Human Capital and Growth

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A. Introduction

The labor market plays a key role in the process of economic development. This includes many factors underlying the formation of human-related capital, often referred to as embodied capital.

There are many issues concerning the causes and consequences of human capital accumulation within the endogenous growth framework. We will discuss selected topics, based on the modern literature summarized below:

● Intergenerational human capital mobility: Chen-Peng-Wang (2009)
B. Measurement of Human Capital

- Conventional studies use crude measures of human capital, such as:
  - literacy rate
  - primary (P)/secondary (S)/higher (H) education enrollment
  - P/S/H education attainment
  - years of schooling
- It is more appropriate to use refined measures:
  - Bils and Klenow (2000) use weighted enrollment rate: \( E = 6P + 6S + 5H \)
  - Tallman and Wang (1994):
    - use weighted attainment rates to compute aggregate effective education: \( E = 1P + 1.4S + 2H \), or, \( 1P + 2S + 4H \)
    - then, setting \( H = E \) and log-differentiating the aggregate production function,
      \[
      \frac{\dot{y}}{y} = \frac{\dot{A}}{A} + \alpha \left( \frac{K}{K} - n \right) + (1 - \alpha) \frac{\dot{E}}{E},
      \]
      one obtains the estimates \( \dot{y} / y \)
    - straightforward growth-accounting shows that human capital accounted for 45%, 20% and 28% of output growth in Taiwan, Korea and Thailand, respectively

- Observation in the U.S.: on BGP despite falling investment goods price and a less-than-one elasticity of substitution between capital and labor (Chirinko et al. 2011; Oberfield-Raval 2014)
- Uzawa revisited
1. The Puzzle

- **Production:** \( Y_t = F(A_t K_t, B_t L_t, s_t) \)
  - disembodied technologies: A, B
  - years of schooling: s
- **Investment specific technological change via q (embodied):** \( Y_t = C_t + I_t / q_t \)
- **Capital evolution:** \( \dot{K}_t = I_t - \delta K_t \)
- **Disembodied technological change via A:** \( \gamma_A \)
- **Total capital-augmenting technological change:** \( \gamma_K \equiv g_A + g_q \)
- **Elasticity of substitution between capital and labor:** \( \sigma_{KL} \equiv (F_L F_K) / (F_{LK} F) \)
- **If a BGP exists with constant capital and labor income shares, then**
  \[
  (1 - \sigma_{KL}) \gamma_K = \sigma_{KL} \frac{F_L}{F_K} \frac{\partial (F_s / F_L)}{\partial K} s
  \]
  - Uzawa: s is constant, then BGP with constant capital and labor income shares requires \( \sigma_{KL} = 1 \) or \( \gamma_K = 0 \)
  - Aggregate human capital \( H(BL, s) \): so \( F_s / F_L = H_s / H_L \) independent of K and hence BGP with constant capital and labor income shares again requires \( \sigma_{KL} = 1 \) or \( \gamma_K = 0 \).
2. The Basic Model

- Dynastic utility of a family with N members alive (growing at an exogenous rate $n$):
  \[
  u(t_0) = \int_{t_0}^{\infty} N_t e^{-\rho(t-t_0)} \frac{C_t^1-\eta}{1-\eta} dt
  \]

- Labor: $L_t = D(s_t) N_t$, with D decreasing in $s$ to capture the time foregone as a result of schooling

- Output per effective labor (BL): $f(k_t, s_t) \equiv F(k_t, 1, s_t)$ with $k_t = A_t K_t / B_t L_t$
  - (A1) $f(k, s) = D(s)^{-\mu\beta} h[kD(s)^\mu]$, with $\mu > 0$
    - $h$ strictly increasing and strictly concave
    - $f$ strictly log supermodular in $k$ and $s$
    - under A1, $\sigma_{KL} < 1$ and $\partial (F_s / F_L) / \partial K > 0$
  - (A2) (i) $\beta \geq d_{\text{max}}$; (ii) $\frac{\mu\beta - 1}{\mu - 1} \in (d_{\text{min}}, d_{\text{max}})$, where $\mathcal{E}_h(z) \equiv zh'(z) / h(z)$,
    - (i) ensures MPs nonnegative
    - (ii) ensures interior schooling choice
  - example: $F(AK, BL, s) = (BL)^{1-\beta} \left\{ (AK)^{-\alpha} + [D(s)^{-\mu} BL]^{-\alpha} \right\}^{-\beta/\alpha}$ and $h(z) = (1 + z^{-\alpha})^{-\beta/\alpha}$
• Social planner’s problem:

\[
\max_{\{c_t, s_t\}} \int_{t_0}^{\infty} N_t e^{-\rho(t-t_0)} \frac{c_t^{1-\eta} - 1}{1-\eta} dt
\]

\[
Y_t \leq B_t L_t D(s_t)^{-\mu \beta} h \left[ \frac{A_t K_t}{B_t L_t} D(s_t)^{\mu} \right] ;
\]

s.t.

