Optimal Timing of College Subsidies
Enrollment, Graduation and the Skill Premium

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The skill premium has been rising in the US from 50% in 1980 to 90% now.
Motivation

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- Policies which increase the supply of college educated labor would dampen the skill premium ("Race between Technology and Education", Goldin and Katz (2008)).
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- But almost half of the college enrollees in the US drop out.

- It is important to understand how policy can affect graduation.
This paper

- I consider a new college subsidy scheme whose amount varies with year of college, i.e., freshmen, sophomores, etc...: year-dependent subsidies
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- Questions: What timing of subsidies will maximize the number of college graduates and social welfare?
What I do

- A quantitative heterogeneous agent overlapping generation lifecycle model with
  - borrowing constraints
  - endogenous enrollment/graduation decisions.
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  - endogenous enrollment/graduation decisions.

- Examine the effect of year-dependent subsidies on graduation, the skill premium, and welfare.
  - Focus on the relative sizes across years in college (slope).
  - I fix the total budget of college subsidies from now on.
Outline

1 Introduction

2 Model

3 Calibration

4 Results

5 Conclusion
Demography

- I focus on steady state from now on.
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- OLG: each individual has one offspring living with them until independence.
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- Once an individual finishes their schooling, they will be high school graduates \((e = HS)\), college dropouts \((CD)\), or college graduates \((CG)\).
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- Once an individual finishes their schooling, they will be high school graduates \((e = HS)\), college dropouts \((CD)\), or college graduates \((CG)\).

- After that, they face a standard life cycle problem with income risk, incomplete markets for insurance, and borrowing constraints.
Timeline

- j
- 1
- 2
- \( \hat{j}_f \)
- \( \hat{j}_b \)
- \( \hat{j}_r \)
- J

**Events:**
- receive transfer from parents
- observe college ability \( \theta_c \)
- start living w/ children
- transfer to offspring
- retire

**Observations:**
- enroll or not
- observe high school ability \( \theta_h \)

**Survival Rate:** \( \varphi_j \)
Preferences: three parts

The lifetime utility is the sum of the following three parts:

- The expected discounted sum

\[
\mathbb{E}_1 \sum_{j=1}^{J} \tilde{\beta}_j u(c_j, \ell_j) \text{ where } u(c, \ell) = \frac{(c^\mu \ell^{1-\mu})^{1-\gamma}}{1-\gamma}
\]

where \( c_j \) denotes consumption and \( \ell_j \) is leisure at age \( j \).
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where \( c_j \) denotes consumption and \( \ell_j \) is leisure at age \( j \).

2. Expected utility of college attendance:

\[ \lambda_j(\theta_c, \phi) = \lambda + \lambda^\theta \theta_c + \lambda^\phi \phi \]

College utility depends on college ability \( \theta_c \) and college taste \( \phi \).
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$$\mathbb{E}_1 \sum_{j=1}^{J} \tilde{\beta}_j u(c_j, \ell_j)$$

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$$\lambda_j(\theta_c, \phi) = \lambda + \lambda^\theta \theta_c + \lambda^\phi \phi$$

College utility depends on college ability \( \theta_c \) and college taste \( \phi \).

3. Parental altruism: They enjoy their children’s lifetime utility with a weight \( \nu \).
Key Factors of Educational Decisions

Common factors

- Tuition $p_e$, subsidies $s_1(q), s_2(q)$, and credit limits $A_1^c, A_2^c$.

- The price of effective labor $w^{CG}, w^{CD}, w^{HS}$.
Key Factors of Educational Decisions

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2. Idiosyncratic factors: enrollment
   - Initial asset $a$, family income $q$, and taste $\phi \sim N(0,1)$
   - High school ability $\theta_h$: signal of $\theta_c$ and labor productivity $\varepsilon_{jHS}(\theta_h, \eta), \varepsilon_{jCD}(\theta_h, \eta)$.
   - Idiosyncratic transitory productivity $\eta \sim \Pi^{HS}(\cdot)$
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3. Idiosyncratic factors: graduation
   - Realized college ability $\theta_c$ affects college utility $\lambda_j(\theta_c, \phi)$ and $\varepsilon^{CG}_j(\theta_c, \eta)$
   - Idiosyncratic transitory productivity $\eta \sim \Pi^{CD}(\cdot)$
Education stage: Enrollment

\[ V_0(a, \theta_h, \eta, q, \phi) = \max[V_{1}^c(a, \theta_h, \eta, q, \phi), V_1(a, HS, \theta_h, \eta)] \]

- Individuals only observe \( \theta_h \) but not \( \theta_c \) before the enrollment decision.
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- Individuals only observe \( \theta_h \) but not \( \theta_c \) before the enrollment decision.

- College ability is correlated with high school ability.

\[ \theta_c = \theta_h + \epsilon_c \text{ and } \epsilon_c \sim N(0, \sigma_c^2) \]
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\[ \theta_c = \theta_h + \epsilon_c \text{ and } \epsilon_c \sim N(0, \sigma_c^2) \]

- I assume enrollees are overoptimistic on college abilities.

\[ \theta_c = \mu_c(\theta_h) + \theta_h + \epsilon_c \text{ and } \epsilon_c \sim N(0, \sigma_c^2), \quad \text{(Perceived law of motion)} \]

where

\[ \mu_c(\theta_h) = \mu_{c0} + \mu_{c1}\theta_h \]
Education stage: First half of college

\[ V_1^c(a, \theta_h, \eta, q, \phi) = \max_{c, h, a', y} u(c, 1 - h - \bar{h}) + \mathbb{E}_{\theta_c | \theta_h} \lambda_1(\theta_c, \phi) \]

\[ + \beta \mathbb{E}_{\theta_c | \theta_h} \mathbb{E}_{\eta'} \max \left[ V_2^c(a', \theta_c, \eta', q, \phi), V_2(\bar{a}'(a'), CD, \theta_h, \eta') \right] \]

subject to

\[ c + a' + p_e = a + y + s_1(q) - T(c, a, y) \]

\[ y = w^{HS} \varepsilon_1^{HS}(\theta_h, \eta)h, \quad a' \geq -A_1^c, \quad c \geq 0, \quad 0 \leq h \leq 1 - \bar{h} \]

\[ \theta_c = \theta_h + \mu_c(\theta_h) + \epsilon_c, \quad \epsilon_c \sim N(0, \sigma_c^2), \quad \eta' \sim \Pi^{CD} \]

- They can work as high school graduates.
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- They can work as high school graduates.
- Going to college requires a fraction \( \bar{h} \) of time.
Education stage: First half of college

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V_1^c(a, \theta_h, \eta, q, \phi) = \max_{c, h, a', y} u(c, 1 - h - \bar{h}) + \mathbb{E}_{\theta_c | \theta_h} \lambda_1(\theta_c, \phi) \\
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\end{aligned}]
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\]

