A Dynamic Model of Health, Education, and Wealth with Credit Constraints and Rational Addiction

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Motivation

- Estimate a dynamic model of health, education, and wealth

- Motivated, in part, by the large disparities in health, education, and wealth
  - socioeconomic determinants
  - pathways, mechanisms
Relationships Between Early Endowments and Environments and College Graduation

Q: borrowing constraints or preference/ability heterogeneity?
More educated individuals have better health later in life.

(a) Health Status Poor/Fair

(b) Regular Smoking

Source: NLSY97 white males aged 25 to 30.

Disparities in wages and wealth by education:
Better health early in life is associated with higher educational attainment and higher wealth level in the adulthood.

Data source: NLSY97 white males. Initial health is measured by health status at age 17.
What does this paper do?

- Develops a framework to analyze the dynamic relationship between health, education, and wealth
  1. human capital production and health production
  2. addictive preferences in unhealthy behavior
  3. endogenous borrowing constraint

- Quantify the importance of socioeconomic determinants of human capital and health inequality

- Estimates causal relationships and economic mechanisms
  1. effects of early cognitive, noncognitive, and health endowments
  2. effects of parental education and wealth
  3. effects of education on health and wealth
  4. effects of health on schooling and wealth
Human capital, education, and credit constraints


Education and health

- Schultz (1962), Becker (1964), Grossman (1972)

Rational addiction and unhealthy behavior

Relative Contributions

- A uniform framework for endogenous human capital, health capital, health behavior, education, and wealth over lifecycle in the presence of financial market frictions

- Pros:
  - lifecycle dynamics
  - different mechanisms
  - reverse causality
  - unobserved cognitive and noncognitive abilities
  - parental factors

- Cons: assumptions on functional forms and distributions
  - We do not account for serially correlated uncertainty or unanticipated health shocks
An agent makes following decisions at every age $t = t_0, \ldots, T$

- consumption $c_t$ and savings $s_{t+1}$
- unhealthy behavior $d_{q,t} \in \{0, 1\}$, e.g. smoking
- schooling $d_{e,t} \in \{0, 1\}$
- working $d_{k,t} \in \{0, 0.5, 1\}$

Time constraint: $d_{k,t} + d_{e,t} < 2$, and $d_{e,t} = 0$ for $t > 27$. 
Model: State Variables

An age-$t$ agent is characterized by a vector of state variables that determines preferences, technology, and outcome equations

$$\Omega_t \equiv (t, \theta_c, \theta_n, h_t, e_t, s_t, q_t, k_t, d_{e,t-1}, e_p, s_p)$$

- latent cognitive and noncognitive ability $(\theta_c, \theta_n)$
- latent health capital stock $h_t$
- years of schooling $e_t$
- net worth $s_t$
- addiction stock ("habit") $q_t = (1 - \delta_q)q_{t-1} + d_{q,t-1}$
- work experience $k_t = k_{t-1} + d_{k,t-1} - \delta_kk_t 1(d_{k,t-1} = 0)$
- previous schooling decision $d_{e,t-1}$
- parents’ education and net worth $(e_p, s_p)$
Model: Preferences and Technology

- Preferences:
  \[ U(c_t, d_q,t, d_e,t, d_k,t; \Omega_t) = u_c(c_t; \Omega_t) + d_q,t \cdot u_q(q_t, h_t, e_t, \theta_c, \theta_n, \epsilon_q,t) \]
  \[ + u_{ek}(d_e, d_k; h_t, \theta_c, \theta_n, d_{e,t-1}, e_p, \epsilon_e,t, \epsilon_k,t) \]

  - Unhealthy behavior is *addictive* if \( \frac{\partial u_q}{\partial q_t} > 0 \).

- Health capital production function:
  \[ h_{t+1} = H(h_t, d_q,t, d_e,t, d_k,t, c_t, e_t, \theta_c, \theta_n, t, \epsilon_h,t). \]

  - Temporary health shock has a persistent impact on future health.

