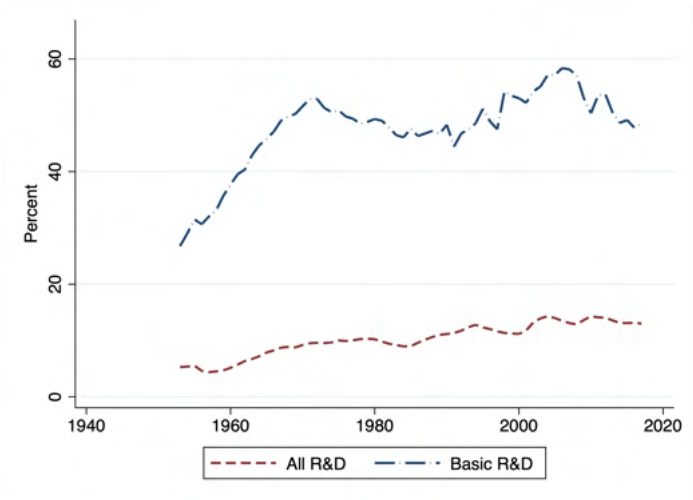
CIGS End-of-Year Macroeconomic Conference
December 2021

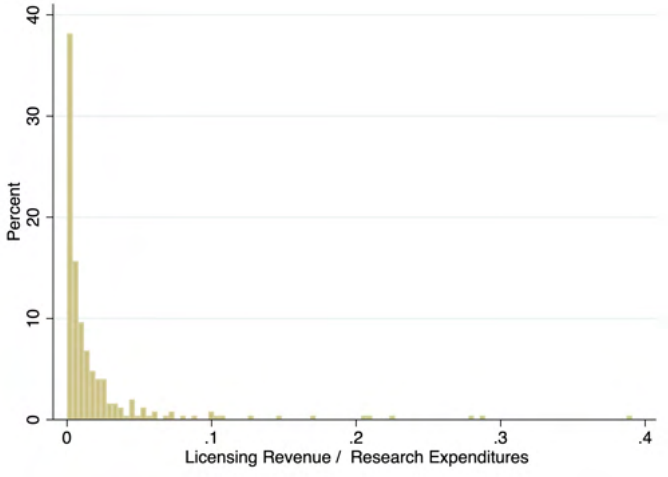
R&D Contribution of Higher Education Sector



Why Do Universities Spend on R&D?

1. **Paradigmatic Models of R&D:** Patents and Profits

University Patent Revenue is Tiny



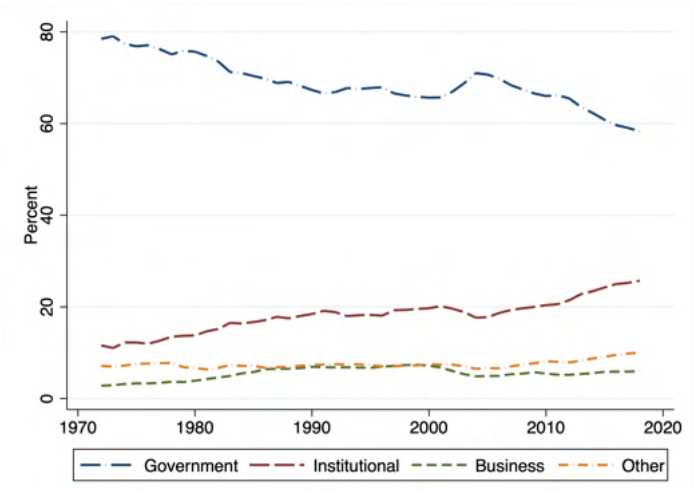
Why Do Universities Spend on R&D?

1. **Paradigmatic Models of R&D:** Patents and Profits

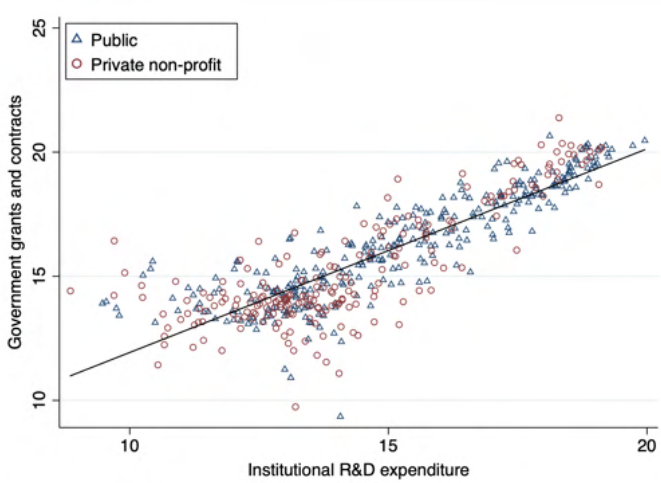
2. **The Traditional View:** Government Research Grants and Subsidies

The Cross-Subsidization of University R&D

Levels



University R&D and Government Grants



Why Do Universities Spend on R&D?