- They can work as high school graduates.
- Going to college requires a fraction \( \bar{h} \) of time.
- At the beginning of \( j = 2 \), they observe \( \theta_c \) and \( \eta' \) and make a dropout decision.
Education stage: Second half of college

\[ V_2^c(a, \theta_c, \eta, q, \phi) = \max_{c,h,a',y} u(c, 1 - h - \tilde{h}) + \lambda_2(\theta_c, \phi) + \beta \mathbb{E}_{\eta'} V_3(\tilde{a}(a'), CG, \theta_c, \eta) \]

subject to

\[ c + a' + p_e - s_2(q) - y + T(c, a, y) = \begin{cases} 
(1 + r)a & \text{if } a \geq 0 \\
(1 + r^s)a & \text{if } a < 0 
\end{cases} \]

\[ y = w^{CD} \varepsilon_2^{CD}(\theta_c, \eta) h, \quad a' \geq -A_2^c \quad c \geq 0, \quad 0 \leq h \leq 1 - \tilde{h}, \quad \eta' \sim \Pi^{CG} \]

- They can work as college dropouts.
Education stage: Second half of college

\[ V^C_c(a, \theta_c, \eta, q, \phi) = \max_{c,h,a',y} u(c, 1 - h - \bar{h}) + \lambda_2(\theta_c, \phi) + \beta \mathbb{E}_{\eta'} V_3(\tilde{a}(a'), CG, \theta_c, \eta) \]

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- They can work as college dropouts.
- At the end of the period, one completes college and draws \( \eta' \) from \( \Pi^{CG} \).

▶ Financial Market
After the education stage

- Individuals face a standard lifecycle problem with borrowing limit $A^e$. 

[Working Stage]
After the education stage

- Individuals face a standard lifecycle problem with borrowing limit $A^e$.  

- At $j_b$, individuals transfer asset to offspring after observing their high school ability.
After the education stage

- Individuals face a standard lifecycle problem with borrowing limit $A^e$. ▶ Working Stage

- At $j_b$, individuals transfer asset to offspring after observing their high school ability. ▶ Transfer

- I assume retirees offer no labor, receive pension $p(e, \theta)$, and have no access to loans. ▶ Retirement Stage
Goods Sector

- A representative firm produces final good from capital $K$ and aggregate labor $H$:
  \[ Y = F(K, H) = K^\alpha H^{1-\alpha} \]
Goods Sector

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- $H$ is composed of two skills: skilled labor $H^S$ and unskilled labor $H^U$:
  \[ H = (a(H^S)^\rho + (1 - a)(H^U)^\rho)^{\frac{1}{\rho}} \]
  where $\frac{1}{1-\rho}$ is the elasticity of substitution.
Goods Sector

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where $\frac{1}{1-\rho}$ is the elasticity of substitution.

- College graduates work as skilled labor: $w^{CG} = w^S$

- High school graduates and college dropouts work as unskilled labor:

$$w^{HS} = w^{CD} = w^U$$

Share of skilled labor by college dropout
A representative college requires $\kappa$ units of skilled labor to provide education.

$$p_e E - w^S \kappa E$$

where $E$ is the measure of college enrollees and $p_e$ is tuition.
A representative college requires $\kappa$ units of skilled labor to provide education.

$$p_e E - w^S \kappa E$$

where $E$ is the measure of college enrollees and $p_e$ is tuition.

I assume colleges are competitive and there is free entry: $p_e = w^S \kappa$
Government

- The government collects tax $T(c, a, y)$ and spends the revenues on
  - college subsidies

\[
G_e = \sum_{j=1,2} \int_{S_j^c} s_j(q) d\mu_j^c
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    G_c = gY
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    \]
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    \[
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    \]
  - retirement benefits
    \[
    \sum_{j=j_r}^{J} \int_{S_j} p(e, \theta) d\mu_j
    \]
Government

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  - other government consumption
    
    $$G_c = gY$$
  
  - retirement benefits
    
    $$\sum_{j=j_r}^j \int_{S_j} p(e, \theta) d\mu_j$$

- The tax function is assumed to be
  
  $$T(c, a, y) = \tau_c c + \tau_k ra_{a \geq 0} + \tau_l y - d \frac{Y}{N}$$
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Calibration Strategy

There are two sets of parameters:
Calibration Strategy

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- Those estimated outside of the model or fixed based on the literature.
Calibration Strategy

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- Those estimated outside of the model or fixed based on the literature.
- The remaining parameters to match moments given the first set of parameter values.
Labor Productivity

- I assume labor productivity

\[ \ln \epsilon_j^e(\theta, \eta) = \ln \epsilon^e + \ln \psi_j^e + \epsilon_0^e \theta + \ln \eta \]
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- where \( \psi_j^e \) is the age profile of workers at age \( j \) estimated from PSID.
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- After filtering out age effects, I regress hourly wages on \( \ln \text{AFQT80} \).
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</tr>
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<tbody>
<tr>
<td>log AFQT</td>
<td>.61</td>
<td>.74</td>
<td>1.31</td>
</tr>
<tr>
<td></td>
<td>(.32)</td>
<td>(.32)</td>
<td>(.24)</td>
</tr>
</tbody>
</table>
Transitory Labor Productivity Process

- I assume $\pi_{\eta}^e(\eta' | \eta)$ is a two-state Markov chain approximating

  $$\ln \eta' = \rho^e \ln \eta + \epsilon_\eta^e, \quad \epsilon_\eta^e \sim N(0, \sigma_\eta^2)$$
Transitory Labor Productivity Process

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  \[
  \ln \eta' = \rho^e \ln \eta + \epsilon^e_\eta, \quad \epsilon^e_\eta \sim N(0, \sigma^e_\eta^2)
  \]

- Minimum Distance Estimator separately for each education level.

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<td>$\rho^e$</td>
<td>0.94</td>
<td>0.95</td>
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</tr>
<tr>
<td>$\sigma^e_\eta^2$</td>
<td>0.017</td>
<td>0.021</td>
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Intergenerational Ability Transmission

- New independent individuals draw their high school abilities $\theta_h'$.
  \[ \theta_h' = m + m_\theta \theta + \epsilon_\theta, \quad \epsilon_\theta \sim N(0, \sigma_h^2) \]

- I regressed children’s ability on parents’ ability to get $m_\theta = 0.46$. 


## Subsidies and Loans

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- The government subsidizes the education sector $10,477 in the data.
- In the model, students receive all subsidies but pay the full cost of education.
- In the current system, college subsidies are constant and $s_1(q) = s_2(q) = \bar{s}(q)$. 
Subsidies and Loans

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<th>$q$</th>
<th>family income</th>
<th>subsidies to students</th>
<th>subsidies to colleges</th>
<th>total $\bar{s}(q)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>- $30,000</td>
<td>$2,820</td>
<td>$10,477</td>
<td>$13,297</td>
</tr>
<tr>
<td>2</td>
<td>$30,000 - $80,000</td>
<td>$668</td>
<td>$10,477</td>
<td>$11,145</td>
</tr>
<tr>
<td>3</td>
<td>$80,000 -</td>
<td>$143</td>
<td>$10,477</td>
<td>$10,620</td>
</tr>
</tbody>
</table>

- The government subsidizes the education sector $10,477 in the data.

