The Role of Education Signaling in Explaining the Growth of College Wage Premium

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Introduction

- Well-known Facts: simultaneous increase in the supply of college graduates (i.e. skilled worker) and the price of skilled workers (i.e. skill premium) in the US since 1980.

  Explanations: Skill-biased technical change, capital-skill complementarity, imperfect substitutability across age groups, to name a few.

- I propose a new mechanism that contributes to the reconciliation of the above two facts.

- It is based on the idea of education signals (Spence, 1973, and Stiglitz, 1975).

- I show this channel is quantitatively significant in explaining the rise of college wage premium observed in the US since 1980.
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- Enrollment Rate (Lag=6): LHS Axis
- College Wage Premium: RHS Axis
Consider a static model.

- Population of size 1. All high school graduates.
- Talent is private info. Half high talent, $\bar{\theta}$. Half low talent, $\theta$.
- Distribution of wealth in the population $F(k)$.
- College incurs a fixed cost $Q$. Fraction of college-goers $1 - F(Q)$.
- High talent completes college w.p. $\bar{p}$. Low talent complete college w.p. $\underline{p}$. Naturally, $\bar{p} > \underline{p}$.
- Wage offer is the expected talent conditional on the degree.
Toy Model

The wage offer to college graduates is

$$\bar{W} = \frac{\bar{p}}{\bar{p} + \overline{p}} \theta + \frac{\overline{p}}{\bar{p} + \overline{p}} \theta.$$

The wage offer to the high school graduates is

$$\bar{W} = \frac{1 - \bar{p}(1 - F(Q))}{2 - (\bar{p} + \overline{p})(1 - F(Q))} \theta + \frac{1 - \overline{p}(1 - F(Q))}{2 - (\bar{p} + \overline{p})(1 - F(Q))} \theta.$$

Note that $W$ is decreasing in the college attendance $1 - F(Q)$. 
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Note that \( \bar{W} \) is decreasing in the college attendance \( 1 - F(Q) \).
Dynamic Model: Endowment and Preference

Consider a continuous time discrete choice problem.

- 1 unit measure of dynastic families.
- Each dynasty is characterized by \((\theta, k_0)\):
  - Talent \(\theta\) is distributed as \(G(\theta)\) over \([0, \bar{\theta}]\).
  - Initial capital endowment at time 0 is distributed as \(F(k_0)\) over \([0, \bar{k}_0]\).
- Each agent in the dynasty is endowed with 1 unit of labor.
- Each agent is born a high school graduate.
- Each agent is risk neutral and maximizes:

\[
U(t; \theta, k_0) = \int_t^\infty c(\tau; \theta, k_0) e^{-r\tau} d\tau.
\]
Dynamic Model: Time-line

At each instant,

1. Agent $i$ from dynasty $(\theta, k_0)$ chooses if to go college:
   - Yes: Pays $Q$. Completes college w.p. $p(\theta)$. Enter the labor market. Assume $p'(\theta) > 0$.
   - No: Enter the labor market.

2. Supply 1 unit of labor, get a wage (contingent on degree) and return on capital.

3. Save a fraction $\phi$ of total income for the next generation.

4. Exit.
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Technology

- Competitive firms hire skilled and unskilled labor and rent capital.
- Worker’s talent is modeled as efficient units in a CES production function:

\[ Y(k, u, s) = A\{\mu k^\sigma + (1 - \mu)[\lambda u^\rho + (1 - \lambda)s^\rho]\}^{\frac{\sigma}{\rho}} \]

where

\[ u = \Psi_u h_u = E[\theta | HSG] h_u; \]
\[ s = \Psi_s h_s = E[\theta | CG] h_s. \]

- The skill premium has the familiar form:

\[ \pi = \frac{1 - \lambda}{\lambda} \left( \frac{h_u}{h_s} \right)^{1 - \rho} \left( \frac{\Psi_s}{\Psi_u} \right)^\rho. \]

- The growth in skill premium can be decomposed as:

\[ g_\pi = (1 - \rho)(g_{h_u} - g_{h_s}) + \rho(g_{\Psi_s} - g_{\Psi_u}). \]
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I construct a *wealth-separating* equilibrium in which the decision to go to college depends on the contemporaneous wealth level only.

