

Population Aging and the Market for Higher Education: Implications for Education Finance Reform

Dirk Krueger Alexander Ludwig Irina Popova

University of Pennsylvania, CEPR and NBER
EUI, Florence, Goethe University Frankfurt, and CEPR
University of Bonn and ECONtribute

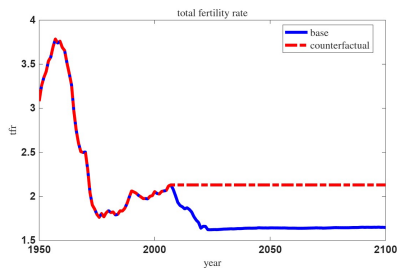
Seminar at the University of Regensburg

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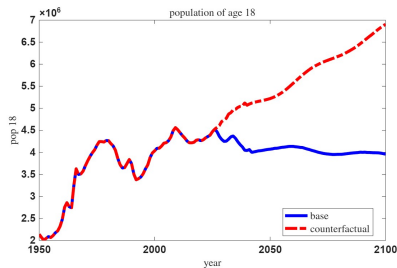
Motivation: Macro Trends in the College Market

- **Demographic cliff** in higher education:
 - ▶ Smaller predicted high-school graduation classes: 5% down from 2025 to 2032 (NCES Digest of Education Statistics, 2023).
 - ▶ Declining enrollments: 2021 enrollments ca 15% lower than in 2010 (NCES Digest of Education Statistics, 2023)
 - ▶ College closures: about 100 institutions closed between AY 2022/23 and AY 2023/24 (2024 NCES statistics).
- Potential future **shortages of STEM** graduates
 - ▶ STEM is immigrant heavy (NSF Board, 2024) & change in immigration policies can lead to severe STEM shortages.
 - ▶ STEM careers are getting shorter and are subject to technological obsolescence (Deming and Noray, 2020)
 - ▶ STEM occupations expected to grow faster than non-ST (BLS 2025)
- **Broad Agenda:** How will/should **private higher education** & **public higher education (policy)** respond to these trends?
- **Today's Talk:** Analysis of **reduced public college funding** against backdrop of **shrinking size of high-school graduates**.

Motivation: (Projected) Demographic Cliff



(a) Total Fertility Rate



(b) Population Age 18

Notes: Projected fertility rate and total population. Own calculations based on UN projections and Human Mortality Database.

This Paper

- **General equilibrium** model of **college and labor market** with demographic and (**later**: technological) change. Key aspects:
 - ▶ Endogenous demand and supply of college education, **heterogeneous college quality and majors**.
 - ▶ Full **life cycle** model with **college quality- and major-specific wage premia** after college.
 - ▶ Thought experiments: **reduction in public subsidies** for higher education in presence of **demographic cliff**.
- Idiosyncratic Motivation: Krueger, Popova and Ludwig (2025):
 - ▶ Focused on model of early childhood human capital accumulation & college choice
 - ▶ Evaluated fundamental education reforms (free college, better public high schools, mix of both)
 - ▶ But: mapping from college choice (demand) to labor market outcomes was exogenous and policy invariant. [▶ Literature](#)

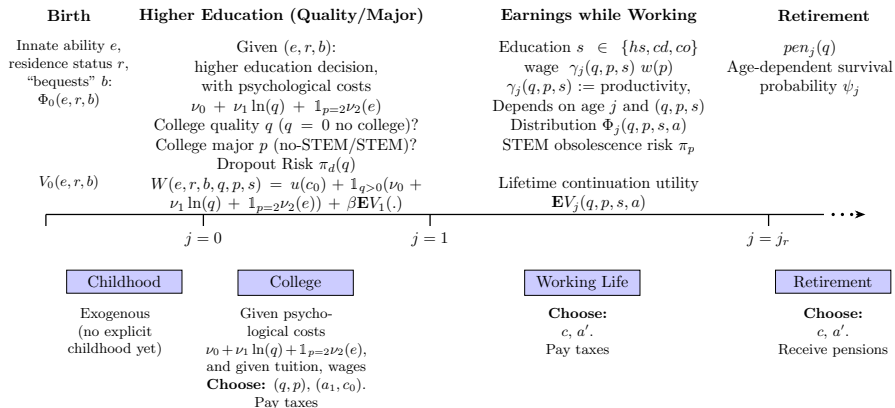
Outline

- ① Motivation
- ② **The Model**
- ③ Calibration
- ④ Thought Experiments
- ⑤ Conclusion

The Model: Broad Overview

- **Life cycle** (exposition: $j = 0, 1$) model with equil. college market
- Demand: life-cycle households choose **college quality** q and **program** p
 - ▶ Initial conditions: ability e , residence r , assets b .
 - ▶ Choose **college quality** q and **program of study** p , given labor market payoffs, utility costs & benefits from each potential (q, p) .
 - ▶ In model, each (q, p) combination is a **separate college type**.
- Supply: Competitive, **profit-maximizing colleges** market with **CRTS** technology (Cai and Heathcote, 2022). Colleges choose
 - ▶ Per-student discretionary **expenditures** i .
 - ▶ **Average ability** \bar{e} of students.
to deliver quality $q = \bar{e}^\theta i^{1-\theta}$. Program-specific **fixed cost** $\kappa(p)$.
- GE with neoclassical production. Non-college, college labor of different programs are **differentially substitutable** to capital.
- Government budget constraint with **education subsidies**, **financial aid**, **income taxes**, consumption taxes.