\[
L_t = D(s_t) N_t ;
\]

\[
\dot{K}_t = q_t (Y_t - N_t c_t) - \delta K_t .
\]

• Bounded growth: (A3) \( \rho > n + (1-\eta) \left[ \gamma_L + \frac{\mu \beta - 1}{(1-\beta)\mu} \gamma_K \right] \)

• Along a BGP, \( g_Y = g_K - g_q \) and \( g_D = -\gamma_K / \mu (1-\beta) \), so \( g_Y = n + \gamma_L + \gamma_K (\mu \beta - 1) / \mu (1-\beta) \)

  ○ per capita output growth \( (g_Y - n) \) is rising with labor augmenting technical progress and total capital-augmenting technological change

  ○ capital income share is constant given by \( \theta_K = \frac{\mu \beta - 1}{\mu - 1} \)

  ○ no puzzle

• Key: labor quantity (L) and quality (s) do not enter production symmetrically
3. Decentralized Economy with Time-in-School

- Time in school: \( D(s) = 1 - s \)
- Production efficiency \( \Rightarrow \) factor demand
  - \( f_k(k_t, s_t) = r_t \)
  - \( f(k_t, s_t) - r_t k_t = w_t(s_t) \)

- Then, BGP features standard KR equation with:
  - \( E_n [\kappa (s_t, r_t) (1 - s_t)^\mu] = \frac{\mu \beta - 1}{\mu - 1} \)
  - \( \dot{s}_t = (1 - s_t) \frac{\gamma K}{\mu (1 - \beta)} \): schooling grows at a declining rate
  - capital share constant as in the social planner problem
  - so, no puzzle

- Results can be generalized to models with manager-worker team work, directed technological change, and continuous-time OLG with survival rates a la Yaari (1965) and Blanchard (1985)
D. The Role of Teachers: Tamura (2001)

- Empirical facts of Schooling across U.S. States: 1901-90
  - enrollment rate (73.3 to 92.1%): ↑ by 6% over 1901-60; 12% over 1960-90
  - class size (36.9 to 16.9 students/teacher): ↓ by 12 1901-60 & 8 over 1960-90
  - relative teacher salary (from 1.53 to 2.35 to 1.76 teacher to average income ratio): ↑ by 0.8 over 1901-60 and ↓ 0.6 over 1960-90

1. The Model

- Two-period lived overlapping generations with constant population
- Altruistic Preferences: \( U = \frac{\epsilon_i^n}{\sigma} + \beta \frac{h_{i+1}^n}{\sigma} \), \( 0 < \beta < 1 \) and \( \sigma < 1 \)
- School Quality and Human Capital Evolution:
  - teacher quality (teacher-parents human capital ratio):
    \[
    Q_i = \frac{\text{average human capital of school district } i \text{ teachers}}{\text{average human capital of school district } i \text{ parents}} = \frac{E[h_i^T]}{E[h_i^P]}
    \]
- class size (student-teacher ratio):

\[
C_{it} = \frac{\text{number of students in school district } i}{\text{number of teachers in school district } i} = \frac{N_{it}}{N_{it}^T}
\]

- Human capital accumulation (HC):

\[
h_{it+1} = A h_{it}(C_{it}^{-\epsilon}Q_{it}^{1-\epsilon})^\nu, \quad 1 > \epsilon > 0, \quad 1 > \nu > 0
\]

- Individual Budget Constraints (BC):

\[
c_{it} = h_{it}(1 - \tau_{it})
\]

- Local Governments’ Budget Constraints (GBC):
  - poor school districts (\(N_{Pt} = \alpha\)):
    \[
    \alpha \tau_p h_p = N_{Pt}^T E[h_p^T]
    \]
  - rich school districts (\(N_{Rt} = 1-\alpha\)):
    \[
    (1 - \alpha) \tau_R h_R = N_{Rt}^T E[h_R^T]
    \]

