The Evolution of U.S. Wages: Skill Prices versus Human Capital

Lutz Hendricks

UNC

Preliminary and incomplete
February 29, 2012
**Motivation**

**Mean log weekly wage, ages 35-44**

**College wage premium, ages 35-44**
Motivation

Possible interpretations for the rise in the college wage premium:

1. The relative **price** of college labor has increased due to skill-biased technical change.

2. The relative **quality** of college labor has increased due to selection / human capital investment.

The question: How important are price and quality movements?
Why Is Labor Quality Interesting?

Expansion of schooling

Rising IQs of college students
The Questions

1. What part of the rise in the college wage premium reflects
   1. rising skill price of college educated labor?
   2. rising quality of college educated labor?

2. More generally: How can we extract skill prices from measured wages?
Identification Problem

- Measured wages confound skill prices and labor qualities.
- How can the two be disentangled?
The Idea

View the age wage profiles of various cohorts through the lens of human capital theory.

Theory implies:

1. Concave age efficiency profiles.
2. When skill prices grow, wages of all cohorts move together.
3. As schooling expands, the relative abilities of college / high school educated workers change.
The Approach

- Develop a model of school choice and on-the-job training.
- Heterogeneous worker abilities.
- Construct age wage profiles of synthetic cohorts.
- Calibrate the model to fit those profiles.
- The model measures:
  - unobserved skill prices and labor qualities
  - the abilities of workers by [schooling, cohort]
1. One-third of the growth in the college wage premium is growth in the relative human capital of college educated workers.

2. Half of the college wage premium in 2000 reflects the relative human capital of college graduates.

3. Unskilled wages did not fall nearly as much as the data suggest.
The expansion of education changes the relative abilities of college / high school students:
- Hendricks / Schoellman (2011)

Disentangling skill prices / labor qualities:
- Heckman et al. (1998); Bowlus / Robinson (2011) - flat spot method

Age wage profiles contain information about endowments:
- Huggett et al. (2006) - focus on inequality

The college premium through the lens of human capital theory
- Guvenen / Kuruscu (2010) - focus on inequality
- Heckman et al. (1998)
A Roy/Ben-Porath Model
Demographics

- Size of cohort $\tau$: $N_\tau$ (exogenous).
- Individuals live from model ages $t = 1$ (physical age 16) through $T$ (physical age 65).
- $\nu = \tau + t - 1$ is the time period.
Preferences

- Individuals maximize the discounted present value of lifetime earnings.
- Equivalent: maximize utility with perfect credit markets.
Endowments

Drawn at birth:

- learning ability $a$.
- human capital $h_1$.
- preference for schooling $p$.
- correlated

Time endowment (market hours): $\ell_{t,s,\tau}$. 
Schooling

- Discrete school levels:
  - high school dropout (HSD) and graduate (HSG)
  - college dropout (CD) and graduate (CG)

- School durations: $T_s$, fixed

- Human capital at start of work

$$h_{T_s+1} = F(h_1, a, s; \tau)$$  (1)
On-the-job Training

\[ h_{t+1,\tau} = (1 - \delta)h_{t,\tau} + G(h_{t,\tau}, l_{t,\tau}, a, \tau + t - 1) \] (2)

\( l_{t,\tau} \): study time
\[ Y_v = J(L_{1v}, \ldots, L_{sv}; \omega_v) \]  

where

- \( \omega_v \): vector of parameters
- \( L_{s,v} \): effective labor supply of type \( s \)

Skill prices equal marginal products:

\[ w_{s,v} = \frac{\partial J}{\partial L_{s,v}} \]
Household Problem

Timing

1. Draw endowments: $a, h_1, p$
2. Choose schooling $s$
3. Study for $T_s$ periods and produce $h_{T_s+1}$
4. Work for $T - T_s$ periods
   In each period, divide time endowment $\ell$ into training time $l$ and work time $\ell - l$
Household Problem
Work phase

\[ V(h_{t,\tau}, t, a, s, \tau) = \max_{l_{t,\tau}} y(l_{t,\tau}, h_{t,\tau}, t, s, \tau) + R^{-1} V(h_{t+1,\tau}, t+1, a, s, \tau) \]