In other words, the policy function, $e(k(t; \theta, k_0))$, has the following form:

$$e(k(t; \theta, k_0)) = \begin{cases} 
1, & \text{if } k(t; \theta, k_0) \geq Q \\
0, & \text{if } k(t; \theta, k_0) < Q 
\end{cases}.$$

**Proposition**

For sufficiently high $\rho$, sufficiently low $\lambda$ and $Q$, there exists a wealth-separating equilibrium where the college enrollment rate increases together with the skill premium.
Equilibrium

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*For sufficiently high \( \rho \), sufficiently low \( \lambda \) and \( Q \), there exists a *wealth-separating* equilibrium where the college enrollment rate increases together with the skill premium.*

I allow both the **signaling mechanism** and the **skill-biased technical change** (SBTC) to be at work (due to Proposition 2).

Recall the efficiency units of the two types of labor:

\[
\psi_s(t) = (1 + \gamma_{SBTC})^t E_t[\theta | CG] = (1 + \gamma_{SBTC})^t \frac{\int_0^\bar{\theta} \theta p(\theta) dG}{\int_0^\bar{\theta} p(\theta) dG},
\]

\[
\psi_u(t) = E_t[\theta | HSG] = \frac{\int_0^\bar{\theta} \theta dG - x(t) \int_0^\bar{\theta} \theta p(\theta) dG}{1 - x(t) \int_0^\bar{\theta} p(\theta) dG}.
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Counter-factual to assess the contribution of the signaling mechanism: fixing \( x(t) = x(0), \forall t. \)

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Strategy for the Quantitative Exercise

**Step 1** Calibrate the model equilibrium characterized by a pair of differential equations.

- **Outer loop** Choose $\gamma_{SBTC}$ to minimize the distance between the model skill premium and the data.

- **Inner loop** Given $\gamma_{SBTC}$, choose the saving rate $\phi$ to minimize the distance between the model enrollment rate and the data.

**Step 2** Simulate the skill premium in the calibrated model fixing the enrollment rate at the initial level. The difference between the growth of the counter-factual skill premium and that of the model skill premium is the measure of the contribution of the signaling story.
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Data and Parameters

Skill Premium

College Enrollment Rate
*Digest of Education Statistics 2007* (NCES). Ratio between the total enrollment over the total number of high school completers.

College Completion Rate
*Digest of Education Statistics 2007* (NCES). Ratio between the number of bachelor's degrees conferred in $t$ and the total college enrollment in $t - 4$.

Cost of College
*Trends in College Pricing 2009* and *Trends in Student Aid 2009*. Difference between the sticker price of college and the total aid.

Initial Income Distribution in 1980
CPS March 1980. Age group 40-50. Normalized so the 51$^{th}$ percentile is exactly $Q$. 
# Data and Parameters

<table>
<thead>
<tr>
<th>Model</th>
<th>Value</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho$</td>
<td>0.4</td>
<td>It implies an elasticity of substitution between skilled and unskilled labor of 1.67 (Krusell et al., 2000).</td>
</tr>
<tr>
<td>$\mu$</td>
<td>$1/3$</td>
<td>Income share of capital.</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>$-1$</td>
<td>It implies an elasticity of substitution between capital and aggregated labor of 0.5 (Antras, 2004).</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.6</td>
<td>Income share of unskilled labor out of total labor income.</td>
</tr>
</tbody>
</table>
Motivated by Carneiro and Lee (2011), I further allow the expected talent of CG to decline over time:

$$\int_0^{\bar{\theta}} \theta p_0(\theta) dG \cdot (1 + \omega)^t.$$

The rate of decline $\omega$ is calibrated so that the skill premium predicted by a model with $\omega = 0$ and the skill premium predicted by a model with the quality decline is roughly 17.25%.
Result: Enrollment Rates, Model vs. Data
Result: Model Skill Premium with and without Signaling
Conclusion

- I examine the hypothesis that increasing access to college in the US since 1980 has sharpened the signaling content of a high school degree (as a signal of low ability) and hence contributed towards the rising college wage premium.

- Quantitatively, this particular signaling story accounts for about 15% of the increase in the college wage premium over the sample period.
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Characterization of the Equilibrium

Let $K(t)$ be the aggregate capital at $t$ and $\hat{k}_0(t)$ be the cut-off wealth level at which agents start to attend college at $t$.

\[
\begin{cases}
    \dot{K}(t) = \phi Y(K(t) - x(t)Q) - x(t) \int_0^\theta p(\theta) dG, x(t) \int_0^\theta p(\theta) dG, \\
    \hat{k}_0(t) = -\phi[R(t)Q + W_t]
\end{cases}
\]

where $x(t) = 1 - F(\hat{k}_0(t))$, and $\hat{k}_0(t) \geq 0$, with $K(0) = \int_0^{\hat{k}_0} k_0 dF(k_0)$ and $k_0(0) = Q$. 
Skill Premium with Constant Quality of College

![Graph showing Skill Premium with Constant Quality of College](chart.png)