- In the model, students receive all subsidies but pay the full cost of education.

- In the current system, college subsidies are constant and $s_1(q) = s_2(q) = \bar{s}(q)$.

- Students’ interest rate is the prime rate plus $\nu^s = 2.3\%$, annual.
Subsidies and Loans

<table>
<thead>
<tr>
<th>$q$</th>
<th>family income</th>
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- Students’ interest rate is the prime rate plus $\nu^s = 2.3\%$, annual.

- The loan limit for the first half $A_1^c$ is $6,125 \ (= 2,625 + 3,500)$ from Stafford loan.

- The loan limit for the second half $A_2^c$ is $23,000$. 
### The Remaining Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu_c^0$</td>
<td>college ability bias intercept</td>
<td>0.190</td>
</tr>
<tr>
<td>$\mu_c^1$</td>
<td>college ability bias slope</td>
<td>-0.409</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>college utility intercept</td>
<td>-23.2</td>
</tr>
<tr>
<td>$\lambda^\theta$</td>
<td>college utility slope</td>
<td>241</td>
</tr>
<tr>
<td>$\lambda^\phi_1$</td>
<td>first period college taste</td>
<td>64.1</td>
</tr>
<tr>
<td>$\lambda^\phi_2$</td>
<td>second half college taste</td>
<td>41.3</td>
</tr>
<tr>
<td>$a^S$</td>
<td>productivity of skilled labor</td>
<td>0.457</td>
</tr>
<tr>
<td>$\epsilon^{CD}$</td>
<td>productivity of CD</td>
<td>1.02</td>
</tr>
<tr>
<td>$\sigma_c$</td>
<td>s.d. of college ability</td>
<td>0.340</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>education cost</td>
<td>0.226</td>
</tr>
<tr>
<td>$\mu$</td>
<td>consumption share of preference</td>
<td>0.418</td>
</tr>
<tr>
<td>$\beta$</td>
<td>time discount rate</td>
<td>0.938</td>
</tr>
<tr>
<td>$\nu$</td>
<td>altruism</td>
<td>0.0948</td>
</tr>
<tr>
<td>$d$</td>
<td>lump-sum transfer ratio</td>
<td>0.125</td>
</tr>
<tr>
<td>$\iota$</td>
<td>borrowing wedge ($r^- = r + \iota$)</td>
<td>18.0%</td>
</tr>
<tr>
<td>$m$</td>
<td>intergenerational ability transmission intercept</td>
<td>-0.0471</td>
</tr>
<tr>
<td>$\sigma_h$</td>
<td>intergenerational ability transmission s.d.</td>
<td>0.171</td>
</tr>
</tbody>
</table>
## Matched Moments

<table>
<thead>
<tr>
<th>Moment</th>
<th>Model</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enrollment rate of ability quartile</td>
<td>(figure)</td>
<td>(figure)</td>
</tr>
<tr>
<td>Graduation rate of ability quartile</td>
<td>(figure)</td>
<td>(figure)</td>
</tr>
<tr>
<td>Enrollment rate of family income quartile</td>
<td>(figure)</td>
<td>(figure)</td>
</tr>
<tr>
<td>Graduation rate of family income quartile</td>
<td>(figure)</td>
<td>(figure)</td>
</tr>
<tr>
<td>Skill premium for CG</td>
<td>90.8%</td>
<td>90.2%</td>
</tr>
<tr>
<td>Skill premium for CD</td>
<td>19.6%</td>
<td>19.9%</td>
</tr>
<tr>
<td>Expected/Actual graduation rate — 1</td>
<td>0.431</td>
<td>0.433</td>
</tr>
<tr>
<td>Education cost/mean income at 48</td>
<td>0.320</td>
<td>0.33</td>
</tr>
<tr>
<td>Hours of work</td>
<td>33.8%</td>
<td>33.3%</td>
</tr>
<tr>
<td>$K/Y$</td>
<td>1.298</td>
<td>1.325</td>
</tr>
<tr>
<td>Transfer/mean income at 48</td>
<td>67.0%</td>
<td>66%</td>
</tr>
<tr>
<td>Log pre-tax/post-tax income</td>
<td>61.2%</td>
<td>61%</td>
</tr>
<tr>
<td>Borrowers</td>
<td>6.59%</td>
<td>6.3%</td>
</tr>
<tr>
<td>Mean of AFQT</td>
<td>-0.0135</td>
<td>0</td>
</tr>
<tr>
<td>Standard deviation of AFQT</td>
<td>0.217</td>
<td>0.213</td>
</tr>
</tbody>
</table>
Optimism

- A survey shows that students believe that there is an 86% chance of graduating while only 60% graduate
Optimism

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- To match this fact, the calibrated $\mu_c^0$ is positive and
  - the bias for the mean ability is 48% of the standard deviation of college ability.
Optimism

- A survey shows that students believe that there is an 86% chance of graduating while only 60% graduate.

- To match this fact, the calibrated $\mu^0_c$ is positive and:
  - the bias for the mean ability is 48% of the standard deviation of college ability.

- Low ability students are more optimistic ($\mu^1_c < 0$), which is consistent with data.
Model Fit

**Figure:** Enrollment rates

**Figure:** Graduation rates
Validation 1: Partial Equilibrium Effect of Year-Invariant subsidies

- I simulate the partial equilibrium response of enrollment to an $1,000 increase in subsidies for all the enrollees evenly.
Validation 1: Partial Equilibrium Effect of Year-Invariant subsidies

- I simulate the partial equilibrium response of enrollment to an $1,000$ increase in subsidies for all the enrollees evenly.

  - The additional subsidies are given to only one generation.
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  - The fraction of college graduates increases by 0.45 percentage points.
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- I simulate the partial equilibrium response of enrollment to an $1,000 increase in subsidies for all the enrollees evenly.
  - The additional subsidies are given to only one generation.
  - All the prices and the distribution of initial state are fixed at the current level.
- The aggregate enrollment rate of the affected generation increases by 1.05 percentage points in the simulation, which is broadly in the range.
  - The fraction of college graduates increases by 0.45 percentage points.
  - The fraction of college dropouts increases by 0.60 percentage points.
Validation 2: Sluggish increase in college graduates

- In the US, the number of college graduates increased sluggishly despite the increase in the skill premium.
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- In the US, the number of college graduates increased sluggishly despite the increase in the skill premium.
- Derive the two steady states’ $a^S$ and $\epsilon^{CD}$ imitating 1980 and 2000 skill premiums.
Validation 2: Sluggish increase in college graduates

- In the US, the number of college graduates increased sluggishly despite the increase in the skill premium.

- Derive the two steady states’ $a^S$ and $\epsilon^{CD}$ imitating 1980 and 2000 skill premiums.

- Compare the changes of the numbers of college graduates and dropouts with data.