1. **Paradigmatic Models of R&D:** Patents and Profits
2. **The Traditional View:** Government Subsidies and Research Grants
3. A "**Culture of Science**" and research as amenity

This Paper

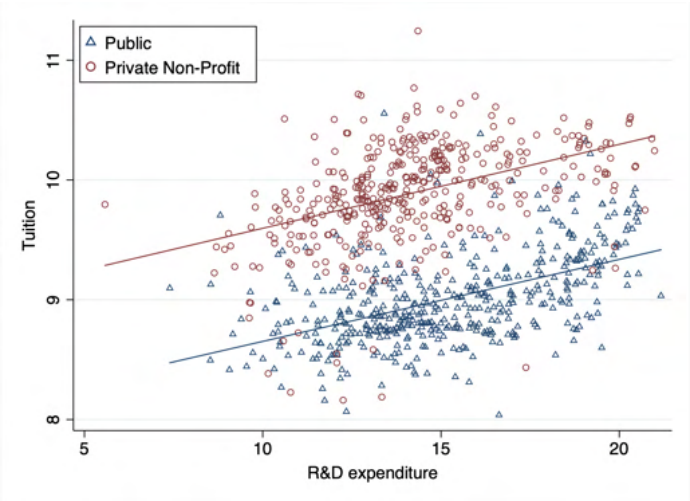
Idea: University R&D motivated by competition for tuition and talented students

- R&D as investment to improve their position in the hierarchy of colleges
- Command higher tuition; attract better students and faculty.
- Does not require imperfect appropriability, gov. funding, or patents

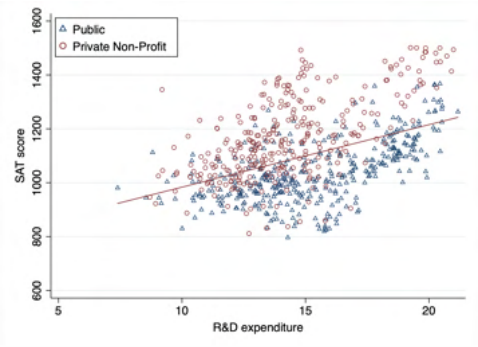
Implications: University R&D depends on market structure of higher education

- R&D increases with student willingness-to-pay for quality
- R&D increases with competition between universities

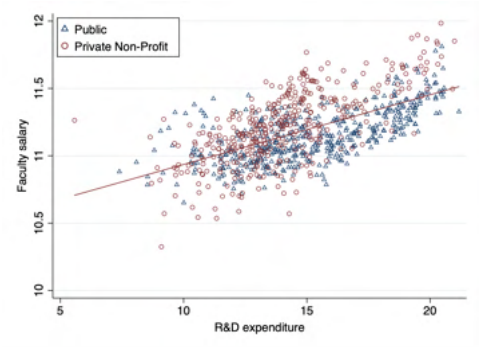
Research Universities in the Market for Higher Education



Research Universities in the Market for Higher Education

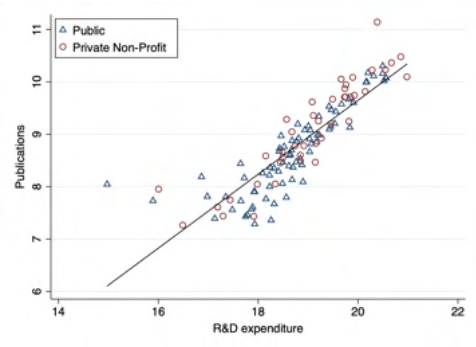


(a) Student Ability

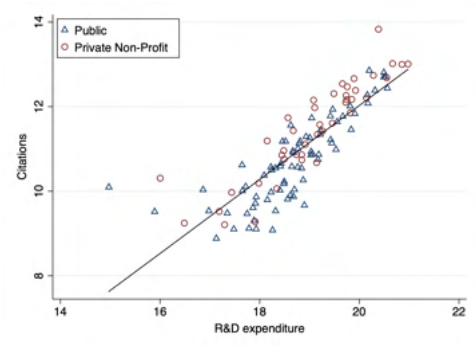


(b) Teacher Quality

Research Universities in the Market for Higher Education



(a) Publications



(b) Citaitons

Our Approach

- **Develop a model** consistent with new facts where university R&D is shaped by competition for tuition and talented students.
- **Characterize equilibrium through series of propositions** which highlight manner in which R&D depends on market for higher education.
- **Calibration using administrative microdata** replicating features of higher education, including institutional heterogeneity in revenues and expenditures.
- **Policy counterfactual** quantifying impact on university R&D of proposed expansion in federal need-based financial aid.

The Model

Outline

The Model

- Dynamic general equilibrium model of market for higher education sector
- Heterogeneous intergenerational households facing financial frictions
- Colleges engaged in research and teaching subject to student peer-effects

The Equilibrium

- Endogenous hierarchy of college qualities
- Two-sided student sorting by ability and family background
- Cross-subsidization of R&D depending on demand and competition.

Households

$$\mathcal{U}(h,z) = \max_{c,k} \left\{ (1-\beta) \left[\sum_{a=1}^{10} \delta^{a-1} \ln c_a \right] + \beta \mathbb{E} \left[\mathcal{U}(h',z') \right] \right\}$$

subject to budget constraint

$$(1+\bar{a}_c) \sum_{a=1}^{10} \left(\frac{1}{1+r} \right)^{a-10} c_a + \phi(y) p(k,z) = (1-a_y) \left[\sum_{a=1}^{10} \left(\frac{1}{1+r} \right)^{a-10} (w_a \cdot h)^{1-\tau_y} \right]$$

where the child's ability is given by,

$$z = (\xi_z h)^{\alpha_h} \qquad \ln \xi_z \sim \text{i.i.d.} \mathcal{N} \left(-\sigma_z^2/2, \sigma_z^2 \right)$$

and human capital technology,

$$h' = z q(k)^{\alpha_q} \xi_y \qquad \ln \xi_y \sim \text{i.i.d.} \mathcal{N} \left(-\sigma_y^2/2, \sigma_y^2 \right)$$

Universities

$$V(k) = \max_{\phi, \mu_q, \mu_k, e_q, e_k} \ln q + \beta V(k')$$

subject to budget constraint

$$\underbrace{G(k_j)\left(e_{jl} + w\bar{h}_l\right)}_{\text{Research}} + \underbrace{e_{jq} + w\bar{h}_q}_{\text{Instruction}} = \mathbb{E}_{\phi_j(.)}[p(k, z)]$$

the education technology with peer-effect

$$q = \zeta(\phi; p) \times \bar{h}_q^{\omega_h} e_q^{\omega_e} k^{\omega_k} \quad \text{with} \quad \ln \zeta(\phi; p) = \omega_z \, \mathbb{E}_{\phi(.)}[\ln(z)] - \sigma_u^2(\phi; p)$$

and research technology,

$$k' = k^{\gamma_k} e_k^{\gamma_e} \bar{h}_k^{1-\gamma_e-\gamma_h}$$

- Research can improve its reputation and tuition while teaching expenditure can't.