subject to

- law of motion for \( h \)
- definition of period earnings

\[ y(l_{t,\tau}, h_{t,\tau}, t, s, \tau) = w_{s,t+\tau-1} h_{t,\tau}(l_{t,s,\tau} - l_{t,\tau}) \]  \hspace{1cm} (5)

time constraint \( 0 \leq l \leq \bar{l}_{t,s,\tau} \)
School phase

\[ W_s(h_1, a, p, \tau) = \ln \left( R^{\tau_s+1} V(h_{\tau_s+1}, T_s + 1, a, s, \tau) \right) + \pi_\tau p T_s + \mu_{s, \tau} \]

\[ h_{\tau_s+1} = F[h_1, a, s; \tau] \]

\( \pi_\tau p T_s \): a stand-in friction to ability sorting
\( \mu_{s, \tau} \): chosen so that the model matches observed schooling for each cohort

School choice:

\[ W(h_1, a, p, \tau) = \max_s W_s(h_1, a, p, \tau) \]
For now: partial equilibrium.

Skill prices $w_{s,v}$ are exogenous.
Calibration
Calibration Strategy

Choose parameters to match:

1. **Age wage profiles**
   mean log wages for 5 synthetic cohorts (CPS data)

2. **IQ scores of college / high school students.**

3. **$\beta_{IQ}$**: coefficient from regressing log wage (age 40) on IQ (and school dummies)
IQ

- In the data: cognitive test scores (AFQT)
  - measured around age 18
  - NLSY79

- In the model: a noisy measure of $a$ and/or $h_1$

\[
IQ = \gamma_{IQ,a}a + \left(1 - \gamma_{IQ,a}\right)\left(\ln h_1 - \mathbb{E}\ln h_1\right)/\sigma_{h_1} + \sigma_{IQ}\varepsilon_{IQ}
\]
## Fixed parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T$</td>
<td>Lifespan</td>
<td>50</td>
</tr>
<tr>
<td>Birth cohorts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cohort 1</td>
<td>1930 - 1936</td>
<td></td>
</tr>
<tr>
<td>Cohort 2</td>
<td>1937 - 1943</td>
<td></td>
</tr>
<tr>
<td>Cohort 3</td>
<td>1944 - 1950</td>
<td></td>
</tr>
<tr>
<td>Cohort 4</td>
<td>1951 - 1957</td>
<td></td>
</tr>
<tr>
<td>Cohort 5</td>
<td>1958 - 1964</td>
<td></td>
</tr>
<tr>
<td>$T_s$</td>
<td>School duration</td>
<td>(1, 3, 5, 7)</td>
</tr>
<tr>
<td>$\ell_{t,s,\tau}$</td>
<td>Market hours</td>
<td>CPS data</td>
</tr>
<tr>
<td>$R$</td>
<td>Gross interest rate</td>
<td>1.04</td>
</tr>
</tbody>
</table>
Calibrated Parameters

- **Job training**: \( h_{t+1} = (1 - \delta)h_t + e^{\theta A(s,0)}e^{g_A t}(h_t l_t)\alpha \)
  - calibrated: \( \delta, \theta, A(s,0), g_A, \alpha \)
- **Schooling**: \( F(h_1, a, s, \tau) \)
  - same as job-training technology with \( l_t = 1 \).
- **Preferences**: \( \pi_t = \pi_1(1 + g_{\pi})^\tau \)
  - calibrated: \( \pi_1, g_{\pi} \)
- **IQ**: \( \gamma_{IQ, a}, \sigma_{IQ} \)
Calibrated Parameters

- **Endowments:** \((a, \ln h_1, p) \sim N\)
  - normalized: \(E(a) = E(p) = 0, \ Var(a) = Var(p) = 1\)
  - \(E(\ln h_1 | \tau) = g_{h1} \tau\)
  - calibrated: correlations, \(g_{h1}, \sigma_{h1}\).

