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

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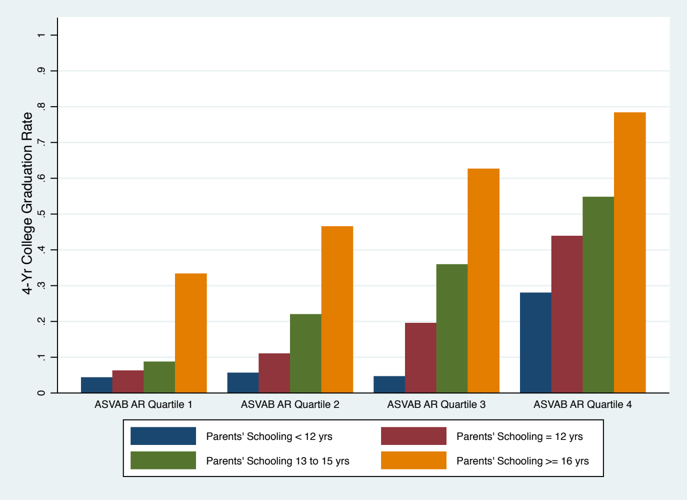
Motivation

- 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

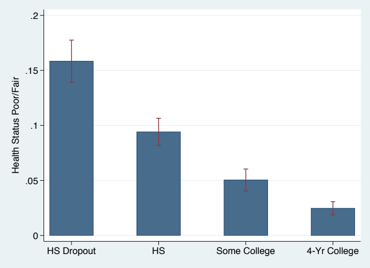
Relationships Between Early Endowments and Environments and College Graduation



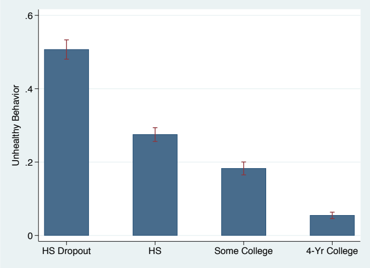
- Q: borrowing constraints or preference/ability heterogeneity? More

Disparities in Health and Wealth by Education

- More educated individuals have better health later in life.



(a) Health Status Poor/Fair



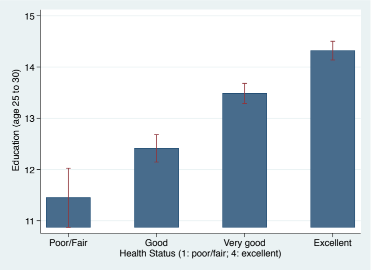
(b) Regular Smoking

Source: NLSY97 white males aged 25 to 30.

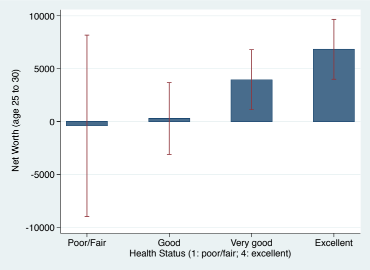
- Disparities in wages and wealth by education: Evidence

"Effects" of Initial Health Endowment

- Better health early in life is associated with higher educational attainment and higher wealth level in the adulthood.



(c) Education & Initial Health



(d) Net Worth & Initial Health

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, noncogntive, 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

Related Literature

1. Human capital, education, and credit constraints
   - Mixed evidence from NLSY79: Keane and Wolpin (2001), Carneiro and Heckman (2002), Cameron and Taber (2004), Navarro (2011), Caucutt and Lochner (2012)
   - Evidence of constraints from NLSY97: Belley and Lochner (2007), Bailey and Dynarski (2011), Lochner and Monge-Naranjo (2012)
2. Education and health
   - Schultz (1962), Becker (1964), Grossman (1972)
   - Kenkel (1991), DeCicca, Kenkel and Mathios (2002), Case, Lubotsky, and Paxson (2002), Carman (2013), Heckman, Humphries, Urzua, and Veramendi (2015)
3. Rational addiction and unhealthy behavior
   - Becker and Murphy (1988), Becker, Grossman, and Murphy (1991, 1994), Chaloupka (1991), Gruber and Koszegi (2001), Sundmacher (2012), Darden (2013)

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

Model: Decision Variables

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

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

- latent cognitive and noncognitive ability (θ_c, θ_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 $k_t = k_{t-1} + d_{k,t-1} - \delta_k k_t \mathbf{1}(d_{k,t-1} = 0)$
- previous schooling decision $d_{e,t-1}$
- parents' education and net worth (e_p, s_p)

Model: Preferences and Technology

- **Preferences:**

$$
\begin{aligned}
U(c_t, d_{q,t}, d_{e,t}, d_{k,t}; \Omega_t) = \quad & u_c(c_t; \Omega_t) + d_{q,t} \cdot u_q(q_t, h_t, e_t, \theta_c, \theta_n, \epsilon_{q,t}) \\
& + u_{ek}(d_e, d_k; h_t, \theta_c, \theta_n, d_{e,t-1}, e_p, \epsilon_{e,t}, \epsilon_{k,t})
\end{aligned}
$$

  - Unhealthy behavior is *addictive* if $\partial u_q / \partial q_t > 0$.