<table>
<thead>
<tr>
<th></th>
<th>1980</th>
<th>2000</th>
<th>change (model)</th>
<th>change (data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>college graduate premium</td>
<td>46.2%</td>
<td>90.9%</td>
<td>44.7pp</td>
<td>43.2pp</td>
</tr>
<tr>
<td>college dropout premium</td>
<td>12.1%</td>
<td>19.6%</td>
<td>7.5pp</td>
<td>7.4pp</td>
</tr>
<tr>
<td>share of college graduates</td>
<td>28.0%</td>
<td>32.9%</td>
<td>4.9pp</td>
<td>4.98pp</td>
</tr>
<tr>
<td>share of college dropouts</td>
<td>42.8%</td>
<td>41.3%</td>
<td>-1.5pp</td>
<td>2.41pp</td>
</tr>
</tbody>
</table>
Outline

1 Introduction

2 Model

3 Calibration

4 Results

5 Conclusion
Main Exercises

Exercise 1: Increase overall spending **without changing the structure of subsidies**, financed by increased tax on labor income.
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- **Exercise 2:** Keep total spending fixed but choose subsidies by year (**year-dependent subsidies**) to maximize the number of college graduates in steady state.
Main Exercises

- Exercise 1: Increase overall spending \textbf{without changing the structure of subsidies}, financed by increased tax on labor income.

- Exercise 2: Keep total spending fixed but choose subsidies by year (\textit{year-dependent subsidies}) to maximize the number of college graduates in steady state.

- Exercise 3: Keep total spending fixed and choose subsidies to maximize welfare in steady state.
Exercise 1: Year Invariant Subsidies

<table>
<thead>
<tr>
<th></th>
<th>$G_e$</th>
<th>$0.75 \tilde{G}_e$</th>
<th>$\tilde{G}_e$</th>
<th>$1.5\tilde{G}_e$</th>
<th>$2\tilde{G}_e$</th>
</tr>
</thead>
<tbody>
<tr>
<td>enrollment rate</td>
<td>72.7%</td>
<td>74.2%</td>
<td>77.2%</td>
<td>77.8%</td>
<td></td>
</tr>
<tr>
<td>share of college graduates</td>
<td>32.1%</td>
<td>32.9%</td>
<td>34.2%</td>
<td>35.0%</td>
<td></td>
</tr>
<tr>
<td>skill premium</td>
<td>95.0%</td>
<td>90.9%</td>
<td>82.8%</td>
<td>78.3%</td>
<td></td>
</tr>
</tbody>
</table>
Exercise 2: Year Dependent Subsidies That Maximize College Graduates

\[
\max_{g_1, g_2, \tau} \int_{S_{CG}^2} d\mu_{2|CG}^G
\]

subject to

\[
g_1 \int_{S_{1|CG}^1} \bar{s}(q) d\mu_{1|CG}^c + g_2 \int_{S_{2|CG}^2} \bar{s}(q) d\mu_{2|CG}^c = G_e
\]

and the government budget constraint where \( s_j(q) = g_j \bar{s}(q) \).
Exercise 2: Year Dependent Subsidies That Maximize College Graduates

\[
\max_{g_1, g_2, \tau} \int_{S_2^{CG}} d\mu_2^{CG}
\]

subject to

\[
g_1 \int_{S_1^c} \bar{s}(q) d\mu_1^c + g_2 \int_{S_2^c} \bar{s}(q) d\mu_2^c = G_e
\]

and the government budget constraint where \( s_j(q) = g_j \bar{s}(q) \).

<table>
<thead>
<tr>
<th>( s_j(q) )</th>
<th>year-invariant ( \tilde{G}_e )</th>
<th>year-dependent ( \bar{G}_e )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( s_1(1) )</td>
<td>$13,599</td>
<td>$4</td>
</tr>
<tr>
<td>( s_1(2) )</td>
<td>$11,447</td>
<td>$4</td>
</tr>
<tr>
<td>( s_1(3) )</td>
<td>$10,922</td>
<td>$3</td>
</tr>
<tr>
<td>( s_2(1) )</td>
<td>$13,599</td>
<td>$42,436</td>
</tr>
<tr>
<td>( s_2(2) )</td>
<td>$11,447</td>
<td>$35,720</td>
</tr>
<tr>
<td>( s_2(3) )</td>
<td>$10,922</td>
<td>$34,082</td>
</tr>
</tbody>
</table>

- Back-loaded
Exercise 2: Year Dependent Subsidies That Maximize College Graduates

<table>
<thead>
<tr>
<th>year-invariant/dependent</th>
<th>invariant $\tilde{G}_e$</th>
<th>dependent $\tilde{G}_e$</th>
<th>invariant $1.5\tilde{G}_e$</th>
</tr>
</thead>
<tbody>
<tr>
<td>enrollment rate</td>
<td>74.2%</td>
<td>68.7%</td>
<td>77.2%</td>
</tr>
<tr>
<td>share of college graduates</td>
<td>32.9%</td>
<td>34.5%</td>
<td>34.2%</td>
</tr>
<tr>
<td>skill premium</td>
<td>90.9%</td>
<td>82.6%</td>
<td>82.8%</td>
</tr>
</tbody>
</table>

- Share of college graduates increases more than increasing the total budget by 50%.
- Skill premium decreases more than increasing the total budget by 50%.
- Enrollment decreases.
In the current system, increasing enrollment encourages more people who are more likely to drop out.
Mechanism

- In the current system, increasing enrollment encourages more people who are more likely to drop out.
- The enrollment margin is not so important from the perspective of getting people to graduate.
Mechanism

- In the current system, increasing enrollment encourages more people who are more likely to drop out.

- The enrollment margin is not so important from the perspective of getting people to graduate.

- It is easier to create incentives for the marginal dropout to finish than to create incentives for the marginal non-enrollee to enroll and finish.
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- The enrollment margin is not so important from the perspective of getting people to graduate.

- It is easier to create incentives for the marginal dropout to finish than to create incentives for the marginal non-enrollee to enroll and finish.

- Decreasing subsidies for the first period serves mainly to discourage people who are unlikely to graduate from enrolling.
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- Decreasing subsidies for the first period serves mainly to discourage people who are unlikely to graduate from enrolling.

- The higher subsidies for the second period encourages marginal dropouts to finish.

- In addition, we can shift subsidies away from college dropouts to college graduates.
Exercise 3: Year Dependent Subsidies That Maximize Welfare of Newborns

\[
\sum_j N_j \left( \int V_j(s_j)d\tilde{\mu}_j(s_j) + \int V_j^c(s_j^c)d\tilde{\mu}_j(s_j^c) \right)
\]

subject to

\[
g_1 \int_{S_1^c} \bar{s}(q)d\mu_1^c + g_2 \int_{S_2^c} \bar{s}(q)d\mu_2^c = G_e
\]

and the government budget constraint where \(s_j(q) = g_j\bar{s}(q)\).

- The government recalculates the lifetime values with rational expectation.
Exercise 3: Year Dependent Subsidies That Maximize Welfare of Newborns

\[
\sum_j N_j \left( \int V_j(s_j) d\mu_j(s_j) + \int V_j^c(s_j^c) d\mu_j(s_j^c) \right)
\]

subject to

\[
g_1 \int_{s_1^c} \bar{s}(q) d\mu_1^c + g_2 \int_{s_2^c} \bar{s}(q) d\mu_2^c = G_e
\]

and the government budget constraint where \( s_j(q) = g_j \bar{s}(q) \).

