The Return to College: Selection Bias and Dropout Risk

Lutz Hendricks (University of North Carolina)  
Oksana Leukhina (University of Washington)

QSPS, Utah State University  
May 24, 2013
College graduates earn about $500,000 more than high school graduates

55% enter college, 55% of those graduate
The Questions

- What part of the measured college earnings premium is due to selection?
- How large are ex-ante returns to college for various individuals?
- What governs the college entry and dropping out decisions?
- Counterfactuals: relax borrowing constraints, dual enrollment programs
The Approach

- We develop a model of college choice.
- We calibrate the model for the 1960 birth cohort.
- The calibrated model is used to answer our questions.
Model Features

- Ability affects earnings and chance of graduating from college
- Students do not perfectly observe their abilities
  - Update their beliefs as they progress through college
- Heterogeneity in ability signals, assets and college costs
- Preference shocks - diminish sorting by ability
- Dropping out of college is a choice
  - Dropout risk is important for the ex ante return to college
- College has a common consumption value
- Main Contribution: Measure selection bias in a model with dropout risk
50% of the measured college earnings premium is due to ability selection.

Log discounted lifetime earnings is

\[ \log Y(a, n\tau, s, \tau) = \phi_s(a - a) + \mu n\tau + \log Y(s) + \log R^{-\tau}. \]

Selection contribution to log earnings gap is

\[ \phi_{HS}[\mathbb{E}(a - a|CG) - \mathbb{E}(a - a|HS)] \]
\[ \mathbb{E}[\log Y(a, n\tau, s, \tau)|CG] - \mathbb{E}[\log Y(a, n\tau, s, \tau)|HS]. \]

Returns to college graduation increase with ability (complementarity).

Ability signal is the main factor for the entry decision.

Dropouts

- Low signal students never intend to graduate (consumption value)
- Medium signal students receive bad news
- High signal students drop out because of preference shocks
The Model
We follow one cohort from high school graduation.

At age $t = 1$, students

- graduate from high school.
- choose work or college.

Working life segment is standard: permanent income consumers.

In college, students accumulate credits and update beliefs regarding their learning abilities.

Dropping out is a choice.
Each student is of type $j \in 1, ..., J$ which determines
- initial assets $k_1$, a discrete value $\hat{k}_j$,
- ability signal $m$
- net annual college cost $q$
- joint distribution of $(k_1, m, q)$ is a discrete approximation of a joint Normal.

Cumulative college credits endowment $n_1 = 0$.

Learning ability draw $a$, unobserved until start of work.
- The ability grid approximates a standard Normal distribution:

$$
    a = \frac{\alpha_{am} m + \epsilon_a}{(\alpha_{am}^2 + 1)^{1/2}},
$$

with $\epsilon_a \sim N(0,1)$.
Agents enter the model at age 1 and live until age $T$.
Two consumption goods: market $c_F$ and non-market $c_L$.
Lifetime utility is given by
\[
E_0 \sum_{t=1}^{T} \beta^t u(c_t)
\]
where $c_t = C(c_{Ft}, c_{Lt})$.
Each period, choose to work or study.
Cannot reenter college once work is chosen.
- Start of work: age $\tau$.
- Completed schooling: $s \in \{HS, CD, CG\}$.
- Learn ability at start of work - value $V$.
- Value of starting work at age $\tau$:

$$V_W(k_\tau, n_\tau, j, s, \tau) = \sum_{i=1}^{N_a} V(k_\tau, \hat{a}_i, n_\tau, s, \tau) Pr(\hat{a}_i | n_\tau, j, \tau)$$

- Probabilities $Pr(\hat{a}_i | n_\tau, j, \tau)$ are the agent’s beliefs about own $a$. 
Work: Known ability

- Worker’s value after learning $a$

$$V(k_{\tau}, a, n_{\tau}, s, \tau) = \max_{\{c_{Ft}\}} \sum_{t=\tau}^{T} \beta^{t-\tau} u(C[c_{Ft}, \hat{c}_L]) + U_s$$

subject to

$$e^{\phi_s(a-a) + \mu n_{\tau}} Y(s) + Rk_{\tau} = \sum_{t=\tau}^{T} c_{Ft} R^{\tau-t}$$