- **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 (ψ_t) and offered wages:**

$$
\begin{aligned}
\psi_t = & F^{\psi}(h_t, e_t, k_t, \theta_c, \theta_n) \\
\text{wages} = & \psi_t \cdot F^{w}(d_{k,t}, d_{e,t}, \epsilon_{w,t})
\end{aligned}
$$

- **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:**
$s_{t+1} \geq -$student loan limit $-$ private debt limit.
  - student loan limit: flow limit $\bar{l}^g$, total limit $\overline{L}^g$.
  - private borrowing limit: $F^l(\psi_t, t)$

Model Solution

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

$$V_t(\overline{\Omega}_t, \epsilon_t) = \max_{\boldsymbol{d}_t, s_{t+1}} \Big\{ U_t(c_t, d_{q,t}, d_{e,t}, d_{k,t}; \overline{\Omega}_t, \epsilon_t)$$
$$+ \exp(-\rho(h_t, \theta_c, \theta_n)) \mathbb{E}(V_{t+1}(\Omega_{t+1}) | \overline{\Omega}_t, d_{q,t}, d_{e,t}, d_{k,t}, s_{t+1}) \Big\}$$

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

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

Initial Distribution: Latent Factors $(\theta_c, \theta_n, \log h_{t_0})$

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

- Dedicated measurement equations:

$$
\begin{aligned}
Z^*_{c,j} &= X_c\beta_{z,c,j} + \alpha_{z,c,j}\theta_c + \epsilon_{z,c,j}, \quad j = 1, \dots, J_c \\
Z^*_{n,j} &= X_n\beta_{z,c,j} + \alpha_{z,n,j}\theta_n + \epsilon_{z,n,j}, \quad j = 1, \dots, J_n \\
Z^*_{h_t,j} &= X_h\beta_{z,c,j} + \alpha_{z,h,j}\log h_t + \epsilon_{z,h_t,j}, \quad j = 1, \dots, J_h
\end{aligned}
$$

  - 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 $(\theta_c, \theta_n, \log(h_{17}))$ 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

External Calibration

- Parameters that can be clearly identified without using our model are calibrated outside the model: details
  - relative risk aversion coefficient: $\gamma = 1.5$
  - borrowing and lending interest rates: $r_b = 4\%$, $r_l = 1\%$
  - student loan: flow limit \$11K, total limit \$35K
  - 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)

$$\begin{aligned}\text{savings}_t = & a_c \cdot (\text{measure of } \theta_c) + a_n \cdot (\text{measure of } \theta_n) + a_h \cdot (\text{measure of } h_t) \\ & + a_1 t + a_0 + X_t \beta + \epsilon_t\end{aligned}$$

    - 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

$$\max \ \Pi_i \int_{\theta_c, \theta_n, \log(h_{17})} f(Z_i; X_i, \theta_c, \theta_n, \log(h_{17})) dF(\theta_c, \theta_n, \log(h_{17}))$$

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

- 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

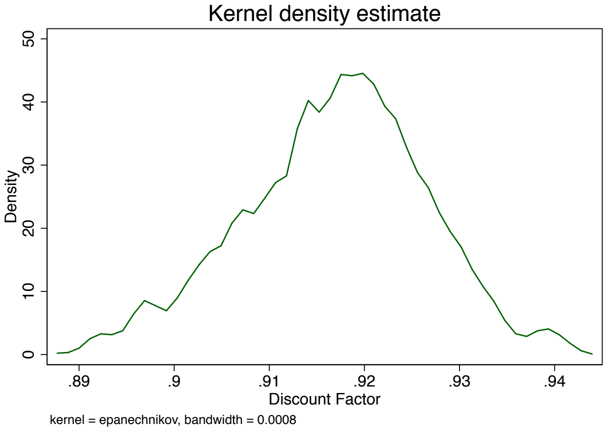
Initial Distribution of Latent Factors $(\theta_c, \theta_c, \log h_{17})$