Government

Tuition subsidies cover fraction $1 - \phi(y)$ of tuition costs, where

$$\phi(y) = \frac{y^{\tau_n}}{1 + a_n}$$

Research subsidies cover fraction $1 - G(k)$ of research expenditures, where

$$G(k) = \bar{G} k^{-\tau_G}$$

Government balances budget each period through (non-distortative) consumption tax.

Firms

Competitive firms maximize profits,

$$\pi = \max_{H_F} \; A(K)H_F - wH_F$$

where TFP depends on a spillover for university R&D

$$A(K) = \bar{A}K^{\iota_k}$$

where aggregate $K = \mathbb{E}[k_j]$.

Marketing Clearing

EQ Def

Higher Education Market

$$\int \int \mathbb{1}\left[k(h,z) \in \mathcal{K}\right] f(h,z) dhdz = \int \mathbb{1}\left[k \in \mathcal{K}\right] g(k) dk$$

Labor Market

$$H_F + \int h\, \mu_q(h|k) g(k) dhdk + \int h\, \mu_k(h|k) g(k) dhdk = \int h\, f(h,z) dhdz$$

Final Goods Market

$$F(H_F) = \int_i c_i\, di + \int \left(e_{kj} + e_{qj}\right) dj$$

Analytical Properties of the Equilibrium

Student Sorting and the Tuition Schedule

Proposition

The equilibrium student sorting across colleges is given by,

$$q_t(e,z) = \left(\frac{e}{\underline{p}_t}\right)^{\epsilon_{1t}} z^{\epsilon_{2t}}$$

The equilibrium before-financial-aid tuition schedule is given by

$$p_t(k,z) = \underline{p}_t q(k)^{\frac{1}{\epsilon_{1t}}} z^{-\frac{\epsilon_{2t}}{\epsilon_{1t}}}$$

where $\underline{p}_t$, $\epsilon_{1t}, \epsilon_{2t}$ *are non-negative time-varying aggregates.*

A Simplified Model without Peer-Effects ($\omega_z = 0$)

Proposition

The equilibrium before-financial-aid tuition schedule is given by

$$p_t(k, z) = \underline{p}_t q(k)^{\frac{1}{\epsilon_{1t}}}$$

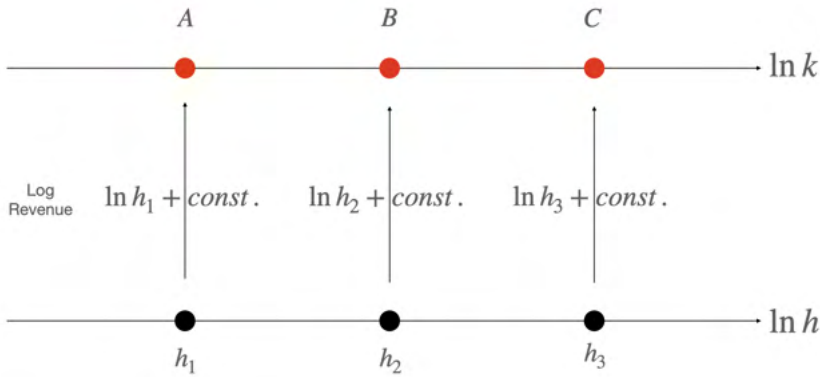
where in the absence of peer-effects, $\epsilon_2 = 0$, and ϵ_1 is given by

$$\epsilon_1 = \omega_h + \omega_k \frac{\Sigma_k}{(1 - \tau_n)\Sigma_h}.$$

Households spend a constant share of income on education given by

$$s = \frac{\beta \alpha_q (1 - \tau_n)\, \epsilon_1}{1 - \beta \alpha_h}.$$

Sorting


A
B
C
ln k
Log
Revenue
ln h1 + const.
ln h2 + const.
ln h3 + const.
ln h
h1
h2
h3

A Simplified Model without Peer-Effects ($\omega_z = 0$)

Proposition

In the steady state, the share of tuition revenue spent on research is given by,

$$s_R = \frac{\beta\, v}{\omega_h + \beta\, v}$$

where v, the marginal value of scientific capital to the university, is given by

$$v = \frac{\omega_h \frac{\Sigma_R}{\Sigma_k} + \omega_k}{\left(1 - \beta\left(\gamma_h \frac{\Sigma_R}{\Sigma_k} + \gamma_k\right)\right)}.$$

Lemma: In equilibrium, $V(k) = v_0 + v \cdot \ln(k)$, so v is sufficient stat for R&D incentive.

Effect of progressive tuition subsidies $\tau_n \uparrow$ without peer effect

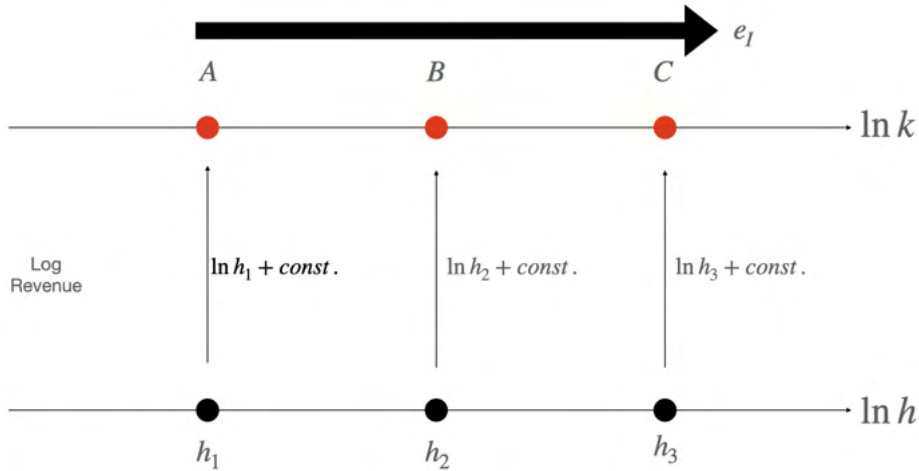
- Tuition Effect: Decreased tuition dispersion decrease research.