The Model: Summary and Time Line



Model Details: Initial Conditions and College Options

- **Ability** $e \in \mathcal{E} = \{e^l, e^h\}$. Measure μ_e with $\sum_{e \in \mathcal{E}} \mu_e = 1$.
- **Residential status** $r \in \mathcal{R} = \{r^i, r^o\}$. Only relevant for college tuition. Measure such that $\sum_{r \in \mathcal{R}} \mu_r = 1$.
- **Initial resources** $b \in \mathcal{B}$ of the person making the college decision. Distribution correlated with student ability, denoted by $F_e(b)$.
- **Joint distribution** over initial states $\Phi_0(e, r, b)$. Goal is to ultimately **make Φ_0 endogenous**.
- Feasible set of **college qualities**: $q \in \Omega = [0, q_{\max}]$ where $q = 0$ means no college. Set \mathcal{Q} of college qualities offered in equilibrium.
- **College program** $p \in \mathcal{P}$. Today $\mathcal{P} = \{0, 1, 2\}$ Choice $p = 1$ means NO-STEM, $p = 2$ means STEM (and $p = 0$ implies no college).
- **Demographics**: cohort $j \in \{0, 1, \dots, J\}$ size given by N_j

Model: College Age

- **Direct utility** from college:

$$\mathbb{1}_{q>0} (\nu_0 + \nu_1 \ln(q) + \mathbb{1}_{p=2}\nu_2(e))$$

- ▶ ν_0 : utility flow from attending any college
 - ▶ $\nu_1 \ln(q)$: direct preference for high-quality college
 - ▶ $\nu_2(e)$: (Dis-)utility from studying STEM, student ability-dependent
- **College dropout risk**. Prob. $\pi_d(q)$. Determines $s \in \{cd, co\}$
 - **Wage gains** from college: life cycle labor productivity $\gamma_j(q, p, s)$.
 - STEM skill **obsolescence risk** π_p during labor market years
 - From $j \geq 1$: Consumption-saving life cycle model with post college & major choice **lifetime expected utility** $V_1(q, p, s, a)$.
 - Sequence of decisions during college years $j = 0$:
 - ① Choice of college quality q , college major p . Then dropout shock.
 - ② Consumption-savings decision (c_0, a_1) .

College Age: Working Backwards

- Consumption-savings choice (c_0, a_1) , given $V_1(q, p, s, a_1)$
- Optimization problem

$$\begin{aligned}W(e, r, b, q, p, s) &= \max_{c_0, a_1} \{u(c_0) + \beta V_1(q, p, s, a_1)\} && s.t. \\(1 + \tau_c)c_0 + a_1 &= b + y_0^n + \mathbb{1}_{q>0}(1 - \varsigma(b))t(e, r, b; q, p) \\y_0^n &= y_0(1 - \mathbb{1}_{q>0}\omega) - T(y_0(1 - \mathbb{1}_{q>0}\omega)) \\a_1 &\geq -\underline{a}_1(q), c_0 \geq 0, q \in \mathcal{Q}\end{aligned}$$

- ▶ **Tuition** $t(e, r; q, p)$, based on ability e , college quality q and program. In equilibrium does not depend on b .
 - ▶ **Public financial assistance** $\varsigma(b)$ based on student resources b .
 - ▶ College **reduces time for work** by ω .
 - ▶ **Progressive** tax code $T(\cdot)$
- Age $j = 0$ (biological age 18) **lifetime expected utility after** college (q, p) choice, dropout realization given by $W(e, r, b, q, p, s)$

College Quality (q) and Major (p) Decision

- Lifetime utility at $j = 0$, given value function $W(e, r, b, q, p, s)$

$$V_0(e, r, b) = \max_{q \in \mathcal{Q}, p \in \mathcal{P}} \{ \mathbb{1}_{q>0} (\nu_0 + \nu_1 \ln(q) + \mathbb{1}_{p=2} \nu_2(e)) \\ + \pi_d(q) W(e, r, b, q, p, cd) + (1 - \pi_d(q)) W(e, r, b, q, p, co) \}$$

- Delivers **college choice functions** $q(e, r, b), p(e, r, b)$.
- Choice $q = 0$ means no college and implies $s = hs$.
- Side remark: computationally we introduce extreme value type I (Gumbel) taste shocks over discretized \mathcal{Q} and \mathcal{P} .
- This turns $q(\cdot), p(\cdot)$ functions into choice probabilities, and implies that colleges of all types are open in equilibrium.

Cross-Sectional Distributions

- **College demand:** probability measure of students of ability e that seek to attend a college with quality in Q , study program p

$$\Phi_e(Q, p) = \sum_r \int_b \mathbf{1}_{\{q(e,r,b) \in Q, p(e,r,b) = p\}} d\Phi_0(e, r, b)$$

- Probability measure Φ_1 of individuals at beginning of working life over states (p, q, s, a) . For $s = co$ and $\{0\} \notin Q$:

$$\Phi_1(Q, P, A, co) = \int_b \sum_e \sum_r (1 - \pi_d(q)) \mathbf{1}_{\{q(e,r,b) \in Q, p(e,r,b) \in P, a_1(e,b,q,p) \in A\}} d\Phi_0(e, r, b)$$

- Similar for $s = cd$ and $\{0\} \notin Q$ as well as $s = hc$ and $Q = \{0\}$.
- Side remark: Prob. measure of individuals after college choice and dropout realization but before consumption-savings choice:

$$\bar{\Phi}_0(e, r, B, Q, P, co) = \int_{b \in B} (1 - \pi_d(q)) \mathbf{1}_{\{q(e,r,b) \in Q, p(e,r,b) \in P\}} d\Phi_0(e, r, b)$$

College Supply (based on Cai and Heathcote, 2022)