2. Equilibrium and Results

- Substituting (GBC’s) into (HC) yields the human capital evolution equations:

\[
\begin{align*}
\text{poor districts:} & \quad h_{Pt+1} = A h_{Pt} \left( \frac{\alpha \tau_p h_p}{\alpha E[h_p^T]} \right)^\epsilon \left( \frac{E[h_p^T]}{h_p^T} \right)^{(1-\epsilon)\nu} = A h_{Pt} \tau_p^\epsilon Q_{Pt}^{(1-2\epsilon)\nu} \\
\text{rich districts:} & \quad h_{Rt+1} = A h_{Rt} \left[ \frac{(1 - \alpha) \tau_R h_R}{(1 - \alpha) E[h_R^T]} \right]^\epsilon \left( \frac{E[h_R^T]}{h_R^T} \right)^{(1-\epsilon)\nu} = A h_{Rt} \tau_R^\epsilon Q_{Rt}^{(1-2\epsilon)\nu}
\end{align*}
\]
Main results:

\[ \frac{h_{i,t+1}}{h_{i,t}} = A \tau_{i,t}^{\epsilon} Q_{i,t}^{(1-2\epsilon)^v} , \text{ increasing in Q iff } \epsilon < 1/2 \]

\[ \frac{h_{R,t+1}/h_{R,t}}{h_{P,t+1}/h_{P,t}} = A \left( \frac{\tau_{R,t}}{\tau_{P,t}} \right)^{\epsilon v} \left( \frac{Q_{R,t}}{Q_{P,t}} \right)^{(1-2\epsilon)^v} \Rightarrow \text{ convergence with } \epsilon < 1/2 \]

3. Empirical Analysis:

- C reduces real per capita income growth, while Q enhances it
- Over the entire sample (1882-1990),
  - enhancement in Q accounts for 60% of real growth
  - reduction in C accounts for 40%
- In the past 4 decades (1950-1990),
  - enhancement in Q accounts for 13% of real growth
  - reduction in C accounts for 85%
- Remark: The role of faculty in college students’ success and intergenerational mobility has also been verified by Chetty-Friedman-Saez-Turner-Yagan (2017)

- Composition of labor can be by race, gender, skills (vertical/horizontal), or, by occupation (workers/managers/entrepreneurs) - the focus of this paper

1. The Model

- Two sectors:
  - auto (team work): workers productivity cannot be easily measured or monitored (incomplete contract)
  - software (individual work): workers productivity can be readily measured and monitored
- Production (a = auto, s = software):
  - auto: 2 tasks with skills $q_j$ of the team member of the $j^{th}$ task ($j = 1, 2$) and with output $= F(q_1, q_2)$, where $F_j > 0$, $F_{jj} < 0$, $F_{12} > 0$ (complementarity), CRS, with $2fq$ measuring the potential output of auto by a pair of talents of $q$ and $f = F(1,1)/2$
  - software: Ricardian technology, with $G(q) = \lambda q$, where $\lambda > 0$ is the inverse of the unit labor requirement
Distribution of talents: uniform distribution over compact support \([q_{\text{min}}, q_{\text{max}}]\)

Preferences: \(U(c_a, c_s), U_1 > 0, U_2 > 0, U_{11} < 0, U_{22} < 0, U_{12} > 0, \) risk neutral, homogeneous of degree one

2. Equilibrium

- Walrasian equilibrium with relative price \(p = P_s/P_a\) and incomplete labor contract
- Labor market clearing: \(L_a + L_s = L\), where 1/2 of \(L_a\) are managers and 1/2 workers with \(L_s\) as entrepreneurs
- Expected income: \(W = w, M = F(.) - w, E = \lambda pq\)
- Occupational choice:
  - low \(q\): workers
  - intermediate \(q\): managers
  - high \(q\): entrepreneurs
3. Results

- Equilibrium wage determination
  - $q_m \uparrow \Rightarrow L_s \downarrow \Rightarrow (L-L_s)/2 \uparrow \Rightarrow w \downarrow$
  - $\Rightarrow$ SS downward-sloping
  - $q_m \uparrow \Rightarrow F_j$, as a result of
    - talent complementarity $\Rightarrow w \uparrow$
  - $\Rightarrow$ AA downward-sloping

- Comparative statics
  - trade effect to s-exporting country:
    - $p \uparrow \Rightarrow s^s \uparrow$ and for given $w$, $q_m \downarrow$
    - (SS shifts down)
    - $\Rightarrow w \downarrow$, $q_m \downarrow$ and inequality $\uparrow$
  - mean-preserving spread (with $q_m$ sufficiently low):
    - $\Rightarrow$ for given $w$, $q_m \downarrow$ (SS shifts down)
    - for given $q_m$, $F_j$ lower, so $w \downarrow$ (AA down)
    - $\Rightarrow w \downarrow$, $q_m \downarrow$, $s^s \uparrow$ and inequality $\uparrow$

