Marshall Lectures:

The Economics and Psychology of Human Development and Inequality

Lecture II: Understanding the Origins of Inequality and Understanding Effective Interventions and the Channels Through Which They Work.

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The Marshall Lectures 2010-2011
Lady Mitchell Hall
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1. Multiple Abilities Generate Life Outcomes Through Multiple Channels

Human Capabilities Predict Outcomes

- Cognitive capacities at age t: θ_t^C

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- A_t^j are other background and situational factors.

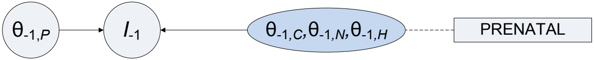
A Life Cycle Framework for Organizing Studies and Integrating the Evidence on Life Cycle Skill Formation

$\theta_t = (\theta_C, \theta_N, \theta_H)$ capacities at t

I_t: investment at t

$\theta_{t+1} = f_t(\theta_t, I_t, \theta_{t,P})$

$\theta_{t,p}$ is parental home environment.



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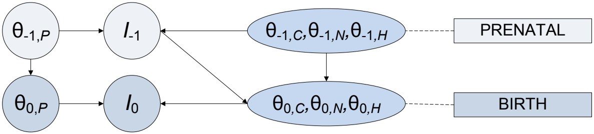

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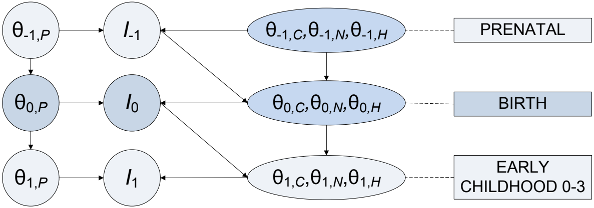

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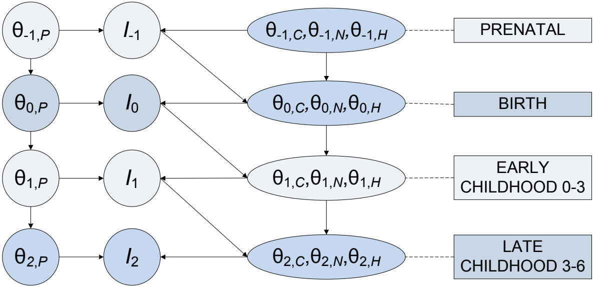

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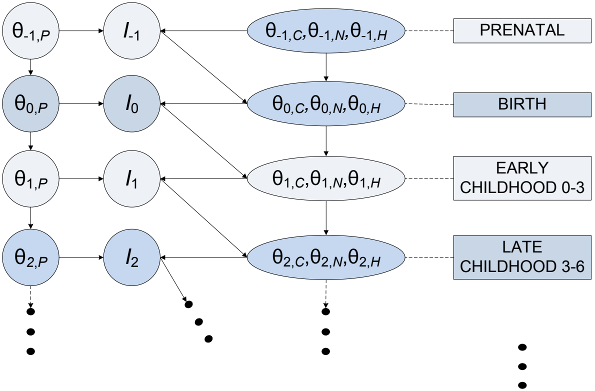

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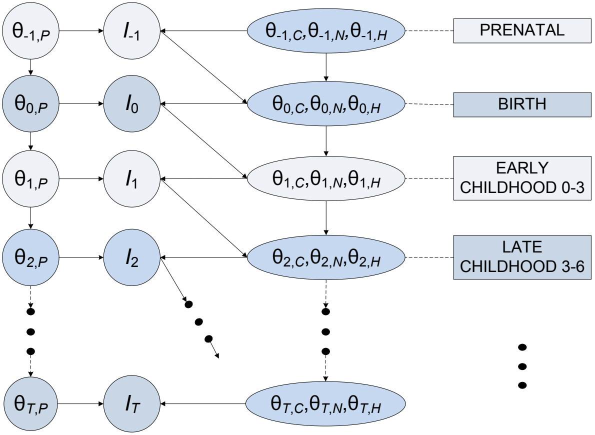

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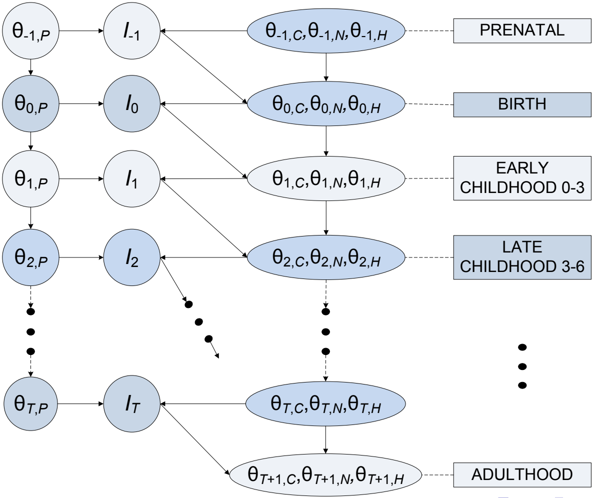
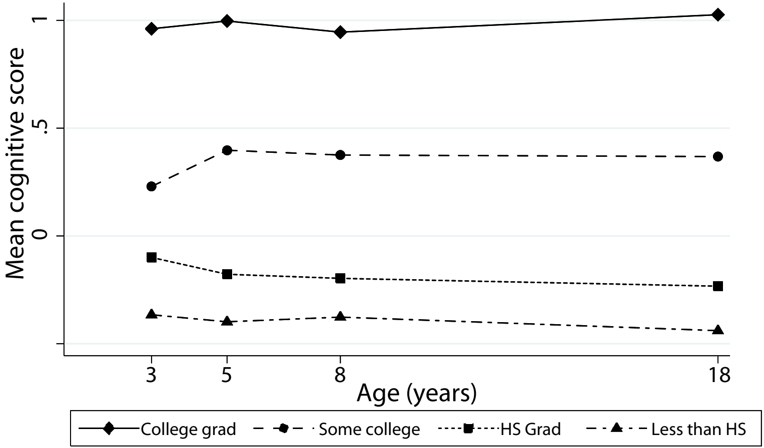


2. Ability gaps among individuals and across socioeconomic groups open up at early ages and persist for both cognitive and noncognitive traits.

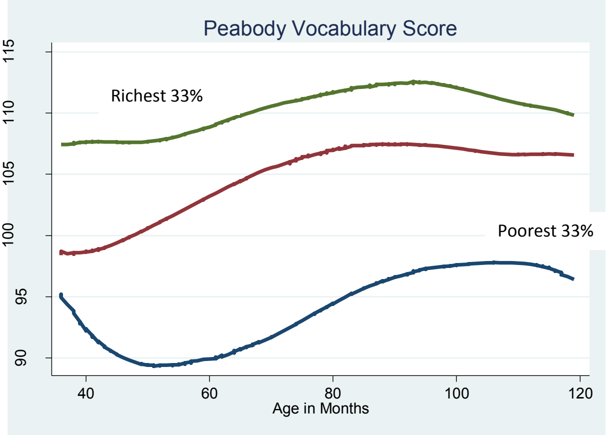
Trend in mean cognitive score by maternal education



Each score standardized within observed sample. Using all observations and assuming data missing at random. Source: Brooks-Gunn et al. (2006).

PEABODY standardized scores of vocabulary by household wealth and child's age, by area in Colombia

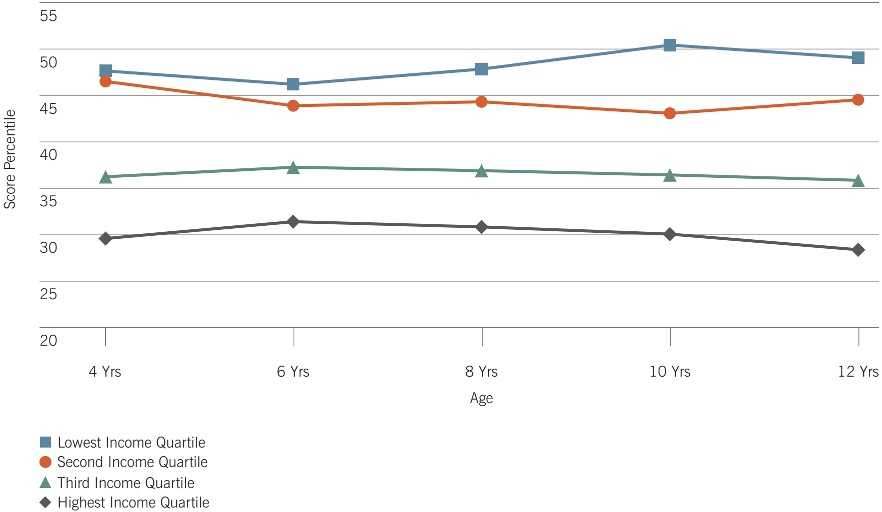
Urban



Source: Longitudinal Colombian Survey, Universidad de los Andes (2010), prepared by Raquel Bernal

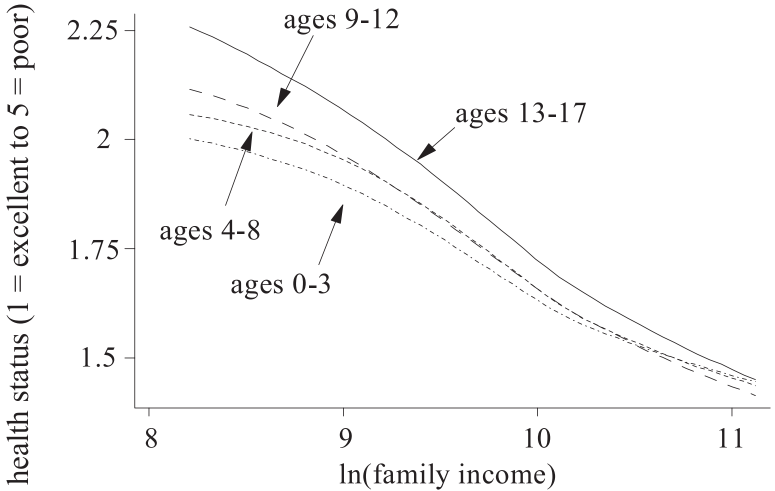
Average percentile rank on anti-social behavior score, by income quartile

(The higher the score, the worse are behavioral problems)



Gaps emerge in health. They *diverge* with age.
A higher score is a worse health outcome.

Health and income for children and adults, U.S. National Health Interview Survey 1986-1995. From Case, A., Lubotsky, D. & Paxson, C. (2002), American Economic Review, Vol. 92, 1308-1334.



Origins of Gaps

- Genes?

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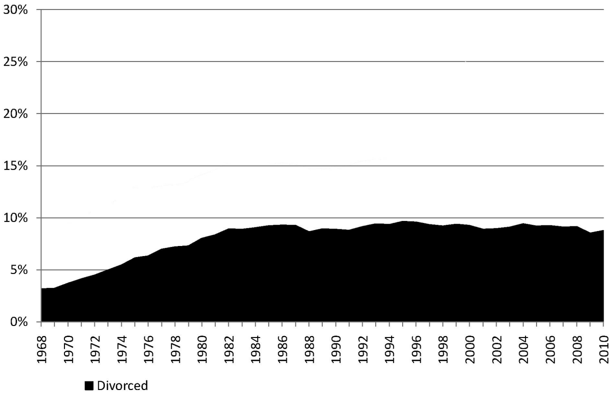
- Exact mechanisms are still being explored. This lecture is a progress report on what is known about these mechanisms.
- All of the evidence points to an important role for the family **environments** in shaping capabilities.