$$\Sigma_R = (1 - \tau_n) \underbrace{\Sigma_h}_{\text{std of log human capital}}$$

- Competition Effect: Decreased knowledge dispersion increases research.

$$\Sigma_k = \frac{1}{1 - \gamma_k} \Sigma_R = \frac{1}{1 - \gamma_k} (1 - \tau_n) \Sigma_h$$

Higher Σ_k leads to less benefit



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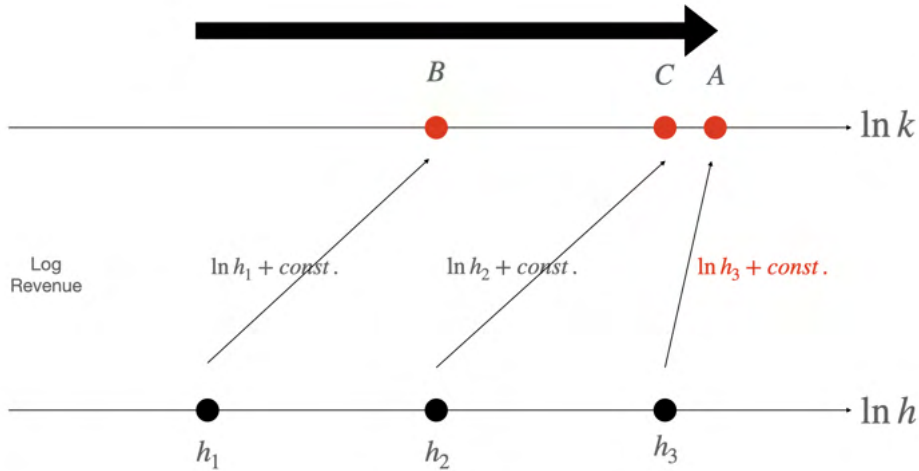

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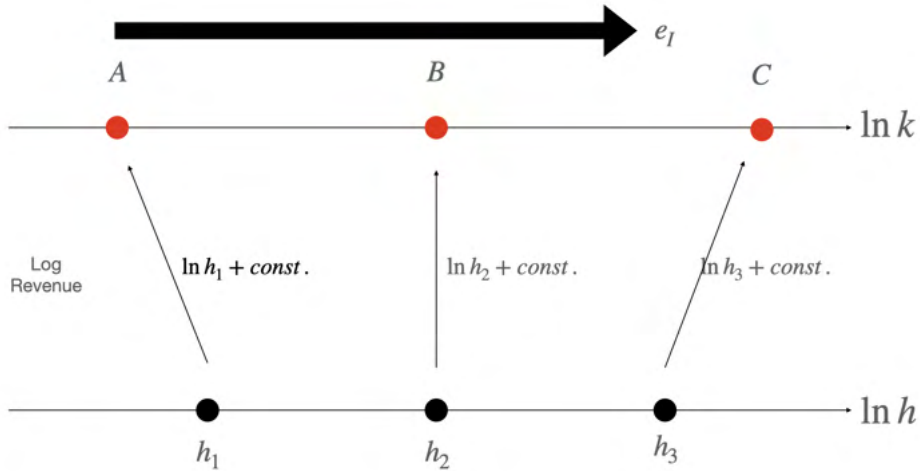

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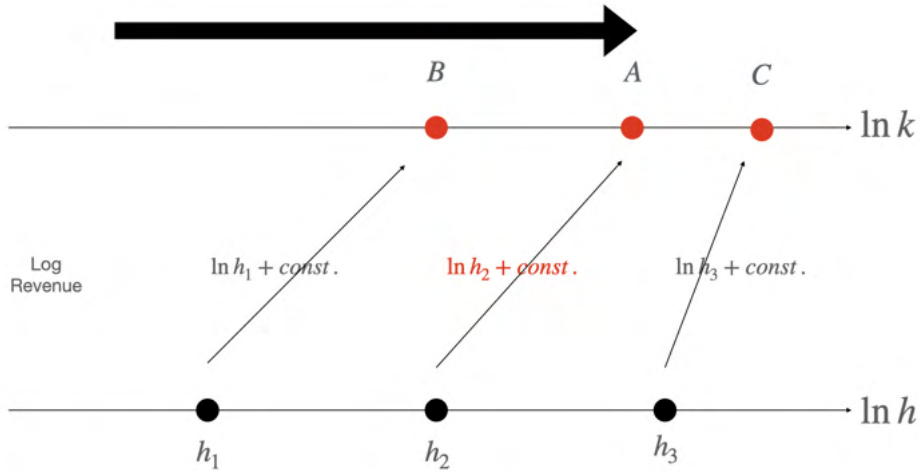


A Quantitative Exercise

Calibration Strategy

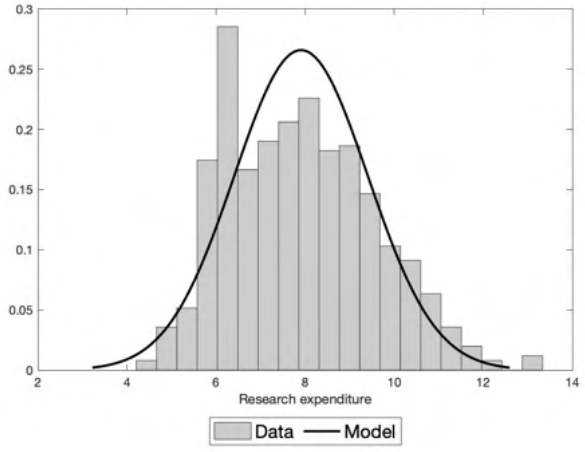
1. Externally calibrate parameters such as preferences, depreciation of knowledge, spillover, and policy
2. match stylized facts from microdata on household education expenditure and university-level heterogeneity in revenues and expenditure