4. Further issues: entrepreneurship (Jiang-Wang-Wang 2010) and venture

- Main idea:
  - the extent of labor-market frictions affects the return to education
  - education raises both initial productivity and rate of on the job learning

1. The Model

- Constant birth $\beta$, permanent exit after matching
- Education: schooling $s$
  - costs $c(s)$ ($c' > 0, c'' > 0$)
  - generates human capital $k = \phi(s)K_o$ ($\phi' > 0, \phi'' < 0, \phi(0) > 0, \phi(\infty) < 1$) (Stokey 1991)
- Production:
  - CRS with OJL at rate $\gamma(s)$ ($\gamma' > 0, \gamma'' < 0, \gamma(\infty) < \delta$)
  - value of production ($a_s > 0$): $a(s) = \int_0^\infty \phi(s)K_0e^{\gamma(s)\tau_E}e^{-\delta\tau_E}d\tau_E = \frac{\phi(s)K_o}{\delta - \gamma(s)}$
  - Assumptions: $a_{ss} < 0; a(0) > v_0$
**Value Functions (setting $\dot{J}_i = 0, \dot{\Pi}_i = 0$):**

\[
\delta J_E = \delta w + 0 \cdot (J_u - J_E)
\]

\[
\delta J_u = 0 + \mu (J_E - J_u)
\]

\[
\delta \Pi_F = \delta (a - w) + 0 \cdot (\Pi_v - \Pi_F)
\]

\[
\delta \Pi_v = 0 + \eta (\Pi_F - \Pi_v)
\]

\[\Rightarrow J_u = \frac{\mu}{\mu + \delta} w, \quad \Pi_v = \frac{\eta}{\eta + \delta} (a - w) \]  (firms take outside option $\Pi_v$ as given)

**Equilibrium Conditions:**

- **Equilibrium Entry:** $\Pi_v = \nu_0$
- **Steady-State Matching:** $\mu U = \eta V = m_o M(U,V)$
  - $M$ is strictly increasing and strictly concave in each argument, satisfying CRS, Inada and boundary conditions (Diamond 1982)
- **Steady-State Population:** $\mu U = \beta$
Solution Method (backward to ensure subgame perfection):

○ Stage 3: Nash bargain upon successful match to determine the wage offer \( w(s,\mu) \) cooperatively by maximizing \( (J_E - J_U)^{1/2}(\Pi_F - \Pi_V)^{1/2} \)

○ Stage 2: equilibrium entry and steady-state matching to determine flow contact rates \( (\mu,\eta) \) given \( s \)

○ Stage 1: maximizing worker expected value at entry \( (J_U) \) net of schooling cost \( (c(s)) \) to pin down \( s \)

2. Equilibrium

- Wage offer: 
  \[
  w = \frac{\mu + \delta}{\mu + 2\delta} (a - \Pi_v) = w(\mu, s, K_0, \Pi_v)
  \]

- Equilibrium entry, matching and schooling:

  ○ (EE) 
    \[
    \frac{\eta}{\eta + \delta} (a - w(\mu, \bullet)) = v_o
    \]

  ○ (SS) 
    \[
    \eta = m_0 M\left(\frac{U}{V}, 1\right) = m_0 M\left(\frac{\eta}{\mu}, 1\right)
    \]

  ○ FOC(s) 
    \[
    \frac{\mu}{\mu + 2\delta} a_s = c_s \Rightarrow s = s(\mu), s_\mu > 0
    \]
Comparative Statics:
- Benchmark Case: the effect of $\mu$ on wage is stronger than on productivity (ensuring EE upward-sloping)
- Growth: $\theta = \gamma(s(\mu))$
  - increasing in $K_0$, $m_0$
  - decreasing in $v_0$
- Unemployment: $U = \beta/\mu$
  - decreasing in $K_0$, $m_0$
  - increasing in $v_0$
- negative growth-unemployment relationship (Okun’s law)
• What if the effect of $\mu$ on wage is weaker than on productivity (EE downward-sloping)
  ○ possibility of multiple equilibria with co-existence of
    - thick labor-market, high education, high growth equilibrium
    - thin labor-market, low education, low growth equilibrium
  ○ small improvements in labor matching efficacy or entry friction can shift an economy from low to high growth equilibrium (no need for big push)