3. Child Rearing Environments Are Deteriorating in Many Countries Around the World

Percent of Children Under 18 Living with One Parent, By Marital Status of Single Parent



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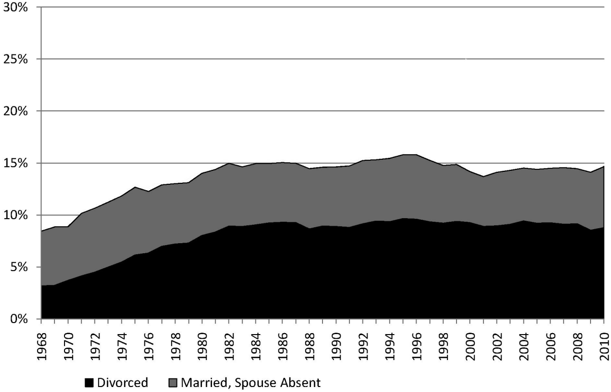

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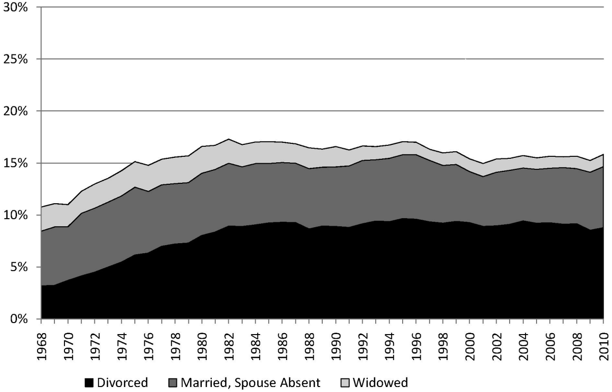

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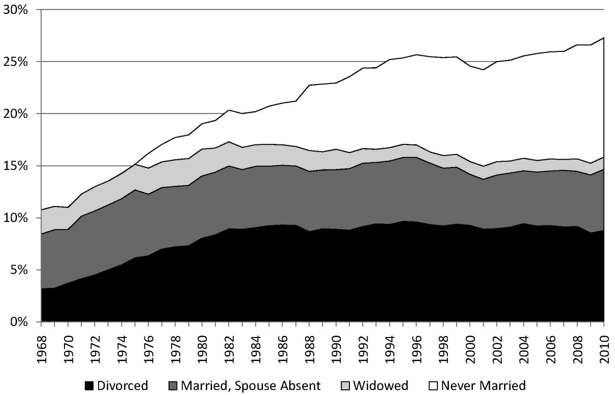

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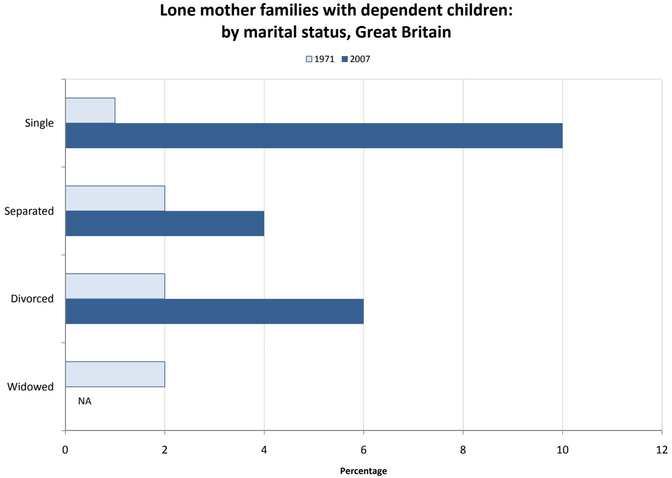
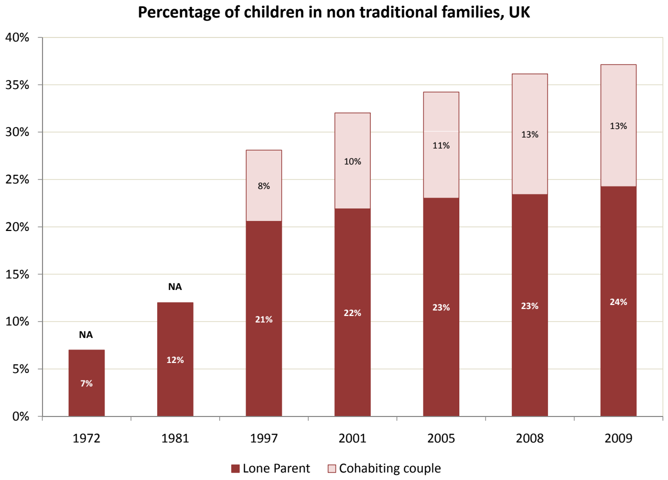
Family Environments in the UK

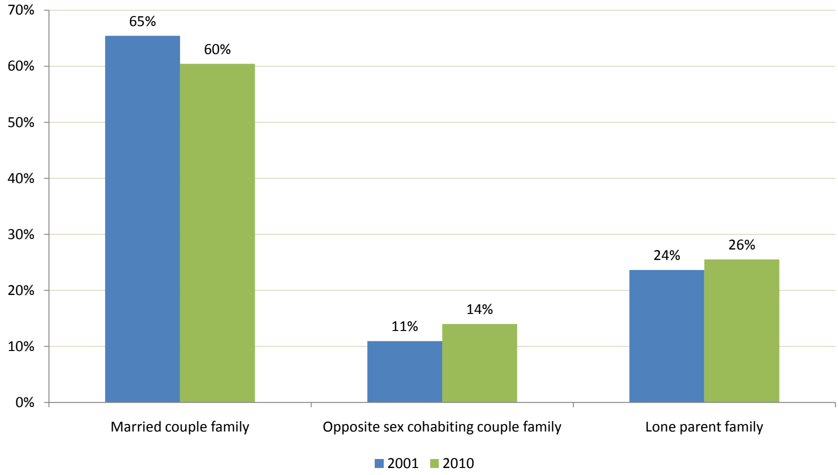


Comment: Children aged under 16, or aged 16 to 18 and in full-time education, in the family unit, and living in the household. Source: Office for National Statistics



Comment: Children aged under 16 and those aged 16 to 18 who have never married and are in full-time education. Source: Office for National Statistics

Percentage of families with dependent children: by family type, UK



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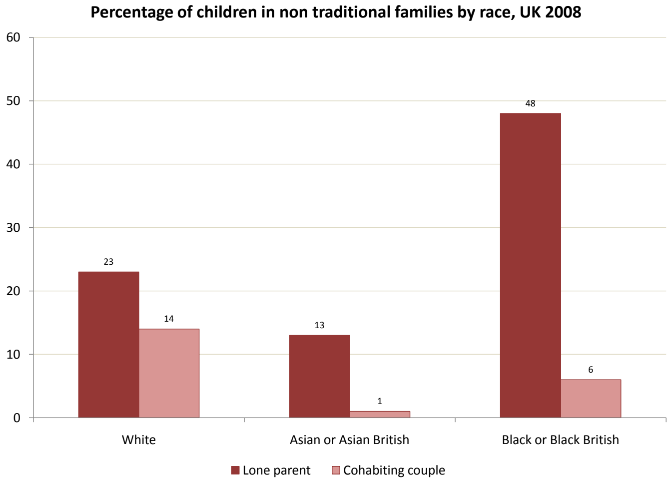

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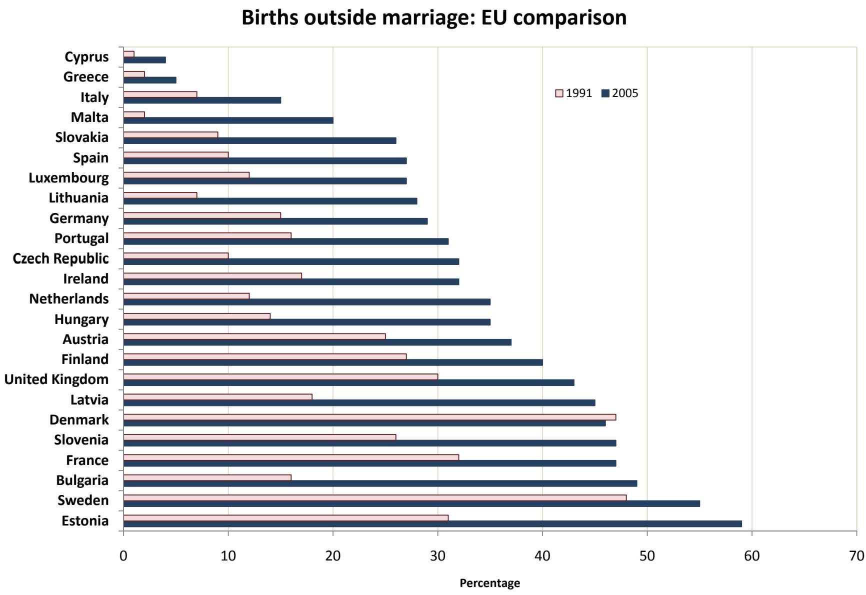
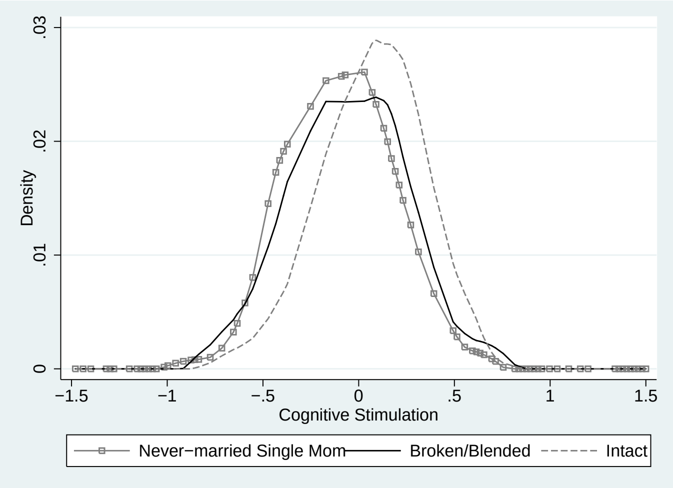


Source: Eurostat

Investment by Family Type

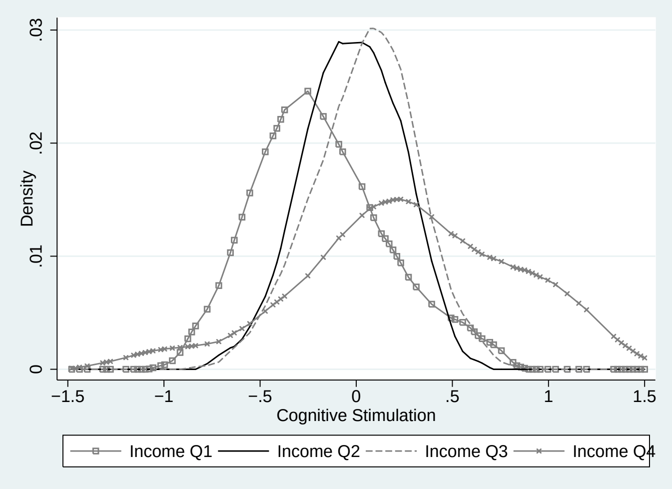
Cognitive Stimulation: Age 0-2, White, By Family Type