- The government recalculates the lifetime values with rational expectation.

<table>
<thead>
<tr>
<th></th>
<th>Current state</th>
<th>Optimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>( s_1(1) )</td>
<td>$13,599</td>
<td>$10,721</td>
</tr>
<tr>
<td>( s_1(2) )</td>
<td>$11,447</td>
<td>$9,025</td>
</tr>
<tr>
<td>( s_1(3) )</td>
<td>$10,922</td>
<td>$8,611</td>
</tr>
<tr>
<td>( s_2(1) )</td>
<td>$13,599</td>
<td>$19,858</td>
</tr>
<tr>
<td>( s_2(2) )</td>
<td>$11,447</td>
<td>$16,716</td>
</tr>
<tr>
<td>( s_2(3) )</td>
<td>$10,922</td>
<td>$15,949</td>
</tr>
</tbody>
</table>

- Optimal subsidies are back-loaded.
## Aggregates

<table>
<thead>
<tr>
<th></th>
<th>Current state</th>
<th>Optimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>share of college enrollees</td>
<td>74.2%</td>
<td>73.8%</td>
</tr>
<tr>
<td>share of college graduates</td>
<td>32.9%</td>
<td>33.6%</td>
</tr>
<tr>
<td>skill premium</td>
<td>90.9%</td>
<td>87.3%</td>
</tr>
<tr>
<td>welfare gain</td>
<td></td>
<td>+0.15%</td>
</tr>
</tbody>
</table>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Level</th>
<th>Uncertainty</th>
<th>Inequality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal</td>
<td>+0.07%</td>
<td>+0.15%</td>
<td>+0.04%</td>
<td>−0.09%</td>
</tr>
</tbody>
</table>

- Back-loaded subsidies improve welfare.
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<th>Optimal</th>
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<td>welfare gain</td>
<td></td>
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</tbody>
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<table>
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<td>+0.04%</td>
<td>−0.09%</td>
</tr>
</tbody>
</table>

- Back-loaded subsidies improve welfare.

- The level effect is positive while inequality at the initial state increases.
## Welfare

<table>
<thead>
<tr>
<th></th>
<th>Current state</th>
<th>Optimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y$</td>
<td>0.318</td>
<td>0.318</td>
</tr>
<tr>
<td>$K$</td>
<td>0.413</td>
<td>0.413</td>
</tr>
<tr>
<td>$C$</td>
<td>0.211</td>
<td>0.211</td>
</tr>
<tr>
<td>$w^S$</td>
<td>0.355</td>
<td>0.352</td>
</tr>
<tr>
<td>$w^U$</td>
<td>0.405</td>
<td>0.408</td>
</tr>
<tr>
<td>std $c$</td>
<td>0.129</td>
<td>0.129</td>
</tr>
<tr>
<td>std $a$</td>
<td>0.478</td>
<td>0.475</td>
</tr>
<tr>
<td>std $h$</td>
<td>0.0834</td>
<td>0.0833</td>
</tr>
<tr>
<td>std wage</td>
<td>0.544</td>
<td>0.540</td>
</tr>
</tbody>
</table>
Welfare

<table>
<thead>
<tr>
<th></th>
<th>Current state</th>
<th>Optimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y$</td>
<td>0.318</td>
<td>0.318</td>
</tr>
<tr>
<td>$K$</td>
<td>0.413</td>
<td>0.413</td>
</tr>
<tr>
<td>$C$</td>
<td>0.211</td>
<td>0.211</td>
</tr>
<tr>
<td>$w^S$</td>
<td>0.355</td>
<td>0.352</td>
</tr>
<tr>
<td>$w^U$</td>
<td>0.405</td>
<td>0.408</td>
</tr>
<tr>
<td>std $c$</td>
<td>0.129</td>
<td>0.129</td>
</tr>
<tr>
<td>std $a$</td>
<td>0.478</td>
<td>0.475</td>
</tr>
<tr>
<td>std $h$</td>
<td>0.0834</td>
<td>0.0833</td>
</tr>
<tr>
<td>std wage</td>
<td>0.544</td>
<td>0.540</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$q = 1$</th>
<th>$q = 2$</th>
<th>$q = 3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta = 1$</td>
<td>+0.6%</td>
<td>+0.1%</td>
<td>+0.5%</td>
</tr>
<tr>
<td>$\theta = 2$</td>
<td>+0.2%</td>
<td>−0.4%</td>
<td>+0.5%</td>
</tr>
<tr>
<td>$\theta = 3$</td>
<td>−0.8%</td>
<td>−0.3%</td>
<td>+0.5%</td>
</tr>
<tr>
<td>$\theta = 4$</td>
<td>−0.9%</td>
<td>−0.0%</td>
<td>+0.4%</td>
</tr>
</tbody>
</table>

- High-ability poor-family enrollees lose welfare.
Conclusion

- Back-loaded subsidies maximize the number of college graduates and social welfare.
Conclusion

- Back-loaded subsidies maximize the number of college graduates and social welfare.
- The number of college graduates increases and the skill premium decreases as much as the case with increasing the total budget by 50%.
Conclusion

- Back-loaded subsidies maximize the number of college graduates and social welfare.

- The number of college graduates increases and the skill premium decreases as much as the case with increasing the total budget by 50%.

- Enrollment decreases despite an increase in college graduates. Policies increasing enrollment might be misguided.
Student Loan Transformation

- The fixed payment to repay full debt for 20 years (10 periods) \( d \) is given by
  \[
  a' = \sum_{t=0}^{9} \frac{d}{(1 + r^s)^t} = \frac{d}{1 + r^s} \frac{1 - (1 + r^s)^{-10}}{1 - (1 + r^s)^{-1}} = d \frac{1 - (1 + r^s)^{-10}}{r^s}
  \]

- To have the same payment schedule \( d \) with interest \( r^- \), the initial balance has to be
  \[
  \tilde{a}(a') = \sum_{t=0}^{9} \frac{d}{(1 + r^-)^t} = \frac{d}{1 + r^-} \frac{1 - (1 + r^-)^{-10}}{1 - (1 + r^-)^{-1}} = d \frac{1 - (1 + r^-)^{-10}}{r^-}
  \]