- Labor market skills (\( \psi_t \)) and offered wages:
  \[ \psi_t = F^\psi(h_t, e_t, k_t, \theta_c, \theta_n) \]
  \[ \text{wages} = \psi_t \cdot F^w(d_{k,t}, d_{e,t}, \epsilon_{w,t}) \]

- Subjective discount rate: \( \rho(h_t, \theta_c, \theta_n) \)
Model: Budget Constraint and Credit Constraint

- **Budget constraint:**
  \[ c_t + d_{e,t} \cdot \text{tuition} + d_{q,t} \cdot p_q + s_{t+1} = (1 + r)s_t + \text{wages} + \text{parental transfer}(d_{e,t}, d_{k,t}, e_p, s_p) + \text{gov transfer}. \]

- **Credit constraint:**
  \[ s_{t+1} \geq -\text{student loan limit} - \text{private debt limit}. \]
  - student loan limit: flow limit $\bar{l}^g$, total limit $\bar{L}^g$.
  - private borrowing limit: $F^l(\psi_t, t)$
Model Solution

- **Value function** $V_t(\cdot), \ t = 1, \ldots T$

$$V_t(\Omega_t, \epsilon_t) = \max_{d_t,s_{t+1}} \left\{ U_t(c_t, d_{q,t}, d_{e,t}, d_{k,t}; \Omega_t, \epsilon_t) ight. \\ \left. + \exp(-\rho(h_t, \theta_c, \theta_n)) \mathbb{E}(V_{t+1}(\Omega_{t+1})|\Omega_t, d_{q,t}, d_{e,t}, d_{k,t}, s_{t+1}) \right\}$$

subject to constraints on budget, borrowing limit, and technology.

- **Terminal value function**: $V_{T+1}(s_{T+1}, h_{T+1})$. 


Cognitive ability, noncognitive ability, and health are measured with error.

Dedicated measurement equations:

\[
Z_{c,j}^* = X_c \beta_{z,c,j} + \alpha_{z,c,j} \theta_c + \epsilon_{z,c,j}, \quad j = 1, \ldots, J_c
\]

\[
Z_{n,j}^* = X_n \beta_{z,c,j} + \alpha_{z,n,j} \theta_n + \epsilon_{z,n,j}, \quad j = 1, \ldots, J_n
\]

\[
Z_{h,t,j}^* = X_h \beta_{z,c,j} + \alpha_{z,h,j} \log h_t + \epsilon_{z,h,t,j}, \quad j = 1, \ldots, J_h
\]

Continuous measure \( Z = Z^* \), binary measure \( Z = (Z^* \geq 0) \), a ordered categorial measure (such as health status) can be modeled as a ordered choice model for underlying \( Z^* \).

Estimation of this factor model provides initial distribution of \( (\theta_c, \theta_n, \log(h_{t0})) \) conditional on observable variables.
Data Description

- National Longitudinal Survey of Youth 1997 (NLSY97)
  - white males aged 17-31 over 1997 to 2011
  - 2103 individuals with 27,213 observations
  - measures of health: health status, BMI, health conditions
  - measures of cognitive ability: ASVAB subscores
  - measures of noncognitive ability (early adverse behaviors): had violent behavior; stole anything worth more than $50; had sex before age 15
  - key choice and outcome variables over time: unhealthy behavior (regular smoking), schooling, working full-time, working part-time, wages, net worth
Parameters that can be clearly identified without using our model are calibrated outside the model:

- relative risk aversion coefficient: $\gamma = 1.5$
- borrowing and lending interest rates: $r_b = 4\%$, $r_l = 1\%$
- student loan: flow limit $11\text{K}$, total limit $35\text{K}$
- college tuition and fees, college room and board: IPEDS data
- college grants and scholarship by parental wealth terciles: NLSY97
- government means-tested transfers and unemployment benefit: NLSY97
- parental monetary transfer function: NLSY97
Identification

- Parameters on initial distribution of factors (cognitive ability, noncognitive ability, and health) and measurement system
  - At least three measurements for each unobserved factor

- Parameters on discount rate are identified from the savings distributions.
  - Euler equation under CRRA utility
    \[
    \gamma \cdot (\log c_{t+1} - \log c_t) = -\rho(\theta_c, \theta_n, h_t) + \log(1 + r).
    \]