Lifetime earnings

- $U_s$ captures the utility derived from $s$ type job characteristics, common to all agents.
- We impose $Y(CD) = Y(HS)$ and $\phi(CD) = \phi(HS)$, $Y(CG) \geq Y(CD)$ and $\phi(CG) \geq \phi(CD)$. 
Choices: Age $t = 1$

Draw endowments: type $j = (k_1, m, q)$ and $n_1 = 0$

Choose fixed college consumption: $c_{F,j_c,j}$

Work as HS graduate
$V_W(k_1, 0, j, HS, 1)$

Try college
$V_C(0, j_c, j, 1)$
College Consumption Choice: Age $t = 1$

- Discrete set of values indexed by $j_c = 1, \ldots, N_c$, type-specific.
- $c_{F,j_c,j}$ maximizes lifetime utility s.t. to preference shocks $p_{jc}$ drawn independently from a type I extreme value distribution:

$$j_c = \arg\max \{ V_C(0, j_c, j, 1) + \pi_c p_{jc} \}$$

- Consumption value choice probabilities $Pr(j_c|j)$ have a closed form solution.
The agent solves

$$\max \{ V_C(0, j_c, j, 1) + \pi p_{ct}, V_W(k_1, 0, j, HS, 1) + \pi p_{wt} \},$$

where $p_{ct}$ and $p_{wt}$ are independent draws form a type I extreme value distribution.

College choice probability $\Pr(\text{college} | j_c, j)$ has a closed form solution.
## Choices: In College, Age $t$

<table>
<thead>
<tr>
<th>$V_C(n_t,jc,j,t)$</th>
<th>$V_W(n_{t+1},j,CG,t+1)$</th>
<th>$V_W(n_{t+1},j,CD,t+1)$</th>
<th>$V_C(n_{t+1},jc,j,t+1)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consume $cF_{jc,j}$, accumulate $k_{jc,j,t+1} = Rk_{jc,j,t} - cF_{jc,j} - \hat{q}_j$.</td>
<td>Graduate</td>
<td>Drop out</td>
<td>Study in $t+1$</td>
</tr>
<tr>
<td>Draw $n_{t+1}$. Update beliefs about $a$.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Choices: In College, Age $t$

- State: $n_t, j_c, j, t$.
- Receive $\bar{c}_L$ for free, consume $c_{F,j_c,j}$ chosen previously.
  - budget constraint: $k_{j_c,j,t+1} = R k_{j_c,j,t} - c_{F,j_c,j} - \hat{q}_j$.
  - borrowing constraint: $k_{t+1} \geq k_{\text{min},t+1}$.
- Attempt a fixed number of credits $n_c$.
- Complete each with probability $\text{Pr}_c(a)$.
  - $n_{t+1}$ is a draw from the Binomial distribution $B(n_c,t,\text{Pr}_c(a))$.
- Update beliefs about $a$.
- Choose whether to study or work next period
  - must work (as a $\text{CG}$) if $n_{t+1} \geq n_{\text{grad}}$,
  - must work (as a $\text{CD}$) if $n_{t+1} < n_{\text{grad}}$ and $t = T_c$. 
Bellman equation $V_C(n_t, j_c, j, t) =$

$$= u(C[c_{F_jc,j}, \bar{c}_L]) + \beta \sum_{n_{t+1}} Pr(n_{t+1} | n_t, j, t)V_{EC}(n_{t+1}, j_c, j, t + 1)$$

where $V_{EC}(n_{t+1}, j_c, j, t + 1) =$

$$= \begin{cases} 
V_W(k_{j_c,j,t+1}, n_{t+1}, j, CG, t + 1) \\
V_W(k_{j_c,j,t+1}, n_{t+1}, j, CD, t + 1) \\
E \max \left\{ V_C(n_{t+1}, j_c, j, t + 1) + \pi p_{ct} \\
V_W(k_{t+1}, n_{t+1}, j, CD, t + 1) + \pi p_{wt} \right\} 
\end{cases}$$

if $n_{t+1} \geq n_{grad}$

if forced to drop

otherwise
Calibration
Datasets Employed

- Sample: Men born around 1960.
- For college attendance, performance, and financing: High School & Beyond Study (sophomore cohort) and PETS (transcript study)
- For earnings: NLSY79 and CPS.
For the calibration, we need to map $m$ into something observable.