- Colleges operate CRTS production technology under perfect competition. **Quality production function:**

$$q = \bar{e}^\theta i^{1-\theta}$$

where $\bar{e} = \eta(e^h)e^h + (1 - \eta(e^h))e^l$

- Revenues of colleges per student:
 - Tuition $t(e, r, b; q, p)$. Equilibrium object
 - Subsidies $\vartheta(e, r; q, p)$. Public **policy choice!**
 - $v(e; q, p) := \max_{(b,r)} [t(e, r, b; q, p) + \vartheta(e, r; q, p)]$: revenue from preferred (b, r) type. Note: colleges do not care about (b, r) directly.
- Costs of colleges
 - Per student **discretionary spending** i . Choice of college.
 - Major-specific fixed cost per student $\kappa(p)$. **Not a choice.**
- College problem: choose **expenditures, student composition** $(i, \eta(e^h))$ to maximize profits. Choosing $\eta(e^h)$ is equivalent to \bar{e} .

$$\pi(q, p) = \max_{i, \eta(e^h)} \{v(e^l, q, p) - \eta(e^h)(v(e^l, q, p) - v(e^h, q, p)) - i - \kappa(p)\}$$

$$\text{s.t. } q = \bar{e}^\theta i^{1-\theta}$$

Equilibrium in the College Market

- Recall policy functions for college choice. $q(e, r, b), p(e, r, b)$.
- College market clearing:** for each $e \in \{e^l, e^h\}$, all $Q \subseteq \Omega$, all p

$$\sum_r \int_b \mathbf{1}_{\{q(e,r,b) \in Q, p(e,r,b) = p\}} d\Phi_0(e, r, b) = \int_{q \in Q} \eta(e, q, p) d\chi(q, p) \text{ s.t.}$$
$$(q(e, r, b) = q^*, p(e, r, b) = p^*) \Rightarrow (r, b) \in \arg \max \{t(e, r, b, q^*, p^*) + \vartheta(e, r, q^*, p^*)\}$$

- For each e , colleges admit highest revenue-generating students.
- Equilibrium $\chi(Q, p)$: for each ability e , measure of students seeking to attend college in quality subset Q and program p is equal to total measure of students of that ability choosing (Q, p) .
- Cai-Heathcote (2022), Prop. 1, 2: Any equilibrium allocation can be supported by tuition schedule of the form

$$t(e, r^o, q, p) = t(r^o, q, p) - d(q, p)(e - e^l)$$
$$t(e, r^i, q, p) = t(e, r^o, q, p) - (\vartheta(e, r^i; q, p) - \vartheta(e, r^o; q, p))$$

- Key equilibrium object: **ability discount $d(q, p)$** .

Wages and the Labor Market after College

- Today: Labor productivity $\gamma_j(q, p, s)$ deterministic, with

$$\gamma_j(0, 0, hs) = \epsilon_j \quad (\text{No-College})$$

$$\gamma_j(q, 1, co) = \epsilon_j(q > 0) (1 + a \cdot (q)^c) \quad (\text{No-Stem})$$

$$\gamma_j(q, 2, co) = \epsilon_j(q > 0) (1 + a \cdot (b \cdot q)^c) \quad (\text{STEM})$$

$$\gamma_j(q, p, cd) = \varrho \gamma_j(q, p, co) \quad (\text{Dropouts})$$

where $a, b, c > 0$, $\varrho < 1$. Labor income $\gamma_j(p, q, s)w(p)$ ▶ Profiles

- Total labor supply of skill $p \in \{\text{no coll.}, \text{non-STEM}, \text{STEM}\}$

$$L(p) = \sum_{s \in \{cd, co\}} \int_q \int_a^{j_r - 1} \sum_{j=1} \gamma_j(q, p, s) \Phi_j(dq, p, da, s) N_j$$

- Aggregate production

$$Y = \sum_{p \in \{0, \mathcal{P}\}} \lambda(p) \left(\alpha K(p)^{\rho(p)} + (1 - \alpha) (\Gamma L(p))^{\rho(p)} \right)^{\frac{1}{\rho(p)}}$$

- $\sigma(p) = \frac{1}{1 - \rho(p)}$: **substitution elasticity** between capital, labor $K(p)$, $L(p)$ of skill p . Assume $\sigma(0) > \sigma(1) > \sigma(2)$. Caunedo et al. (2023)

Government Budget Constraint

$$\sum_e \sum_r \int_b \mathbb{1}_{\{q(e,r,b)=q, p(e,r,b)=p\}} (\vartheta(e, r; q, p) + \varsigma(b)t(e, r; q, p)) \Phi_0(e, r, db) N_0$$
$$= T^c + T^k + T - G$$

- T : Aggregate labor income tax revenues from progressive $T(\cdot)$

$$T = \sum_e \sum_r \int_b \int_q \sum_p \sum_s T(y_0(b, r, e, q, p, s)) \bar{\Phi}_0(e, r, db, dq, p, s) N_0$$
$$+ \sum_{j=1}^J \int_q \sum_p \sum_s \int_a T(y_j(q, p, s, a)) \Phi_j(q, p, s, a) N_j$$

- G : Exog. government spending not related to higher education
- T^c : Aggregate consumption tax revenues
- T^k : Aggregate capital income tax revenues
- Separate PAYGO social security system with $\tau^{SS}, pen_j(q)$

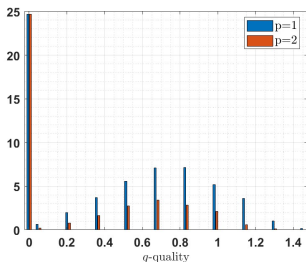
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- ② **Calibration**
- ③ Thought Experiments
- ④ Conclusion

