The Economics and Econometrics of Human Development
A Framework for Analyzing Human Development Over The Life Cycle

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- A framework for thinking about the dynamics of skill formation over the life cycle.

Two Intuitively Obvious Points Confirmed by a Lot of Recent Research

1. Good mothers and supportive family environments promote successful, flourishing lives of children. Early environments shape *in part* later life outcomes.
2. They are not the sole determinants and possibilities for later effective interventions exist, but depends on the nature of the capability created.
3. More than smarts matter for success in life.

Many Open Questions

1. How important are investments and environments in the early years compared to later-stage investments and environments?
2. More generally, how should investments be staged over the life cycle to promote human flourishing?
3. How resilient are people to early adversity? What environments promote resilience?
4. How effective are later life compensations for early life effects of adversity?
5. How to measure the array of traits that matter for success in life?
6. What are effective policies to promote human flourishing?

An Agenda for Understanding and Promoting Human Development

1. Understand the **mechanisms** of family influence.
   a. Genetics
   b. Parental Investment and Environments
   c. Epigenetics
   d. Interactions of Family with Environments
      i. Credit markets and financing of skills
      ii. Neighborhood effects, peer effects, and parental influence on choice of peers
      iii. Schooling effects and parental support of children in school

2. Document the multiplicity of capabilities that matter for success in life.
   a. Cognition (fluid and crystallized)
      i. IQ
      ii. Achievement
   b. "Noncognitive" — personality traits
      i. Conscientiousness
      ii. Self-control, time preference
      iii. Motivation
   c. Biology and Health
3. Understand the dynamics of life-cycle skill acquisition:
   a. Synergies among the capabilities in producing future capabilities
   b. Synergies between investments and capabilities
   c. Critical and sensitive periods in investment

4. Integrate the study of interventions to promote human development with studies of family influence.
   a. How interventions supplement (or disrupt?) family life
   b. Parental responses to interventions, including support of children in schools
5. Evaluate the effects of a variety of interventions made at various stages of the life cycle on the development of capabilities.
   a. Experiments with long-term followup
   b. Alternative longitudinal study designs based on observational data
   c. No necessary primacy for social experiments, although they can play an important role in evaluating mean effects of interventions.

6. Recognize that various interventions previously implemented differ.
   a. The populations targeted differ.
   b. The objectives and philosophies of the programs differ.
   c. The measurement systems of the backgrounds and outcomes of the interventions differ.
   d. The methods of evaluation differ.
   e. Need to integrate the studies of family influence with the intervention studies to understand how interventions affect family life.
   f. Need to compare alternative policies in comparable metrics, i.e. rates of return to policies or cost-benefit analyses.
7. To place the evaluation of specific policies to compensate for disadvantage on a common footing need to move beyond collections of "treatment effects" of policies, which are hard to interpret or use as the basis for policy when a variety of competing proposals are on the table.

8. Understand the mechanisms producing the treatment effects that can be compared across interventions.
9. Meta-analyses—standard in the field of child development—sweep these issues under the rug, replacing rates of returns and cost-benefit analyses with aggregates of p-values.
10. Prioritize among competing policy proposals or evaluate them in a common metric. This is true for a comparison of a variety of policies that compete with childhood policies for funding.
11. Collect long-term longitudinal data on families and effects of interventions.
    i. Collect information on biology, labor market, parenting variables, credit market, and links across generations and with peers and neighbors
    ii. Experiments may be embedded in longitudinal studies
    iii. Creative use of and supplementation of person registries

Today I present and apply a framework for analyzing human development that:

1. Recognizes the multiplicity of capabilities that matter for success in life.
2. Integrates the study of the family and the literature on family influence, with the intervention literature.
3. Accounts for multiple channels of influence in promoting human capabilities.
4. Allows analysts and governments to compare and prioritize alternative policies over the life cycle.

Recent Studies in the Economics of Human Development Establish That:

1. A core, low-dimensional, set of capabilities — the capacities that promote functioning — explains a variety of diverse socioeconomic outcomes.
2. Cognitive and noncognitive capabilities are both important causal determinants of life-cycle outcomes with equal strength for many outcomes.
3. Biology and health are also important determinants of life-cycle success and life-cycle development.
4. Capabilities are not set in stone. There is strong evidence of genetic components, but capabilities evolve and can be shaped in part by investments and environments.

5. Critical and sensitive periods:
   a. Earlier for cognitive capabilities
   b. Later for noncognitive capabilities
   c. Varies depending on the particular biological capability
6. Gaps across socioeconomic groups in both types of capabilities open up early:
   a. Persist strongly for cognitive capabilities
   b. Less strongly for noncognitive capabilities
   c. Widen for many biological capabilities

7. Many early childhood interventions operate primarily through boosting noncognitive capabilities—IQ barely budged—if at all—by many interventions.
8. Adolescent cognitive remediations are largely ineffective but noncognitive interventions can be effective.
9. Today I present a dynamic state space framework that formalizes these ideas and is a guide for synthesizing evidence across diverse interventions for making policy and for understanding the mechanisms governing human development.

Modeling Human Capability Formation

- Capabilities are the capacities to function (Sen, 1985).
- An agent at age t is characterized by a vector of capabilities:

$$\theta_t = (\theta_{C,t}, \theta_{N,t}, \theta_{H,t})$$

  - $\theta_{C,t}$ is a vector of cognitive abilities (e.g., IQ) at age t,
  - $\theta_{N,t}$ is a vector of noncognitive abilities at age t (e.g., patience, self control, temperament, risk aversion, and neuroticism).
  - $\theta_{H,t}$ is a vector of health stocks for mental and physical health at age t.

- The framework has four main ingredients:
  (a) **Outcome Functions** that show how capabilities, effort and incentives determine outcomes;
  (b) **Dynamic Technologies** for producing capabilities;
  (c) **Parental Preferences** that help shape the investments in skills;
  (d) **Constraints** reflecting access to credit markets, time constraints, and constraints arising from social interactions.

Formal models of child outcomes and investment in children

- Activities can be very general.
- The *outcome from activity j at age t* is $Y_{j,t}$, where

$$Y_{j,t} = \psi_j \left(\underbrace{\theta_{C,t}, \theta_{N,t}, \theta_{H,t}}_{\theta_t}, e_{j,t} \right), \quad j \in \underbrace{\{1, \ldots, J_t\}}_{\substack{\text{set of} \\ \text{available} \\ \text{activities}}} \tag{1}$$

- $e_{j,t}$ is effort devoted to activity j at time t
- Effort supply function depends on rewards and endowments:

$$e_{j,t} = \delta_j \left(R_{j,t}, A_t \right) \tag{2}$$

- $R_{j,t}$ is the reward per unit effort in activity j
- A_t represents other determinants of effort which might include some or all of the components of θ_t.

Capability Formation Process

- The capability formation process is governed by a multistage technology.
- Each stage corresponds to a period in the life cycle of a child.

- The *technology of capability formation* (Cunha and Heckman, 2007) captures essential features of human and animal development.
- It expresses the stock of period $t+1$ capabilities (θ_{t+1}) in terms of period t capabilities, (θ_t), investments, (I_t), and parental environments $(\theta_{P,t})$:

$$\theta_{t+1} = f_t(\theta_t, I_t, \theta_{P,t}). \tag{3}$$

- θ_0 is the vector of initial endowments determined at birth or at conception.

- An important feature of the technology that explains many findings in the literature on skill formation is *complementarity of capabilities with investment:*

$$\frac{\partial^2 f_t(\theta_t, I_t, \theta_{P,t})}{\partial \theta_t \partial I_t'} \geq 0. \tag{4}$$

- *Static complementarity* between period t capabilities and period t investment.
- The higher θ_t, the higher the productivity of investment I_t.

- There is also *dynamic complementarity*.
- Technology (3) determines period $t+1$ capabilities (θ_{t+1}).
- This generates complementarity between investment in period t and investment in period s, $s > t$.
- Higher investment in period t raises θ_{t+1} because technology (3) is increasing in I_t.
- This in turn raises θ_s because the technology is increasing in θ_τ, for τ between t and s.
- This, in turn, raises $\dfrac{\partial f_s(\cdot)}{\partial I_s}$ because θ_s and I_s are complements, as a consequence of (4).

- Dynamic complementarity explains the evidence that early nurturing environments affect the ability of animals and humans to learn.
- It explains why investments in disadvantaged young children are so productive.
- They enhance the productivity of later investments.
- Dynamic complementarity also explains why investment in low ability (low θ_t) adolescents and adults often has such low returns—because the stock of θ_t is low.

- Using the technology, one can define *critical* and *sensitive* periods for investment.
- If $\frac{\partial f_t(\cdot)}{\partial I_t} = 0$ for $t \neq t^*$, t^* is a critical period for that investment.
- If $\frac{\partial f_t(\cdot)}{\partial I_t} > \frac{\partial f_{t'}(\cdot)}{\partial I_{t'}}$ for all $t \neq t^*$, t is a sensitive period.
- The technology is consistent with the body of evidence on critical and sensitive periods.
- Will discuss parental preferences, child-parent interactions, and constraints later.

Evidence on Inequality and Human Development

1. Multiple Capabilities Shape Human Achievement

- Cognitive traits (θ_C)
  a. **crystallized** and **fluid intelligence**
  b. different age profiles for their development
- Socioemotional or noncognitive traits: personality traits and preference parameters (θ_N)
- Health θ_H (mental and physical health)
- Each trait evolves over time. Levels of each trait are positively (but not perfectly) correlated over time.

These capabilities or traits have direct **causal** effects on

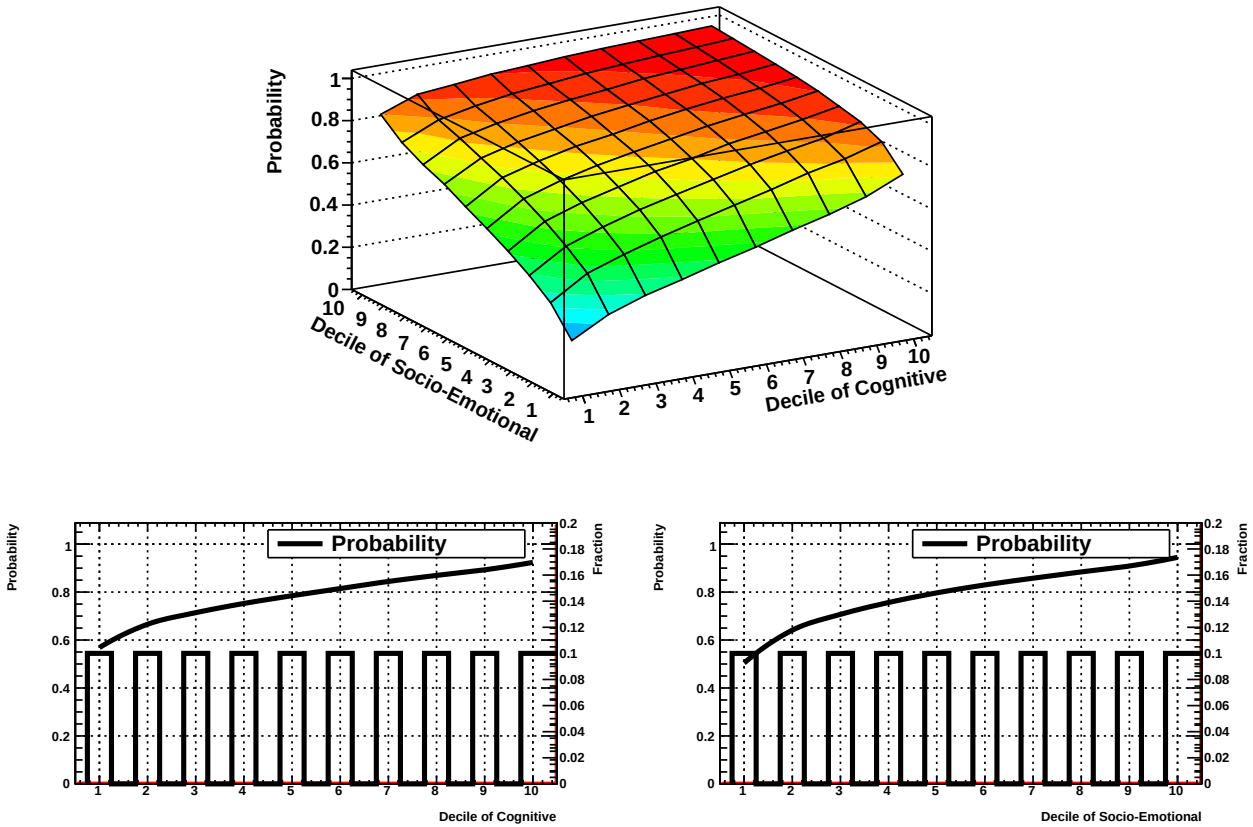
wages (controlling for schooling),	schooling,
performance on achievement tests,	crime,
compliance with health protocols,	smoking,
adult health outcomes (mental and physical),	teenage pregnancy

and many other aspects of social and economic life.