	θ_c: Cognitive	θ_n: Noncognitive	$\log h_{17}$: Log Health
		Mean	
Parents Wealth 3rd Tercile	0.304	1.507	1.257
	(0.050)	(0.093)	(0.068)
Parents Wealth 2nd Tercile	0.000	1.027	0.430
	(0.050)	(0.085)	(0.065)
Parents 4-Yr College	0.354	1.378	0.180
	(0.069)	(0.141)	(0.090)
Parents Some College	0.314	0.782	0.172
	(0.043)	(0.077)	(0.062)
Parents High School	0.241	0.570	0.108
	(0.055)	(0.107)	(0.080)
Constant	-0.541	-1.545	-0.621
	(N.A.)	(N.A.)	(N.A.)
		Variance Matrix	
	1.000		
	(N.A.)		
	0.280	1.000	
	(0.050)	(N.A.)	
	0.143	0.369	1.000
	(0.039)	(0.059)	(N.A.)

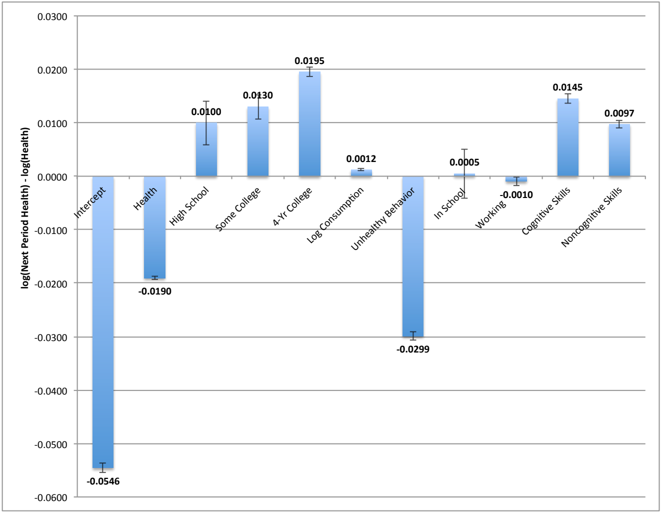
Constant terms are normalized such that $\mathbb{E}(\theta_c) = \mathbb{E}(\theta_n) = \mathbb{E}(\log(h_{17})) = 0$.

Estimates on Discount Factor: $\exp(-\rho(\theta_c, \theta_n, h_t))$

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



Estimates on Health Capital Production: $\log h_{t+1} - \log h_t$



Sorting into Education (Age 30)

- Sorting into education based on cognitive ability

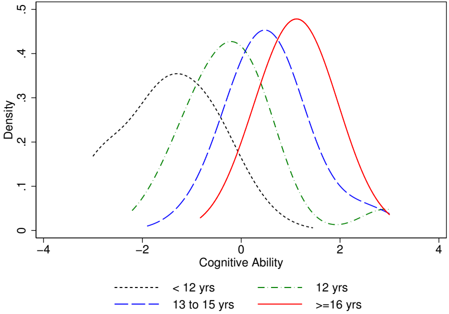


Figure : Density of Cognitive Ability Conditional on Age-30 Education

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

- Sorting into adult health status: results

Inequality Decomposition by Initial Heterogeneity (1/2)

- 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 $\Rightarrow$ quantitative importance of cognitive ability on inequality

Inequality Decomposition by Initial Heterogeneity (2/2)

	Inequality (age 30)		Inequality Reduction (%)	
	Health	Skill	Health	Skill
Baseline	0.8218	0.3843	N/A	N/A
Equalizing Cognitive Ability	0.7467	0.1997	9.14	48.03
Equalizing Noncognitive Ability	0.7185	0.3737	12.58	2.74
Equalizing Initial Health	0.3907	0.3722	52.46	3.15
Equalizing Parental Factors	0.8186	0.3724	0.39	3.09

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.