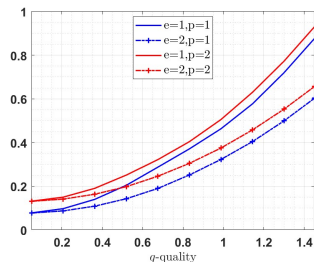
Calibration Strategy

- Calibrate demographics to pre-2008 (pre-2026 from perspective of age 18) steady state.
 - ▶ Benchmark pop growth rate $n=1\%$. Demographic cliff: Permanent decline in fertility rate s.t. long-run population growth $n=0\%$.
- Calibrate college resource costs, subsidies, borrowing limits and “standard” parameters exogenously
 - ▶ Benchmark college subsidy rate: 40% for $r = r^i$, 10% for $r = r^o$. (Cai-Heathcote (2022), also NCES statistics). Reform: set $\vartheta = 0$.
- Calibrate college preference parameters $\nu_0, \nu_1, \nu_2(e)$ such that **college enrollment rate & tuition spending** in line with data
- Calibrate dropout risk $\pi_d(q)$ such that **dropout rate** is 50%
- Calibrate labor productivity parameters in $\gamma_j(p, q, s)$ such that **equilibrium wage premia** by (p, q, s) in line with data.
- Calibrate tax level parameter τ such that marginal labor income tax rate (at avg. earnings) in line with data [▶ Calibration Details](#)

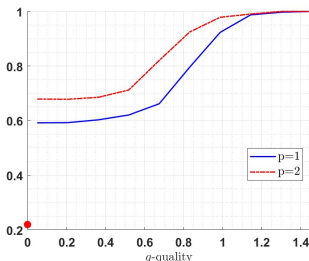
Initial Steady State (NB: $q = 0$ Means No College)



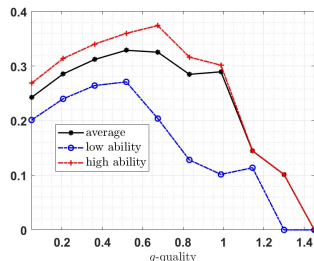
(c) Equilibrium q Histogram



(d) Equil. tuition ($\Delta(\kappa) \approx 0.06$)



(e) share of high ability students (f) share of students in STEM



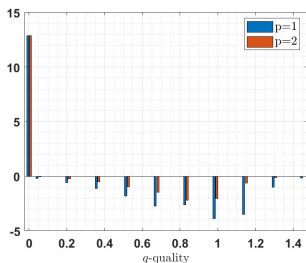
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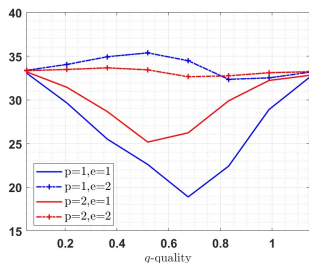
Thought Experiment (I): Removal of College Subsidies

- Why? Recent reduction in public funding for U.S. universities
- **This** version: cut public subsidy $\vartheta = 0\%$. Compare **steady states**
- Summary and intuition for results:
 - ▶ Partial Equil. (prices, gross tuition fixed): Net-of-subsidy tuition \uparrow .
 - ★ **Less students go** (especially low e). Attendees (especially high e) **shift to lower q** colleges. Highest q colleges virtually disappear.
 - ★ Improved ability composition \bar{e} of remaining college students. Aggregate STEM share still falls.
 - ▶ General Equil.: (q, p) -specific tuition schedule & $(r, w(p))$ adjust.
 - ★ High e students less scarce in college \Rightarrow **tuition discounts fall**
 - ★ Contraction in L (driven by $L(1), L(2)$) lowers r , increases $w(p)$. Especially for $L(p)$ least substitutable with capital $\Rightarrow \frac{w(2)}{w(0)} \uparrow, \frac{w(1)}{w(0)} \uparrow$
 - ▶ Aggregates & Public Finance:
 - ★ Large decline in Y, K driven by $L(1), L(2) \downarrow$. Income tax receipts \downarrow .
 - ★ $\vartheta \downarrow$ creates net **deficit** for government, requires $\tau \uparrow$

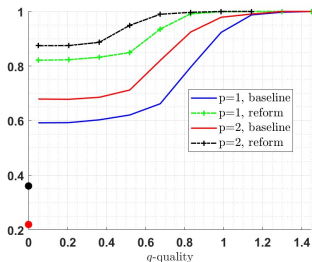
Removal of College Subsidies in General Equilibrium



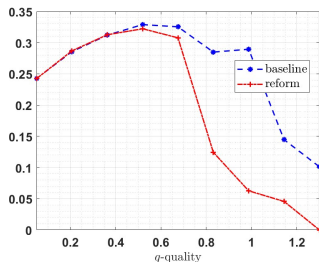
(a) q distribution: change in %p



(b) $\% \Delta$ in equil. tuition schedule



(c) share of high ability students



(d) share of students in STEM

Experiments: Prices, Aggregates, Public Finance

Reform	r	$w(0)$	$w(1)$	$w(2)$	Lab. Inc. Tax
Subsidy cut	-0.14%p	0.75%	0.83%	0.86%	2.37%p

Table: Factor prices, tax rate relative to benchmark steady state

Reform	Output	Capital	Aggr. Labor	Output (pc)
Subsidy cut	-9.42%	-10.20%	-9.91%	-9.42%

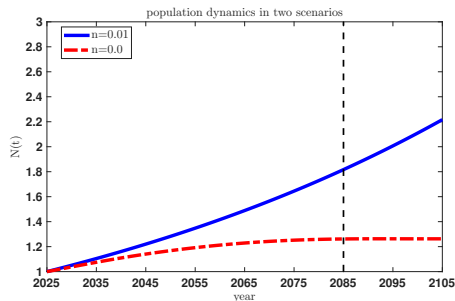
Table: Aggregates relative to benchmark steady state