Internal Calibration Model Fit

Parameter Values

	Description	Source	Data	Model
Households Sector	Standard deviation (log) household income	CBO	0.84	0.88
	Reg. test-scores on parent's earning (slope)	NLSY	0.12	0.13
	Reg. test-scores on parent's earning (R^2)	NLSY	0.11	0.11
	Share of household income spent on education	OECD	1.6%	1.6%
	Inter-generational elasticity (IGE)	Mazumber (2015)	0.4	0.40
Higher Edu. Sector	Standard deviation (log) university revenues	IPEDS	0.63	0.59
	Tuition share in total university revenue	IPEDS	0.83	0.83
	Tuition elasticity w.r.t. total revenue	IPEDS	0.64	0.71
	Research share in total university expenditure	IPEDS & HERD	0.24	0.25
	Research elasticity w.r.t. total revenue	IPEDS & HERD	0.14	2.51
	Teaching quality spillover from research	Biasi (2021)	0.013	0.013
	Equipment expenditure share in teaching	IPEDS	0.40	0.40
	Equipment expenditure share in research	IPEDS & HERD	0.54	0.54

A Validation Exercise



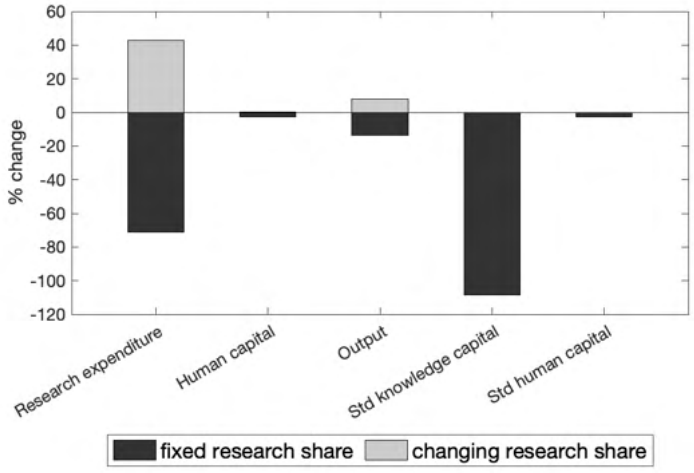
Counter-factuals

1. Long-run effect of removing research grants on university research
2. Long-run effect of removing federal student financial aid on university research
3. Transition of One-time permanent shift in federal student financial aid $\{a_n, \tau_n\}$. Estimated from NPSAS micro-data to match expenditure by family background

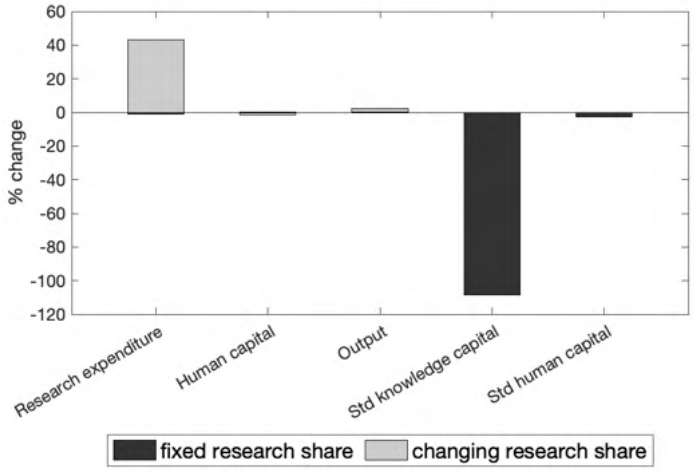
$$\log(\text{net tuition}) = \tau_n \cdot \log(\text{household income}) + \mathbf{X}'\beta + \epsilon$$

setting level (internally) to match average public subsidy to higher education

Long-Run Impact of Removing Research Grants



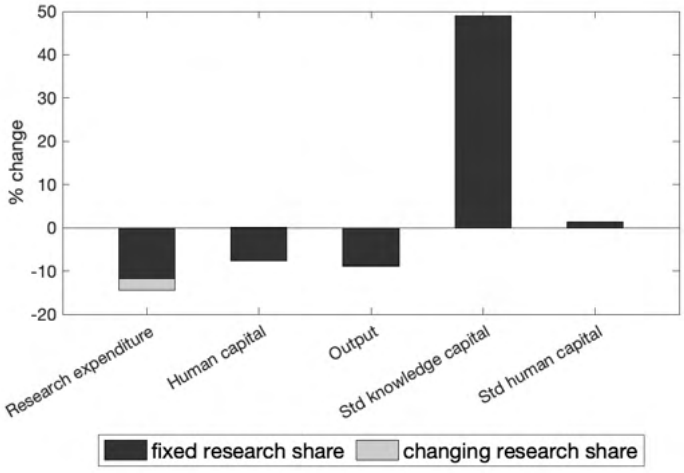
Long-Run Impact of Removing Meritocracy: the long-run