Identifying moments:
- covariance terms based on regression analysis: \((a_c, a_n, a_h)\)
  \[
  \text{savings}_t = a_c \cdot (\text{measure of } \theta_c) + a_n \cdot (\text{measure of } \theta_n) + a_h \cdot (\text{measure of } h_t) \\
  + a_1 t + a_0 + X_t \beta + \epsilon_t
  \]
- average savings \(\Rightarrow\) intercept parameter of \(\rho(\theta_c, \theta_n, h_t)\)
Estimation Method

**Step 1:** Estimate parameters of the factor model - simulated MLE

- joint distribution of initial health, cognitive and noncognitive ability

\[
\max \prod_i \int_{\theta_c, \theta_n, \log(h_{17})} f(Z_i; X_i, \theta_c, \theta_n, \log(h_{17})) dF(\theta_c, \theta_n, \log(h_{17}))
\]

**Step 2:** Estimate 59 parameters on preferences and technology of the structural model - Simulated MM:

- targeted moments:
  - covariance terms from regression analysis for savings, health status transition, log wage, probabilities of schooling, working, and engaging unhealthy behavior, and working
  - average choice probabilities (on schooling, working, and engaging unhealthy) for every age; health status transition dynamics; net worth distributions; average net worth by different education categories, etc
# Initial Distribution of Latent Factors \( (\theta_c, \theta_n, \log h_{17}) \)

<table>
<thead>
<tr>
<th></th>
<th>( \theta_c ): Cognitive</th>
<th>( \theta_n ): Noncognitive</th>
<th>( \log h_{17} ): Log Health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parents Wealth 3rd Tercile</td>
<td>0.304</td>
<td>1.507</td>
<td>1.257</td>
</tr>
<tr>
<td></td>
<td>( 0.050 )</td>
<td>( 0.093 )</td>
<td>( 0.068 )</td>
</tr>
<tr>
<td>Parents Wealth 2nd Tercile</td>
<td>0.000</td>
<td>1.027</td>
<td>0.430</td>
</tr>
<tr>
<td></td>
<td>( 0.050 )</td>
<td>( 0.085 )</td>
<td>( 0.065 )</td>
</tr>
<tr>
<td>Parents 4-Yr College</td>
<td>0.354</td>
<td>1.378</td>
<td>0.180</td>
</tr>
<tr>
<td></td>
<td>( 0.069 )</td>
<td>( 0.141 )</td>
<td>( 0.090 )</td>
</tr>
<tr>
<td>Parents Some College</td>
<td>0.314</td>
<td>0.782</td>
<td>0.172</td>
</tr>
<tr>
<td></td>
<td>( 0.043 )</td>
<td>( 0.077 )</td>
<td>( 0.062 )</td>
</tr>
<tr>
<td>Parents High School</td>
<td>0.241</td>
<td>0.570</td>
<td>0.108</td>
</tr>
<tr>
<td></td>
<td>( 0.055 )</td>
<td>( 0.107 )</td>
<td>( 0.080 )</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.541</td>
<td>-1.545</td>
<td>-0.621</td>
</tr>
<tr>
<td></td>
<td>(N.A.)</td>
<td>(N.A.)</td>
<td>(N.A.)</td>
</tr>
</tbody>
</table>

## Variance Matrix

<table>
<thead>
<tr>
<th></th>
<th>1.000</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(N.A.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.280</td>
<td></td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>( 0.050 )</td>
<td></td>
<td>(N.A.)</td>
<td></td>
</tr>
<tr>
<td>0.143</td>
<td>0.369</td>
<td></td>
<td>1.000</td>
</tr>
<tr>
<td>( 0.039 )</td>
<td>( 0.059 )</td>
<td>(N.A.)</td>
<td></td>
</tr>
</tbody>
</table>

Constant terms are normalized such that \( \mathbb{E}(\theta_c) = \mathbb{E}(\theta_n) = \mathbb{E}(\log(h_{17})) = 0 \).
Estimates on Discount Factor: $\exp(-\rho(\theta_c, \theta_n, h_t))$

- Discounted factor increases with cognitive ability, noncognitive ability, and health.