- We assume that the NLSY Armed Forces Qualification Test (denoted by $IQ$) is a noisy measure of $m$:

$$IQ = \frac{\alpha_{IQ,m}m + \varepsilon_{IQ}}{\left(\alpha_{IQ,m}^2 + 1\right)^{1/2}} \sim N(0,1)$$

with $\varepsilon_{IQ} \sim N(0,1)$.

- We assume that $IQ$ quartiles correspond to HS GPA quartiles in HS&B.
### Fixed Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferences</td>
<td>Discount factor</td>
<td>0.98</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Elasticity of substitution</td>
<td>0.50</td>
</tr>
<tr>
<td>$\rho$</td>
<td>Scale of preference shocks at consumption choice</td>
<td>0.200</td>
</tr>
<tr>
<td>$\pi_c$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>College</td>
<td>Maximum duration of college</td>
<td>6</td>
</tr>
<tr>
<td>$T_C$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$n_{grad}$</td>
<td>Number of credits to graduate</td>
<td>20</td>
</tr>
<tr>
<td>$n_c$</td>
<td>Number of credits attempted</td>
<td>5</td>
</tr>
<tr>
<td>$k_{min}$</td>
<td>Borrowing limit</td>
<td>$19,750$</td>
</tr>
<tr>
<td>Other</td>
<td>Gross interest rate</td>
<td>1.04</td>
</tr>
<tr>
<td>$R$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. Parameters that govern the endowment distribution and IQ noise,
2. $\gamma(s)$: Lifetime earnings functions,
3. $\phi_s$: Effect of ability on lifetime earnings
4. $\mu$: Governs the contribution of earned credits to earnings,
5. $\gamma_1, \gamma_2, \gamma_{\text{min}}$: The probability of passing a credit is given by $\gamma + \frac{\gamma_{\text{max}} - \gamma_{\text{min}}}{1 + e^{-\gamma_2 a}}$,
6. $\bar{c}_L$: The consumption value of college,
7. $\pi$: Scale of preference shocks,
8. $U(s)$: Common preference for job of type $s$. 
## Calibration Targets

<table>
<thead>
<tr>
<th>Target</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifetime earnings by (test score quartile, schooling)</td>
<td>NLSY</td>
</tr>
<tr>
<td>Fraction in population by (test score quartile, schooling)</td>
<td>NLSY</td>
</tr>
<tr>
<td>Dropout rate by (test score quartile, year in college)</td>
<td>HS&amp;B</td>
</tr>
<tr>
<td>Average time to BA degree (years)</td>
<td>HS&amp;B</td>
</tr>
<tr>
<td>Mean and standard deviation of initial assets</td>
<td>HS&amp;B</td>
</tr>
<tr>
<td>Mean and standard deviation of college costs $q$</td>
<td>HS&amp;B</td>
</tr>
<tr>
<td>Fraction of students in debt, by year in college</td>
<td>HS&amp;B</td>
</tr>
<tr>
<td>Mean student debt, by year in college</td>
<td>HS&amp;B</td>
</tr>
<tr>
<td>Fraction of credits passed, by graduation status and year</td>
<td>HS&amp;B</td>
</tr>
</tbody>
</table>
Calibrated Model
### Calibrated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \phi_{HS}, \phi_{CD}, \phi_{CG} )</td>
<td>Effect of ability on earnings</td>
<td>0.150, 0.150, 0.189</td>
</tr>
<tr>
<td>( Y(HS), Y(CG) )</td>
<td>Lifetime earnings factor</td>
<td>0.9, 0.9</td>
</tr>
<tr>
<td>( \mu )</td>
<td>Earnings gain per credit</td>
<td>0.015</td>
</tr>
<tr>
<td>( \pi )</td>
<td>Scale of preference shocks</td>
<td>0.883</td>
</tr>
<tr>
<td>( \bar{c}_L )</td>
<td>Consumption in college</td>
<td>0.001</td>
</tr>
<tr>
<td>( U(s) )</td>
<td>Preference for job type ( s )</td>
<td>CD: -0.76, CG: -2.37</td>
</tr>
<tr>
<td>( \gamma_{min}, \gamma_1, \gamma_2 )</td>
<td></td>
<td>0.57, 2.11, 8.00</td>
</tr>
<tr>
<td>( Pr_c(a) )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Passing Rate and Probability of Graduation by $a$

![Graph showing the passing rate and probability of graduation by ability.]