- As a result,
  \[
  \tilde{a}(a') = a' \times \frac{r^s}{1 - (1 + r^s)^{-10}} \times \frac{1 - (1 + r^-)^{-10}}{r^-}
  \]
Working Stage

\[
V_j(a, e, \theta, \eta) = \max_{c,h,a',y} u \left( \frac{c}{1 + 1_{j\neq f} \zeta}, 1 - h \right) + \beta \mathbb{E}_{\eta'|\eta} V_{j+1}(a', e, \theta, \eta')
\]

subject to

\[
c + a' - y + T(c, a, y) = \begin{cases} 
(1 + r)a & \text{if } a \geq 0 \\
(1 + r^-)a & \text{if } a < 0 
\end{cases}
\]

\[
y = w^e e_j^e(\theta, \eta) h, \quad a' \geq -A^e, \quad c \geq 0, \quad 0 \leq h \leq 1, \quad \eta' \sim \pi^e(\cdot | \eta)
\]

where \(1_{j\neq f}\) is an indicator function which is one when the individual lives with its children \((j \in [j_r, j_b - 1])\).
Transfer

\[ V_j(a, e, \theta, \eta) = \max_{c(\theta_h'), h(\theta_h'), a'(\theta_h'), y(\theta_h)} \mathbb{E}_{\theta_h'|e, \theta} \{ u(c(\theta_h'), 1 - h(\theta_h')) + \tilde{V}_{j+1}(a', \theta, \theta_h', e, \eta) \} \]

subject to

\[ c(\theta_h') + a'(\theta_h') - y(\theta_h') + T(c(\theta_h'), a(\theta_h'), y(\theta_h')) = \begin{cases} (1 + r)a & \text{if } a \geq 0 \\ (1 + r^-)a & \text{if } a < 0 \end{cases} \]

\[ y(\theta_h') = w^e \mathbb{E}_j^e(\theta, \eta) h(\theta_h'), \quad a' \geq -A^e \quad c(\theta_h') \geq 0, \quad 0 \leq h(\theta_h') \leq 1, \quad \eta' \sim \pi^e(\cdot|\eta) \]

where

\[ \tilde{V}_{j+1}(a, \theta, \theta_h', e, \eta) = \max_{b \in [0, a]} \beta \mathbb{E}_{\eta'|\eta} V_{j+1}(a-b, e, \theta, \eta') + \nu \mathbb{E}_{\eta''|\phi} V_0(b, \theta_h', \eta'', \tilde{q}(w^e \mathbb{E}_j^e(\theta, \eta)), \phi) \]

for all \( \theta_h' \).

- Individuals can make parental transfers \( b \) to their children only at this age.

- Before making any decisions, individuals observe only their children’s high school ability \( \theta_h' \) from \( \pi_\theta(\theta_h'|e, \theta) \).
Family income level

- Family income level

\[ \tilde{q}(w^e \varepsilon_j^e(\theta, \eta)) = \begin{cases} 
1 & \text{if } w^e \varepsilon_j^e(\theta, \eta) \times 0.35 \in [0, q_1] \\
2 & \text{if } w^e \varepsilon_j^e(\theta, \eta) \times 0.35 \in [q_1, q_2] \\
3 & \text{else} 
\end{cases} \]

where \( q_1 \) and \( q_2 \) correspond to $30,000 and $80,000.
Retirement Stage

$$V_j(a, e, \theta) = \max_{c, a'} u(c, 1) + \beta \varphi_{j+1} V_{j+1}(a', e, \theta)$$

subject to

$$c + a' = (1 + r)\varphi_j^{-1} a + p(e, \theta) - T(c, \varphi_j^{-1} a, 0)$$

$$a' \geq 0 \quad c \geq 0$$

- The sources of income is asset earnings and retirement benefits $p(e, \theta)$.

- The asset inflated by $\varphi_j^{-1}$ reflects that assets of expiring households are distributed within cohorts (perfect annuity market).
Social Security

- The average life time income is
  \[ \hat{y}(e, \theta) = \frac{\sum_{j=j_0+2}^{j_r-1} w^e \xi_j^e(\theta, 1) \bar{h}}{j_r - 2} \]

- The pension formula is given by
  \[ p(e, \theta) = \begin{cases} 
  s_1 \hat{y}(e, \theta) & \text{for } \hat{y}(e, \theta) \in [0, b_1) \\
  s_1 b_1 + s_2 (\hat{y}(e, \theta) - b_1) & \text{for } \hat{y}(e, \theta) \in [b_1, b_2) \\
  s_1 b_1 + s_2 (b_2 - b_1) + s_3 (\hat{y}(e, \theta) - b_2) & \text{for } \hat{y}(e, \theta) \in [b_2, b_3) \\
  s_1 b_1 + s_2 (b_2 - b_1) + s_3 (b_3 - b_2) & \text{for } \hat{y}(e, \theta) \in [b_3, \infty) 
  \end{cases} \]

where \( s_1 = 0.9, s_2 = 0.32, s_3 = 0.15, b_1 = 0.22\bar{y}, b_2 = 1.33\bar{y}, b_3 = 1.99\bar{y}, \) \( \bar{y} = $28,793 \) annually.
Financial Market

- There is no insurance market and individuals can self-insure using only risk-free assets.

- Borrowing wedge:
  - Overseeing cost $i$ for workers: $r^- = r + i$
  - Overseeing cost $i + i^s$ for enrollees: $r^s = r^- + i^s$

- Borrowing limit:
  - $A^e$ for workers with education $e$
  - $A^c_j$ for enrollees at age $j$
Share of Skilled Labor from College Dropouts

- Two separate data:
  - the fraction of jobs requiring each education level
  - the fraction of workers acquiring each education level

- Interpreting jobs for college dropouts and more as skilled labor.

<table>
<thead>
<tr>
<th></th>
<th>skilled</th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>CG 23%</td>
<td>CD 11%</td>
<td>HS 39%</td>
<td>HD 27%</td>
</tr>
<tr>
<td>jobs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>28%</td>
<td>39%</td>
<td>24%</td>
<td>9%</td>
</tr>
<tr>
<td>population</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6% 33%
Government Budget

- Government Budget Constraint

\[ G_c + G_e + \sum_{j=j_r}^{J} \int_{s_j} p(e, \theta) d\mu_j = \sum_{j=1,2} \int_{s_j^c} T(c_j^c(s_j^c), a_j^c(s_j^c), y_j^c(s_j^c)) d\mu_j^c \]

\[ + \sum_{j} \int_{s_j} T(c_j(s_j), a_j(s_j^s), y_j(s_j^s)) d\mu_j^s \]

where

\[ G_c = gF(K, H) \]

\[ G_e = \sum_{j=1,2} \int_{s_j^c} s_j(q, \theta) d\mu_j^c \]
Market clearing

- Aggregate labor

\[ H^S + \kappa E = H^{CG} \]
\[ H^U = H^{HS} + H^{CD} \]

where

\[ H^{CG} = \sum_{j=3}^{j_r-1} \int_{S_j^{CG}} \epsilon_{j}^{CG}(\theta, \eta) h_j(s_j) d\mu_{j}^{CG} \]
\[ H^{CD} = \sum_{j=2}^{j_r-1} \int_{S_j^{CD}} \epsilon_{j}^{CD}(\theta, \eta) h_j(s_j) d\mu_{j}^{CD} + \int_{S_2^C} \epsilon_{2}^{CD}(\theta, \eta) h_2^c(s_2^c) d\mu_{2}^{c} \]
\[ H^{HS} = \sum_{j=1}^{j_r-1} \int_{S_j^{HS}} \epsilon_{j}^{HS}(\theta, \eta) h_j(s_j) d\mu_{j}^{HS} + \int_{S_1^C} \epsilon_{1}^{HS}(\theta, \eta) h_1^c(s_1^c) d\mu_{1}^{c} \]