Males

Source: Seong Hyeok Moon (2008) analysis of CNLSY data

Cognitive Stimulation: Age 0-2, White, By Family Income Quartile



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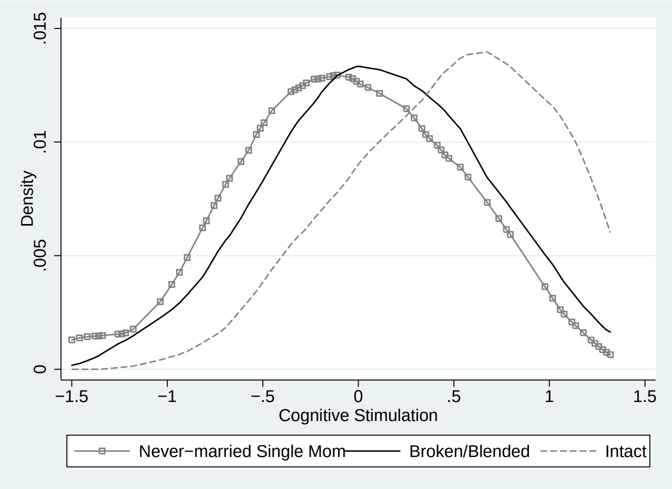
Cognitive Stimulation: Age 10-11, White, By Family Type

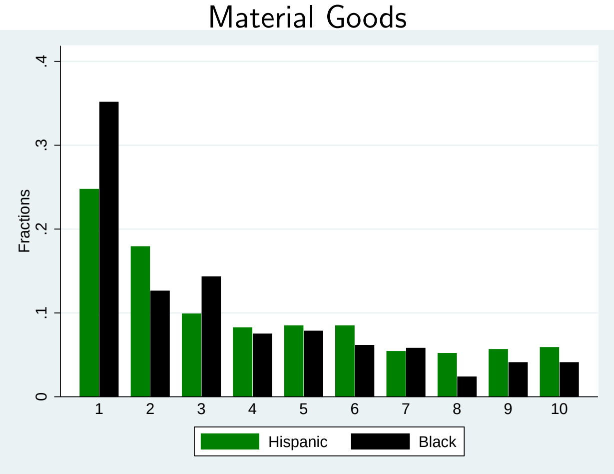


Females

Source: Seong Hyeok Moon (2008) analysis of CNLSY data

There Are Substantial Differences in Family Investment and Parenting Practices Across Ethnic Groups in the U.S.

Hispanic and Black PI in White Distribution: intact family, adjusted for mother's education, age 0-3



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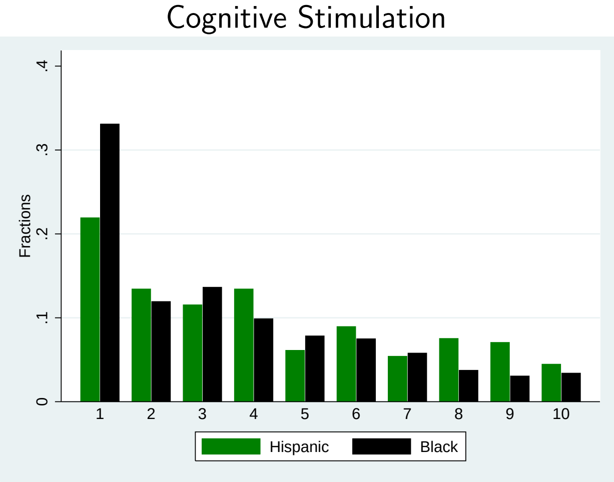

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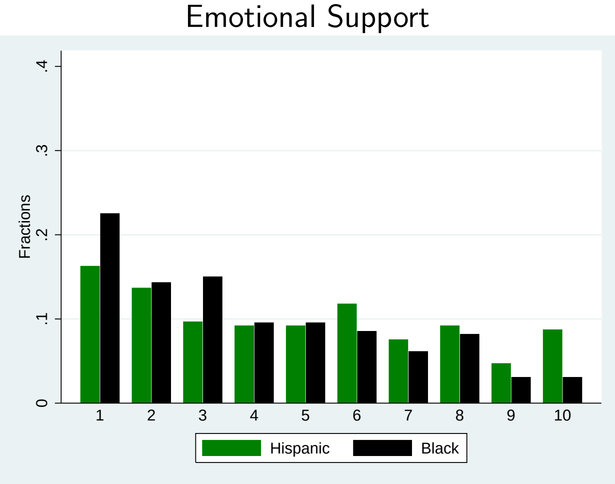
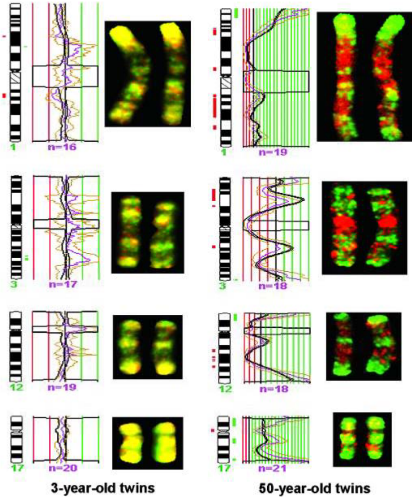


Source: Moon (2010)

4. Epigenetics and the Role of Genes
Experience gets embodied in the biology of the organism.

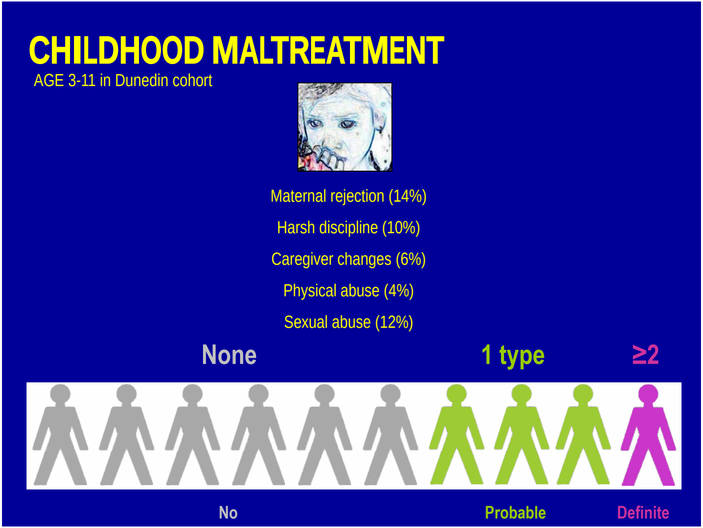
Evidence on gene-environment interactions: experience gets under and stays under the skin.

Gene expression patterns in young and old identical twins

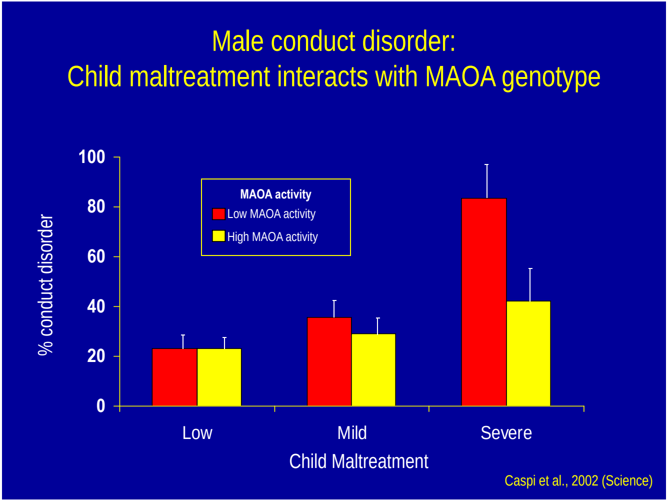


Source: Fraga, Ballestar et al. (2005)

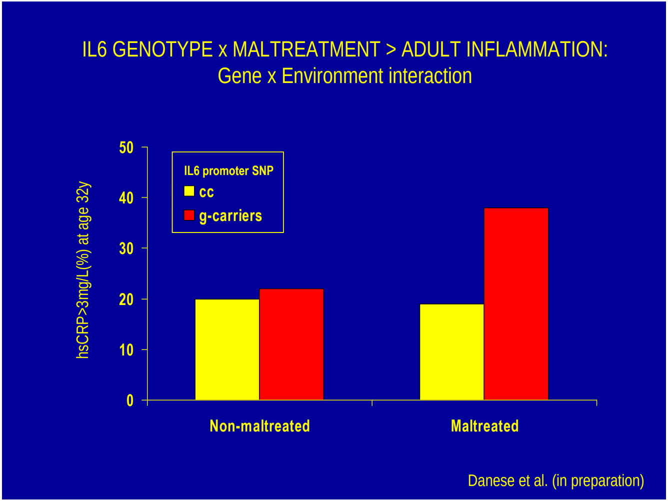
Gene Expression is Triggered by Environments



Source: Moffitt, "Gene-Environment Interaction in Problematic and Successful Aging," NIA Meeting Feb 12, 2008.



Caspi, McClay et al. (2002).



Source: Danese, Moffitt et al. (2008)

Open Question

- The quantitative importance of these epigenetic interactions on economic and social outcomes remains to be determined — what % of variance in outcomes explained by them?

5. Evidence on Critical and Sensitive Periods in Skill Development

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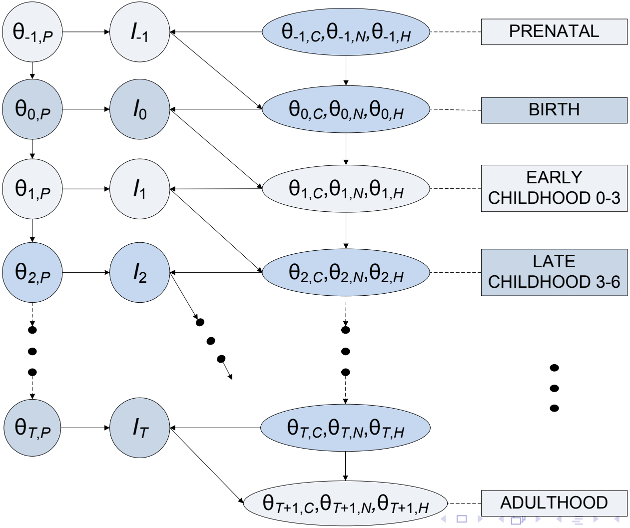

6. Enriched Early Environments Compensate In Part For Risk Features of Disadvantaged Environments

Early Intervention Programs for Disadvantaged Children

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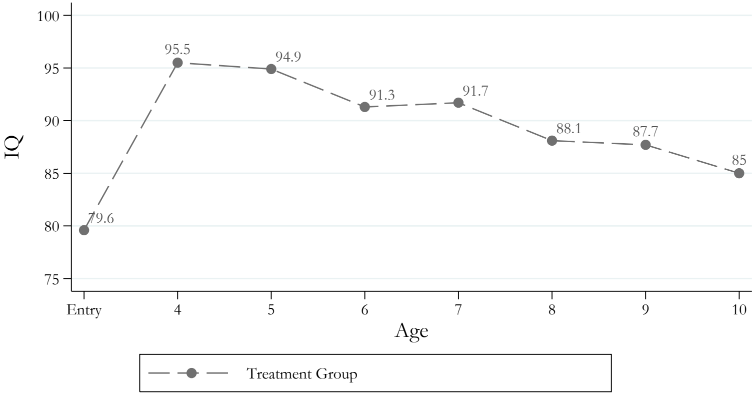
- The evidence from it and other programs shows that supplementing early family life can permanently boost life outcomes.
- Family and environment matters.