- **Skill prices:** \(w_{s,v}\)
  - calibrate at 5 dates; cubic spline in between.
Calibrated Parameters

Highlights:

1. $\alpha = 0.27$
   estimates in the literature: 0.5 to 1

2. $g_{h1} = -0.010$
   mean log wages are falling over time in the data
## Calibrated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>On-the-job training</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A(s)$</td>
<td>Productivity</td>
<td>0.662 0.768 0.951 0.913</td>
</tr>
<tr>
<td>$g(A(s))$</td>
<td>Productivity growth rate</td>
<td>0.0006</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Curvature</td>
<td>0.267</td>
</tr>
<tr>
<td>$\delta_h$</td>
<td>Depreciation rate</td>
<td>0.043</td>
</tr>
<tr>
<td><strong>Endowments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma_{h_1}$</td>
<td>Dispersion of $h_1$</td>
<td>0.032</td>
</tr>
<tr>
<td>$g(h_1)$</td>
<td>Growth rate of $h_1$</td>
<td>-0.0098</td>
</tr>
<tr>
<td>$\theta$</td>
<td>Ability scale factor</td>
<td>0.152</td>
</tr>
<tr>
<td>$\pi$</td>
<td>Psychic cost scale factor</td>
<td>0.186</td>
</tr>
<tr>
<td>$g(\pi)$</td>
<td>Growth rate of $\pi$</td>
<td>-0.0451</td>
</tr>
<tr>
<td>$\gamma_{pa}$</td>
<td>Governs correlation of $\pi$ and $a$</td>
<td>0.501</td>
</tr>
<tr>
<td>$\gamma_{ha}$</td>
<td>Governs correlation of $\ln h_1$ and $a$</td>
<td>0.445</td>
</tr>
<tr>
<td>$\gamma_{hp}$</td>
<td>Governs correlation of $\ln h_1$ and $\pi$</td>
<td>0.204</td>
</tr>
<tr>
<td>$\sigma_{IQ}$</td>
<td>Noise in IQ</td>
<td>0.876</td>
</tr>
<tr>
<td>$\gamma_{IQ,a}$</td>
<td>Governs correlation of $a$ and $IQ$</td>
<td>0.790</td>
</tr>
</tbody>
</table>
Age Wage Profiles

Slopes of age wage profiles

Intercepts of age wage profiles
Model Fit

Birth year

Mean IQ percentile score

College data
College model
No college data
No college model
Results
The question:

*How much do the growth rates of wages differ from the growth rates of skill prices?*

The experiment:

Compare the paths of data wages $z_{s,v}$ with model skill prices $w_{s,v}$. 
Revisions to Wage Growth

Change in mean log wage, 1964–2009

School group

Data

Model

HSD

HS

CD

CG

−0.4

−0.3

−0.2

−0.1

0

0.1

0.2

0.3

−0.4

−0.3

−0.2

−0.1

0
One-third of the rise in the college wage premium is due to human capital, not skill prices.
Revisions to Wage Growth

<table>
<thead>
<tr>
<th>School group</th>
<th>Skill price growth</th>
<th>Skill premium growth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data</td>
<td>Model</td>
</tr>
<tr>
<td>HSD</td>
<td>-32.7</td>
<td>-1.3</td>
</tr>
<tr>
<td>HS</td>
<td>-20.6</td>
<td>-10.3</td>
</tr>
<tr>
<td>CD</td>
<td>-9.0</td>
<td>-15.8</td>
</tr>
<tr>
<td>CG</td>
<td>20.2</td>
<td>17.0</td>
</tr>
</tbody>
</table>

Result:

One-third of the rise in the college wage premium is due to human capital, not skill prices.
Revisions to Wage Growth

Model Data

Year -- HSD

Mean log wage


Year -- HS

Mean log wage


Year -- CD

Mean log wage


Year -- CG

Mean log wage

The question:

*How much would a person with given $h$ earn as a HSG / CG?*

The question makes sense, if HSG $h$ and CG $h$ have the same units:

- Just compare $w_{s,v}$ with $z_{s,v}$.

The question is nonsense, if HSG $h$ and CG $h$ have different units.