- Capital

\[ K = \sum_{j=1}^{j_r-1} \int_{S_j} a'_j(s_j) d\mu_j + \sum_{j=1,2} \int_{S_j^c} a'_j^c(s_j^c) d\mu_j^c \]

- Education

\[ E = \sum_{j=1,2} \int_{S_j^c} d\mu_j^c \]
Equilibrium

Definition

A stationary equilibrium is a list of value functions of workers and college enrollees \( \{V_j(s_j), V_j^c(s_j^c)\} \), decision rules of enrollment \( d_0(s_0) \) and graduation \( d_1(s_1^c) \), decision rules of consumption, asset holdings, labor, output, parental transfers of workers \( \{c_j(s_j), a_j^c(s_j), h_j(s_j), y_j(s_j), b(s_j)\} \), decision rules of college enrollees \( \{c_j^c(s_j^c), a_j^c(s_j^c), h_j^c(s_j^c), y_j^c(s_j^c)\} \), aggregate enrollees, capital, and labor inputs \( \{E, K, H^S, H^U\} \), prices \( \{r, w^S, w^U, p_e\} \), policies \( \tau_\ell \), measures \( \mu = \{\mu_j^c(s_j^c), \mu_j(s_j), \mu_j^e(s_j^e)\} \) such that

1. Taking prices and policies as given, value functions \( \{V_j^c(s_j^c), V_j(s_j)\} \) solve the household Bellman equation*\( s \) and \( d_0(s_0), d_1(s_1^c) \), \( \{c_j(s_j), a_j^c(s_j), h_j(s_j), y_j(s_j), b(s_j)\} \), \( \{c_j^c(s_j^c), a_j^c(s_j^c), h_j^c(s_j^c), y_j^c(s_j^c)\} \) are associated decision rules.

2. Taking prices and policies as given, \( K, H^{HS}, H^{CG} \) solve the optimization problem of the good sector and \( E \) solves the optimization problem of the education sector.

3. The government budget is balanced.

4. Human capital, asset, and education markets clear.

5. Measures \( \mu \) are reproduced for each period.
Labor Productivity Process Estimation

- PSID: SRC sample, only people with 8 or more individual-year observations
- keep only positive hours of labor aged 25-63
- eliminate extreme changes in earnings
- quadratic ages are separately estimated by education group with year dummies

<table>
<thead>
<tr>
<th></th>
<th>HS</th>
<th>CD</th>
<th>CG</th>
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<tr>
<td>Age</td>
<td>.0530181</td>
<td>.0684129</td>
<td>.0955783</td>
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<tr>
<td></td>
<td>(.0030501)</td>
<td>(.0040353)</td>
<td>(.0036997)</td>
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<tr>
<td>Age²</td>
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<td>-.0006872</td>
<td>-.0009521</td>
</tr>
<tr>
<td></td>
<td>(.0000356)</td>
<td>(.0000474)</td>
<td>(.0000429)</td>
</tr>
</tbody>
</table>
Labor Productivity

- For high school graduates, $\theta = \theta_h$ which is approximated by $\ln \text{AFQT80}$.

- For college dropouts and college graduates, I use high school ability ($\theta_c = \theta_h + \epsilon_c$).

\[
\ln \epsilon^e + \ln \psi_j^e + \epsilon_\theta^e \theta_c + \ln \eta = \ln \epsilon^e + \ln \psi_j^e + \epsilon_\theta^e \theta_h + (\ln \eta + \epsilon_\theta^e \epsilon_c)
\]

because $\theta_h$ is uncorrelated with $\ln \eta + \epsilon_\theta^e \epsilon_c$. 
Markov Chain Approximation

- Two state Markov chain with education-specific states for \(\{-\sigma, \sigma\}\) and transition matrix

\[
\begin{bmatrix}
\pi_e & 1 - \pi_e \\
1 - \pi_e & \pi_e
\end{bmatrix}
\]

where

\[
\rho^{e2} = 2\pi_e - 1
\]

\[
\sigma_e = \frac{\sigma}{\sqrt{1 - \rho^{e2}}}
\]
## Parameters Determined outside the Model

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Interpretation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma$</td>
<td>Coef of relative risk aversion</td>
<td>4</td>
</tr>
<tr>
<td>$\bar{h}$</td>
<td>Study time</td>
<td>0.25</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>Adult equivalence scale</td>
<td>0.3</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Capital share</td>
<td>33.3%</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Depreciation (annual)</td>
<td>7.55%</td>
</tr>
<tr>
<td>$\rho$</td>
<td>Elasticity of substitution in production $1.41$</td>
<td>0.2908</td>
</tr>
<tr>
<td>$i^S$</td>
<td>Stafford interest premium (annual)</td>
<td>2.3%</td>
</tr>
<tr>
<td>$A^c_1$</td>
<td>Borrowing constraint for 1st half (Stafford loan)</td>
<td>$6,125$</td>
</tr>
<tr>
<td>$A^c_2$</td>
<td>Borrowing constraint for 2nd half (Stafford loan)</td>
<td>$23,000$</td>
</tr>
<tr>
<td>$A^{HS}$</td>
<td>Borrowing constraint, HS (SCF)</td>
<td>$17,000$</td>
</tr>
<tr>
<td>$A^{CD}$</td>
<td>Borrowing constraint, CD (SCF)</td>
<td>$20,000$</td>
</tr>
<tr>
<td>$A^{CG}$</td>
<td>Borrowing constraint, CG (SCF)</td>
<td>$34,000$</td>
</tr>
<tr>
<td>$\tau_c$</td>
<td>Consumption tax rate</td>
<td>7%</td>
</tr>
<tr>
<td>$\tau_k$</td>
<td>Capital income tax rate</td>
<td>27%</td>
</tr>
<tr>
<td>$g$</td>
<td>Gov cons to GDP ratio</td>
<td>17.1%</td>
</tr>
</tbody>
</table>
The residual process is assumed to be

\[ y_{ia} = \alpha_i + z_{ia} + u_{ia} \]

where

\[ z_{ia} = \rho z_{i-1} + \epsilon_{\eta i} \], \[ \epsilon_{\eta i} \sim N(0, \sigma_{\eta}^2) \]

Then

\[ \text{cov}(y_{ia}, y_{ia-d}) = \sigma_{\alpha}^2 + \rho^d \frac{1 - \rho^2}{1 - \rho^2} \sigma_{\eta}^2 + \mathbb{1}_{d=0} \sigma_u^2 \]
Responding to the consumption loss at the first period

<table>
<thead>
<tr>
<th></th>
<th>% of subsidy loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsidies</td>
<td>-100%</td>
</tr>
<tr>
<td>Labor income</td>
<td>+24%</td>
</tr>
<tr>
<td>(Price of an hour of working)</td>
<td>+13%</td>
</tr>
<tr>
<td>(Leisure)</td>
<td>(-0.061)</td>
</tr>
<tr>
<td>Transfer from parents</td>
<td>+0.03%</td>
</tr>
<tr>
<td>Reducing savings</td>
<td>+65%</td>
</tr>
<tr>
<td>Less tuition</td>
<td>+4%</td>
</tr>
<tr>
<td>Consumption</td>
<td>-7%</td>
</tr>
</tbody>
</table>

- Consumption at the first period does not decrease much because:

  - The wage of college enrollees increases due to a smaller skill premium.
Responding to the consumption loss at the first period

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- Consumption at the first period does not decrease much because:
  - The wage of college enrollees increases due to a smaller skill premium.
  - They work for longer hours.
Responding to the consumption loss at the first period

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- Consumption at the first period does not decrease much because:
  
  - The wage of college enrollees increases due to a smaller skill premium.
  