Perry preschool program: IQ, by age and treatment group



Source: Perry Preschool Program. IQ measured on the Stanford Binet Intelligence Scale (Terman & Merrill, 1960). Test was administered at program entry and each of the ages indicated.

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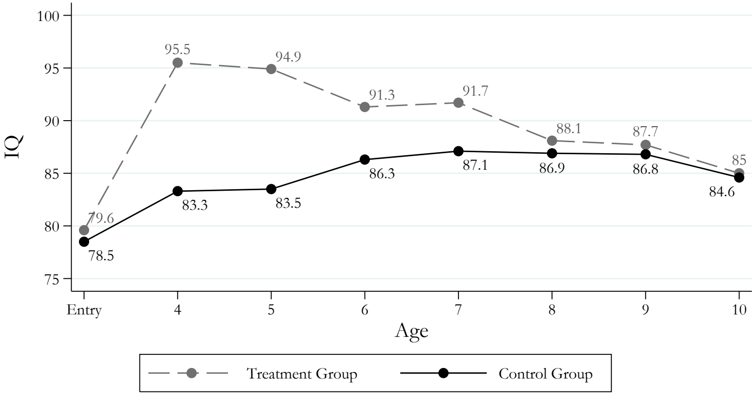

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Figure 1: Personal Behavior Index by Treatment Group

(1 is bad; 5 is good)

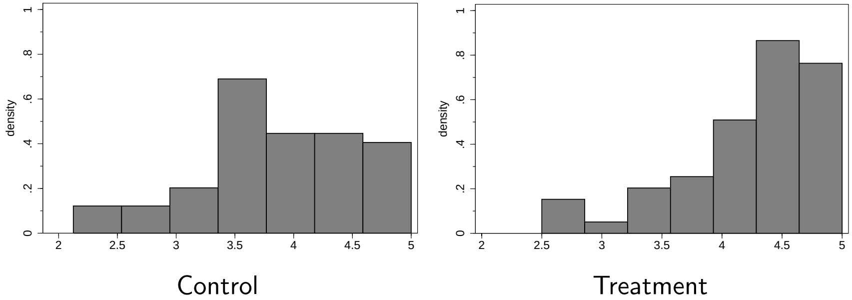
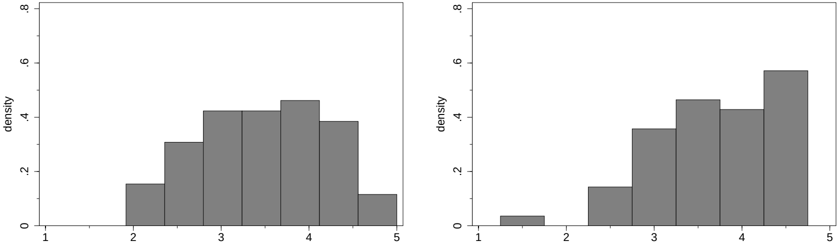


Figure 2: Socio-Emotional Index by Treatment Group

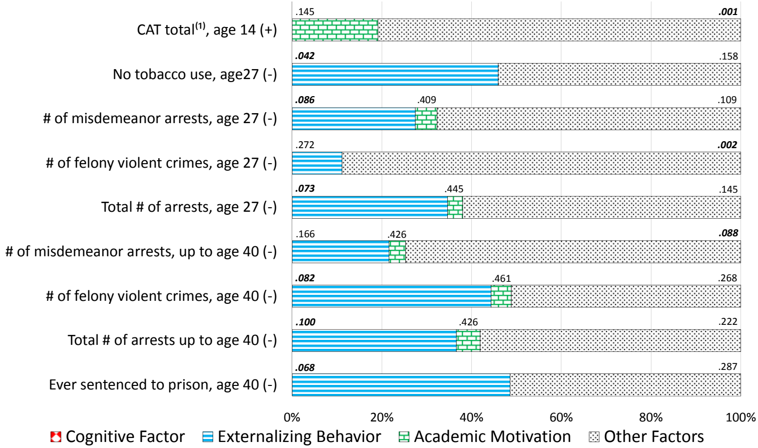
(1 is bad; 5 is good)



Control Treatment

Decomposing Treatment Effects of the Perry Program

Decomposition of Treatment Effects, Males



Evidence on the Effectiveness of Early Childhood Interventions in LDCs

LDCs

- Less public infrastructure

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- Less public infrastructure
- Extreme disadvantage (ex. hygienic conditions: no access to safe water, sanitation etc).
- Prevalence of diseases and malnutrition.
- Nutrition and health are important aspects

Guatemalan intervention

1. 8 year-long nutrition intervention

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4. Fresco as placebo: Kool-Aid like drink, just sugar
5. Total of 2400 children

Outcomes 25 years later: Long lasting impacts on

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2. Reading scores (14% improvement in reading comprehension test)
3. 30 to 40% higher earnings, for men
4. Grade attained, $\uparrow$ for women only (0.11 grades per year more, and less likely to drop out)

Jamaican intervention program

Program description

Initial Study

- **Long term follow-up** of cognitive stimulation program through home visits

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- **Long term follow-up** of cognitive stimulation program through home visits
- Intervention **very early in life**: started between 9 and 24 months of age, and lasted 2 years
- 129 stunted kids living in Kingston, Jamaica.
- Randomized trial
- Sample of non-stunted kids also followed for comparison purposes

The cognitive intervention

- The stimulation comprised weekly play sessions at home with a community health aid, for 2 years, 1 hr per week

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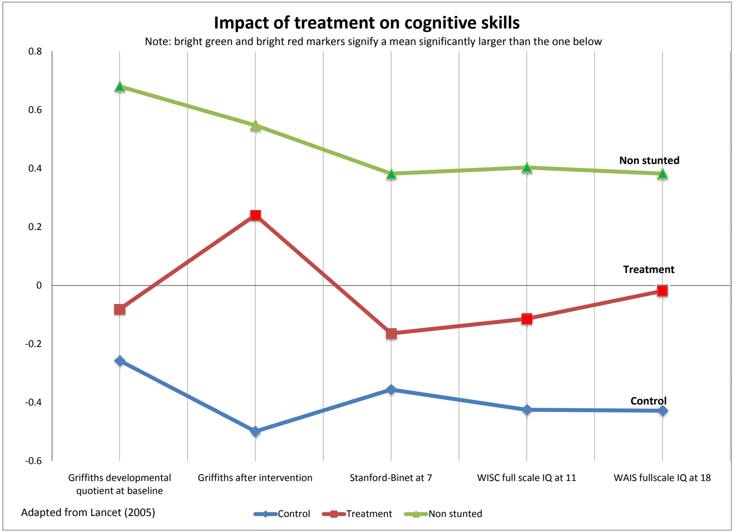
- The stimulation also **actively involved mothers**

The cognitive intervention

- The stimulation comprised weekly play sessions at home with a community health aid, for 2 years, 1 hr per week
- The stimulation also **actively involved mothers**
- Very similar to home visits in Perry program

Previous follow-up showed long lasting impact on cognitive outcomes



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- Did not fully catch up with non-stunted kids

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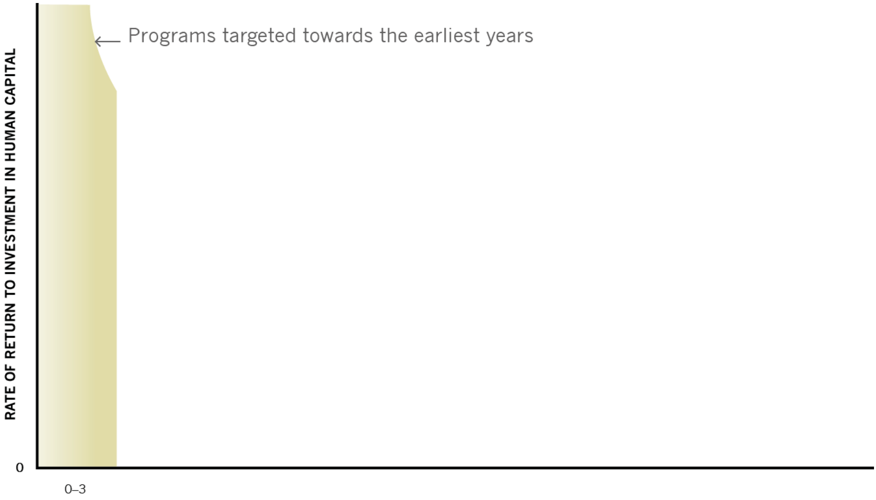
- Returns are the highest for adolescents with the greatest abilities.

Returns to a unit dollar invested.



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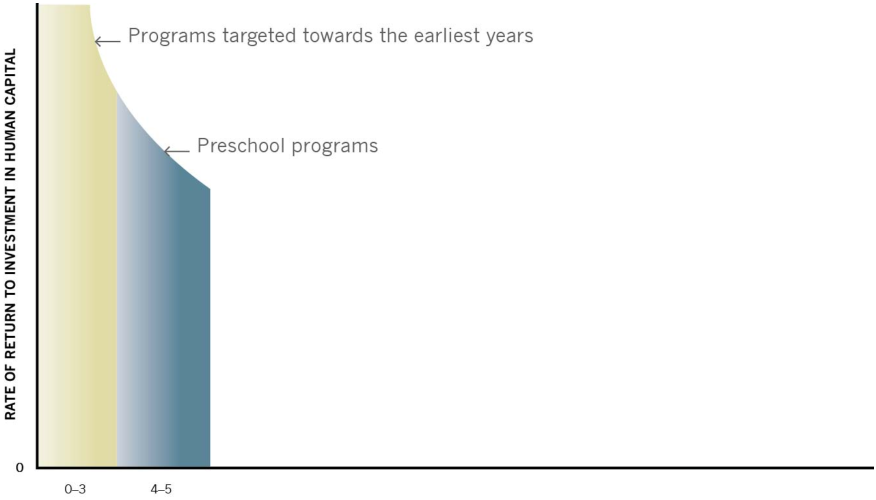

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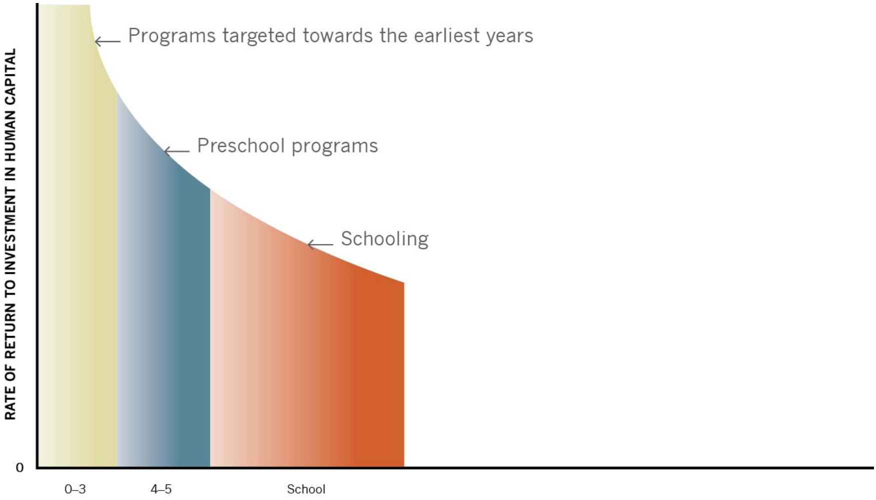

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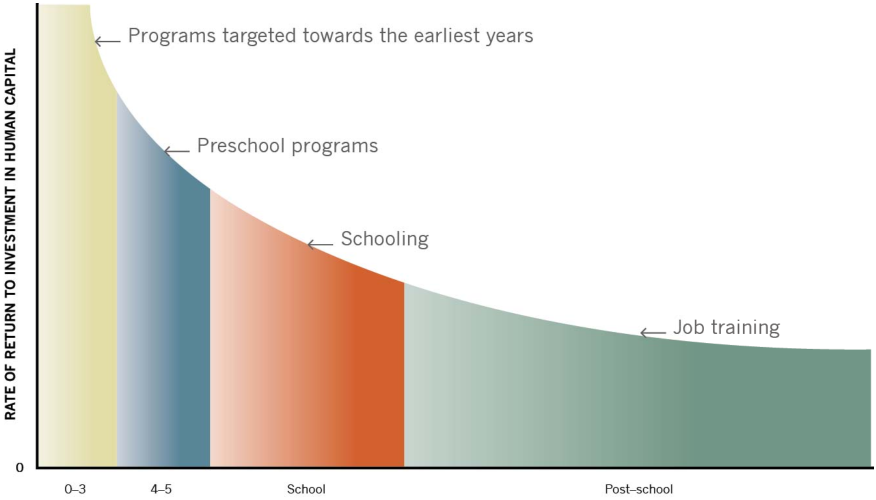

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8. Constraints Operating on the Family and the Child

- Inability of children to buy good parents and good environments.