Reform	Edu. Spend.	Total Rev. (PE)	Lab. Tax Rate Δ (GE)
Subsidy cut	-1.09%p	-1.46%p	2.37%p

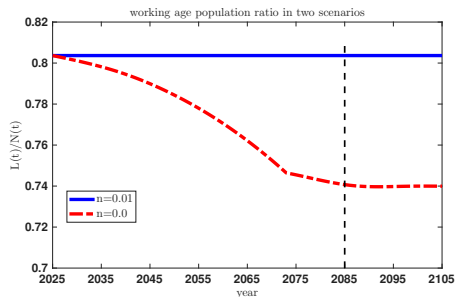
Table: Fiscal variables relative to benchmark steady state GDP

- Net long-run (steady state) fiscal consequences of higher education public funding cuts negative. Consistent with Hendren and Sprung-Keyser (2020).

Thought Experiment (II): Demographic Cliff



(e) Total Population



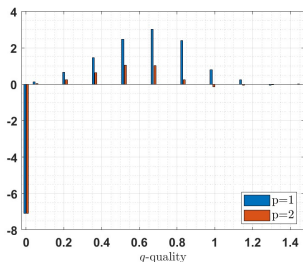
(f) Working Age to Population Ratio

- Benchmark (pre-2008): population growth 1%. Stationary population distribution with $n = 1\%$ and empirical mortality rates.
- Demographic cliff: Permanent decline in fertility rate s.t. long-run population growth $n = 0\%$. No change in mortality rate. Adult pop. changes in 2026.
- Population distribution in 2085. Drop in level of adult population of 31%.

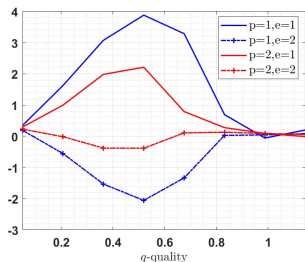
Thought Experiment (II): Demographic Cliff

- Stylized version: benchmark $n=1\%$ v/s demographic cliff $n=0\%$.
- Compare scenarios in 2085: \approx steady state with $\Delta N = -31\%$
- General equilibrium is key (households are not directly affected).
- Standard effects of population aging: **labor scarcer**, households need to save more if pension benefits fall $\Rightarrow r \downarrow, k(p), w(p) \uparrow$.
- Tuition and college market:
 - ▶ **College wages** $\uparrow \Rightarrow$ increase in college attendance. New entrants have lower (e, b) , thus expansion at the lower and middle range.
 - ▶ Average student quality at these universities falls, ability discount increases, aggregate STEM share falls.
 - ▶ **Absolute number of students declines**, mostly at high q .
- Aggregates & Public Finance:
 - ▶ **Large aggregate contraction** but more **modest per capita decline** in Y, K . Expansion in $L(1), L(2)$ per capita is key.
 - ▶ Large contraction in tax revenue in PE, partially offset by increase in w 's, expansion in college labor. In GE $\Delta \tau > 0$, but **small**.

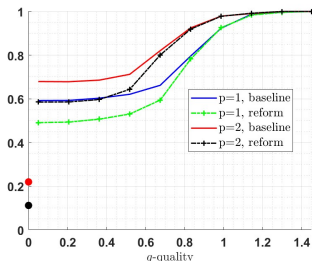
Thought Experiment (II): Demographic Cliff



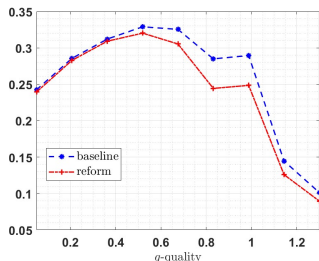
(g) q distribution: change in %p



(h) $\% \Delta$ in equil. tuition schedule



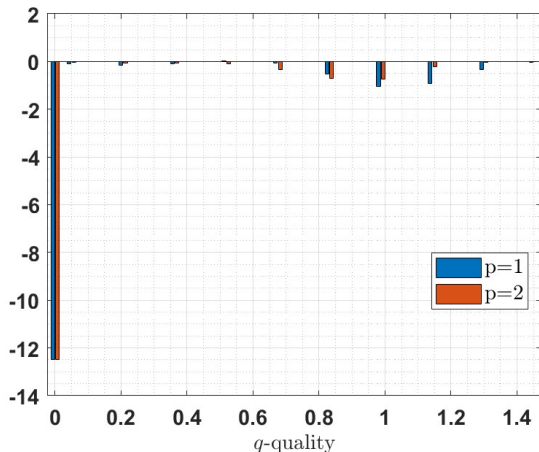
(i) share of high ability students



(j) share of students in STEM

Thought Experiment (II): Demographic Cliff

- Results thus far: demographic cliff not so bad ... but these were **per-capita** plots.
- **Absolute** number of students?