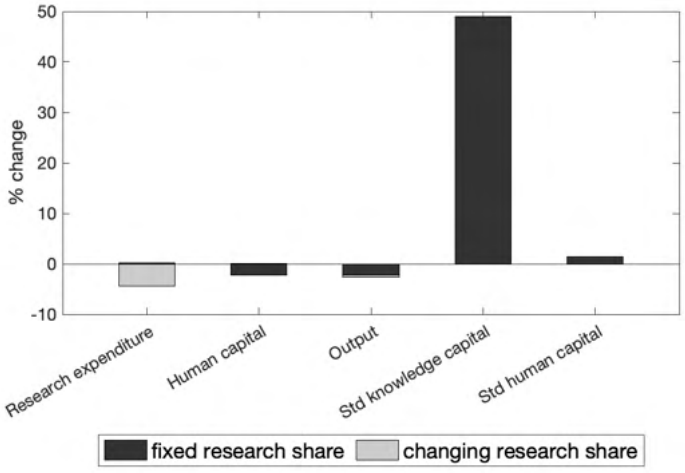
Discussion: Removing Research Grants

- Income inequality decreases by 3%.
- Removing meritocracy **increases** research expenditure. Σ_K decreases and competition effect is large.
- Flat research grants are better than meritocratic grants.

Long-Run Impact of Removing Federal Tuition Subsidies



Long-Run Impact of Removing Progressivity of Tuition Subsidies



Discussion: Removing Tuition Subsidies

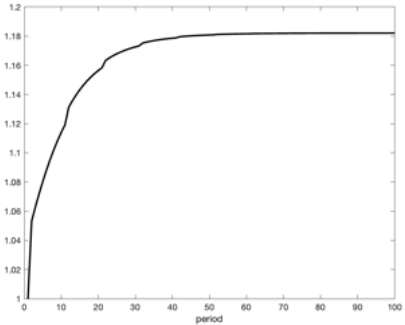
Market Size Effects

- direct increases in university revenue through subsidies

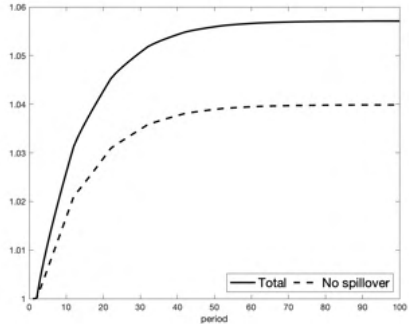
Research Share Effects

- **Tuition Effect:** less incentive to climb hierarchy (decrease $\Sigma_R \rightarrow$ decrease R&D)
- **Competition Effect:** universities become more similar (decrease $\Sigma_k \rightarrow$ increase R&D)
- ... quantitatively, **Competition Effect** dominates

The Transition Path of Expansion of Tuition Subsidies

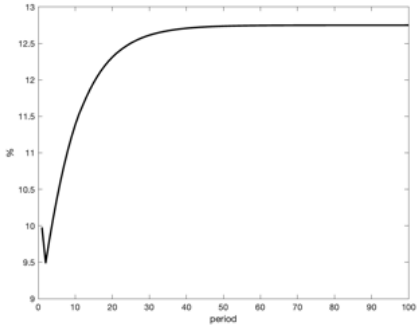


(a) Research Expenditure

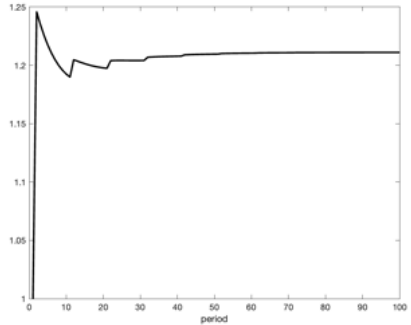


(b) Aggregate Output

The Transition Path: Source of R&D Growth

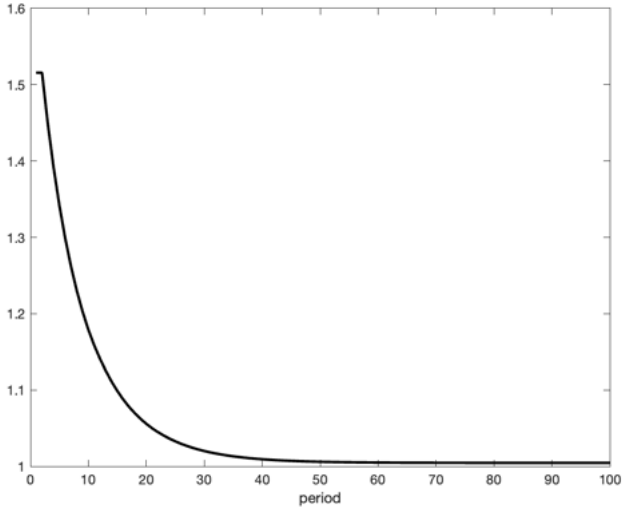


(a) Cross-Subsidization Rate

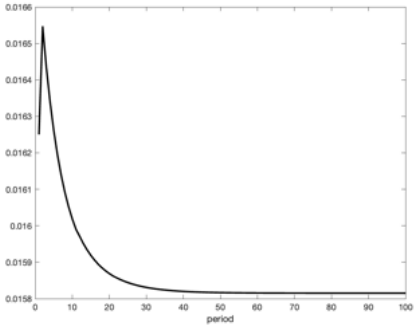


(b) University Revenue

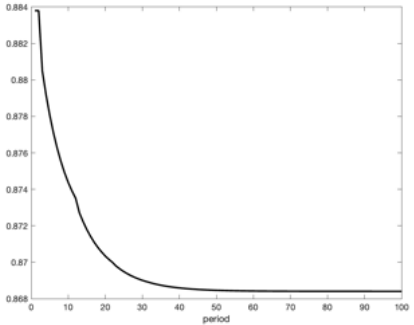
The Transition Path: Competition Effects and Σ_K



The Transition Path: Demand Effects



(a) Household Edu. Expenditure



(b) Household Income Inequality

Discussion: The Transition Path

- Expenditure and tuition jumps immediately because poor households can send children to college with a help of progressive subsidies.
- Expenditure decreases gradually because the difference in quality between high and low ranked colleges decreases.