Evidence on the Predictive Power of Cognitive and Socioemotional Traits

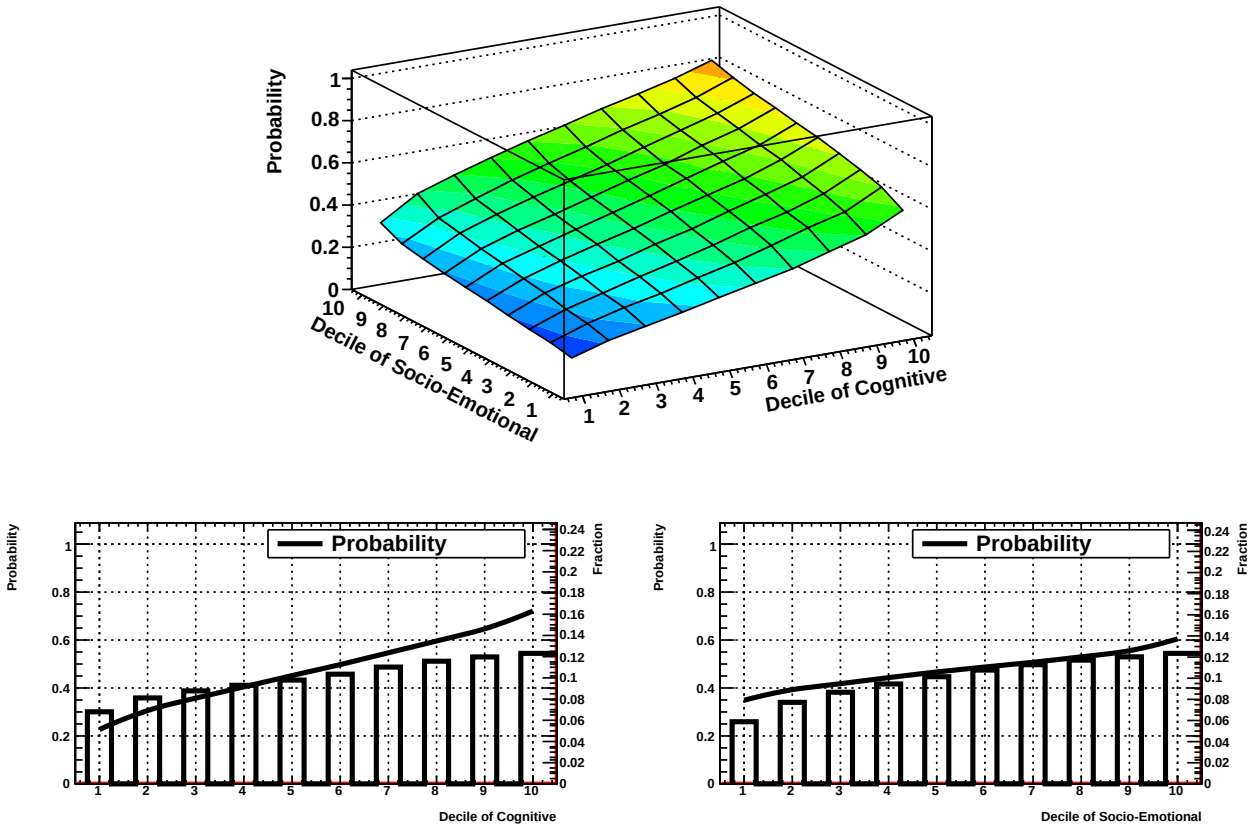
- The following figures show the effect of capabilities on diverse outcomes correcting for the effect of schooling on capabilities and the effect of capabilities on schooling.
- There is a causal effect of schooling on these capabilities.
- The empirical relationships I report next account for reverse causality — measured capabilities may be determined in part by schooling.

Figure 1: The Probability of Educational Decisions, by Endowment Levels, Dropping from Secondary School vs. Graduating



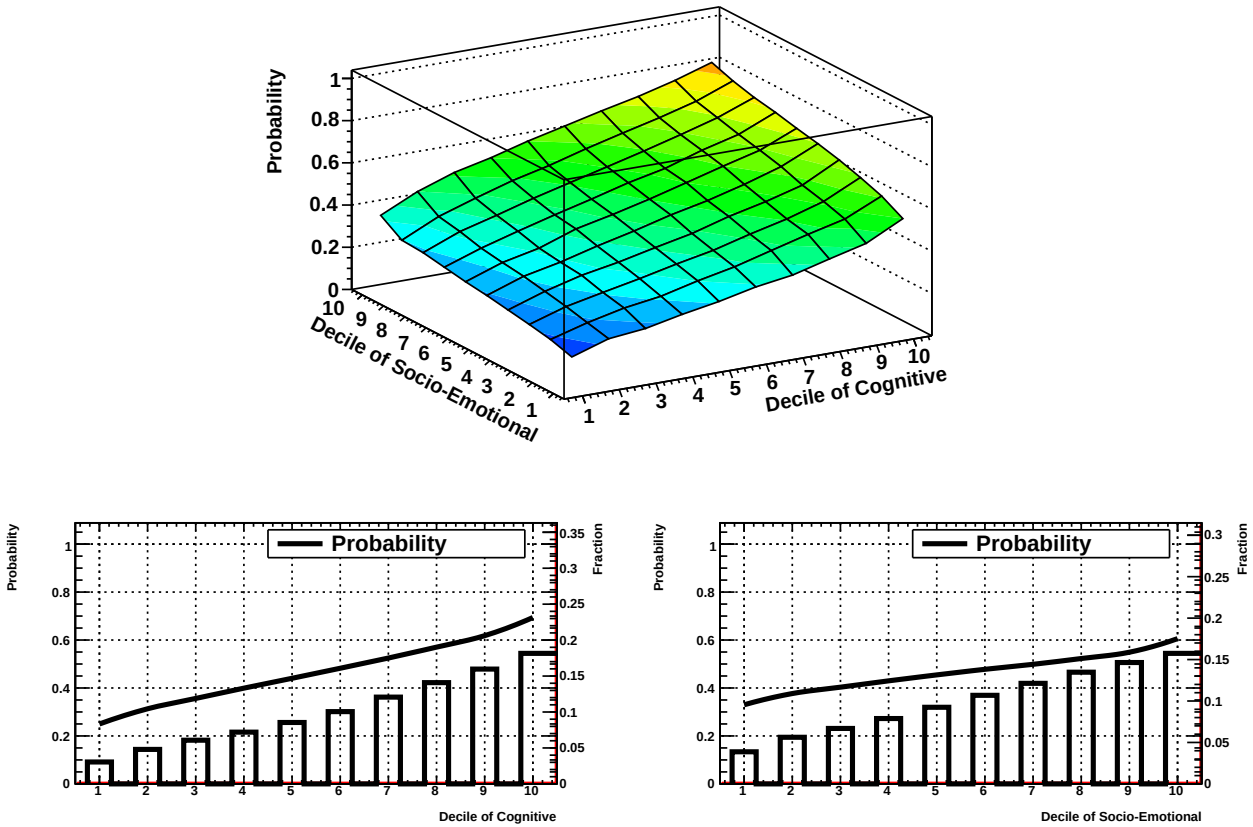
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

Figure 2: The Probability of Educational Decisions, by Endowment Levels, **HS Graduate** vs. College Enrollment



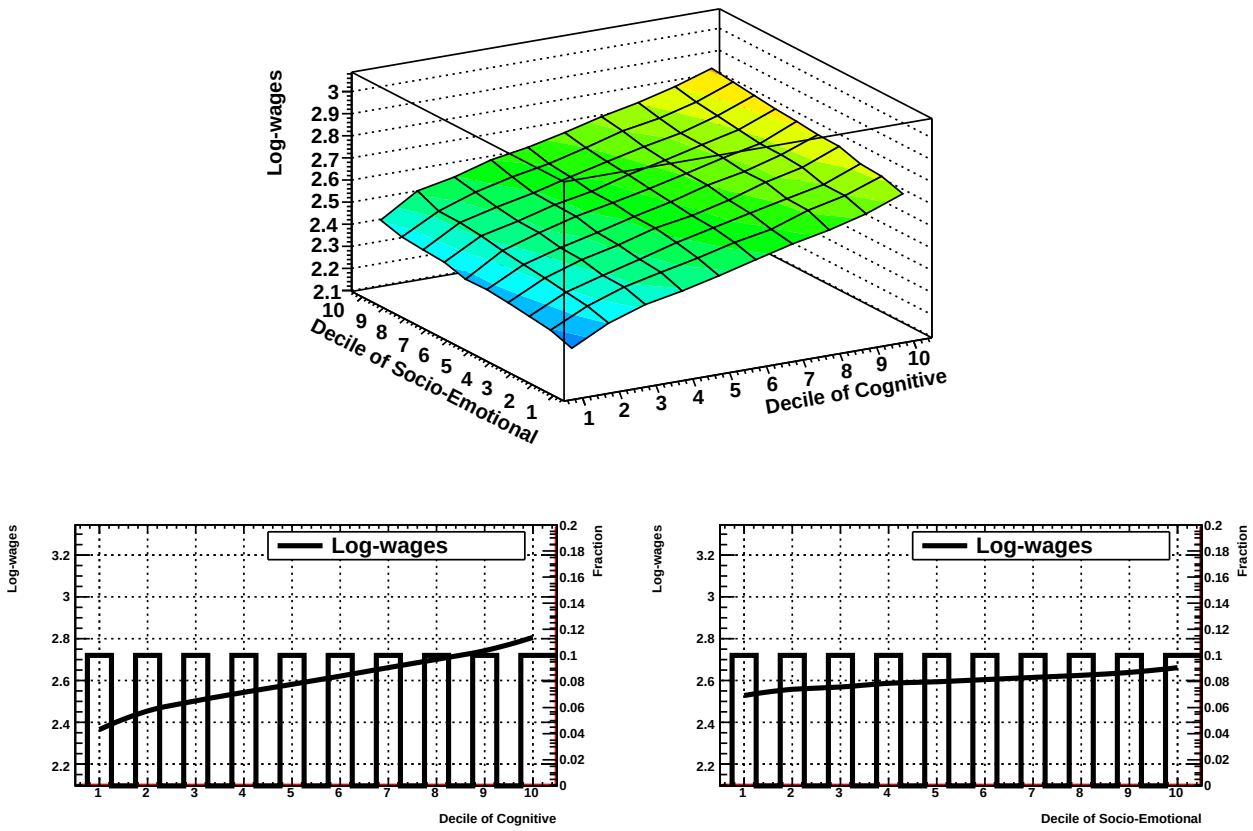
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

Figure 3: The Probability of Educational Decisions, by Endowment Levels, **Some College** vs. **4-year college degree**



