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

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Motivation

Long-term goal:


Why?

- Well known facts:
  - rising college premium, changing returns to experience, rising variance of log (residual) wages, ...
- Several candidate explanations:
  - SBTC, rising return to “ability,” unionization, minimum wage, ...

Open questions:

- Quantitative importance of the various explanations
- Their “indirect” effects. E.g., SBTC → variance of log wages
- Policy analysis
How far can we go in a “standard” human capital model?

Basic ideas:

1. Katz & Murphy
   inverse relationship between supply of college educated labor and college wage premium suggests that skills are imperfect substitutes

2. Kambourov & Manovskii
   changing returns to experience
   need to model experience → Ben-Porath

3. Hendricks & Schoellman
   changing cohort qualities as schooling expands
   need to model discrete school choice

   with human capital, wages are not skill prices
   one main objective: measure skill prices by schooling and year
Approach

Develop a model with

- 4 imperfectly substitutable skill types: HSD, HSG, CD, CG
- discrete school choice
- Ben-Porath on-the-job learning
- no shocks - can only talk about conditional means, not variances

Driving forces:

- expansion of schooling $\rightarrow$ cohort quality
- constant SBTC + fluctuations in cohort sizes (Katz & Murphy)

Calibrate to CPS wage data

- age wage profiles of cohorts born since 1920
The model fits changing age wage profiles “well.”

It replicates:

1. Changing returns to experience (Kambourov & Manovskii)
2. Different evolution of college premium by age (Card & Lemieux)
3. Skill prices look like smoothed versions of observed median wages
4. Human capital does not lead to significant revisions of average wage growth rates
Quantitative models of the evolution of the U.S. wage distribution:

- Heckman, Lochner, Taber (1998); Guvenen & Kuruscu (2010)

Recovering skill prices from wages

- a long-standing issue in labor economics: Juhn et al. (1993, 2005); ...
- Bowlus & Robinson (2012)
Model Outline

- Small open economy (fixed interest rate)
- Overlapping generations
- 4 school groups: HSD, HS, CD, CG
- Exogenous aggregate schooling
- Ben-Porath on-the-job learning
- Constant skill-biased technical change (Katz & Murphy)
- No shocks
Demographics

In period $c$, $N_c$ households are born.
Each lives for $T$ periods.
Life stages:

1. Draw endowments
2. Choose schooling $s \in \{HSD, HS, CD, CG\}$
3. Study in school for $T_s$ periods
4. Learn and earn on the job until retirement at age $T$.

Households maximize lifetime earnings.
\[
\begin{bmatrix}
a \\
\ln(h_1)
\end{bmatrix} \sim N\left( \begin{bmatrix} 0 \\
0
\end{bmatrix}, \begin{bmatrix} 1 & \rho_{a,h_1} \\
\rho_{a,h_1} & \sigma_{h_1}^2
\end{bmatrix} \right)
\]

\[a\]: learning ability in school and on the job
\[h_1\]: human capital endowment
On the job:

\[ h_{t+1} = (1 - \delta_s)h_t + A(a,s)(h_tl_t)^{\alpha_s} \]  \hspace{1cm} (2)

with \( A(a,s) = e^{A_s+\theta a} \).

In school: the same with \( l_t = 1 \):

\[ h_{T_{s+1}} = F(h_1,a,s) \]  \hspace{1cm} (3)
Output is produced from skilled and unskilled (no college degree) labor:

\[ Q_{\tau} = \left[ G_{\tau}^{\rho_{CG}} + (\omega_{CG,\tau} L_{CG,\tau})^{\rho_{CG}} \right]^{1/\rho_{CG}} \]  

(4)

Formula (4) is used to represent the output of skilled labor, where \( Q_{\tau} \) is the output, \( G_{\tau} \) is the aggregate skilled labor, and \( \rho_{CG} \) is the elasticity of substitution between skilled and unskilled labor.

\( G \) aggregates “unskilled” labor:

\[ G_{\tau} = \left[ \sum_{s=HSD}^{CD} (\omega_{s,\tau} L_{s,\tau})^{\rho_{HS}} \right]^{1/\rho_{HS}} \]  

(5)

Formula (5) is used to represent the aggregate of unskilled labor, where \( G_{\tau} \) is the aggregate unskilled labor, \( \omega_{s,\tau} \) is the skill price of labor \( s \), and \( L_{s,\tau} \) is the labor supply of labor \( s \).

\( L \): labor supplies in efficiency units.

Skill prices equal marginal products: \( w_{s,\tau} = \partial Q_{\tau}/\partial L_{s,\tau} \).
Labor Aggregation

Each individual supplies

\[ e_{i,s,c,t} = h_{i,s,c,t}(\ell_{s,c,t} - l_{i,s,c,t}) \]  \hspace{1cm} (6)

efficiency units of labor.