  - They work for longer hours.
  
  - Parents increase transfer.
Correcting bias

- If we can correct bias, do we still need year-dependent subsidies?
Correcting bias

- If we can correct bias, do we still need year-dependent subsidies?
- Find the new optimal year-dependent subsidies given that government eliminates bias costlessly.
Correcting bias

- If we can correct bias, do we still need year-dependent subsidies?

- Find the new optimal year-dependent subsidies given that government eliminates bias costlessly.

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<tr>
<th></th>
<th>Current state</th>
<th>Optimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_1(1)$</td>
<td>$20,344$</td>
<td>$21,750$</td>
</tr>
<tr>
<td>$s_1(2)$</td>
<td>$17,124$</td>
<td>$18,308$</td>
</tr>
<tr>
<td>$s_1(3)$</td>
<td>$16,339$</td>
<td>$17,469$</td>
</tr>
<tr>
<td>$s_2(1)$</td>
<td>$20,344$</td>
<td>$17,808$</td>
</tr>
<tr>
<td>$s_2(2)$</td>
<td>$17,124$</td>
<td>$14,990$</td>
</tr>
<tr>
<td>$s_2(3)$</td>
<td>$16,339$</td>
<td>$14,302$</td>
</tr>
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Correcting bias

- If we can correct bias, do we still need year-dependent subsidies?
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- Front-loaded subsidies are optimal when correcting bias.
### Correcting Bias

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</tr>
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- Correcting bias reduces welfare significantly.
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- Correcting bias reduces welfare significantly.

- Enrollment is excessively low due to no insurance on college ability.
No Optimism

In this paper, optimism is a key factor for college dropouts.

A different approach to explain college dropouts: High option value due to high uncertainty of college ability.

I assume that the standard deviations of college ability can vary across high school ability.

\[ \sigma_c(\theta_h) = \sigma_c \exp(\sigma_c^\theta \theta_h) \]
### No Optimism: The Remaining Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda$</td>
<td>college utility intercept</td>
<td>-16.6</td>
</tr>
<tr>
<td>$\lambda^\theta$</td>
<td>college utility slope</td>
<td>287</td>
</tr>
<tr>
<td>$\lambda_1^\phi$</td>
<td>first period college taste</td>
<td>68.8</td>
</tr>
<tr>
<td>$\lambda_2^\phi$</td>
<td>second half college taste</td>
<td>40.0</td>
</tr>
<tr>
<td>$a^S$</td>
<td>productivity of skilled labor</td>
<td>0.435</td>
</tr>
<tr>
<td>$\epsilon_{CD}$</td>
<td>productivity of CD</td>
<td>0.985</td>
</tr>
<tr>
<td>$\sigma_c$</td>
<td>s.d. of college ability intercept</td>
<td>0.721</td>
</tr>
<tr>
<td>$\sigma_c^\theta$</td>
<td>s.d. of college ability slope</td>
<td>0.158</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>education cost</td>
<td>0.422</td>
</tr>
<tr>
<td>$\mu$</td>
<td>consumption share of preference</td>
<td>0.422</td>
</tr>
<tr>
<td>$\beta$</td>
<td>time discount rate</td>
<td>0.931</td>
</tr>
<tr>
<td>$\nu$</td>
<td>altruism</td>
<td>0.0630</td>
</tr>
<tr>
<td>$d$</td>
<td>lump-sum transfer ratio</td>
<td>0.131</td>
</tr>
<tr>
<td>$\iota$</td>
<td>borrowing wedge ($r^- = r + \iota$)</td>
<td>18.7%</td>
</tr>
<tr>
<td>$m$</td>
<td>intergenerational ability transmission intercept</td>
<td>-0.0384</td>
</tr>
<tr>
<td>$\sigma_h$</td>
<td>intergenerational ability transmission s.d.</td>
<td>0.0764</td>
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</tbody>
</table>
No Optimism: Matched Moments

<table>
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<tr>
<th>Moment</th>
<th>Model</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enrollment rate of ability quartile</td>
<td>(figure)</td>
<td>(figure)</td>
</tr>
<tr>
<td>Graduation rate of ability quartile</td>
<td>(figure)</td>
<td>(figure)</td>
</tr>
<tr>
<td>Enrollment rate of family income quartile</td>
<td>(figure)</td>
<td>(figure)</td>
</tr>
<tr>
<td>Graduation rate of family income quartile</td>
<td>(figure)</td>
<td>(figure)</td>
</tr>
<tr>
<td>Skill premium for CG</td>
<td>90.7%</td>
<td>90.2%</td>
</tr>
<tr>
<td>Skill premium for CD</td>
<td>20.1%</td>
<td>19.9%</td>
</tr>
<tr>
<td>Education cost/mean income at 48</td>
<td>0.308</td>
<td>0.33</td>
</tr>
<tr>
<td>Hours of work</td>
<td>33.3%</td>
<td>33.3%</td>
</tr>
<tr>
<td>(K/Y)</td>
<td>1.241</td>
<td>1.325</td>
</tr>
<tr>
<td>Transfer/mean income at 48</td>
<td>67.2%</td>
<td>66%</td>
</tr>
<tr>
<td>Log pre-tax/post-tax income</td>
<td>60.5%</td>
<td>61%</td>
</tr>
<tr>
<td>Borrowers</td>
<td>6.07%</td>
<td>6.3%</td>
</tr>
<tr>
<td>Mean of AFQT</td>
<td>0.0880</td>
<td>0</td>
</tr>
<tr>
<td>Standard deviation of AFQT</td>
<td>0.204</td>
<td>0.213</td>
</tr>
</tbody>
</table>
No Optimism: Model Fit

**Figure:** Enrollment rates

**Figure:** Graduation rates
Mo Optimism: Optimal Policy

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<tr>
<td>$s_1(1)$</td>
<td>$13,600$</td>
</tr>
<tr>
<td>$s_1(2)$</td>
<td>$11,448$</td>
</tr>
<tr>
<td>$s_1(3)$</td>
<td>$10,923$</td>
</tr>
<tr>
<td>$s_2(1)$</td>
<td>$13,600$</td>
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