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- A large body of evidence (e.g., Carneiro and Heckman, 2003; Dahl and Lochner, 2010) points to the important role of family income in the child's early years in shaping adult capabilities.

9. A Model of Family Skill Formation Consistent with the Evidence and Lessons for Policy

- Build on and extend Cunha and Heckman (2007)

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Recent research in the economics of the family (Cunha et al. 2006, 2007, 2008, 2009, 2010; Moon, 2008; Bernal and Keane, 2009; Del Boca, Flinn and Wiswall, 2010; Tartari, 2010; Conti et al., 2010; Akabayashi, 1995, 2000; Weinberg, 2006; Cosconati, 2009; Caucutt and Lochner, 2011) and research under way improves on earlier work by Becker and Tomes (1986) in the following ways:

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g. Interaction between child and parents in shaping investment. (principle-agent problems)

Overlapping generations model of a one-child family (Cunha and Heckman, 2007)

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- f_t is neoclassical: strictly increasing, strictly concave, and twice continuously differentiable in I_t.

Solve recursively to obtain:

$$\theta_{t+1} = m_t\left(h, \theta_1, I_1, \ldots, I_t\right). \tag{2}$$

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  1. Higher stocks of capabilities at age t promote the productivity of investment at that age;
  2. Investment today raises the stock of skills in future periods and raises the productivity of future investment.

- *Self-productivity*:

$$\frac{\partial f_t\left(h, \theta_t, I_t\right)}{\partial \theta_t} > 0.$$

A. Critical and sensitive periods for investment:

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   2. If
      $$\frac{\partial f_t}{\partial I_t}(\cdot) > \frac{\partial f_{t'}}{\partial I_{t'}}(\cdot) \qquad t \neq t'$$
      then t is a sensitive period, where "$\cdot$" is a common point of evaluation.

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Preferences and the Optimal Lifecycle Profile of Investments

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- State variables for the parent: parental skills, h, the parental financial resources, b, and the initial skill level of the child, θ_1.
- c_1 and c_2 denote the consumption of the household in the first and second period of the lifecycle of the child.
- The budget constraint is:

$$c_1 + I_1 + \frac{c_2 + I_2}{(1+r)} + \frac{b'}{(1+r)^2} = wh + \frac{wh}{(1+r)} + b. \qquad (3)$$

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- $u(\cdot)$ is the utility function.
- Problem of the parent:

$$V\left(h, b, \theta_1\right) = \max\left\{u\left(c_1\right) + \beta u\left(c_2\right) + \beta^2 \delta E\left[V\left(h', b', \theta_1'\right)\right]\right\}. \quad (4)$$

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- The child's adult stock of skills, h':

$$h' = m_2\left(h, \theta_1, I_1, I_2\right). \tag{5}$$

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$$h' = m_2\left(h, \theta_1, \min\left\{I_1, I_2\right\}\right). \qquad (7)$$

- More general technology:

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for $\phi \leq 1$ and $0 \leq \gamma \leq 1$.

- The CES share parameter γ is *a skill multiplier*.

Optimal Investment Strategy for $\phi = 1$ (Perfect Substitutes)

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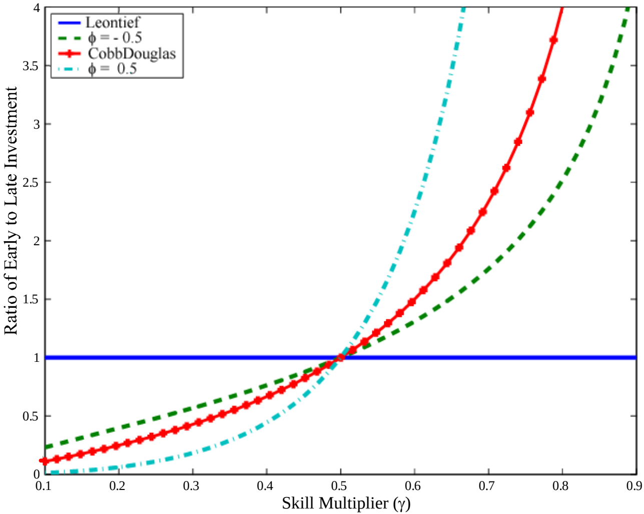
- Productivity of early investment: γ; later investment $(1-\gamma)$.
- Invest early if $\gamma > (1-\gamma)(1+r)$.

- $\phi \to -\infty$ (perfect complementarity), the optimal investment strategy is to set $I_1 = I_2$.

- $-\infty < \phi < 1$:

$$\frac{I_1}{I_2} = \left[\frac{\gamma}{(1-\gamma)(1+r)} \right]^{\frac{1}{1-\phi}} . \tag{9}$$

The Ratio of Early to Late Investment in Human Capital As a Function of the Skill Multiplier for Different Values of Complementarity



(Assumes $r = 0$)

Source: Cunha et al. (2007).

Alternative Market Environments

- **Suppose parents cannot borrow against child's future earnings.**

$$b' \geq 0. \tag{10}$$

- If binding, realized investment $\hat{I}_j$ less than optimal I_j^*

$$\hat{I}_1 \leq I_1^* \text{ (unconstrained)}$$
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- Lower investment in both periods does not affect ratio of investments (I_1/I_2).

Parents Face Lifetime Liquidity Constraints

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- Assume that parents' productivity grows exogenously at rate α.

- s: parental savings.

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- Parents face a sequence of constraints at each stage of the life cycle of the child:

$$c_1 + I_1 + \frac{s}{(1+r)} = wh + b \tag{11}$$

$$c_2 + I_2 + \frac{b'}{(1+r)} = w(1+\alpha)h + s, \tag{12}$$

$s \geq 0$ and $b' \geq 0$.

- Suppose $u(c) = (c^{\lambda} - 1)/\lambda$:

$$\frac{I_1}{I_2} = \left[\frac{\gamma}{(1-\gamma)(1+r)}\right]^{\frac{1}{1-\phi}} \underbrace{\left[\frac{(wh + b - I_1)}{\beta\left((1+\alpha)wh - I_2\right)}\right]^{\frac{1-\lambda}{1-\phi}}}_{\leq 1}.$$

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- $\therefore \frac{1-\lambda}{1-\phi} \in [.83, 1.33]$.
- Evidence of credit constraints at early years that affect child outcomes.

10. Estimating and Interpreting the Estimates of the Technology of Skill Formation

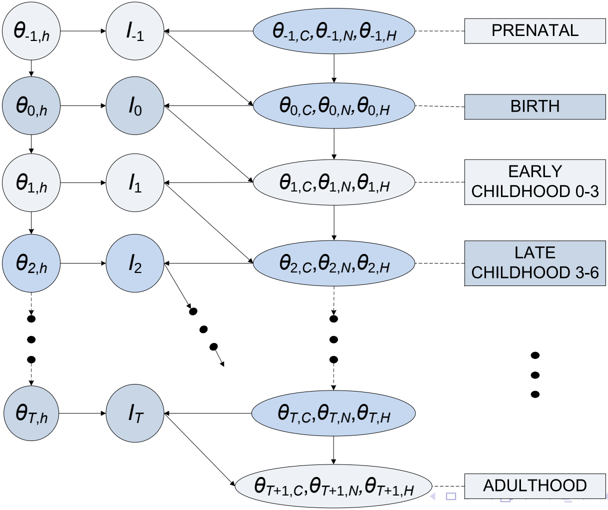
A Life Cycle Framework for Organizing Studies and Integrating Evidence

$\theta_t = (\theta_C, \theta_N, \theta_H)$ capacities at t

$\theta_{t,h}$: parental traits at t

I_t: investment at t

$\theta_{t+1} = f_t(\theta_t, I_t, \theta_{t,h})$: **Technology of Skill Formation**



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  f. Output as measured by test scores is meaningless—any monotonic function of a test score is a test score. Need to set the scale by anchoring in cardinal outcomes of interest e.g. earning, schooling.

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- Anchor scales of θ using observed outcomes (Y), not test scores.

Estimates of the Technology of Skill Formation

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$$\theta_{t+1} = A_t\theta_t + B_t I_t + \eta_t.$$

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Sources of Identification

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e. Complementarity between noncognitive skills and investments becomes slightly *weaker* as children become older. Slightly easier to compensate using interventions in the adolescent years for adversity in the early years using investments in noncognitive skills.

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- Measured parental investments account for 15% of the variation in educational attainment.
- These estimates suggest that the measures of cognitive and noncognitive capabilities are powerful, but not exclusive, determinants of educational attainment and that other factors, besides the measures of family investment that we use, are at work in explaining variation in educational attainment.

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- $F(\theta_{1,q})$ denotes its distribution.

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- The price of investment the same in each period.

- Social planner maximizes per capita aggregate schooling:

$$\max \bar{S} = \frac{1}{Q} \sum_{q=1}^{Q} \underbrace{S\left(\theta_{C,3,q}, \theta_{N,3,q}, \pi_q\right)}_{\substack{\text{schooling attained} \\ \text{as a function of end} \\ \text{of childhood endowment}}} .$$

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- Aggregate budget constraint:

$$\sum_{q=1}^{Q}\left(I_{1,q}+I_{2,q}\right)=2Q.$$

- Technology constraint,

$$\theta_{k,t+1,q} = f_{k,t}\left(\theta_{C,t,q}, \theta_{N,t,q}, \theta_{C,P,q}, \theta_{N,P,q}, \pi_q\right)$$

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- Abstract from child and parental feedback from investment — principle-agent problems at the level of the parent-child and government-parent interactions.

- Figure 3 (for the child's personal endowments) shows the profiles of early (left hand side graph) and late (right hand side graph) investment as a function of child endowments.