Conclusion

- **University R&D is important** but not well described by paradigmatic models, and traditional explanation leaves many facts unexplained.
- This paper **develops a new model of university R&D** driven by competition for tuition and talented students that can quantitatively replicate new key facts
- **Novel policy implications** for inter-dependence of education and R&D policies
  - Model predicts removing meritocracy of research subsidies increase R&D by $\approx 40\%$
  - Model predicts federal tuition subsidies increase R&D by $\approx 15\%$
  - *Work in Progress*: international comparisons of university R&D

Work in Progress: International Comparisons

Country	Gross research	Research Performance by Source				Research Performance by Type			
		Business	Government	Higher Edu.	Nonprofits	Basic	Applied	Development	Other
United States	496.6	356.1	56.1	64.6	19.9	83.9	97.3	315.3	0.0
China	408.8	314.0	66.2	28.6	–	20.8	44.2	344.2	0.0
Japan	170.0	133.5	13.4	20.9	2.2	20.2	33.8	108.3	7.7
Germany	114.8	78.9	16.2	19.9	–	–	–	–	–
South Korea	74.1	57.4	8.7	6.7	1.2	12.7	15.4	45.9	0.0
France	60.8	39.6	8.0	12.3	1.0	14.8	22.9	21.1	2.0
India	50.3	21.9	26.4	2.0	–	8.0	11.2	11.8	19.3
United kingdom	46.3	30.4	3.1	11.9	0.9	7.8	20.0	18.4	0.0

Appendix

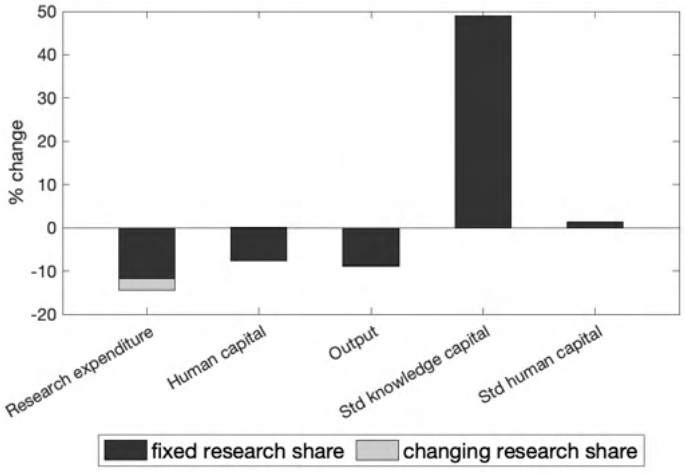
Equilibrium

A sequence of tuition schedules $\{p_t(q,z)\}_{t=0}^{\infty}$, colleges' policy functions $\{\phi_t(k,z), \mu_{It}(k,h), \mu_{qt}(k,h), e_{It}(k), e_{qt}(k), q_t(k)\}_{t=0}^{\infty}$, household's policy functions $\{c_t(h,z), \ell_t(h,z), q_t(h,z)\}_{t=0}^{\infty}$, and distributions of human capital and scientific knowledge $\{f_t(h,z), g_t(k)\}_{t=0}^{\infty}$ such that:

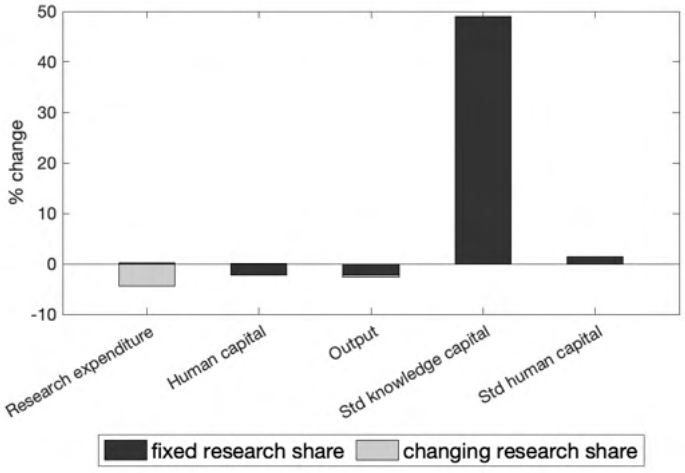
1. Household policy functions $c_t(h,z), \ell_t(h,z), q_t(h,z)$ solve the household problem
2. College policy functions $\mu_{qt}(k,h), \mu_{It}(k,h), \phi_t(k,z), e_{It}(k), e_{qt}(k)$ solve the university problem
3. Distribution $f_t(h,z)$ conforms with intergenerational law of motion for human capital and the sorting rule, $q_t(h,z)$
4. Distribution $g_t(k)$ conforms with law of motion of k and research activities.
5. Education markets, labor markets, and goods markets clear

Return

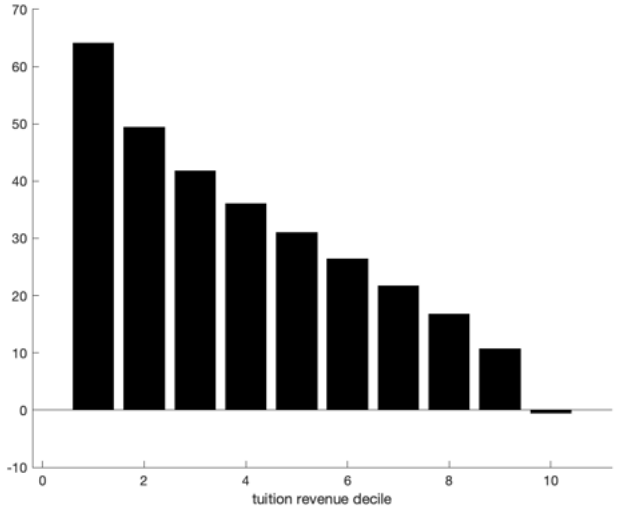
Removing the current US subsidies: the long-run