- The graph on the left plots the probability of passing a course against ability.
- The graph on the right shows the cumulative ability fraction and the corresponding probability.
Calibrated Parameters: Endowments

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endowments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\eta_1, \eta_2$</td>
<td>Dist. of $k_1$</td>
<td>10.00, 4.17</td>
</tr>
<tr>
<td>$\mu_q$</td>
<td>Mean of $q$</td>
<td>3.27</td>
</tr>
<tr>
<td>$\sigma_q$</td>
<td>St. Dev. of $q$</td>
<td>6.06</td>
</tr>
<tr>
<td>Endowment correlations</td>
<td>$\alpha_{MK}$, $\alpha_{MQ}$, $\alpha_{QK}$, $\alpha_{AM}$, $\alpha_{IQ}$, $\alpha_M$</td>
<td>See corr matrix</td>
</tr>
</tbody>
</table>
Calibrated Parameters: Endowments

<table>
<thead>
<tr>
<th></th>
<th>AFQT</th>
<th>$a$</th>
<th>$m$</th>
<th>$q$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFQT</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$a$</td>
<td>0.80</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$m$</td>
<td>0.85</td>
<td>0.93</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>$q$</td>
<td>-0.25</td>
<td>-0.30</td>
<td>-0.28</td>
<td>1.00</td>
</tr>
<tr>
<td>$k_1$</td>
<td>0.07</td>
<td>0.08</td>
<td>0.06</td>
<td>-0.07</td>
</tr>
</tbody>
</table>
The model replicates data targets very well.
College Entry and Completion Rates by IQ

[Bar chart showing the fraction of the population trying college and obtaining a college degree across different AFQT quartiles (1-4).]

Model vs Data comparison for college entry and completion rates.
Earnings Distribution by IQ and Schooling
Dropout Rate by Year, by IQ quartile

![Graph showing dropout rate by year and IQ quartile for different age groups.](image-url)
## Credit Passing Rates

<table>
<thead>
<tr>
<th>Year</th>
<th>College dropouts</th>
<th>College graduates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model</td>
<td>Data</td>
</tr>
<tr>
<td>1</td>
<td>74.2</td>
<td>67.7</td>
</tr>
<tr>
<td>2</td>
<td>72.9</td>
<td>71.8</td>
</tr>
<tr>
<td>3</td>
<td>70.0</td>
<td>66.9</td>
</tr>
<tr>
<td>4</td>
<td>64.0</td>
<td>63.8</td>
</tr>
</tbody>
</table>
## Debt Statistics by Year in College

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean debt</th>
<th>Fraction with debt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model</td>
<td>Data</td>
</tr>
<tr>
<td>1</td>
<td>4,293</td>
<td>3,549</td>
</tr>
<tr>
<td>2</td>
<td>7,150</td>
<td>6,060</td>
</tr>
<tr>
<td>3</td>
<td>8,629</td>
<td>8,045</td>
</tr>
<tr>
<td>4</td>
<td>11,175</td>
<td>9,740</td>
</tr>
</tbody>
</table>
### Initial Assets and College Cost

<table>
<thead>
<tr>
<th>Distribution of $k_1$, HS</th>
<th>Model</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>15,322</td>
<td>12,463</td>
</tr>
<tr>
<td>standard deviation</td>
<td>20,949</td>
<td>23,266</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Distribution of $q$, college</th>
<th>Model</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>-766</td>
<td>-584</td>
</tr>
<tr>
<td>standard deviation</td>
<td>5,146</td>
<td>5,787</td>
</tr>
<tr>
<td>HS GPA quartile</td>
<td>Mean Model</td>
<td>q</td>
</tr>
<tr>
<td>----------------</td>
<td>------------</td>
<td>---</td>
</tr>
<tr>
<td>1</td>
<td>-2,521</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-1,810</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-454</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-232</td>
<td></td>
</tr>
</tbody>
</table>
Results
Log of discounted lifetime earnings
\[
\log Y(a, n_\tau, s, \tau) = \phi_s(a - a) + \mu n_\tau + \log Y(s) + \log R^{-\tau}.
\]