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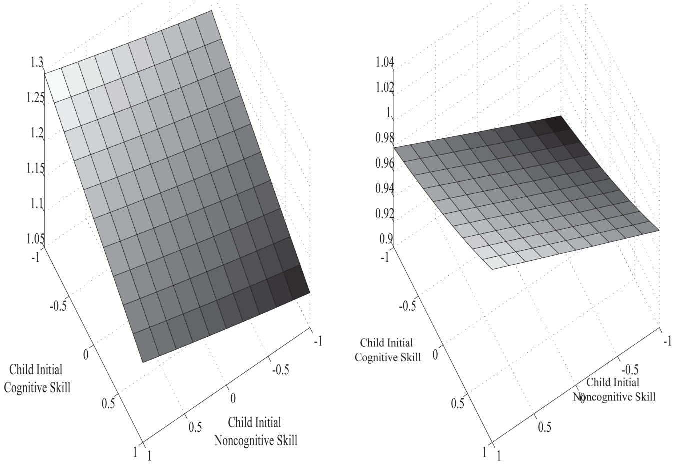
- For the most disadvantaged, the optimal policy is to invest a lot in the early years.
- Moon (2010) shows that, in actuality, society and family together invest much more in the early years of the advantaged compared to the disadvantaged.

Figure 3: **Optimal early (left) and late (right) investments by child initial conditions of cognitive and noncognitive skills maximizing aggregate education.**



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- A similar profile emerges for investments to reduce aggregate crime, which for the sake of brevity, we do not display.

- Figures 4 and 5 reveal that the ratio of optimal early-to-late investment as a function of the child's personal endowments declines with advantage whether the social planner seeks to maximize educational attainment (4) or to minimize aggregate crime (5).

Figure 4: **Ratio of Early to Late Investments by Child Initial Conditions of Cognitive and Noncognitive Skills Maximizing Aggregate Education**

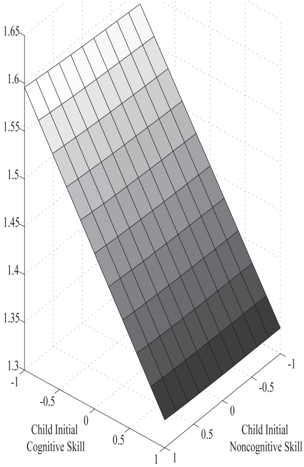
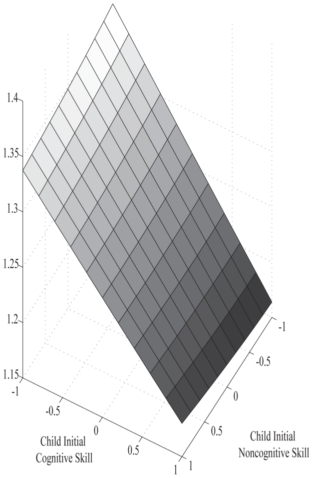


Figure 5: **Ratio of Early to Late Investments by Child Initial Conditions of Cognitive and Noncognitive Skills Minimizing Aggregate Crime**



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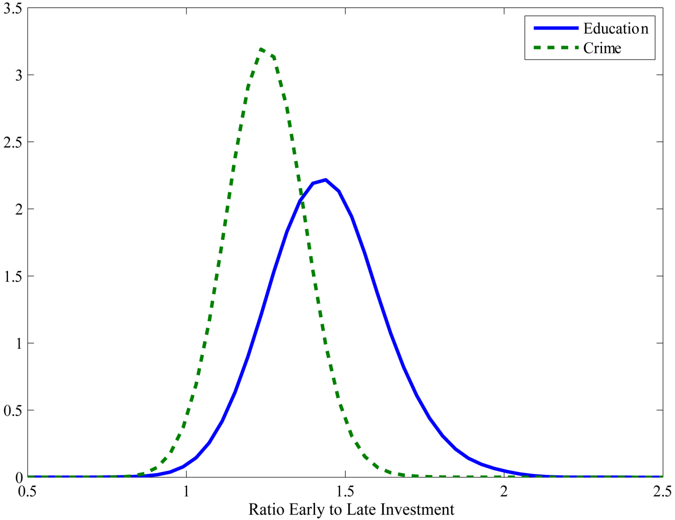
- Crime is more intensive in noncognitive skill than educational attainment, which depends much more strongly on cognitive skills.

Figure 6: Densities of Ratio of Early to Late Investments Maximizing Aggregate Education Versus Minimizing Aggregate Crime



- Because compensation for adversity in noncognitive skills is somewhat less costly in the second period, and because of discounting of costs and concavity of the technology, it is efficient to invest relatively more in noncognitive traits in the second period.

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- The opposite is true for cognitive skills.

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- Targeted strategies are likely to be effective especially for different targets that weight cognitive and noncognitive traits differently.

- Note that even though there is static complementarity in the estimated technology for each period

$$\frac{\partial^2 f_j(\theta_j, I_j, h)}{\partial I_j \partial \theta_j} > 0,$$

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- Not a theorem, but an implication of the empirical estimates.
- Consistent with a large body of empirical research.

Some Economic Intuition for the Simulations

- Given the estimated (weak) complementarity in the production technology within each period, how is it possible to obtain the result that it is optimal to invest relatively more in the early years of the most disadvantaged?

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- Given the estimated (weak) complementarity in the production technology within each period, how is it possible to obtain the result that it is optimal to invest relatively more in the early years of the most disadvantaged?
- The answer hinges on the interaction between different aspects of disadvantage (parental endowments and initial child endowments) and helps to illuminate the operation of dynamic complementarity.

Example:

- A single capability, θ.

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- Suppose that there are two periods for investment, which we denote by periods 1 (early) and 2 (late).
- For each period, there is a different technology that produces skills.

- The technology for period one is:

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- These patterns of complementarity are polar cases that represent, in extreme form, the empirical pattern found for cognitive skill accumulation: that substitution possibilities are greater early in life compared to later in life.

- The problem of society is to choose how much to invest in child A and child B in periods 1 and 2 to maximize total aggregate skills, $\theta_3^A + \theta_3^B$, subject to the resource constraint $I_1^A + I_2^A + I_1^B + I_2^B \leq M$, where M is total resources available to the family.

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- Formally,

$$\max \left[\begin{array}{c} \min\left\{\gamma_1\theta_1^A + \gamma_2 I_1^A + \gamma_3\theta_P^A, I_2^A, \theta_P^A\right\} + \\ \min\left\{\gamma_1\theta_1^B + \gamma_2 I_1^B + \gamma_3\theta_P^B, I_2^B, \theta_P^B\right\} \end{array} \right]$$
$$\text{subject to: } I_1^A + I_2^A + I_1^B + I_2^B \leq M \qquad (13)$$

- When the resource constraint (13) does not bind, as it does not if M is above a certain threshold (determined by θ_P), optimal investments are

$$I_1^A = \frac{(1-\gamma_3)\,\theta_P^A - \gamma_1\theta_1^A}{\gamma_2} \qquad I_1^B = \frac{(1-\gamma_3)\,\theta_P^B - \gamma_1\theta_1^B}{\gamma_2}$$

$$I_2^A = \theta_P^A \qquad I_2^B = \theta_P^B$$

- Notice that if child A is disadvantaged compared to B on both measures of disadvantage, $(\theta_1^A < \theta_1^B$ and $\theta_A^P < \theta_B^P)$, it can happen that

$$I_1^A > I_1^B, \text{ but } I_2^A < I_2^B$$

if

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$$\theta_P^A - \theta_P^B > \frac{\gamma_1}{(1-\gamma_3)}\left(\theta_1^A - \theta_1^B\right), \gamma_3 \neq 1.$$
- Thus, if parental endowments are less negative than the childhood endowments (scaled by $\frac{\gamma_1}{(1-\gamma_3)}$), it is optimal to invest more in the early years for the disadvantaged and less in the later years.

- The higher the self-productivity (γ_1) and the higher the parental environment productivity, γ_3, the more likely will this inequality be satisfied for any fixed level of disparity. So the optimal policy is to invest more in the disadvantaged in the early years.

11. How Does This Research Cause Us to Rethink the Role of Education and Our Education and Human Capital Policies?

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- Schooling also creates the traits that promote successful lives.

The Causal Effects of Schooling on Cognitive and Personality Traits

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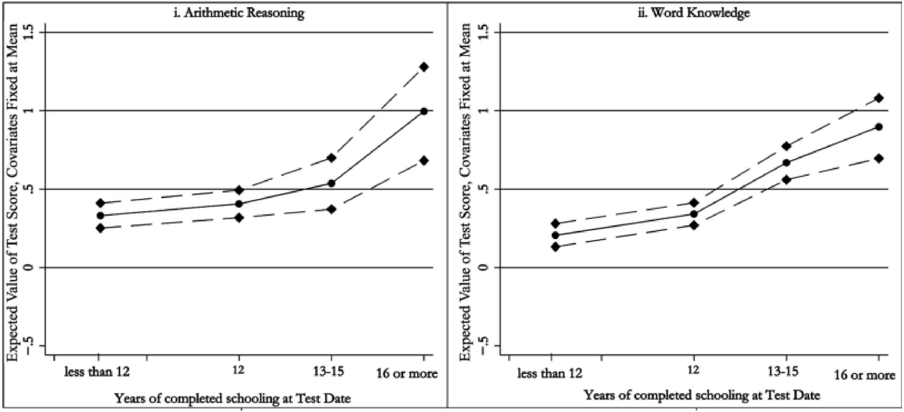
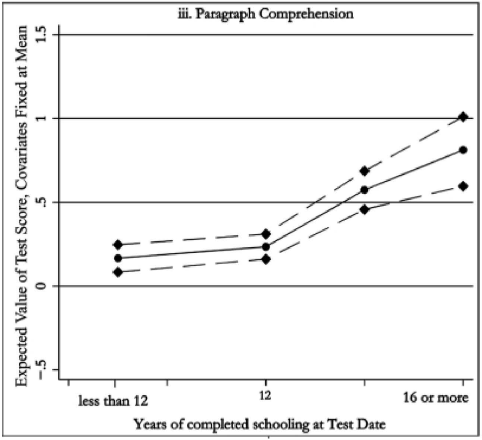
- Use the methodology of Hansen, Heckman and Mullen [2004].
- Two econometric strategies that produce estimates in close agreement.

Figure 7: Causal Effect of Schooling on ASVAB Measures of Cognition



Notes: Effect of schooling on components of the ASVAB. The first four components are averaged to create male's with average ability. We standardize the test scores to have within-sample mean zero, variance one. The model is estimated using the NLSY79 sample. Solid lines depict average test scores, and dashed lines, confidence intervals.
Source: Heckman, Stixrud and Urzua [2006, Figure 4].

Figure 7: Causal Effect of Schooling on ASVAB Measures of Cognition



Notes: Effect of schooling on components of the ASVAB. The first four components are averaged to create male's with average ability. We standardize the test scores to have within-sample mean zero, variance one. The model is estimated using the NLSY79 sample. Solid lines depict average test scores, and dashed lines, confidence intervals.
Source: Heckman, Stixrud and Urzua [2006, Figure 4].