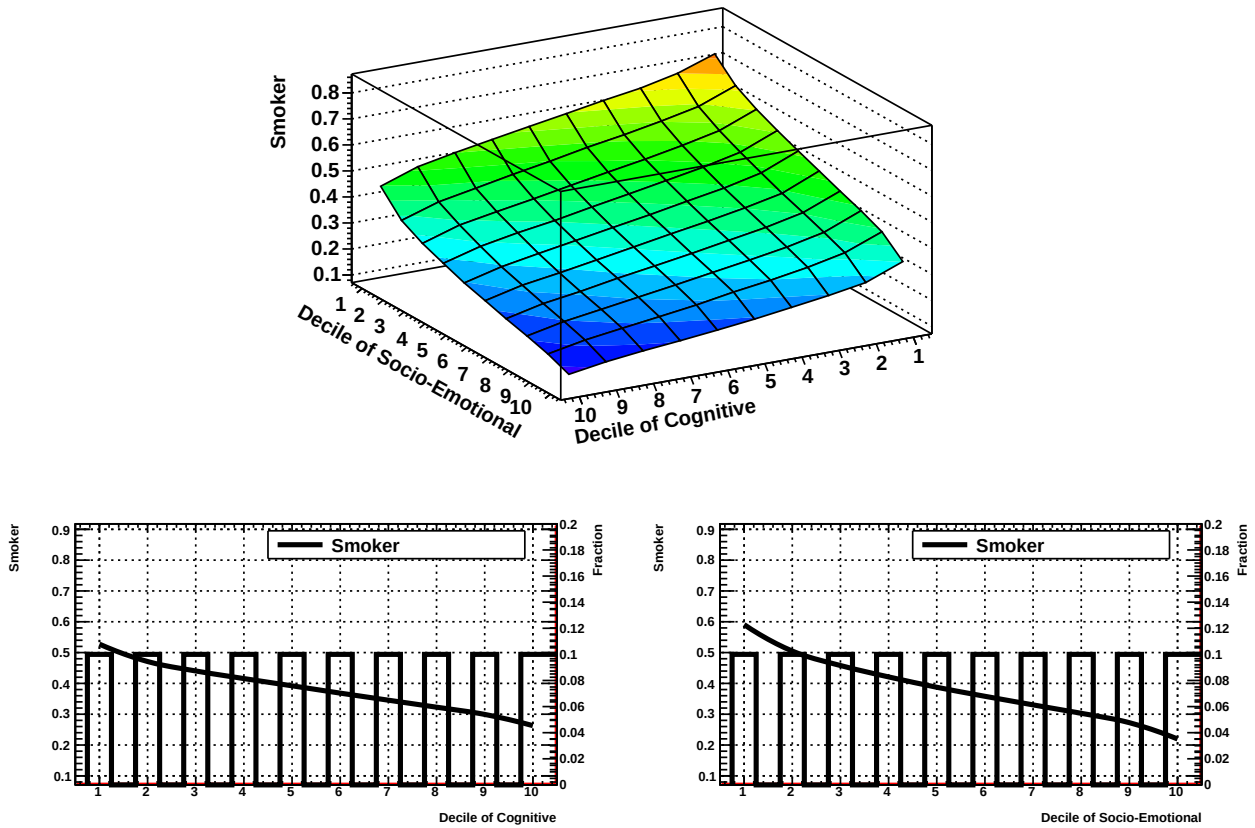
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

Figure 4: The Effect of Cognitive and Socio-emotional endowments, (log) Wages



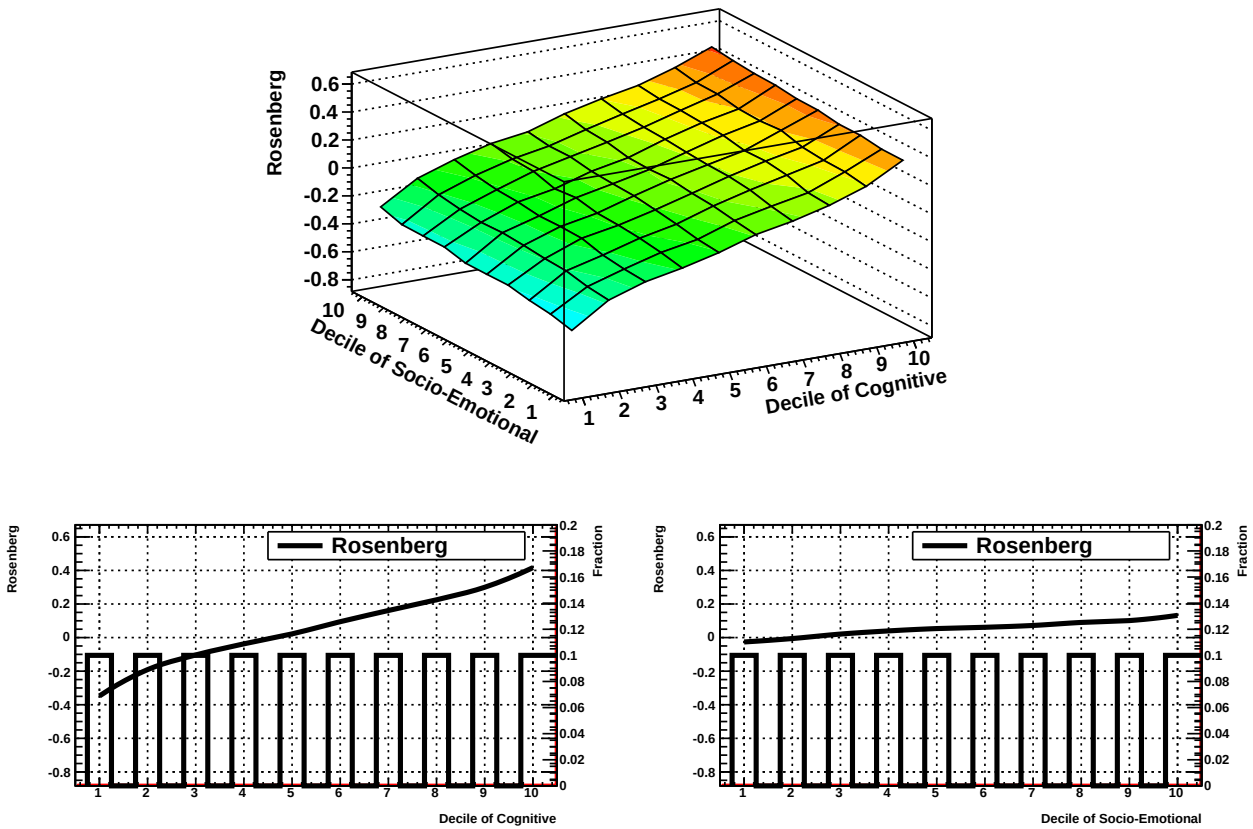
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

Figure 5: The Effect of Cognitive and Socio-emotional endowments, Daily Smoking



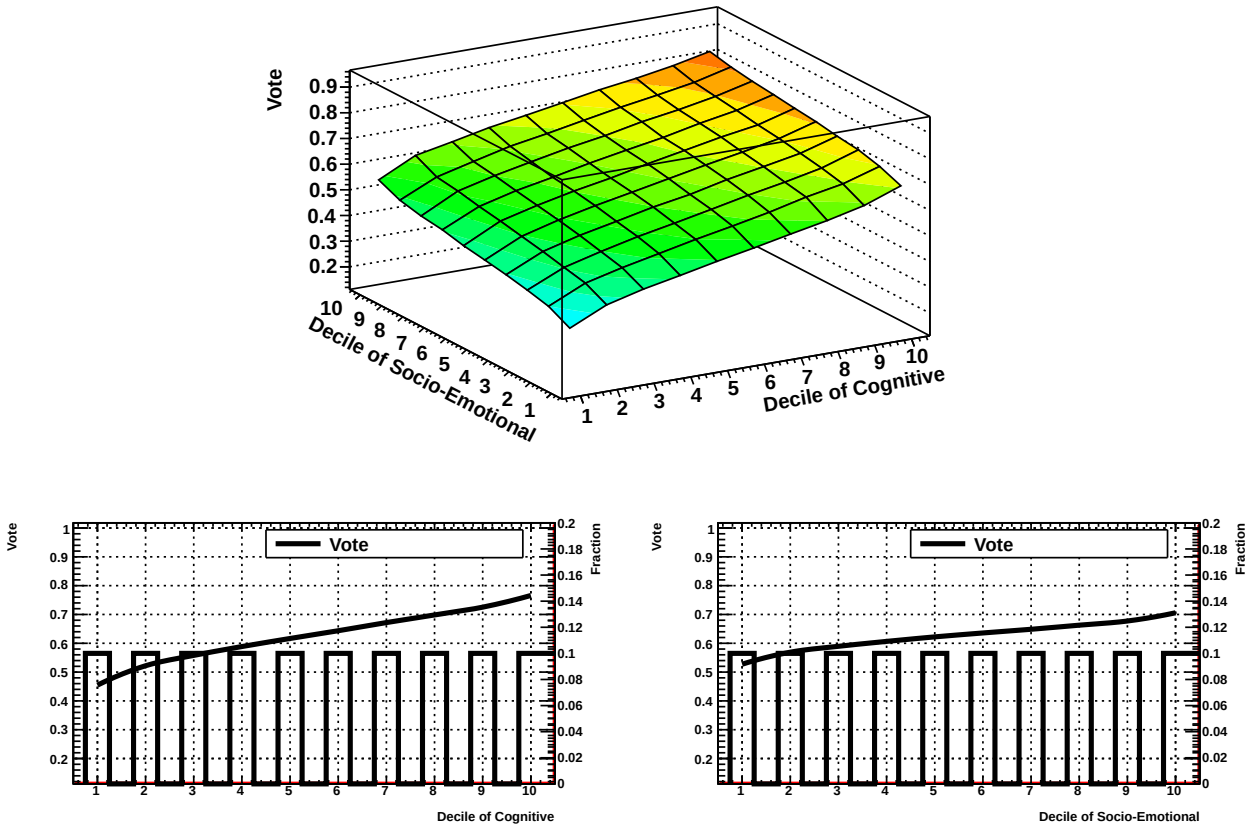
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

Figure 6: The Effect of Cognitive and Socio-emotional endowments, Self-Esteem



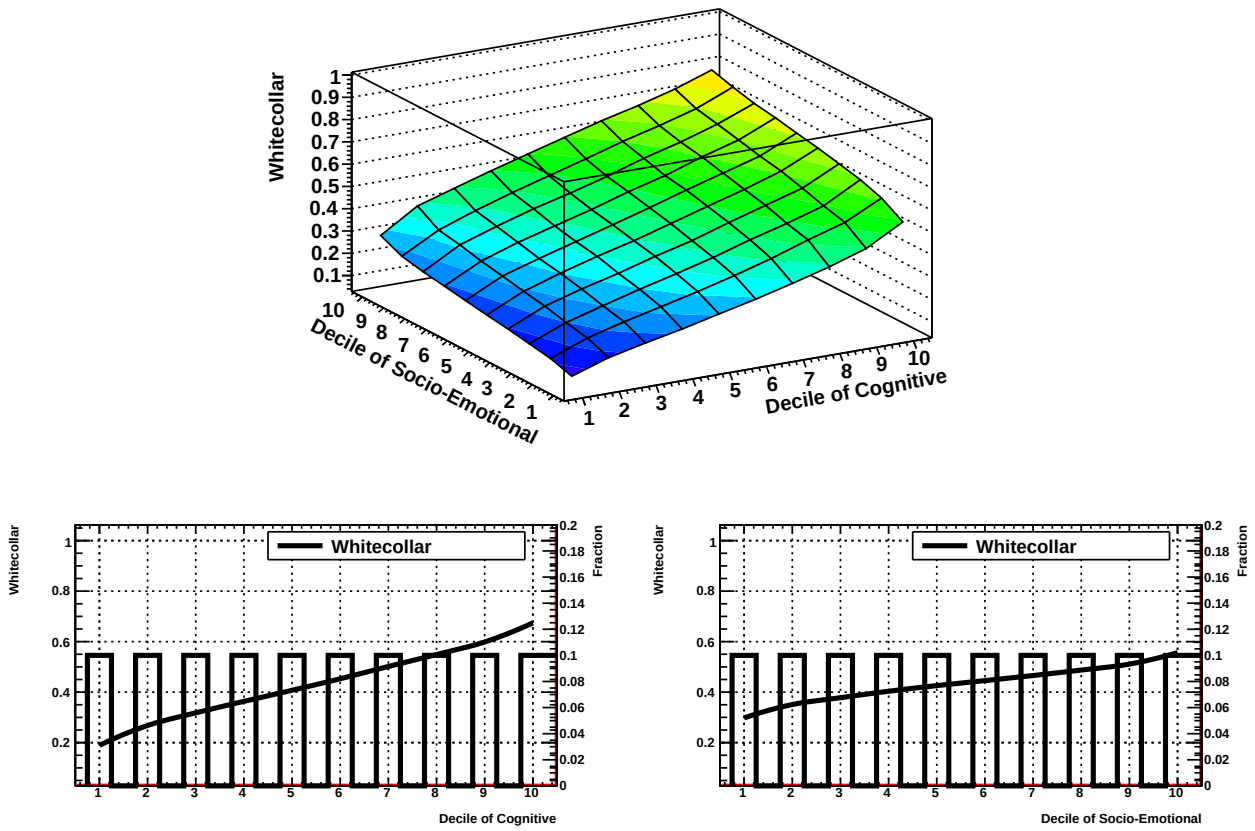
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