Aggregate labor inputs:

\[ L_{s,\tau} = \sum_{t=Ts+1}^{T} \sum_{i=1}^{N_{c(t,\tau)}} p_{i,s,c} e_{i,s,c,t} \]  \hspace{1cm} (7)

where \( p_{i,s,c} \) is the (endogenous) probability that agent \( i \) chooses schooling level \( s \).
$$V(h_{T_s+1}, a, s, c) = \max_{\{l_t\}} \sum_{t=T_s+1}^{T} R^{-t} y(l_t, h_t, t, s, c)$$  \hspace{1cm} (8)$$

subject to

$$y(l, h, t, s, c) = w_{s, \tau(c,t)} h(l_{t,s,c} - l)$$

$$h_{t+1} = (1 - \delta_s) h_t + A(a, s)(h_t l_t)^{\alpha_s}$$

$$0 \leq l_t \leq \ell_{t,s,c}.$$ 

This problem has an analytical solution.
The agent chooses schooling to maximize

\[ W_s(p_s, h_1, a, s, c) = \ln V(F[h_1, a, s], a, s, c) + \mu_{s,c} + \pi p_s + \pi_a T_s (a - a) \]  

(9)

\[ \mu_{s,c} \]: school costs, common to all agents

- allow the model to match each cohort’s schooling exactly

\[ \pi p_s + \pi_a T_s (a - a) \]: “psychic cost”

- generates imperfect school sorting by ability
- \( \pi_a \) governs ability gaps between school groups
- \( p_s \): type I extreme value shocks

This problem has an analytical solution.
Calibration
Simulate 1,000 individuals in each of 18 birth cohorts born between 1920 and 1971.

Set school costs \((\mu_{s,c})\) to exactly match each cohort’s attainment.

For aggregation: assume that non-modeled cohorts are identical to the nearest model cohort.

Restrict relative skill weights to grow at a constant rate (constant SBTC, Katz & Murphy)

Restrict average skill price growth “out of sample” to equal average “in sample” growth
Calibration Targets

1. Median **age wage profiles** for all model cohorts
   CPS, men, 1964 – 2010

2. **Cognitive test scores** moments
   In the model: $IQ = a + noise$
Mean cognitive test scores of college educated and high school educated workers. From Hendricks & Schoellman (2014).

They help identify:

- school sorting by ability (and how it changes over time)
- contribution of ability selection to the level of the college premium
Coefficients of regressing log wage on IQ, IQ*experience, school dummies.
NLSY79, men
They help identify:
- ability dispersion $\theta$
- correlation between $a$ and $h_1$
### 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>65</td>
</tr>
<tr>
<td>$T_s$</td>
<td>School duration</td>
<td>2, 3, 5, 7</td>
</tr>
<tr>
<td>$\ell_{t,s,c}$</td>
<td>Market hours</td>
<td>CPS data</td>
</tr>
<tr>
<td>n/a</td>
<td>Nodes of skill price spline</td>
<td>1935, 1941, 1947, ..., 2023, 2029, 2035</td>
</tr>
<tr>
<td>$R$</td>
<td>Gross interest rate</td>
<td>1.04</td>
</tr>
</tbody>
</table>
Calibrated Parameters

24 parameters are calibrated. They govern:

- endowment distributions
- Ben-Porath technologies
- aggregate technology: skill weights, elasticities of substitution

Curvature of the Ben-Porath technology: \( \alpha_s \approx 0.3 - 0.5 \)

- recent estimates are much higher (Heckman et al. 1998: \( \alpha \approx 0.9 \))
- intuition: when \( \alpha \) is high, \( h \) investment is extremely volatile
- this matters for: flat spot method, gains from training, tax effects, ...
Fit: Wage Profiles, HSG
Fit: Wage Profiles, CG

Log median wage vs Age for different cohorts:
- Age, 1923 cohort
- Age, 1929 cohort
- Age, 1935 cohort
- Age, 1941 cohort
- Age, 1947 cohort
- Age, 1950 cohort
- Age, 1956 cohort
- Age, 1962 cohort
- Age, 1968 cohort
• Good fit of age wage profiles supports Ben-Porath as a credible model wage determination.
• Can account for changing returns to experience without occupation specific human capital (Kambourov & Manovskii).
• Can account for different behavior of college premium for young and old (Card & Lemieux)
Fit: Returns to Experience

Change in mean log wage, ages 25 to 40

Birth year

Model
Data

High school graduates

College graduates
Fit: College Premium

<table>
<thead>
<tr>
<th>Year</th>
<th>College wage premium</th>
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<tbody>
<tr>
<td>1960</td>
<td>0.1</td>
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<tr>
<td>1965</td>
<td>0.2</td>
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<tr>
<td>1970</td>
<td>0.3</td>
</tr>
<tr>
<td>1975</td>
<td>0.4</td>
</tr>
<tr>
<td>1980</td>
<td>0.5</td>
</tr>
<tr>
<td>1985</td>
<td>0.6</td>
</tr>
<tr>
<td>1990</td>
<td>0.7</td>
</tr>
<tr>
<td>1995</td>
<td>0.8</td>
</tr>
<tr>
<td>2000</td>
<td>0.9</td>
</tr>
<tr>
<td>2005</td>
<td>1.0</td>
</tr>
<tr>
<td>2010</td>
<td>1.1</td>
</tr>
</tbody>
</table>

**Age group 26 – 35**

**Age group 46 – 55**
Skill Prices vs Wages

High school graduates
College graduates
Skill Prices vs Wages

Skill prices are essentially **smoothed** (observed) wages

Why so smooth?