An Early Intervention for Disadvantaged Population

- Consider an early intervention, that
  - increases cognitive and noncogntive abilities by 0.1 standard deviation
  - among bottom 10% of cognitive and noncogntive abilities distribution

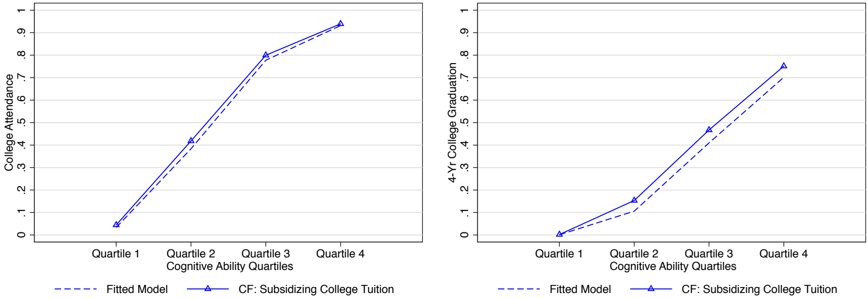
Table : Predicted Percentage Changes after the Early Intervention

	Age 18 to 20	Age 21 to 24	Age 25 to 30
Health	0.66	1.77	3.40
Skill	0.86	1.11	1.42
Consumption	0.36	1.41	2.20

- Results: increasing gains in terms of health, skills, and consumption over time

Baseline model

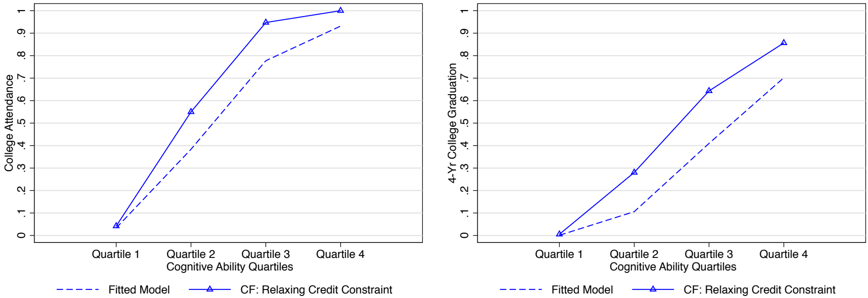
Policy Experiment: College Tuition Subsidy $1000



- College attendance at age 21 increases by 2 ppt (3.6%).
    - elasticity of tuition subsidy: -0.16.

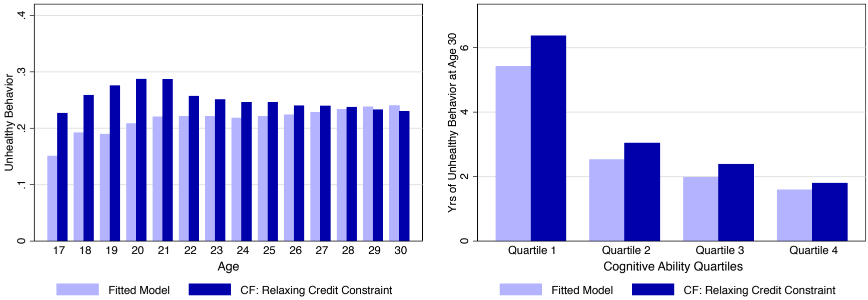
- Effect on unhealthy behavior is negligible.

Policy Experiment: Removing Credit Constraints (1/2)



- College attendance rate at age 21 increases by 10 ppt.
- 4-year college completion rate at age 25 increases.

Policy Experiment: Removing Credit Constraints (2/2)



- Smoking probability first increases at early ages and then decreases after age 23.
- The gradient in unhealthy behavior by ability is increased.

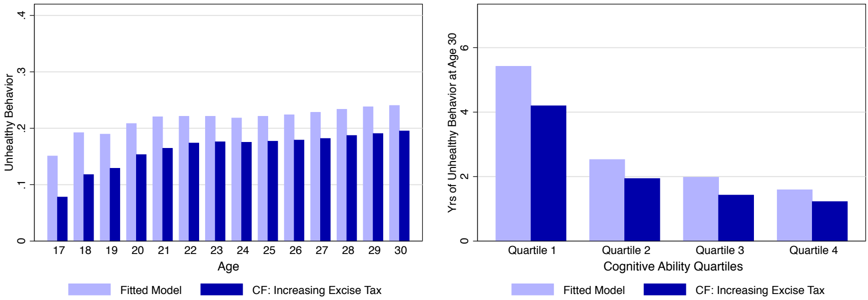
Policy Experiment: Effects on Health

Table : Predicted Percentage Change in Health

	Age 18 to 24		Age 25 to 30	
	p50	mean	p50	mean
Tuition Subsidy	0.08	0.04	0.28	0.23
Relaxing Credit Constraints	-0.19	0.02	1.02	0.91

- Predicted median health first decreases and then increases over time.

Policy Experiment: Revenue-Neutral Excise Tax (1/2)



- 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

	Age 18 to 24		Age 25 to 30	
	p50	mean	p50	mean
Excise Tax	0.41	0.29	0.38	0.33

- 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