Figure 7: The Effect of Cognitive and Socio-emotional endowments, Participated in 2006 election



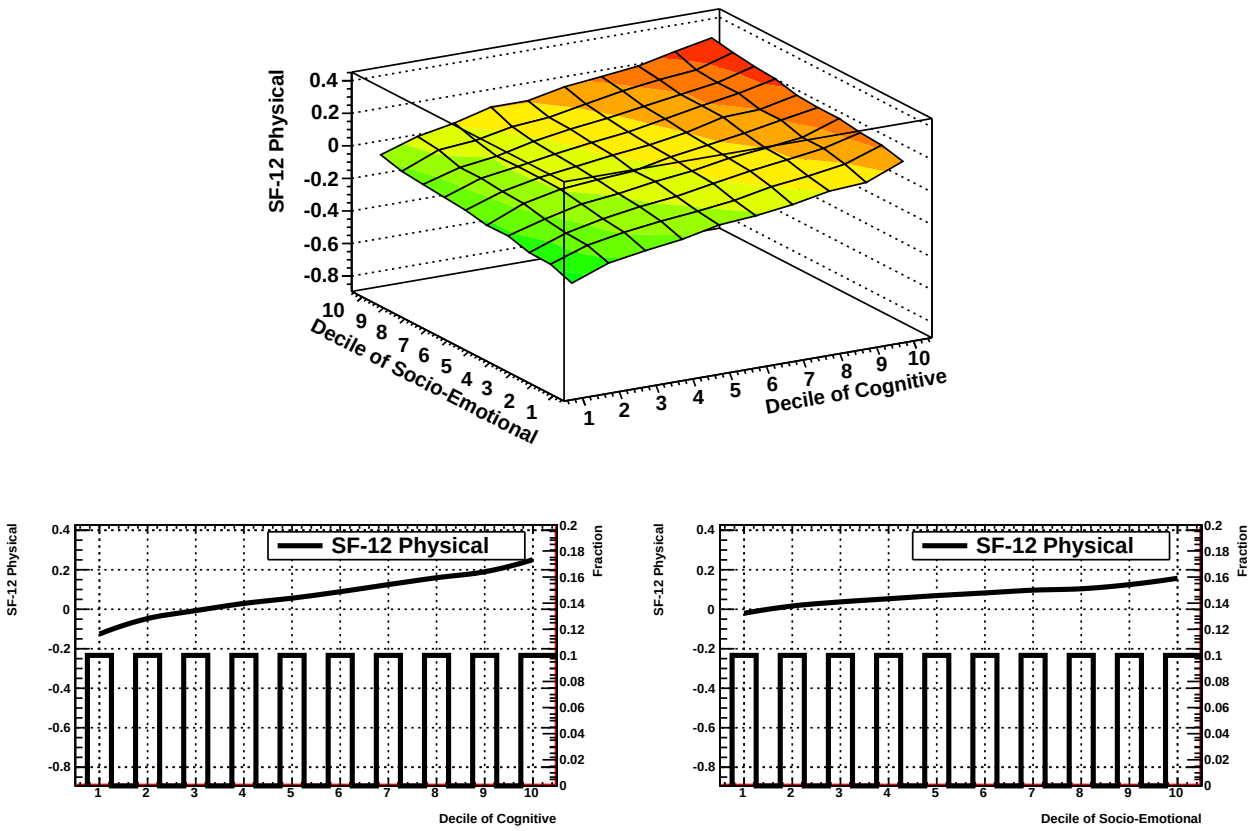
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

Figure 8: The Effect of Cognitive and Socio-emotional endowments on Probability of White-collar occupation (age 30)



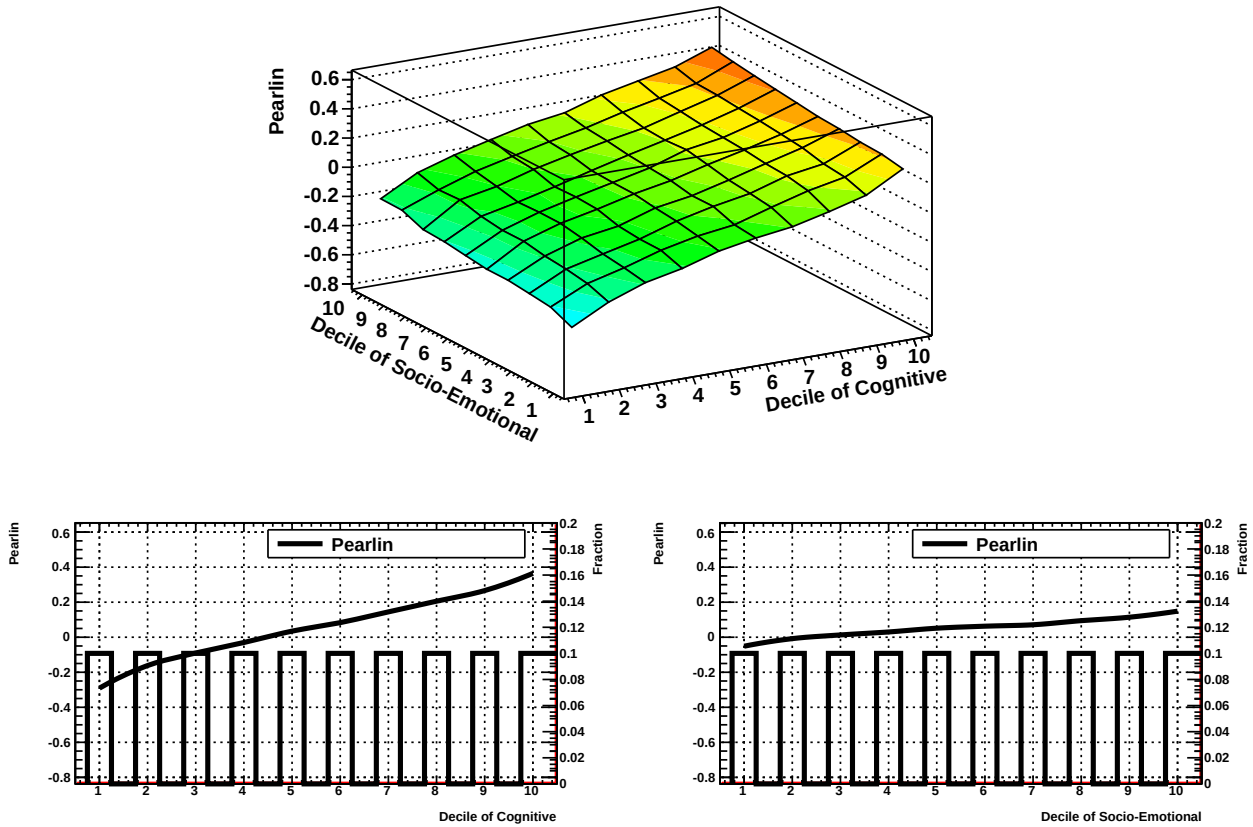
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

Figure 9: The Effect of Cognitive and Socio-emotional endowments on Physical Health at age 40 (PCS-12)



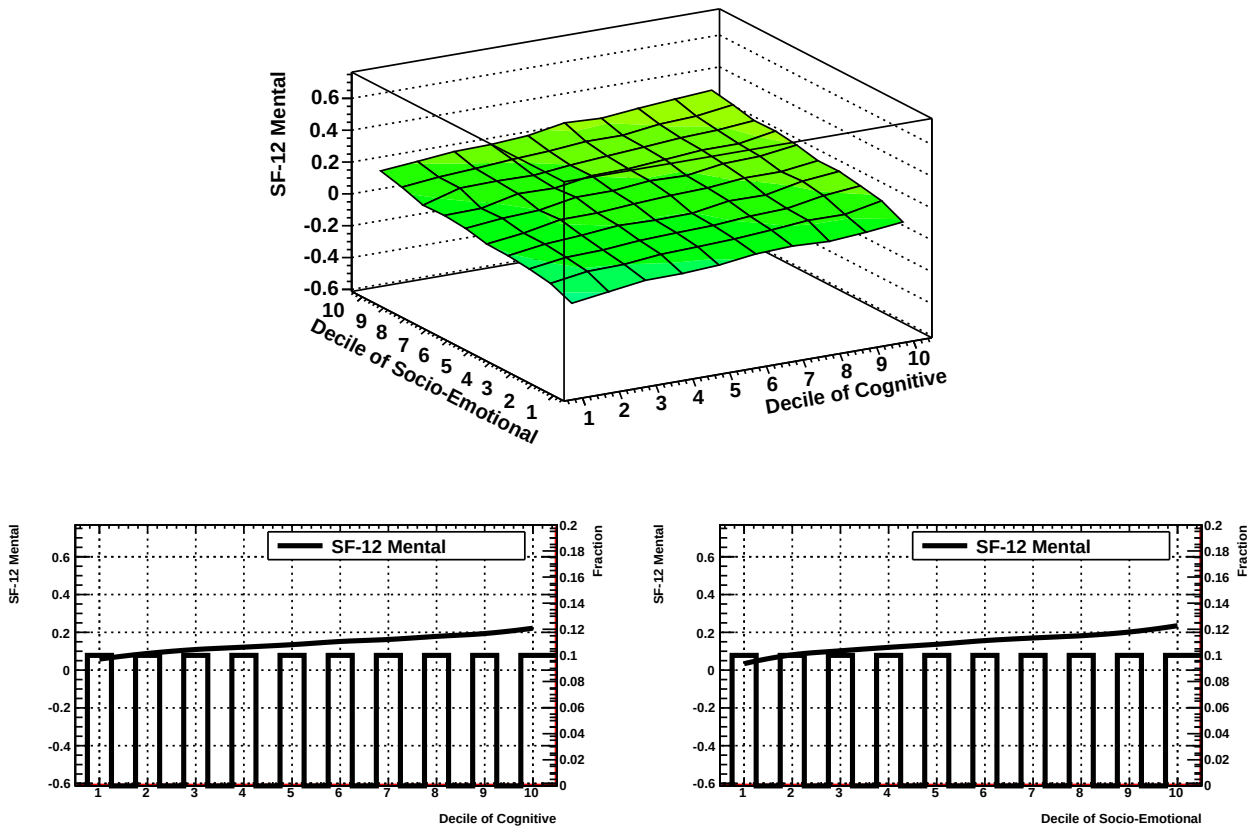
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

Figure 10: The Effect of Cognitive and Socio-emotional endowments on Pearlin's "Personal Mastery Scale"