Experiments: Prices, Aggregates, Public Finance

Reform	r	$w(0)$	$w(1)$	$w(2)$	Lab. Inc. Tax
Subsidy cut	-0.14%p	0.75%	0.83%	0.86%	2.37%p
Demogr. shock	-0.86%p	4.63%	4.92%	5.03%	0.16%p

Table: Factor prices, tax rate relative to benchmark steady state

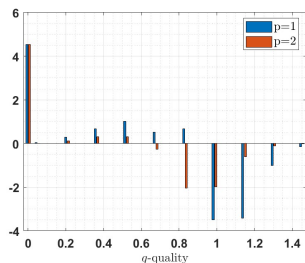
Reform	Output	Capital	Aggr. Labor	Output (pc)
Subsidy cut	-9.42%	-10.20%	-9.91%	-9.42%
Demogr. shock	-32.04%	-26.40%	-37.14%	-2.13%

Table: Aggregates relative to benchmark steady state

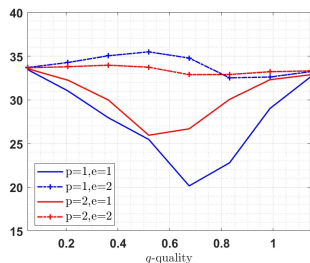
Reform	Edu. Spend.	Total Rev. (PE)	Lab. Tax Rate Δ (GE)
Subsidy cut	-1.09%	-1.46%p	2.37%p
Demogr. shock	0.00%p	-4.69%p	0.16%p
Demogr. shock, G const.	0.00%p	-4.69%p	12.80%p

Table: Fiscal variables relative to benchmark steady state GDP

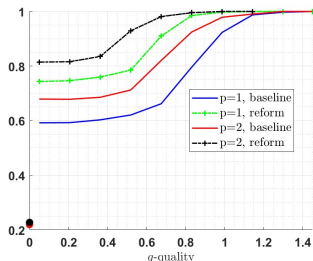
Experiment (III) Demographic Cliff & Subsidy Cut



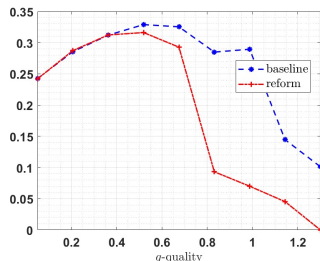
(k) q distribution: change in %p



(l) $\% \Delta$ in equil. tuition schedule



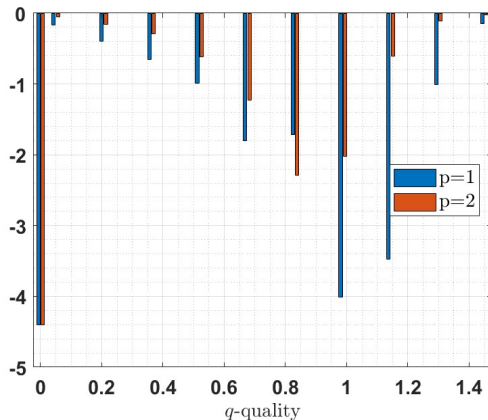
(m) share of high ability students



(n) share of students in STEM

Experiment (III): Demographic Cliff & Subsidy Cut

- Double whammy: fewer high-school grads, less public college funding
- Amplified **aggregate contraction** and **fiscal recession**.
- Demographic shock alone raised college attendance, concentrated absolute enrollment losses at top-quality colleges. With simultaneous subsidy cut, **enrollment falls** and losses spread to **middle- and lower- q** institutions.



Experiments: Prices, Aggregates, Public Finance

Reform	r	$w(0)$	$w(1)$	$w(2)$	Lab. Inc. Tax
Subsidy cut	-0.14%p	0.75%	0.83%	0.86%	2.37%p
Demogr. shock	-0.86%p	4.63%	4.92%	5.03%	0.16%p
Dem. shock & subs. cut	-0.82%p	4.38%	4.67%	4.77%	2.73%p

Table: Factor prices, tax rate relative to benchmark steady state

Reform	Output	Capital	Aggr. Labor	Output (pc)
Subsidy cut	-9.42%	-10.20%	-9.81%	-9.42%
Demogr. shock	-32.04%	-26.40%	-37.14%	-2.13%
Dem. shock & subs. cut	-39.83%	-36.50%	-45.06%	-13.35%

Table: Aggregates relative to benchmark steady state

Reform	Edu. Spend.	Total Rev. (PE)	Lab. Tax Rate Δ (GE)
Subsidy cut	-1.09%p	-1.46%p	2.37%p
Demogr. shock	0.00%p	-4.46%p	0.16%p
Dem. shock & subs. cut	-1.09%p	-5.62%p	2.73%p

Table: Fiscal variables relative to benchmark steady state GDP

Outline

- ① Motivation
- ② The Model
- ③ Calibration
- ④ Thought Experiments
- ⑤ **Conclusion**

Conclusion: What Are We Trying To Do?

- Integrate **equilibrium model of college market** into **life-cycle model of college (major) choice** and labor market outcomes:
 - ▶ “Cai-Heathcote (2022) meets Krueger-Ludwig-Popova (2025)”
- Use it to study
 - ▶ Recent **reduction of public funding** of universities
 - ▶ **Demographic** cliff
- Final goal: study impact on college market, aggregates, public finances when $(n, \vartheta) \downarrow$ is combined with (STEM) skill shortages.
- What is **next?** Many aspects, but specifically...
 - ▶ **Transitions**: so far ignored transitional periods/generations
 - ▶ Changes in **immigration** flows/policies: STEM migrant-heavy!
 - ▶ Introduction of explicit theory of **skill-biased technological change (AI?)** giving rise to STEM shortages (or redundancies?)