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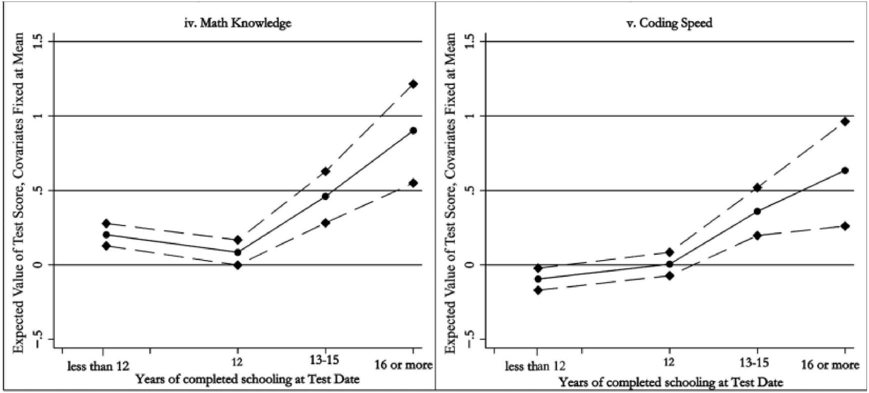

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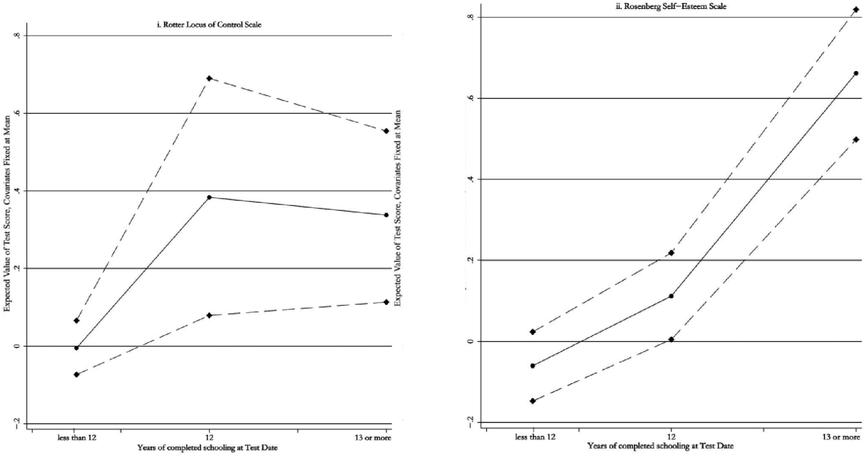
Figure 8: Causal Effect of Schooling on Two Measures of Personality



Source: Heckman, Stixrud and Urzua [2006].

Revisiting the Signalling Debate.

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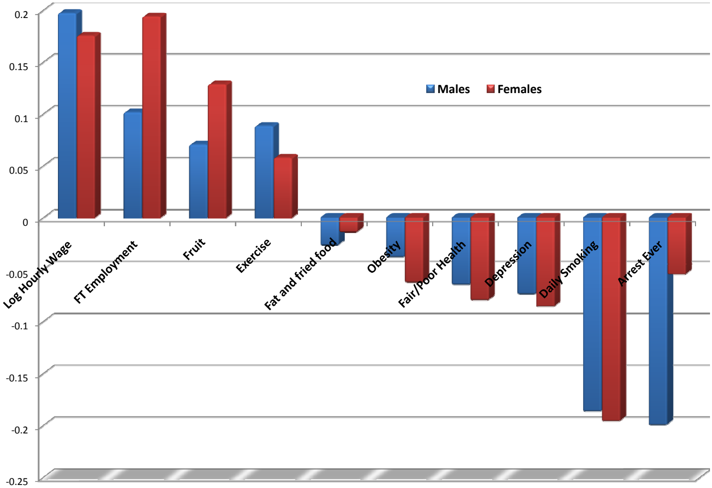
- Is schooling an effective strategy for alleviating poverty or does its effect arise from pre-existing factors present before schooling begins? (The old signalling debate)
- The signalling debate was silent on where the ability came from.
- Our analyses show the importance of the family and early environments in creating capabilities.

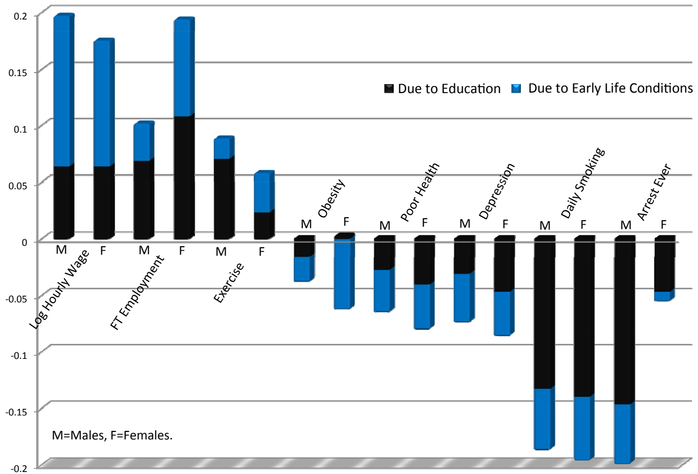
Consider the Causal Effects of Boosting Education Above Current Minimal Schooling Learning Levels as a Strategy for Reducing Inequality and Promoting Productivity

Disparities by Education: Continuation Beyond Compulsory Levels, UK



Note: Authors' calculations using BCS70. Conti, Heckman, Urzua (2010)

Decomposition of the Disparities



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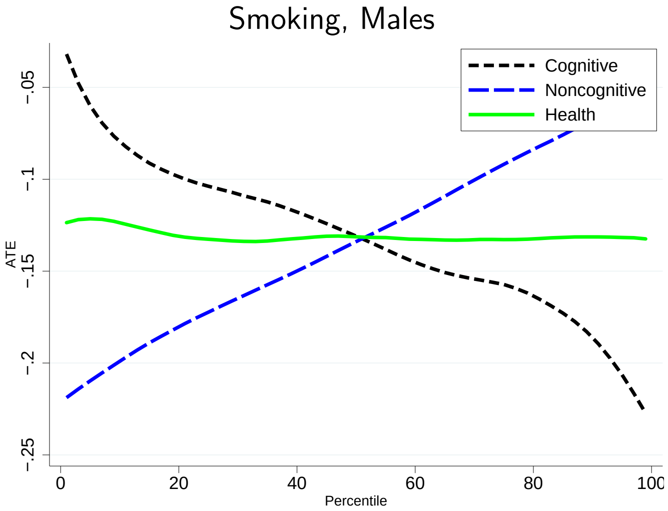
Who benefits?

(conditional on θ)

Treatment Effect Heterogeneity



- Education compensates for low early noncognitive endowments and reinforces high early cognitive endowments.

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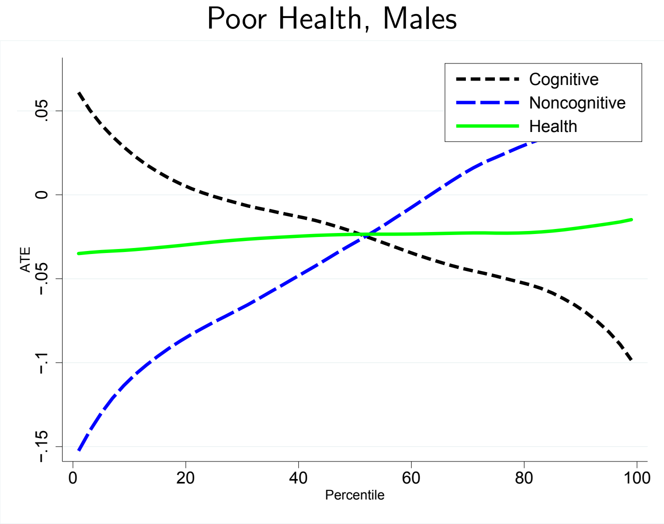

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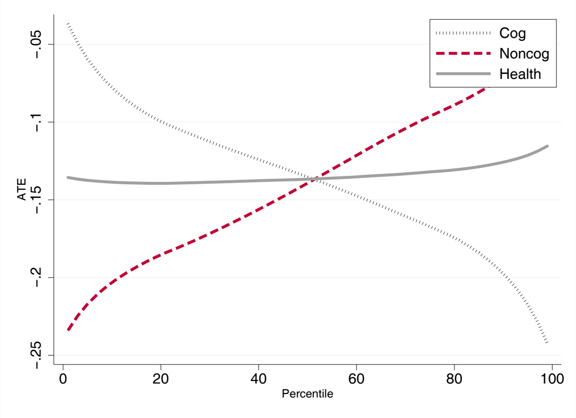
Targeting Educational Strategies

Smoking, Males



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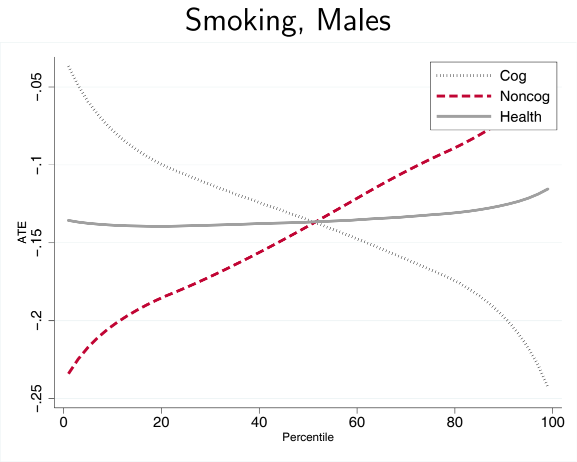
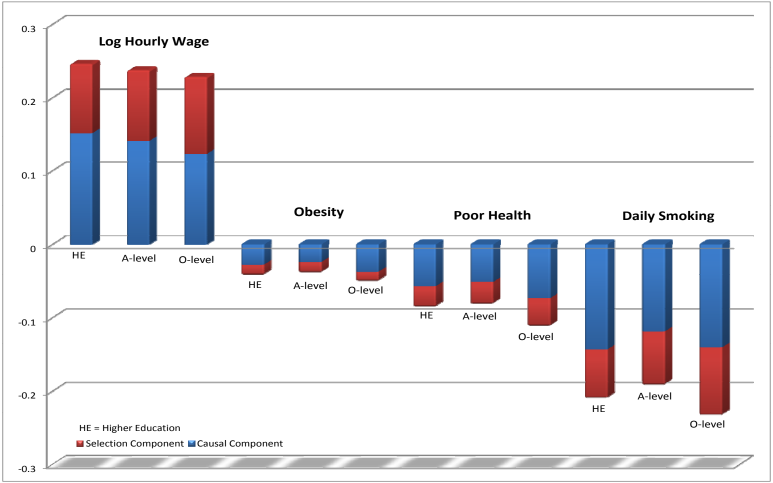


- Education compensates for low noncognitive endowments.
- Reinforces high cognitive endowments.