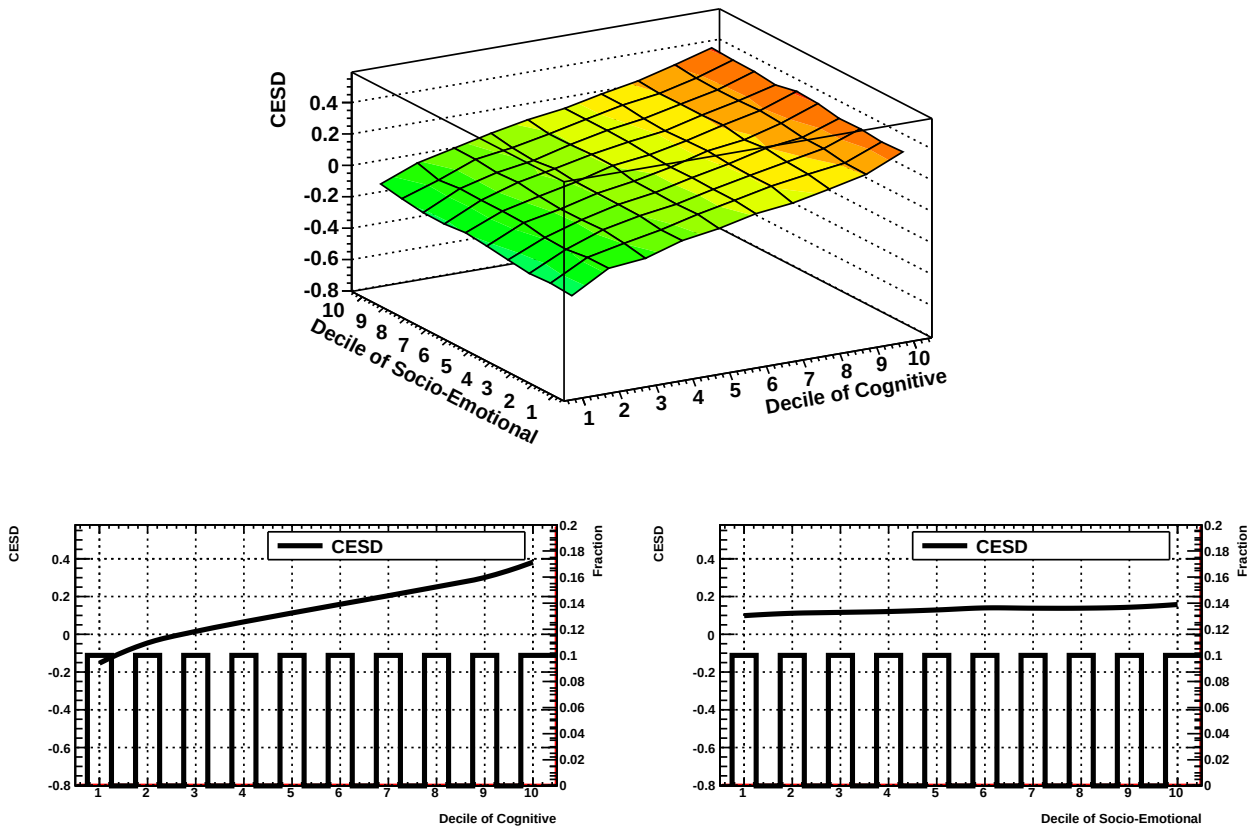
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

Figure 11: The Effect of Cognitive and Socio-emotional endowments on Mental Health at age 40 (MCS-12)



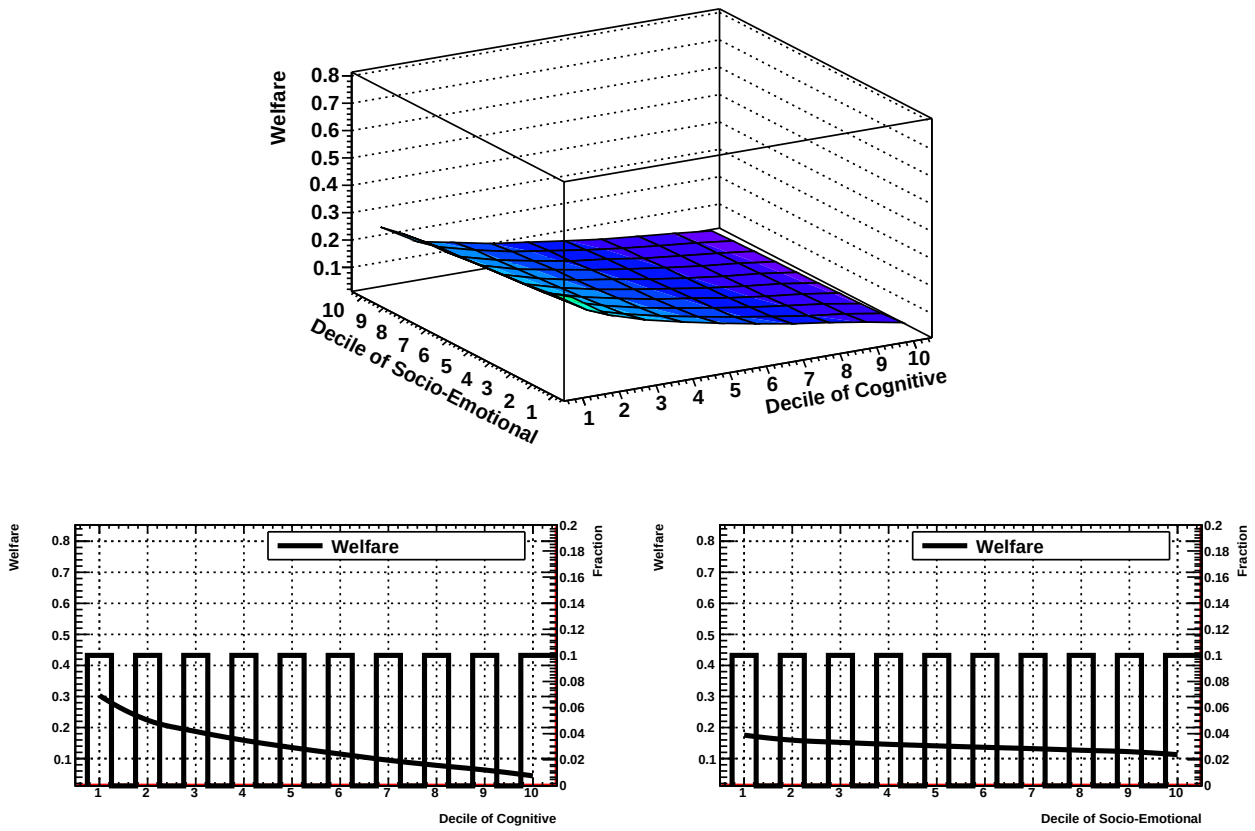
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

Figure 12: The Effect of Cognitive and Socio-emotional endowments on Depression at age 40 (CES-D - Reverse Score)



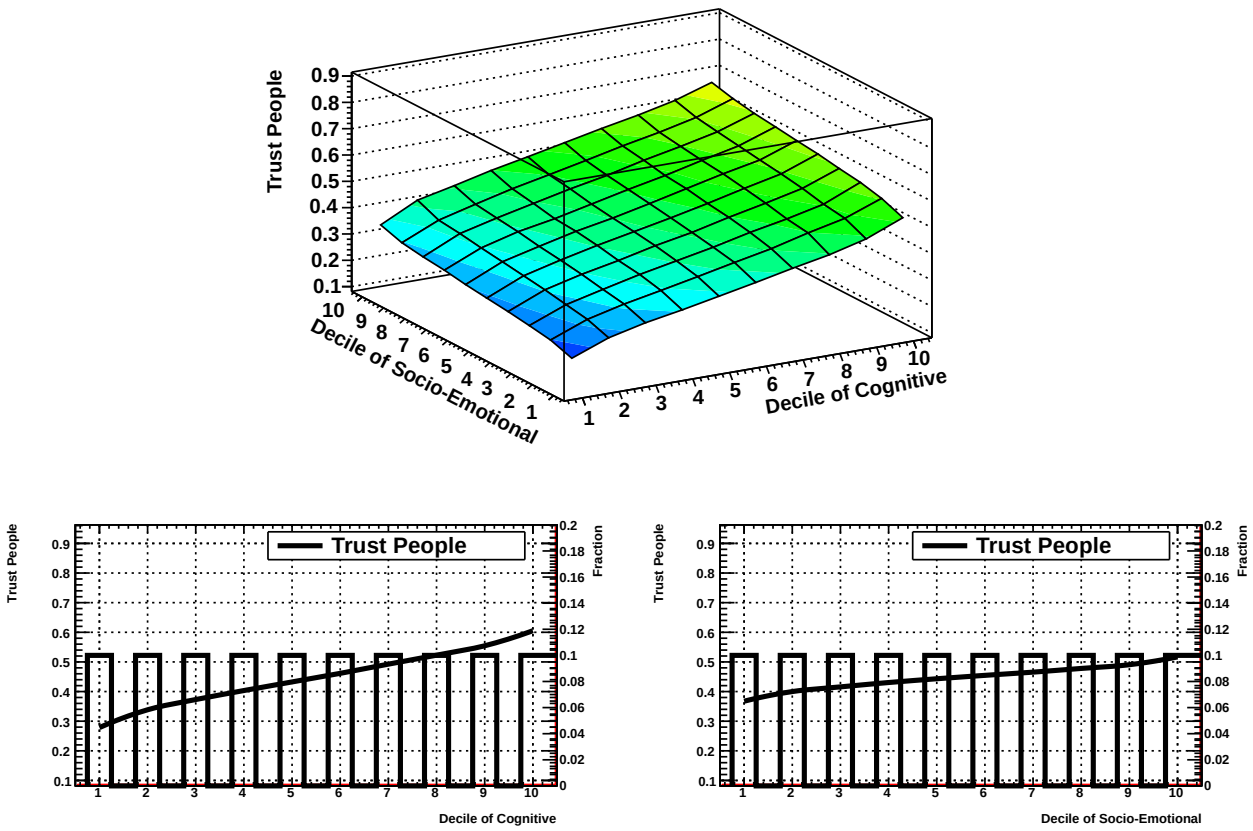
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

Figure 13: The Effect of Cognitive and Socio-emotional endowments on Ever Participated in Welfare (1996-2006)