- human capital investment **amplifies** variation in skill price growth

Skills must be highly **substitutable**

- Katz/Murphy (1992) → Details
  - labor supply = hours worked
  - elasticity of substitution between college / non-college labor ≈ 1.5

- Ben-Porath: ≈ 6
Aggregate labor supplies $\approx$ aggregate hours worked.
Labor efficiency for all school groups is roughly constant.
Reasons:

- Smooth wages $\Rightarrow$ roughly constant human capital investment.
- Small ability dispersion ($\theta = 0.09$) $\Rightarrow$ small changes in cohort qualities as schooling expands.
Selection and the College Premium

Experiment:
- Shut off school sorting
- Recompute aggregate (constant composition) college wage premium

Result:
15 log points of the college premium are due to selection constant over time
The Flat Spot Method

- Heckman, Lochner, Taber (1998)
  - if $\alpha$ is high enough and $\delta = 0$, then $h$ investment stops some time before retirement.
  - for older workers, wage growth = skill price growth

- Bowlus & Robinson (2012)
  - apply this method to CPS data
  - main result: on average, all skill prices grow at the same rate

- What happens if we apply the flat spot method to the wage data generated by this model?
  - using the Bowlus & Robinson flat spot age ranges
  - 44 – 52 for HSD, ..., 50 – 58 for CG
The Flat Spot Method

![Graphs showing log wage trends over years for high school graduates and college graduates.](image)

**High school graduates**

- Model
- Data
- Skill prices

**College graduates**

- Model
- Data
- Skill prices
Results:

1. Skill prices are smoother than flat spot wages.
2. For HSG, the flat spot method overstates the skill price growth rate.

Intuition:

- With low $\alpha$ and $\delta > 0$, $h$ investment continues until retirement
- Study time at age 50 is between $0.1 - 0.15$
- Efficiency is not constant during the flat spot period
  It rises by 10-15 log points after age 50 b/c of falling study time
  This is counteracted by depreciation
The Ben-Porath model is a credible model of wages over the life-cycle.

A simple human capital model replicates
- age wage profiles for most cohorts in CPS data
- returns to experience
- college premium by age

Average human capital (conditional on schooling) is roughly constant over time
- caveat: do not have time-varying school sorting yet

Future work:
- wage shocks / implications for variances
## Calibrated Parameters

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<thead>
<tr>
<th>Parameter</th>
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<th>Value</th>
</tr>
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<tbody>
<tr>
<td>On-the-job training</td>
<td></td>
<td></td>
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<tr>
<td>$A_s$</td>
<td>Productivity</td>
<td>0.13, 0.14, 0.13, 0.12</td>
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<tr>
<td>$\alpha_s$</td>
<td>Curvature</td>
<td>0.15, 0.15, 0.54, 0.54</td>
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<tr>
<td>$\delta_s$</td>
<td>Depreciation rate</td>
<td>0.048, 0.048, 0.045, 0.045</td>
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<td>Endowments</td>
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<tr>
<td>$\sigma_{h1}$</td>
<td>Dispersion of $h_1$</td>
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<tr>
<td>$\theta$</td>
<td>Ability scale factor</td>
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<tr>
<td>$\pi_1$</td>
<td>Psychic cost scale factor</td>
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<tr>
<td>$\gamma_{ap}$</td>
<td>Ability weight in psychic cost</td>
<td>0.076</td>
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<td>$\gamma_{ah}$</td>
<td>Governs correlation of $\ln h_1$ and $a$</td>
<td>0.302</td>
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<tr>
<td>$\sigma_{IQ}$</td>
<td>Noise in IQ</td>
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<tr>
<td>Other</td>
<td></td>
<td></td>
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<tr>
<td>$\Delta w_s$</td>
<td>Skill price growth rate, 1964-2010 [pct]</td>
<td>-0.92, -0.66, -0.73, 0.13</td>
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<tr>
<td>$(1 + \rho_{HS})^{-1}$, $(1 + \rho_{CG})^{-1}$</td>
<td>Substitution elasticities</td>
<td>7.43, 3.64</td>
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</table>
Inverse relationship between
- detrended hours worked college / high school workers
- detrended college wage premium
Study Time Profiles

<table>
<thead>
<tr>
<th>Age</th>
<th>1932</th>
<th>1938</th>
<th>1944</th>
<th>1953</th>
<th>1959</th>
<th>1965</th>
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<tr>
<td>20</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
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<td>0.2</td>
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<td>25</td>
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<td>30</td>
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<tr>
<td>35</td>
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<td>0.1</td>
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<td>0.1</td>
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<tr>
<td>40</td>
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<tr>
<td>45</td>
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<td>0.1</td>
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<td>0.1</td>
</tr>
<tr>
<td>50</td>
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<tr>
<td>55</td>
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<tr>
<td>60</td>
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<td>0.1</td>
</tr>
<tr>
<td>65</td>
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<td>0.1</td>
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<td>0.1</td>
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High school graduates | College graduates