• Sub-Saharan Africa and South Asia have suffered high disease and intense poverty.
• Poor health environments may be important for explaining why geography matters for growth, especially for those countries in sub-Saharan Africa and South Asia long falling in the low-growth trap.
Basic idea:
- Increased life expectancy raises population and lowers capital-labor and land-labor ratios, leading to lower per capita output
- Lengthened life expectancy encourages labor-market participation and saving, resulting in more capital accumulation and higher per capita output
- This non-monotone effects can be best seen from experiences facing initially poor countries
1. The Model

- **Country i’s aggregate output:** \( Y_{it} = (A_{it}H_{it})^{\alpha}K_{it}^{\beta}L_{it}^{1-\alpha-\beta} \)
- **Land:** \( L_{it} = L_i = 1 \)
- **Effective labor:** \( H_{it} = h_{it}N_{it} \)
- **Life expectancy \( \bar{X}_{it} \), affecting:**
  - Population and technology: \( N_{it} = \bar{N}_{i}\bar{X}_{it}^\lambda \) and \( A_{it} = \bar{A}_{i}\bar{X}_{it}^\gamma \)
  - Individual human capital: \( h_{it} = \bar{h}_{i}\bar{X}_{it}^\eta \)
- **Capital accumulation with an exogenous saving rate \( s \):** \( K_{it+1} = s_iY_{it} + (1 - \delta)K_{it} \)

2. The Estimation

- **Regression:**
  \[
  y_{it} = \frac{\alpha}{1-\beta} \log \bar{A}_{i} + \frac{\alpha}{1-\beta} \log \bar{h}_{i} + \frac{\beta}{1-\beta} \log s_i - \frac{\beta}{1-\beta} \log \delta \\
  - \frac{1-\alpha-\beta}{1-\beta} \log \bar{N}_{i} + \frac{1}{1-\beta} [\alpha(\gamma + \eta) - (1-\alpha-\beta)\lambda] x_{ii}
  \]
  depending on life expectancy and an array of other variables
3. Data

<table>
<thead>
<tr>
<th>Life Expectancy</th>
<th>Initially Poor</th>
<th>Initially Middle-Income</th>
<th>Initially Rich</th>
</tr>
</thead>
<tbody>
<tr>
<td>At Birth in 1900</td>
<td>28.77</td>
<td>36.92</td>
<td>49.36</td>
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<td>At Birth in 1940</td>
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<td>At Birth in 1980</td>
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<td>74.30</td>
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<tr>
<td>At Age 20 in 1940</td>
<td>56.96</td>
<td>64.51</td>
<td>70.41</td>
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<tr>
<td>At Age 20 in 1980</td>
<td>70.27</td>
<td>73.59</td>
<td>75.73</td>
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4. Main Findings

- Predicted mortality has a large effect on changes in life expectancy since 1940, but not before
- 1% increase in life expectancy raises population by 1.7-2%
- The effect of life expectancy on per capita real GDP is negligible

- An organizing framework:
  - Production: \( Y_t = AK_t^\alpha L_t^{1-\alpha} \), where \( L = NH_t \ell_t^d \)
  - Human capital: \( H_t = Bh_t^\beta m_t^{1-\beta} \)
  
  where \( h \) measures physical health and \( m \) measures mental knowledge
  - Mincerian equation: \( m_t = M \exp (\zeta E_t) \)
  - log calculus => growth accounting:

\[
\ln \frac{Y_t}{N_t} = \ln A + (1-\alpha) \ln B + (1-\beta)(1-\alpha) \ln M + \alpha \ln \frac{K_t}{N_t} + (1-\beta)(1-\alpha) \zeta E_t + \beta(1-\alpha) \ln \frac{h_t}{N_t}
\]

where, in addition to the residual TFP (the constant term) output growth can be decomposed into 3 components:
- capital accumulation
- education enhancement
- health improvement
**Data:**

Data source: Penn World Table 6.3 and the World Bank.

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<th>Trapped countries</th>
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<td>11.47</td>
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<tr>
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<td>71.84</td>
<td>61.25</td>
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<tr>
<td>2005</td>
<td>79.17</td>
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<tr>
<td></td>
<td>Middle Income High</td>
<td>Middle Income Low</td>
<td>Trapped countries</td>
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Incidents of death per 100,000 population
Results: chance to pull out of poverty trap (41 currently trapped economies)