THANK YOU FOR
ATTENDING

APPENDIX

Calibration Parameters Calibrated Externally

Parameter		Value	Target/Interpretation
$j = 0, 1, j_r, J$	Life stages	18, 22, 66, 100	
$\{\phi_j\}$	Survival Probabilities	see main text	Life Tables SSA
μ_r^i	Share of in-state students	0.5	Cai & Heathcote (2022)
$\eta(e^h)$	Aggr. share high ability students	0.5	Cai & Heathcote (2022)
(e^l, e^h)	Ability levels	(0.375, 1.0)	Cai & Heathcote (2022)
College quality production			
θ	Average ability elasticity	0.5	Normalization
$\bar{\kappa}$	Average college fixed cost	\approx \$9,000	Altonji&Zimmerman (2018)
$\kappa(ST)/\kappa(NO)$	Ratio STEM/No-STEM fixed costs	1.71	Altonji&Zimmerman (2018)
Preferences/endowments/productivity			
(σ, ψ)	Risk aversion, Frisch elasticity	(1, 0.6)	-
$\gamma_q(q=0)$	Non-college labor productivity	1	Normalization
ℓ	Average hours worked	1/3 of time	-
ℓ^{stud}	Student average hours worked	0.25 ℓ	NCES
\bar{b}	Mean initial (family) resources	\$61,200	Average IVT transfer, PSID
ς	Rel. resources $\bar{b}(e^{high})/\bar{b}(e^{low})$	1.35	Cai & Heathcote (2022)
σ^b	Variance of initial resources	0.55	Cai & Heathcote (2022)
$\{\epsilon_j\}$	Age Profile	see main text	PSID 1968-1997
$\underline{a}(j=0, q>0)$	College bor. limit	45,590\$	Krueger & Ludwig (2016)
$\pi_d(q)$	Dropping out probability	0.5	PSID 2011-2017
Aggregate production			
α	Capital share	33.3%	
δ	Depreciation rate	5%	
$\rho(p)$	Subst. Elas. $1/(1 - \rho(p))$ by p	[-0.11, -0.43]	Caunedo et al. (2023)
$\rho(q=0)$	Subst. Elas. $1/(1 - \rho(q=0))$ non-coll.	0.33	Caunedo et al. (2023)
Government			
$\vartheta(r)$	Public subsidy of college education	[10%, 40%]	roughly Cai & Heathcote (2022)
τ_c	Consumption Tax Rate	5.0%	legislation
τ_k	Capital Income Tax Rate	36%	Trabandt & Uhlig (2011)
ξ	Labor Income Tax Progressivity	0.18	Heathcote et al. (2017)
τ^p	Soc Sec Payroll Tax	12.4%	legislation
G/Y	Government consumption to GDP	13.8%	current value

Calibration Parameters Calibrated Inside Model

Parameter		Value	Target/Interpretation
Preferences & Endowments			
β	Discount factor	0.9841	Interest rate
ν_0	Utility cost of college	5.55	Coll. enroll. rate
ν_1	Weight direct utility q	0.25	Net tuition spend. to GDP ratio
$\nu^{STEM}(e)$	Ability-specific utility cost studying STEM	[1.2, 0.85]	STEM share by abil.
a, b, c	Parameters of $\gamma(q, p)$	0.75, 3.00, 0.55	Av. coll. wage prem. wage diff. top to bottom quart. q dist. av. STEM wage prem.
Aggregate production			
Γ	Aggr. wage normal.	1.58	Normal. $w(q=0) = 1$
Government			
τ	Lab. inc. tax level param.	0.245	Marg. lab. inc. tax rate eval. at av. earnings

Empirical Values and Data Sources

Moment	Empirical Value	Data Source
Interest rate (annual)	3.5%	
College enrollment rate	51%	PSID 2011-2017
Net tuition spending to GDP	1.57%	OECD 2020
Average STEM share	24%	NSF 2024 report
STEM share for high ability students	40%	NSLY97
Average college wage premium	77%	PSID 2011-2017
Earnings diff. between top/bottom quartile of q distribution	98%	
Average STEM wage premium	57%	PIACC 2011 & 2012
Marginal labor income tax rate evaluated at average earnings	29%	

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My Broader Research Agenda (1)

- Quantitative public finance in the Auerbach-Kotlikoff (1987) tradition: **OLG models, but with idiosyncratic risk.**
 - ▶ **Social security:** Conesa & Krueger (RED 1999), Krueger & Kubler (AER P&P '04, AER '06)
 - ▶ **Capital & labor income taxation:** Conesa & Krueger (JME '06), Conesa, Kitao & Krueger (AER '09), Holter, Stepanchuk & Krueger (QE '19, WP '25), Krueger, Ludwig & Villalvazo (JPubE, '21), Wu & Krueger (AEJ:M '21, WP '25), Kindermann & Krueger (AEJ:M '22), ...
 - ▶ Interaction with **education policy:** Krueger and Ludwig (AER P&P 2013, JME 2016)
- Covid-19 shock (in my research): Applications to **childhood schooling, human capital accumulation and college choice:** Fuchs-Schuendeln et al. (EJ '22, IMFER '23).
- Child schooling, **college choice and intergen. persistence:** Krueger, Ludwig, Popova (JME, '25)
- **This paper:**
 - ▶ **Model:** college supply & major choice, skill-capital complementarity
 - ▶ **Application:** **Demographic cliff & college subsidy cuts,** STEM-skill biased techn. change (ITC, AI revolution) [▶ Go back](#)

My Broader Research Agenda (2)

- **Incomplete Markets: Theory and Applications:**

Bewley-Aiyagari (SIM) vs. Kehoe-Levine (Limited Commitment, LCM).

- **Theory:** What is the Outside Option?

- ▶ Autarky (with continuum of agents): Krueger and Perri (JET, '11)
- ▶ Joint deviations (social norm): Cole, Krueger, Mailath, Park (ReStud '24)
- ▶ Endogenously determined by competition: Krueger and Uhlig (JME, '06, TE R&R '25), with Li (ReStud, R&R '25)

- **Asset Pricing:** Does market incompleteness matter?