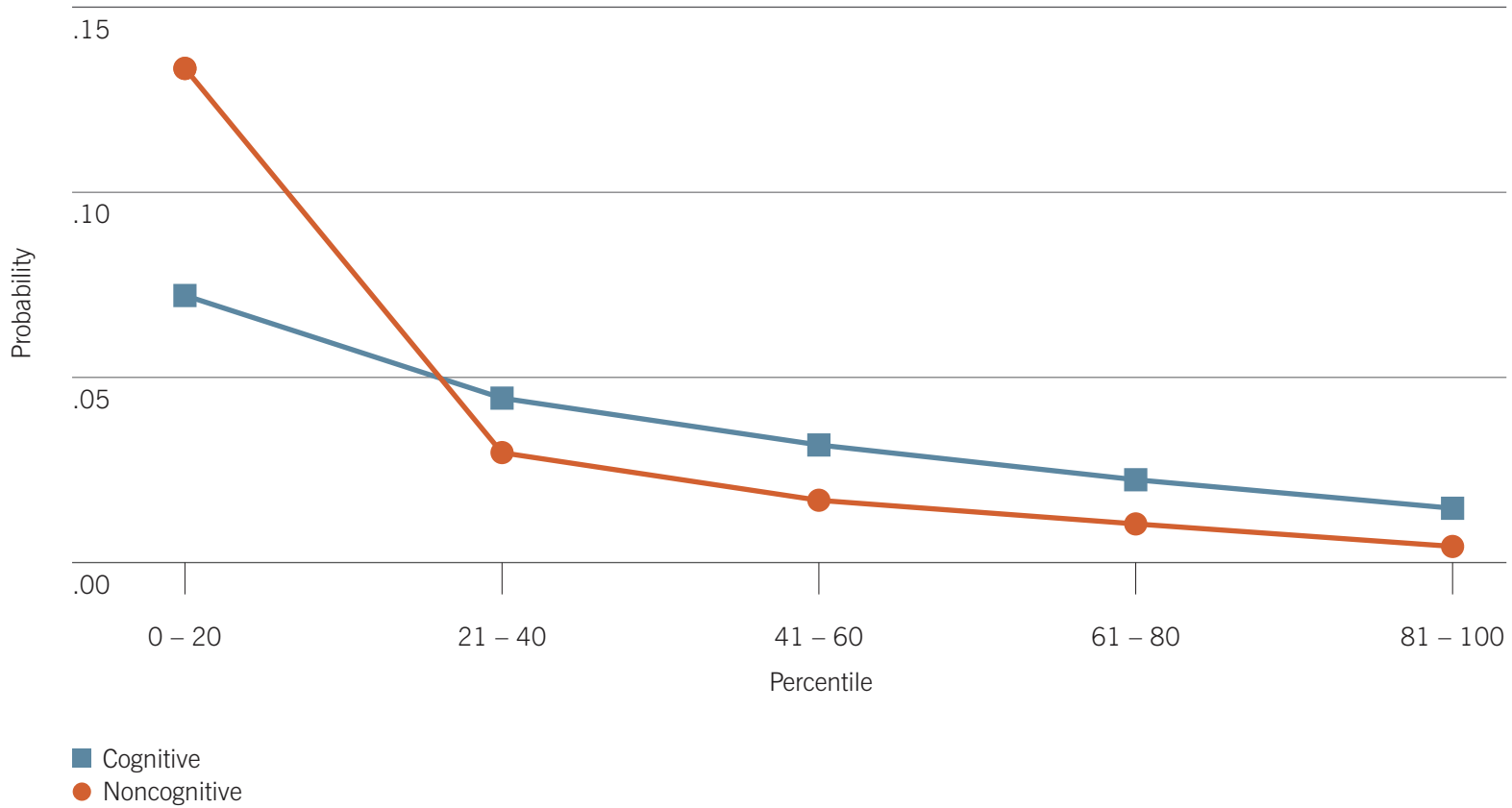
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

Figure 14: The Effect of Cognitive and Socio-emotional endowments on Trusting People (2008)



Source: Heckman, Humphries, Urzua, and Veramendi (2011).

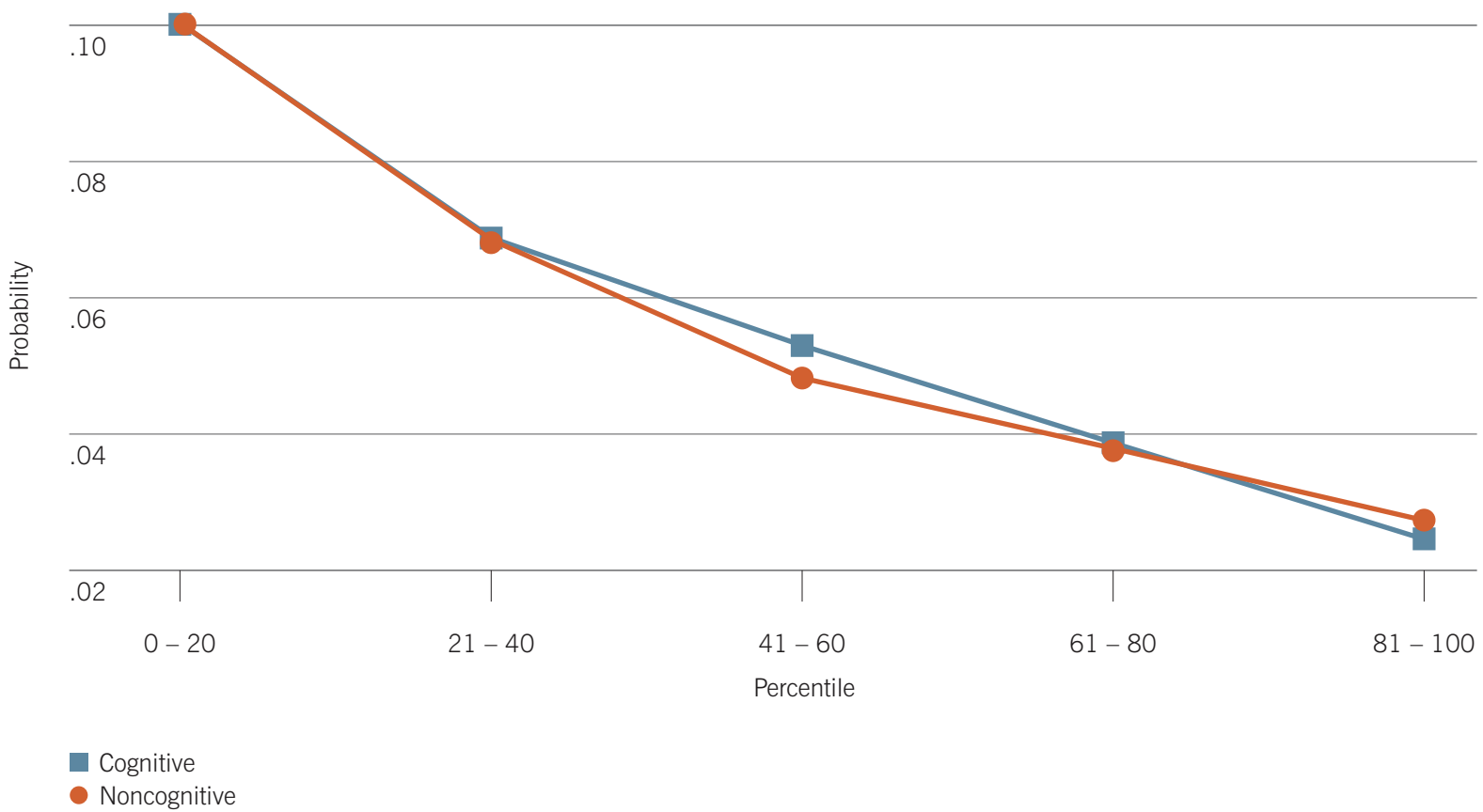
Ever been in jail by age 30, by ability (males)



Note: This figure plots the probability of a given behavior associated with moving up in one ability distribution for someone after integrating out the other distribution. For example, the lines with markers show the effect of increasing socioemotional ability after integrating the cognitive ability.

Source: Heckman, Stixrud, and Urzua (2006).

Probability of being teenage and single with children (females)



Note: This figure plots the probability of a given behavior associated with moving up in one ability distribution for someone after integrating out the other distribution. For example, the lines with markers show the effect of increasing socioemotional ability after integrating the cognitive ability.

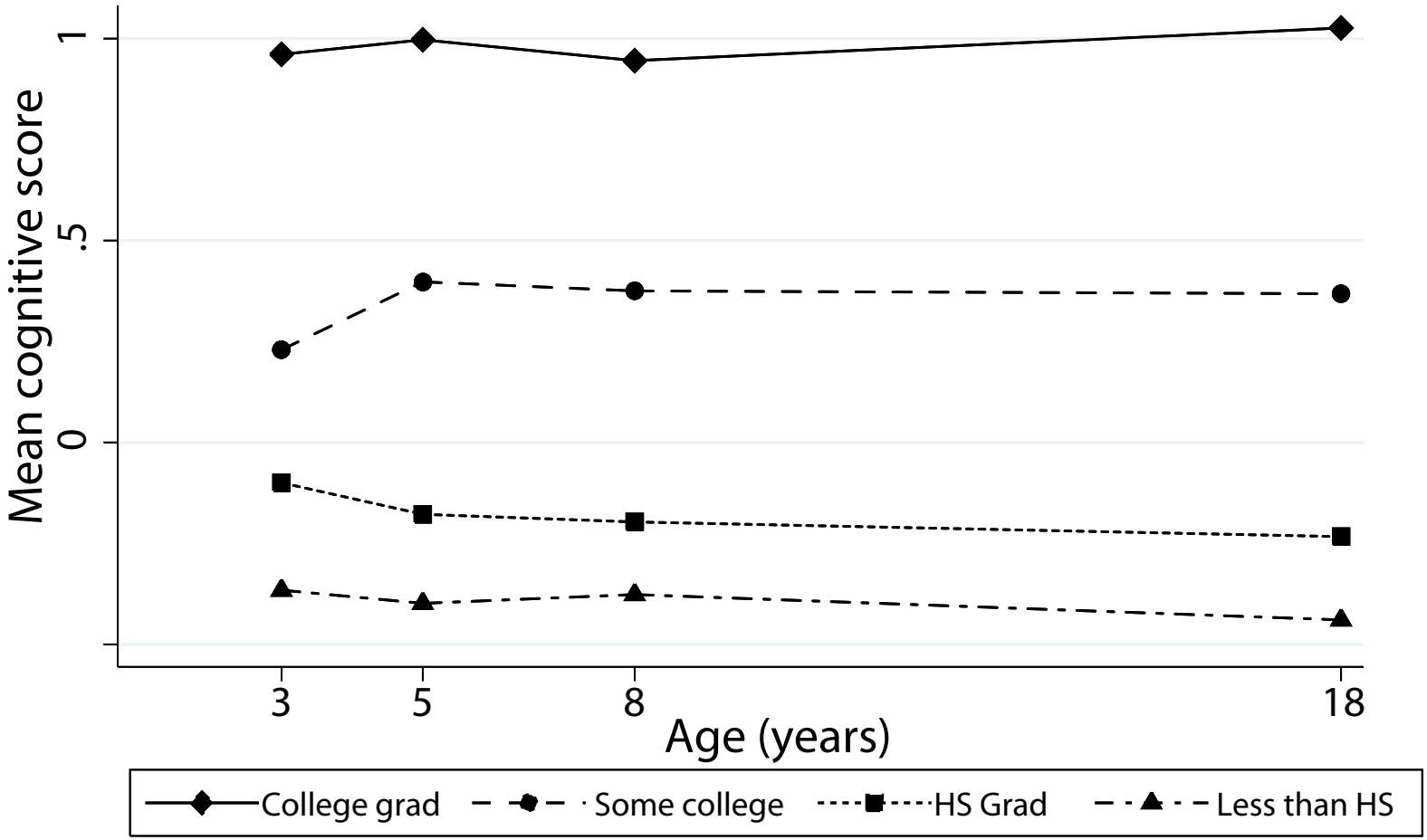
Source: Heckman, Stixrud, and Urzua (2006).

- Emerging evidence that the effect of many (but not all) noncognitive (socioemotional) traits operates primarily though schooling. (Heckman, Humphries, Urzua, and Veramendi, 2011)
- Fixing schooling, and controlling for its endogeneity, effects of both cognitive and noncognitive traits on outcomes are diminished, often entirely eliminated.

2. For both cognitive and personality traits, ability gaps across socioeconomic groups open up at early ages and persist before children enter school.

For health traits, gaps tend to widen with age.