Need a different approach...
Decomposing Wage Revisions

- Why does the model imply large revisions to measured wages?
- What are the contributions of
  - selection: changes in the distribution of \((a, h_1)\) over time?
  - investment: changes in \(l\) over time?
Measured Wages vs Skill Prices

- Measured mean wage in year $\nu$:

$$z_{s,\nu} = w_{s,\nu} \bar{h}_{s,\nu} \quad (6)$$

- Average human capital

$$\bar{h}_{s,\nu} = \sum_{\tau} \frac{N_{\tau} f_{s,\tau}}{\sum N_{\hat{\tau}} f_{s,\hat{\tau}}} \mathbb{E} \left\{ \frac{h_{t,s,\tau}(l_{t,s,\tau} - l_{t,s,\tau})}{l_{t,s,\tau}} \middle| s, \tau \right\} \quad (7)$$

is affected by

- cohort composition
- human capital profiles of all working cohorts

and therefore: past and future skill prices.

- Complicated...
Revisions to Wage Levels

- Consider the wages earned at a fixed age: $t = 40$
- Measured mean wage at age $t$ in year $v$:

$$z_{t,s,v} = w_{s,v} \bar{h}_{t,s,v}$$

(8)

- Average human capital

$$\bar{h}_{t,s,v} = \mathbb{E} \left\{ \frac{h_{t,s,\tau}(\ell_{t,s,\tau} - l_{t,s,\tau})}{\ell_{t,s,\tau}} \middle| t, s, \tau \right\}$$

(9)

depends on
- the human capital of a single cohort
- its endowments and past investments
The question:

*How much do selection / investment contribute to skill premiums at a point in time?*

Experiment: solve the model for 3 scenarios:

1. **Baseline**

2. **No selection:** workers in all school groups have mean endowments
   \[ a = 0 \text{ and } \ln h_1 = g_{h1} \tau \]

3. **Common investment:** workers in all school groups share \( l_{t,s} \)
   set to median age profile of high school graduates

Compute mean log wages at age 40 for each cohort / school group.
Selection and the College Wage Premium

Selection accounts for 30 log points of the college wage premium.
Selection and Wages

![Graphs showing mean log wages over birth years from 1930 to 1965. The graphs illustrate the impact of baseline, median endowments, fixed study time, and data on mean log wages.](image_url)
Decomposing Wage Growth

The question

*How much do changing selection / investment contribute to the growth rates of wages?*

Experiment: Solve the model for 3 scenarios

1. **Baseline**
2. Fix endowments in each school group: \( a, h_1 \)
3. Fix investment in each school group: \( l_{t,s} \)
   at levels of the 1st cohort
## Decomposing Wage Growth

<table>
<thead>
<tr>
<th>School group</th>
<th>Wage growth</th>
<th></th>
<th>Skill premium growth</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Fixed $a, h_1$</td>
<td>Fixed $l$</td>
<td>Baseline</td>
</tr>
<tr>
<td>HSD</td>
<td>-39.0</td>
<td>-30.6</td>
<td>-19.6</td>
<td>-7.4</td>
</tr>
<tr>
<td>HS</td>
<td>-31.6</td>
<td>-22.5</td>
<td>-16.2</td>
<td>0.0</td>
</tr>
<tr>
<td>CD</td>
<td>-27.6</td>
<td>-21.3</td>
<td>-17.7</td>
<td>3.9</td>
</tr>
<tr>
<td>CG</td>
<td>1.5</td>
<td>7.1</td>
<td>8.9</td>
<td>33.0</td>
</tr>
</tbody>
</table>

Changes in mean log wages at age 40, 1964-2009

Changing endowments and investment are equally important for skill premium revisions.
The question:

*How much of the lifetime earnings gap CG / HSG is due to selection?*

The experiment:

- Solve the model with random school assignment.
- Compare lifetime earnings by \((s, \tau)\) with baseline.
Result: 15 log points of the college lifetime earnings premium are due to selection
Changing Student Abilities

![Graph showing changing student abilities from 1930 to 1965. The x-axis represents birth years from 1930 to 1965, and the y-axis represents mean effective ability. The graph includes lines for HSD, HS, CD, and CG, indicating changes in abilities over time.]
A simple human capital model accounts well for the age wage profiles of cohorts observed since 1930.

Labor quality accounts for

- half of the college wage premium (1960 cohort)
- 1/3 of the rise in the college wage premium
- 1/4 of the lifetime college earnings premium (1960 cohort)