- ▶ SIM: Krueger and Lustig (JET, '10)
- ▶ LCM: Krueger, Lustig & Perri (JEEA '08), Ando, Krueger & Uhlig (WP'25)

- **Applications to Consumption Insurance and Inequality**

- ▶ Empirical evaluation of LCM: Krueger & Perri (JEEA, '05, ReStud, '06)
- ▶ Empirical-descriptive evaluation of consumption insurance: Krueger and Perri (NBER MA, '05), Krueger, Malkov & Perri (JECD '24)
- ▶ Consumer Durables & Housing: Fernandez-Villaverde & Krueger (ReStat '07, MD, '11), Bajari, Chan, Krueger and Miller (IER 2013), Jeske, Krueger & Mitman (JME, '13), Hai, Krueger & Postlewaite (QE, '20)
- ▶ Aggregate shocks: Krueger, Mitman & Perri (HoM, '16, ESWC, '17), Glover, Heathcote, Krueger & Rios-Rull (JPE '20)

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Related Literature (Incomplete?!)

- Macro models with **college market equilibrium**:
 - ▶ Cai & Heathcote (2022), Alon, Capelle & Matsuda (2022), Marto & Wittman (2025)
 - ▶ Also important literature in IO: Arcidiacono (2005), Epple, Romano & Sieg (2006), Chao Fu (2014)
- **College choice with college quality** differences:
 - ▶ Blair & Smetters (2021), Hendricks, Herrington and Schoellman (2021), Hendricks, Koreshkova & Leukhina (2024)
- **Education finance and public finance reform** in life cycle models
 - ▶ Vardishvili (2025), Krueger, Popova & Ludwig (2025), Zhou (2025)
- Costs and returns to college majors, and major choice:
 - ▶ Altonji, Arcidiacono & Maurel (2016), Altonji & Zimmerman (2018)
- Demographic change and the college landscape, college closures
 - ▶ NCES Digest of Education Statistics (2023), Kelchen et al. (2024), Conesa et al. (2020)
- Skill-biased technological change, STEM shortages & wage changes
 - ▶ Deming & Noray (2000), Braxton & Taska (2023), Hendricks & Schoellman (2023), Kogan et al. (2024)

The Model: Market Clearing and Equilibrium

Definition

A steady state equilibrium is a measure of colleges $\chi(Q, p)$, college tuition $t(e, r; q, p)$, average ability of students $\bar{e}(q, p)$, per student expenditures $i(q, p)$, profits $\pi(q, p)$ of colleges, household choices $c_j(\cdot)$, $a_{j+1}(\cdot)$, $q(e, r, b)$, $p(e, r, b)$, government policies such that:

- 1 Given college tuition $t(e, r; q, p)$ and government policies, household choices $c_j(\cdot)$, $a_{j+1}(\cdot)$, $q(e, r, b)$, $p(e, r, b)$ solve maximization problem.
- 2 For all (q, p) , maximal revenue function is determined as $v(e, q, p) = \max_{r, b} t(e, r, b; q, p) + \vartheta(e, r; q, p)$, the college input choices $\bar{e}(q, p)$ and $i(q, p)$ solve the college's profit maximization problem, and $\pi(q, p)$ is the associated profit per student.
- 3 Zero profits of colleges: $\pi(q, p) \leq 0$ and $\int_Q \pi(q, p) d\chi(q, p) = 0$, $\forall Q \subseteq \Omega \setminus \{0\}$ and all p .
- 4 The per-period government budget constraint holds in all periods.
- 5 The goods market and the college markets clear.

The Model: Market Clearing Conditions

- **Goods market** clears:

$$C + \delta K + G + I^{college} + FC^{college} = Y$$

where

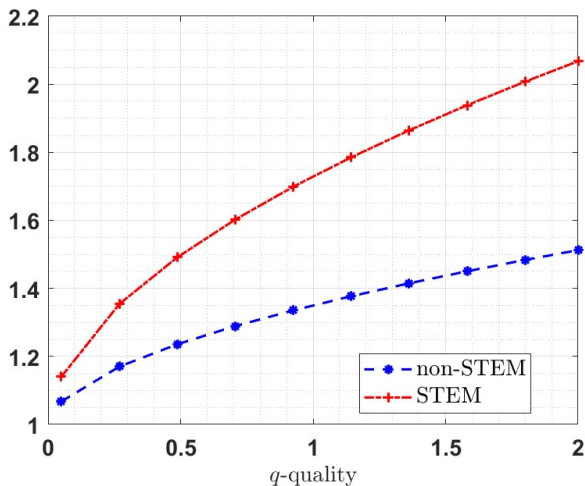
$$\begin{aligned} C &= \sum_r \sum_e \int_b \int_q \sum_p \sum_s c_0(e, r, b, q, p, s) d\bar{\Phi}_0(e, r, b, q, p, s) N_0 \\ &+ \sum_{j=1}^J \sum_e \int_b \int_q \sum_p \sum_s c_j(e, q, p, s, a) \Phi_j(e, q, p, s, a) N_j \end{aligned}$$

- **College market clearing:** for each $e \in \{e^l, e^h\}$, all $Q \subseteq \Omega$, all p

$$\begin{aligned} \sum_r \int_b \mathbf{1}_{\{q(e, r, b) \in Q, p(e, r, b) = p\}} d\Phi_0(e, r, b) &= \int_{q \in Q} \eta(e, q, p) d\chi(q, p) \text{ s.t.} \\ (q(e, r, b) = q^*, p(e, r, b) = p^*) &\Rightarrow (r, b) \in \arg \max \{t(e, r, b, q^*, p^*) + \vartheta(e, r, q^*, p^*)\} \end{aligned}$$

- That is, within an ability level e , colleges admit highest revenue-generating students.

Labor Market Productivity



(o) Labor productivity by quality q , conditional on p