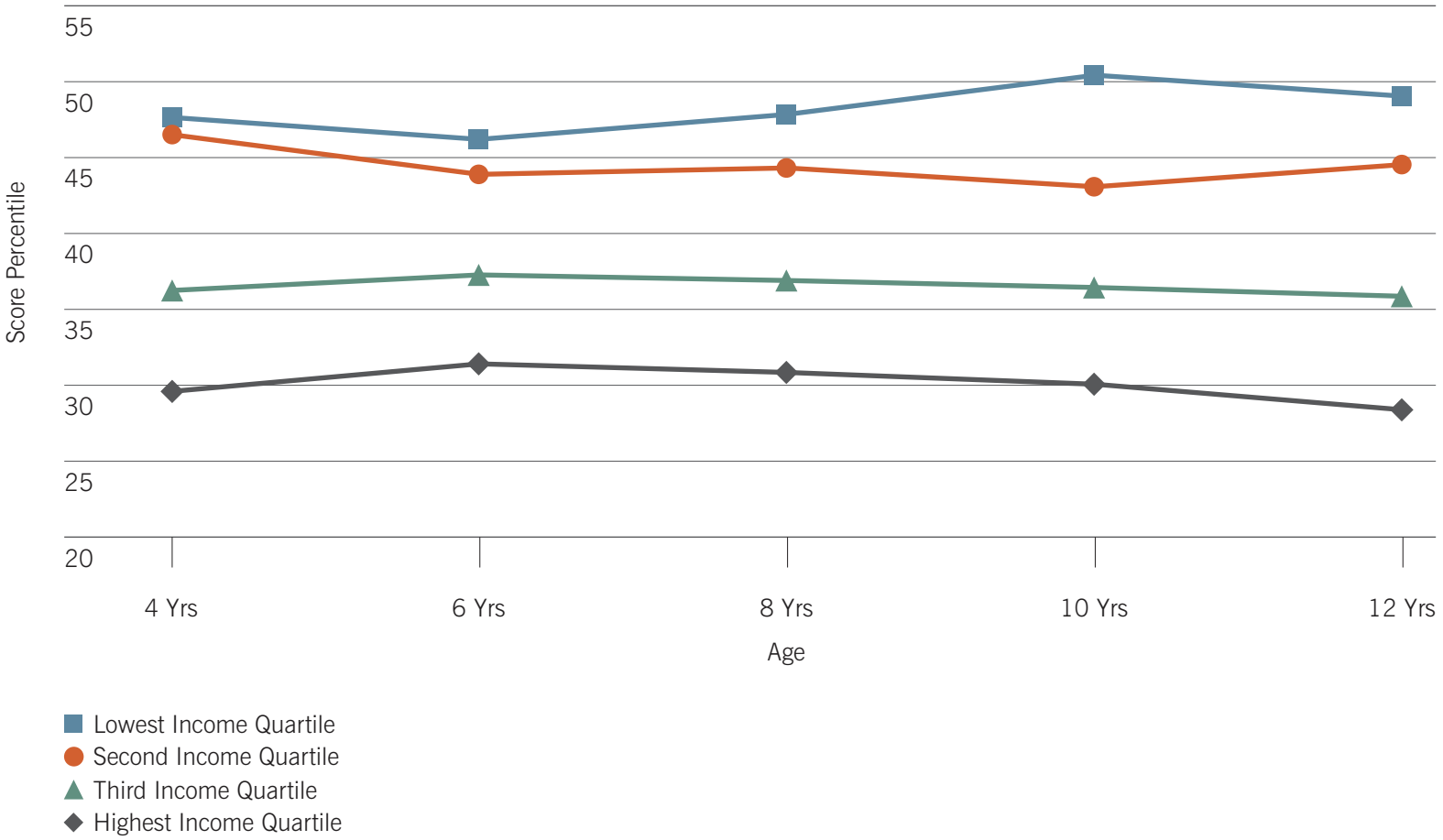
Trend in mean cognitive score by maternal education



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

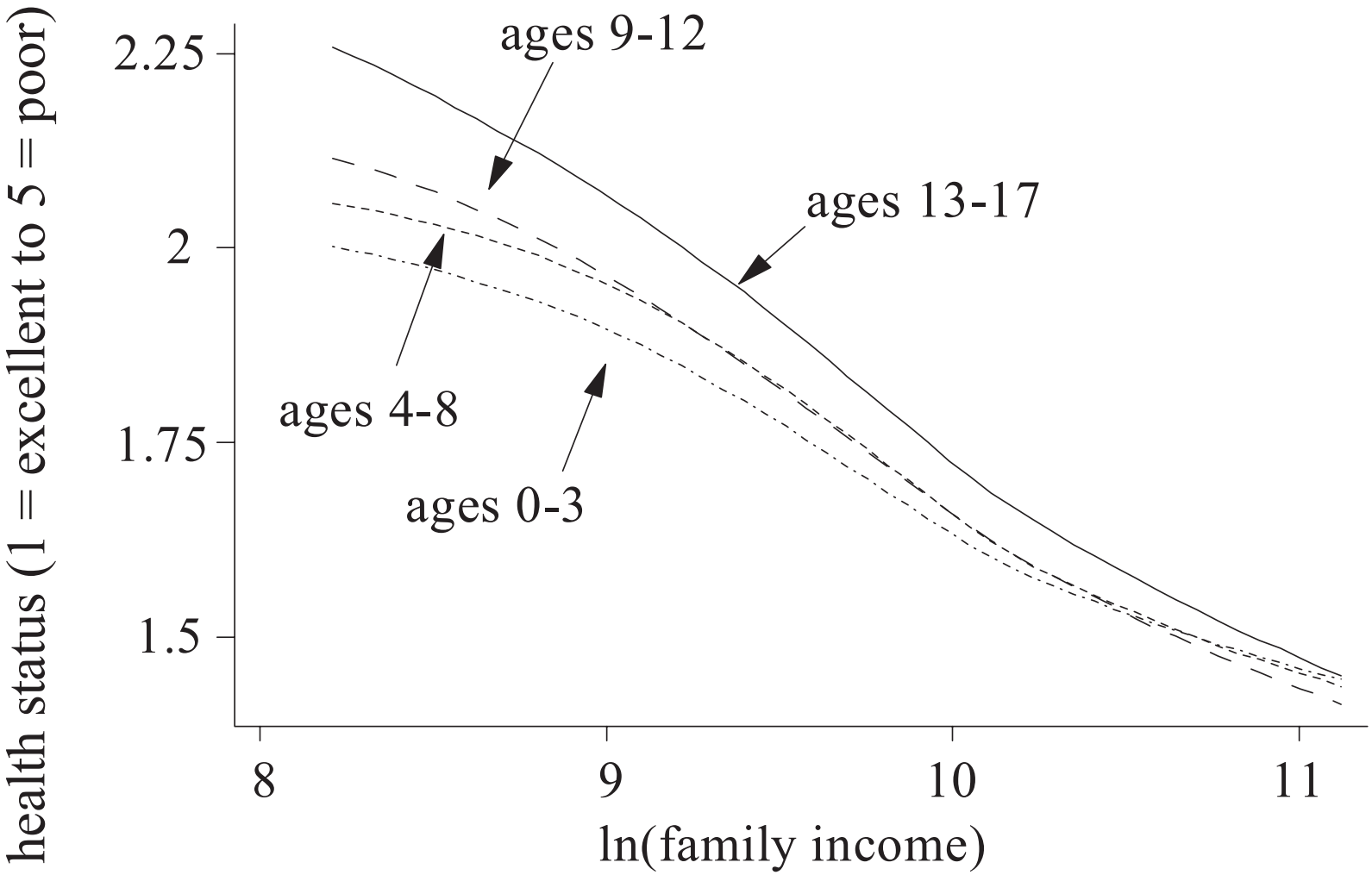
- Controlling for early family environments using conventional statistical methods substantially narrows the gaps.
- There are comparable phenomena in the evolution of gaps in behavioral problems.

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



Gaps also emerge in health. They *diverge* with age.

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.

What is the Role of Families and Environments?

- Which aspects of families and environments are responsible for producing these gaps?
- Genes?
- Family environments and investments? Social interactions?
- The evidence from numerous intervention studies suggests an important role for investments and family environments in determining adult capabilities.
- Evidence for neighborhood effects and social interactions is less clear cut and is still being investigated.
- Some claim that peers are more important than parents.

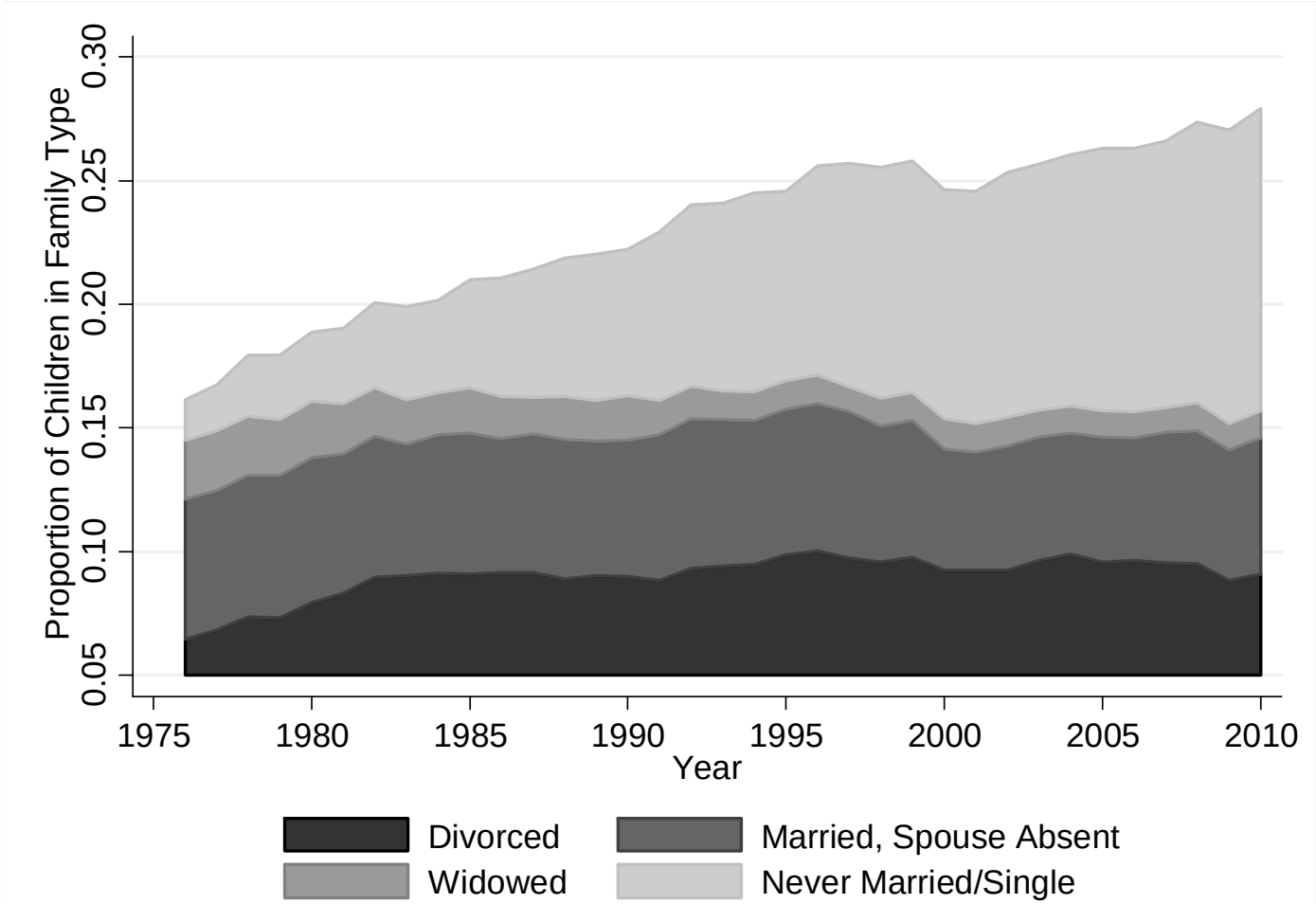
3. Gaps in capabilities by age across different socioeconomic groups have counterparts in gaps in family investments and environments.

- Investment in children varies substantially by family type.
- Differences are persistent over the age of the child.