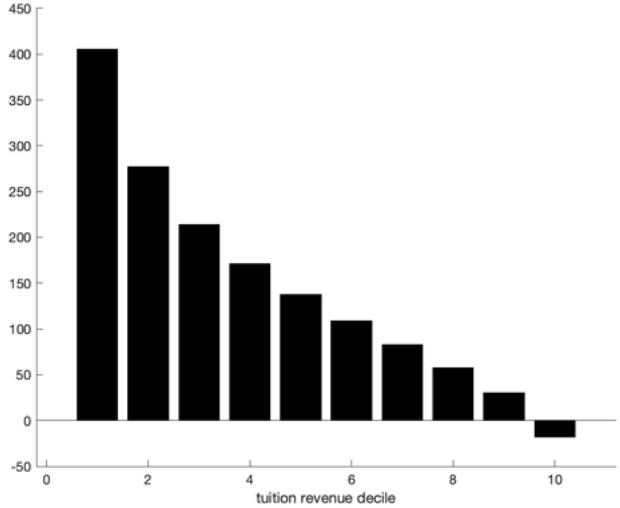
Removing the current US progressivity: the long-run



Tuition revenues for each decile



Research expenditure for each decile



Externally Calibrated Parameters

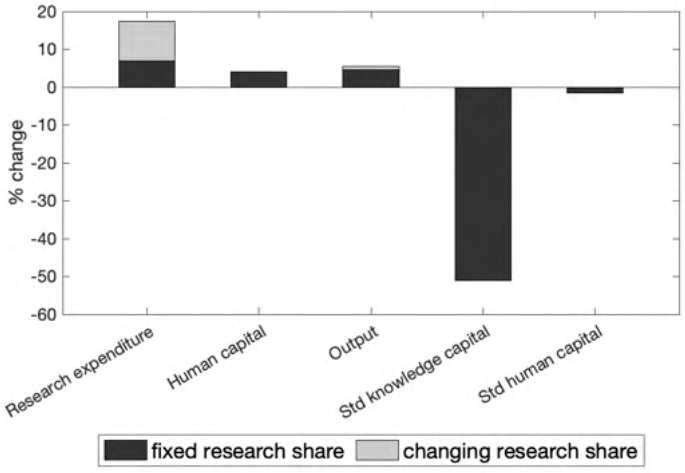
Parameter	Description	Value	Source
δ	Time discount factor	0.85	Standard (annually 0.96)
η	Inv. elast. of labor supply	2.00	Standard
γ_K	Depreciation of knowledge	0.52	Hall et al. (2010)
ι_K	Spillover of knowledge	0.10	Hall et al. (2010)
τ_y	Income Tax Progressivity	0.15	Heathcote et al. (2017)
τ_n	Tuition Subsidy Progressivity	0.18	NPSAS
$\bar{a}_y$	Average household income tax	0.20	CBO
$\bar{a}_n$	Average student education subsidy	0.53	OECD

Internally Calibrated Parameters

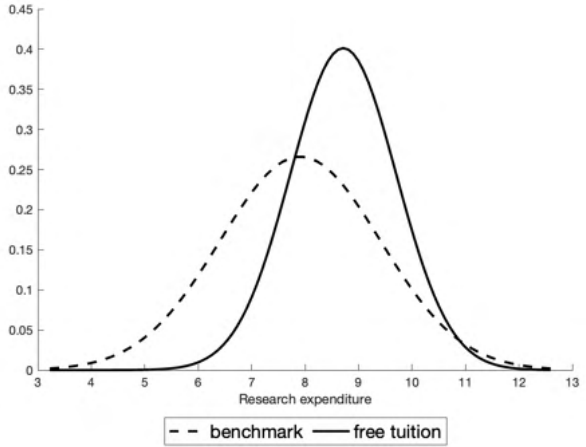
Data Targets

Parameter	Description	Value
β	Inter-generational household preference	0.01
σ_y	Labor market productivity shock	0.01
σ_z	Children ability shock	2.44
α_q	Elasticity of human capital w.r.t. college quality	0.22
α_h	Elasticity of children ability w.r.t. parents' human capital	0.29
β_C	College time preference	0.15
ω_k	Elasticity of school quality w.r.t knowledge	0.09
ω_z	Elasticity of school quality w.r.t peer effects	0.56
ω_e	Elasticity of school quality w.r.t equipment	0.14
γ_e	Elasticity of knowledge w.r.t equipment	0.26
(a_G, τ_G)	External research grant and contract award schedule	(0.01, 0.72)

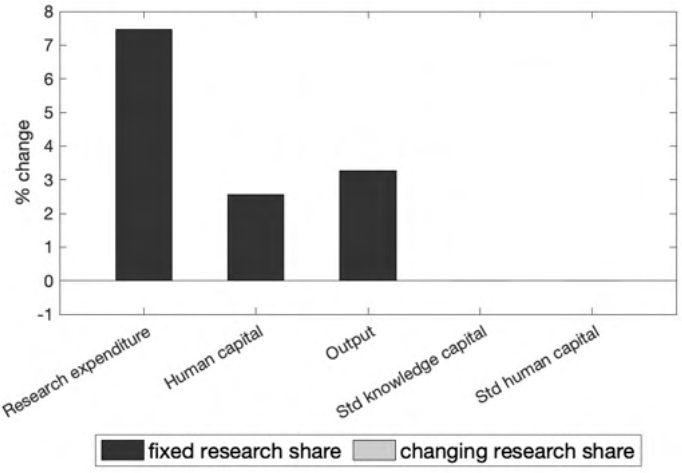
Long-Run Impact of Expansion in Federal Tuition Subsidies



Long-Run Distributional Changes in R&D



Increasing a_n: the long-run



Increasing τ_n: the long-run