- Effects of Education at Higher Levels of Education: UK

The Causal Effect of Education

Decomposition of Observed Disparities, Males; UK Data



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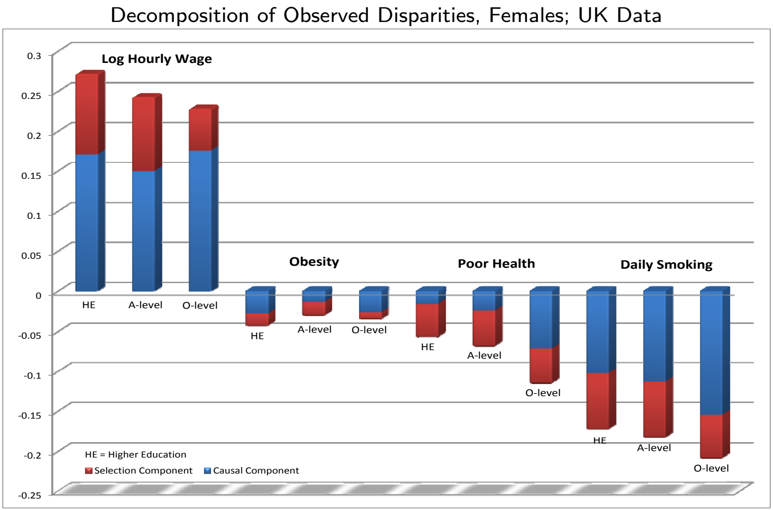
The Causal Effect of Education



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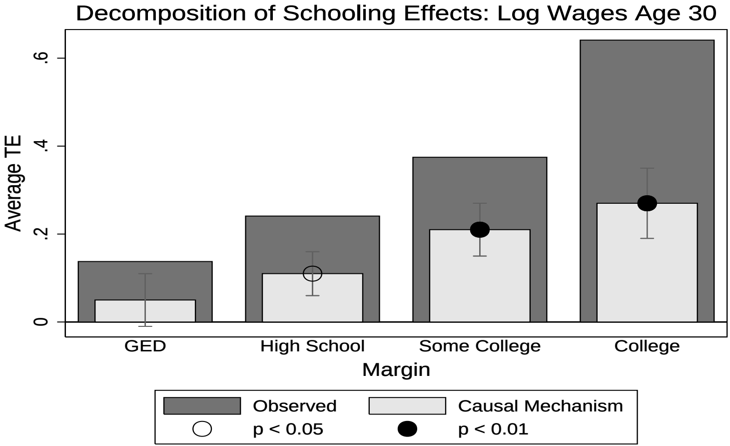
Evidence from U.S.

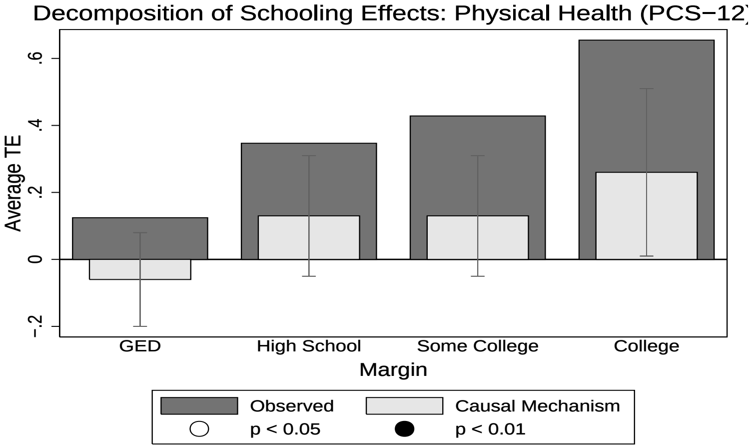
Related Evidence from the U.S.

Effects of Education on Log Wages



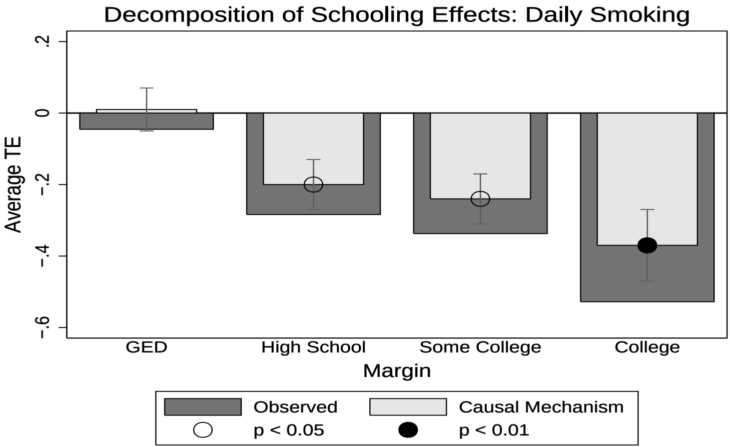
- Like for U.K., the % of the observed disparities in log wages due to education is comparable across educational levels (70%).

Effects of Education on Physical Health



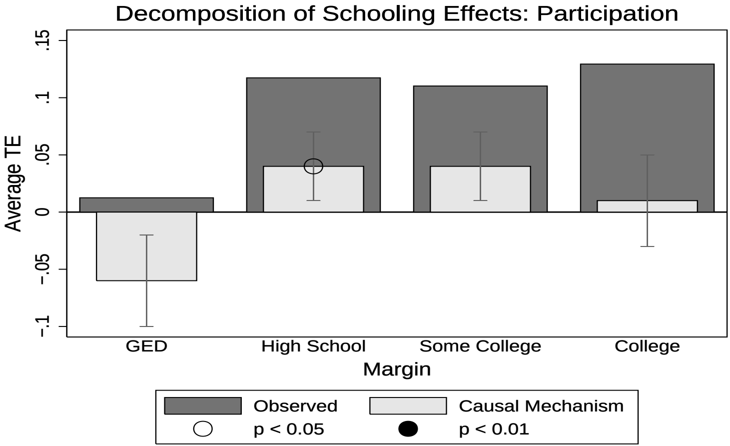
- Like for U.K., the % of the observed disparities in physical health due to education is comparable across educational levels (70%).

Effects of Education on Smoking



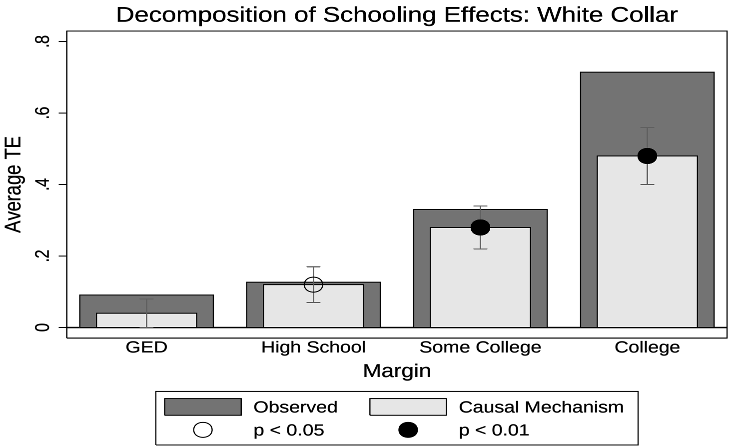
- Like for U.K., the % of the observed disparities in daily smoking due to education is comparable across educational levels (70%).

Effects of Education on Labor Force Participation



- Like for U.K., the % of the observed disparities in Labor Force Participation due to education is comparable across educational levels (70%).

Effects of Education on White Collar Employment



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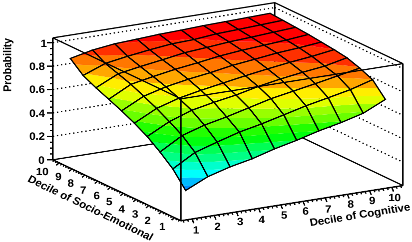
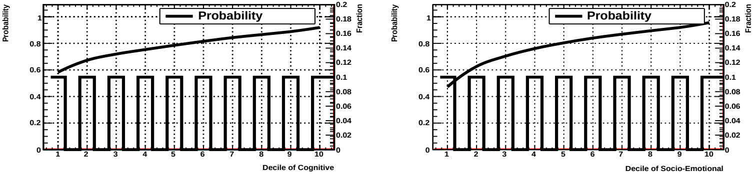
Cognitive and Socioemotional Factors

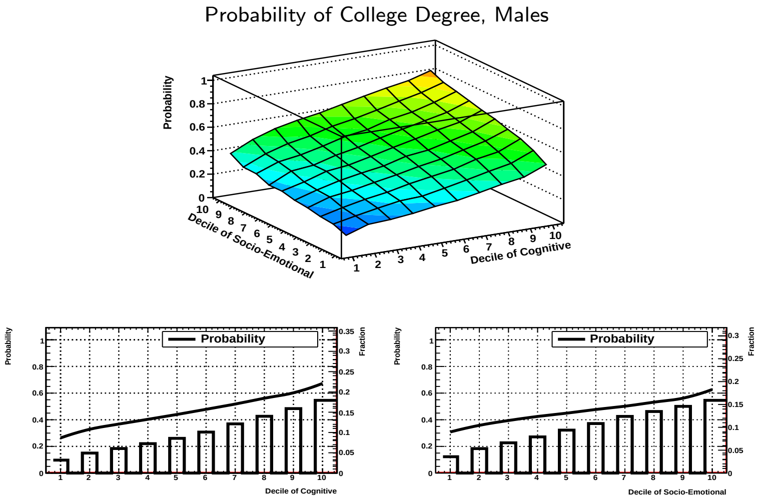
Probability of Graduating from High School, Males





- Adolescent cognitive and socioemotional factors affect the probability of graduating from high school.

Cognitive and Socioemotional Factors



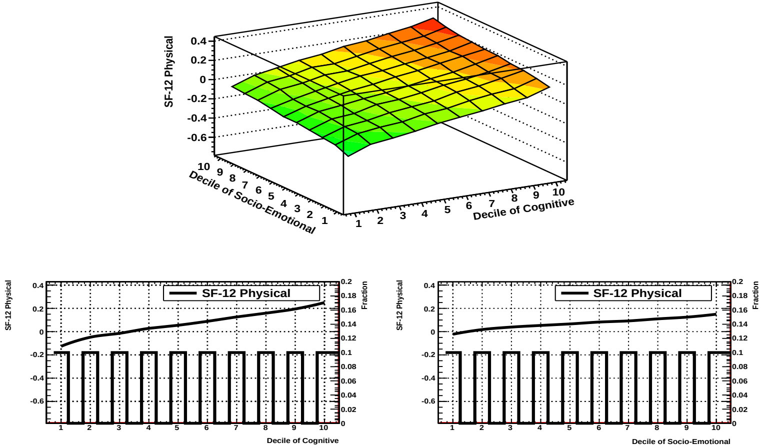
- ...and from college.

Cognitive and Socioemotional Factors

Note: For each outcome we present three figures. The first figure (top) displays the levels of the outcome as a function of cognitive and socio-emotional endowments. In particular, we present the average level of outcomes for different deciles of cognitive and socio-emotional endowments. Notice that we define as "decile 1" the decile with the lowest values of endowments and "decile 10" as the decile with the highest levels of endowments. The second figure (bottom left) displays the average levels of endowment across deciles of cognitive endowments. The bars in this figure indicates the fraction of individuals reporting the respective schooling level for each decile of cognitive endowment. The last figure (bottom right) mimics the structure of the second one but now for the socio-emotional endowment.

Cognitive and Socioemotional Factors

Physical Health, Males: not conditioning on education



- Cognitive and socioemotional adolescent factors in U.S. affect the probability of being in good health.

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- They produce inequality in education, wages, health, crime, and determine a host of important outcomes.

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- Much recent work shows the importance of the early years in shaping skills.

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- Schools matter, but what schools can do depends on the investments made by the parents.
- The true measure of child poverty is the quality of parenting, not income per se, although the former is correlated with the latter.

A Life Cycle Framework for Organizing Studies and Integrating Evidence

$\theta_t = (\theta_C, \theta_N, \theta_H)$ capacities at t

I_t: investment at t

$\theta_{t+1} = f_t(\theta_t, I_t, \theta_{t,P})$

$\theta_{t,p}$ is parental home environment.