Kernel density estimate

- $\text{kernel} = \text{epanechnikov}$, $\text{bandwidth} = 0.0008$
Estimates on Health Capital Production: $\log h_{t+1} - \log h_t$
Sorting into Education (Age 30)

- Sorting into education based on cognitive ability

Figure: Density of Cognitive Ability Conditional on Age-30 Education

- Sorting into education by noncognitive ability
- Sorting into education by initial health

- Sorting into adult health status:
Counterfactual thought experiment of equalizing cognitive ability:

- What will be the level of inequality in human capital and health, if everyone in the economy has the same initial cognitive ability?
- The difference between this counterfactual experiment and the baseline model ⇒ quantitative importance of cognitive ability on inequality
### Inequality Decomposition by Initial Heterogeneity (2/2)

<table>
<thead>
<tr>
<th>Equalizing Factor</th>
<th>Inequality (age 30)</th>
<th>Inequality Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Health</td>
<td>Skill</td>
</tr>
<tr>
<td>Baseline</td>
<td>0.8218</td>
<td>0.3843</td>
</tr>
<tr>
<td>Equalizing Cognitive Ability</td>
<td>0.7467</td>
<td>0.1997</td>
</tr>
<tr>
<td>Equalizing Noncognitive Ability</td>
<td>0.7185</td>
<td>0.3737</td>
</tr>
<tr>
<td>Equalizing Initial Health</td>
<td>0.3907</td>
<td>0.3722</td>
</tr>
<tr>
<td>Equalizing Parental Factors</td>
<td>0.8186</td>
<td>0.3724</td>
</tr>
</tbody>
</table>

Note: Inequality in health and labor market skills are measured using standard deviation of log health and log skills at age 30, respectively. Reduction in inequality is calculated as the percentage reduction in inequality compared to the benchmark case.
Consider an early intervention, that

- increases cognitive and noncognitive abilities by 0.1 standard deviation among bottom 10% of cognitive and noncognitive abilities distribution

<table>
<thead>
<tr>
<th>Table: Predicted Percentage Changes after the Early Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Health</td>
</tr>
<tr>
<td>Skill</td>
</tr>
<tr>
<td>Consumption</td>
</tr>
</tbody>
</table>

Results: increasing gains in terms of health, skills, and consumption over time
College attendance at age 21 increases by 2 ppt (3.6%).
  - elasticity of tuition subsidy: -0.16.

Effect on unhealthy behavior is negligible.
College attendance rate at age 21 increases by 10 ppt.

4-year college completion rate at age 25 increases.
● Smoking probability first increases at early ages and then decreases after age 23.
● The gradient in unhealthy behavior by ability is increased.
Policy Experiment: Effects on Health

Table: Predicted Percentage Change in Health

<table>
<thead>
<tr>
<th></th>
<th>Age 18 to 24</th>
<th>Age 25 to 30</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p50</td>
<td>mean</td>
</tr>
<tr>
<td>Tuition Subsidy</td>
<td>0.08</td>
<td>0.04</td>
</tr>
<tr>
<td>Relaxing Credit Constraints</td>
<td>-0.19</td>
<td>0.02</td>
</tr>
</tbody>
</table>

- Predicted median health first decreases and then increases over time.
The growth of unhealthy behavior is reduced.

Large reduction in unhealthy behavior among the individuals with low ability.
Policy Experiment: Revenue-Neutral Excise Tax (2/2)

Table: Predicted Percentage Change in Health Under Increased Excise Tax

<table>
<thead>
<tr>
<th></th>
<th>Age 18 to 24</th>
<th>Age 25 to 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excise Tax</td>
<td>p50 mean</td>
<td>p50 mean</td>
</tr>
<tr>
<td>0.41</td>
<td>0.29</td>
<td>0.38</td>
</tr>
</tbody>
</table>

- Sizable gains in terms of increases in health

More results: based on ability quartiles
Additional Takeaways

1. Health has a sizable impact on individuals’ education decisions.

2. Parental transfers are important for 4-year college graduation.

3. Rational addiction has important quantitative implications on predicted patterns of unhealthy behavior.
Conclusion

- Develop and structurally estimate a life cycle model with endogenous health, education, and wealth

- Evaluate the quantitative importance of socioeconomic factors and economic mechanisms

- Future work:
  - inequality of health, education, and wealth by race and gender
  - intergenerational issues in health, education, and wealth