Selection contribution to log earnings gap is
\[
\frac{\phi_{HS}[\mathbb{E}(a - a|CG) - \mathbb{E}(a - a|HS)]}{\mathbb{E}[\log Y(a, n_\tau, s, \tau)|CG] - \mathbb{E}[\log Y(a, n_\tau, s, \tau)|HS]} = 0.48,
\]

Price contribution
\[
\frac{\log Y(CG) - \log Y(HS) + (\phi_{CG} - \phi_{HS})\mathbb{E}(a - a|CG)}{(\cdot)} = 0.23,
\]

Credits earned contribution \(\mathbb{E}(\mu n_\tau|CG)/(\cdot) = 0.73\),

Delayed work start \(\mathbb{E}\log R^{-\tau}/(\cdot) = -0.44\).
Schooling Outcomes by $a$ and $m$
Schooling Outcomes by $q$ and $k_1$
Understanding College Entry
Outcomes by Ability Signal

![Graphs showing outcomes by ability signal](image_url)

- Trying college
- Graduating
- Graduating at T

- Cumulative signal fraction
- Fraction
- Lifetime earnings

- HS
- CD
- CG

45 / 58
Understanding College Dropouts
Who are the Dropouts?

- Students who never planned to graduate to begin with (mostly low $m$, low $q$ agents).
- Students who planned to graduate when entered but updated (based on course passing rate) their graduation beliefs downward while in college (mostly medium $m$ agents).
  - $m$ too high relative to $a$
  - just bad luck
- Students whose decisions to continue their studies were reversed by preference shocks (mostly low $m$ agents)
Never Planned to Graduate
Graduation Prospects Updated Downward

- Cumulative m fraction
  - Prob. of graduating at time of dropping out
  - Prob. of graduating at age 1
  - Fraction of dropouts

- Cumulative signal fraction
  - Standard deviation

Graphs showing changes in graduation prospects with varying cumulative m and signal fractions.
Shut Down Preference Shocks

![Graph showing Shut Down Preference Shocks with ability percentile on the x-axis and a range of values on the y-axis. The bars represent different shocks with varying heights.](image-url)
Counterfactual Experiments:

- Easing of Borrowing Constraints
- Dual Enrollment Programs
### Fraction by schooling

<table>
<thead>
<tr>
<th>Schooling</th>
<th>HS</th>
<th>CD</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.47</td>
<td>0.24</td>
<td>0.29</td>
</tr>
<tr>
<td>Relax borrowing constraints</td>
<td>0.39</td>
<td>0.25</td>
<td>0.36</td>
</tr>
</tbody>
</table>

### Mean log ability

<table>
<thead>
<tr>
<th>Schooling</th>
<th>HS</th>
<th>CD</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>-0.48</td>
<td>-0.12</td>
<td>0.95</td>
</tr>
<tr>
<td>Relax borrowing constraints</td>
<td>-0.66</td>
<td>-0.24</td>
<td>0.93</td>
</tr>
</tbody>
</table>
Take 2 Credits as a HS Student

Cumulative ability fraction

Fraction trying college

Baseline
Take course before college

Cumulative ability fraction

Fraction graduating

Baseline
Take course before college

54 / 58
Robustness
Sensitivity to $\phi_{HS}$
Sensitivity to the Preference Shock Scale
Conclusion

- First to model college completion risk jointly with ability selection.
- The calibrated model accounts very well for the data moments we constructed.
- Main result:
  - selection accounts for half of the measured lifetime college premium.
- Returns to college graduation increase with ability (complementarity).
- Ability signal is the main factor for the entry decision.
- Dropouts
  - Low signal students never intend to graduate (consumption value)
  - Medium signal students receive bad news regarding graduation prospects
  - High signal students drop out because of preference shocks