Family Environments

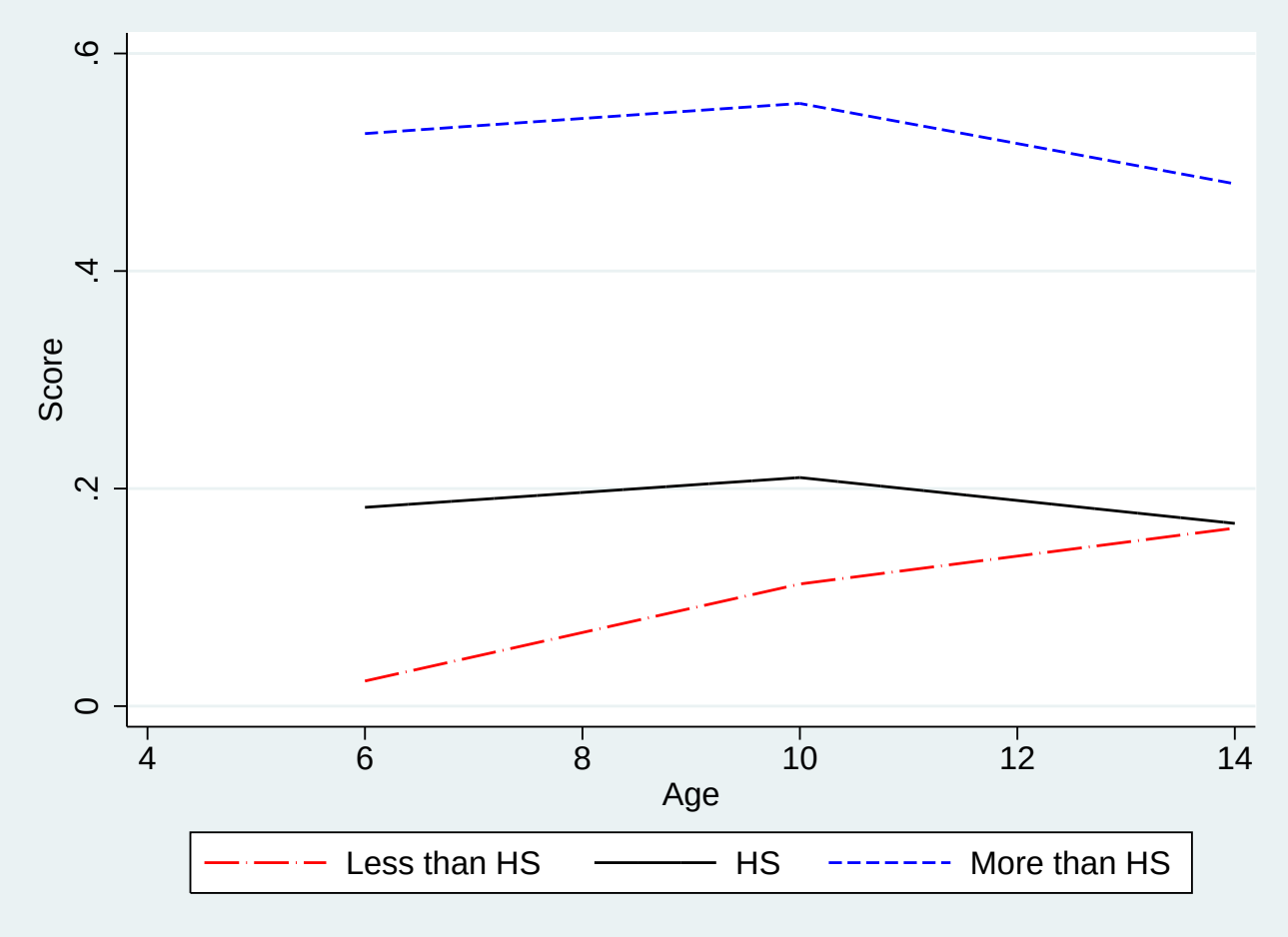
- In the U.S. and many other countries, a divide is opening up between the advantaged and the disadvantaged in the quality of early family environments.
- Those born into disadvantaged environments are receiving relatively less stimulation, child development resources, and access to health care than those from advantaged families.
- Likely fosters persistence of inequality across generations.
- Fewer Danes seem to be in this category.
- Perhaps for this reason, intergenerational family influence much stronger in the U.S. than in Denmark.

Children Under 18 Living in Single Parent Households by Marital Status of Parent



Source: March CPS 1976-2010 ; Note: Parents are defined as the head of the household. Children are defined as individuals under 18, living in the household, and the child of the head of household. Children who have been married or are not living with their parents are excluded from the calculation. Separated parents are included in "Married, Spouse Absent" Category.

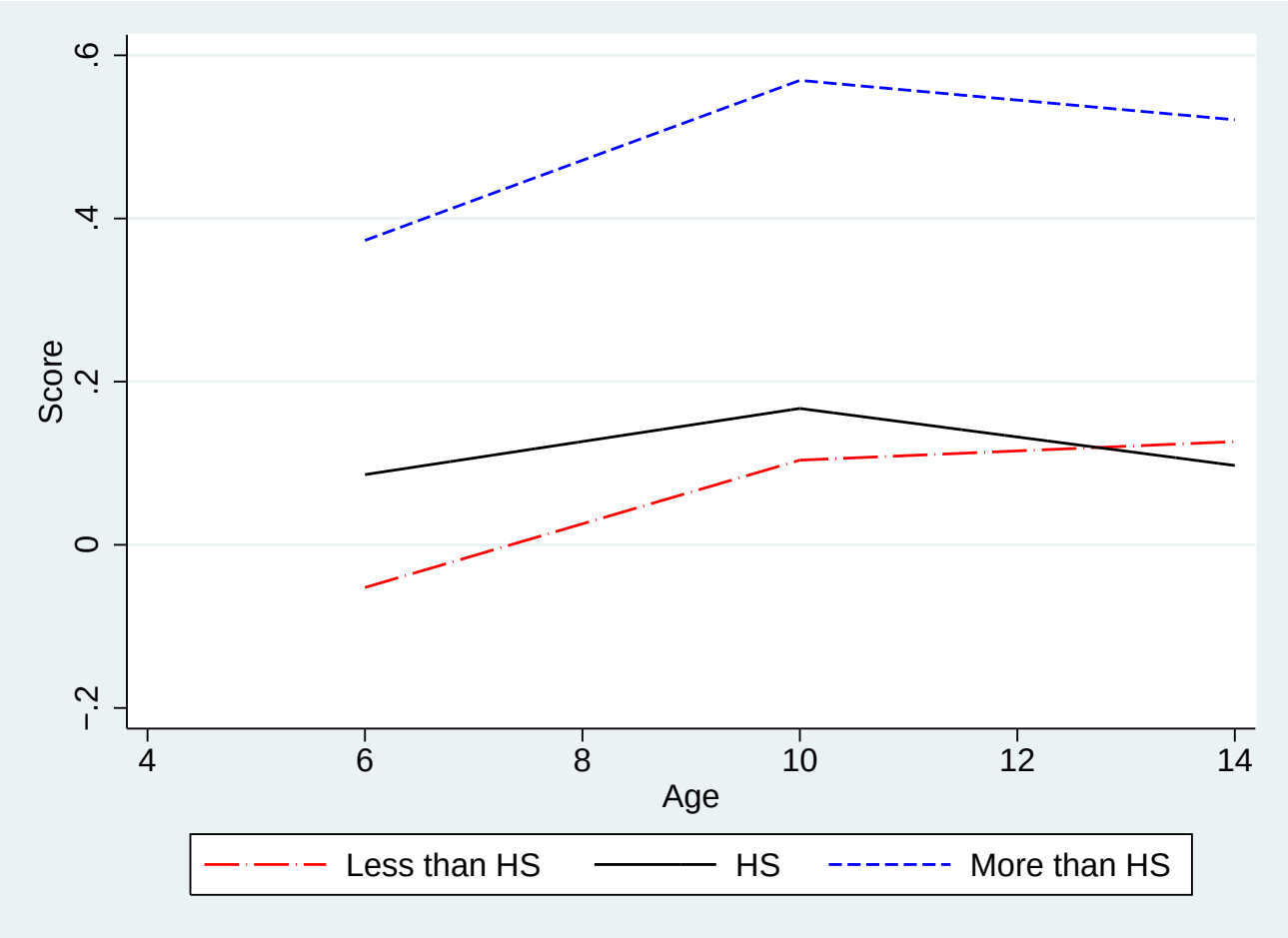
Figure 15: Parental Investment over Childhood among Whites by Mother's Education: Material Resources



Data: A balanced panel from Children of National Longitudinal Survey of Youth 1979.

Source: Moon (2012).

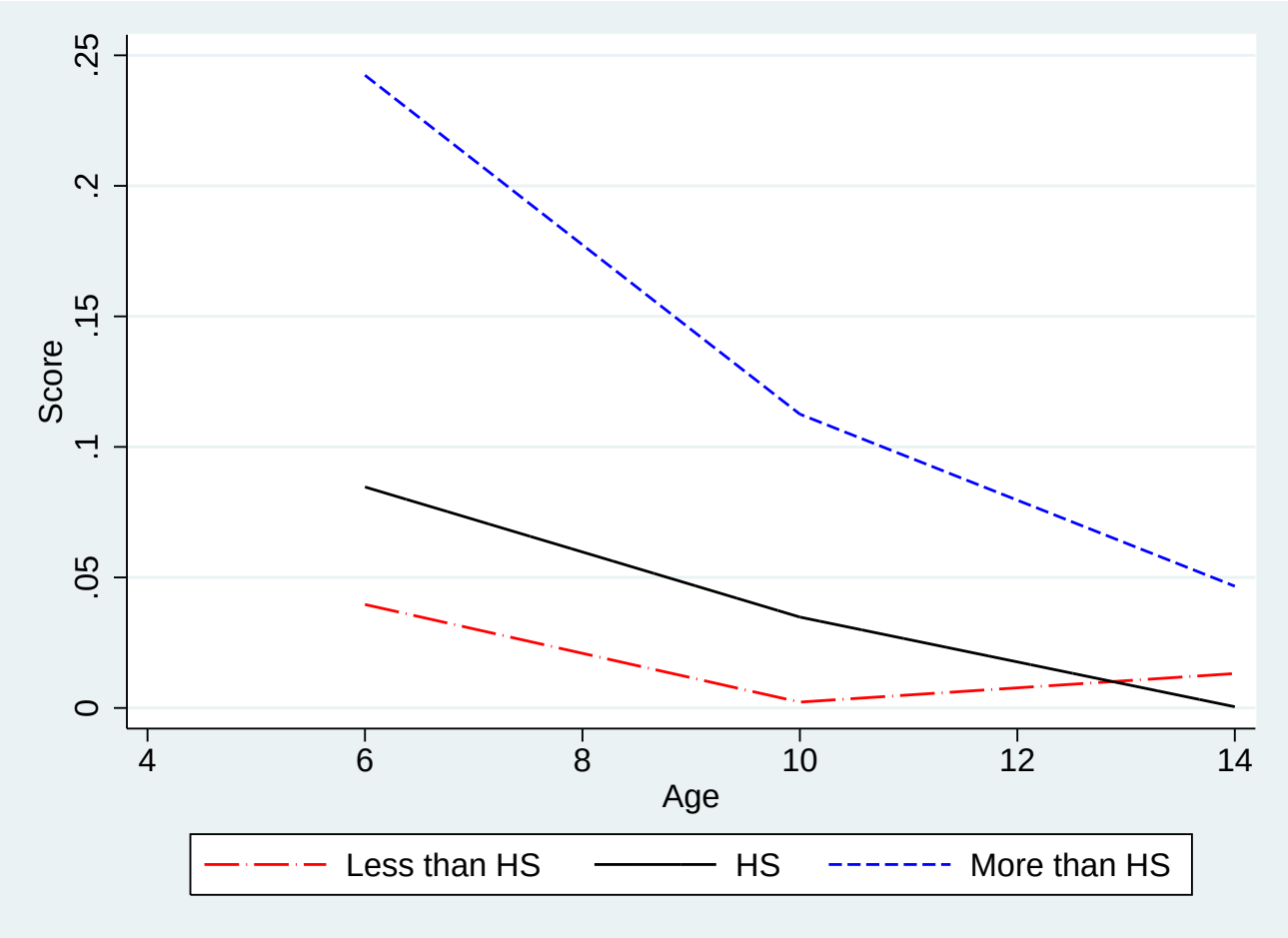
Figure 16: Parental Investment over Childhood among Whites by Mother's Education: Cognitive Stimulation



Data: A balanced panel from Children of National Longitudinal Survey of Youth 1979.

Source: Moon (2012).

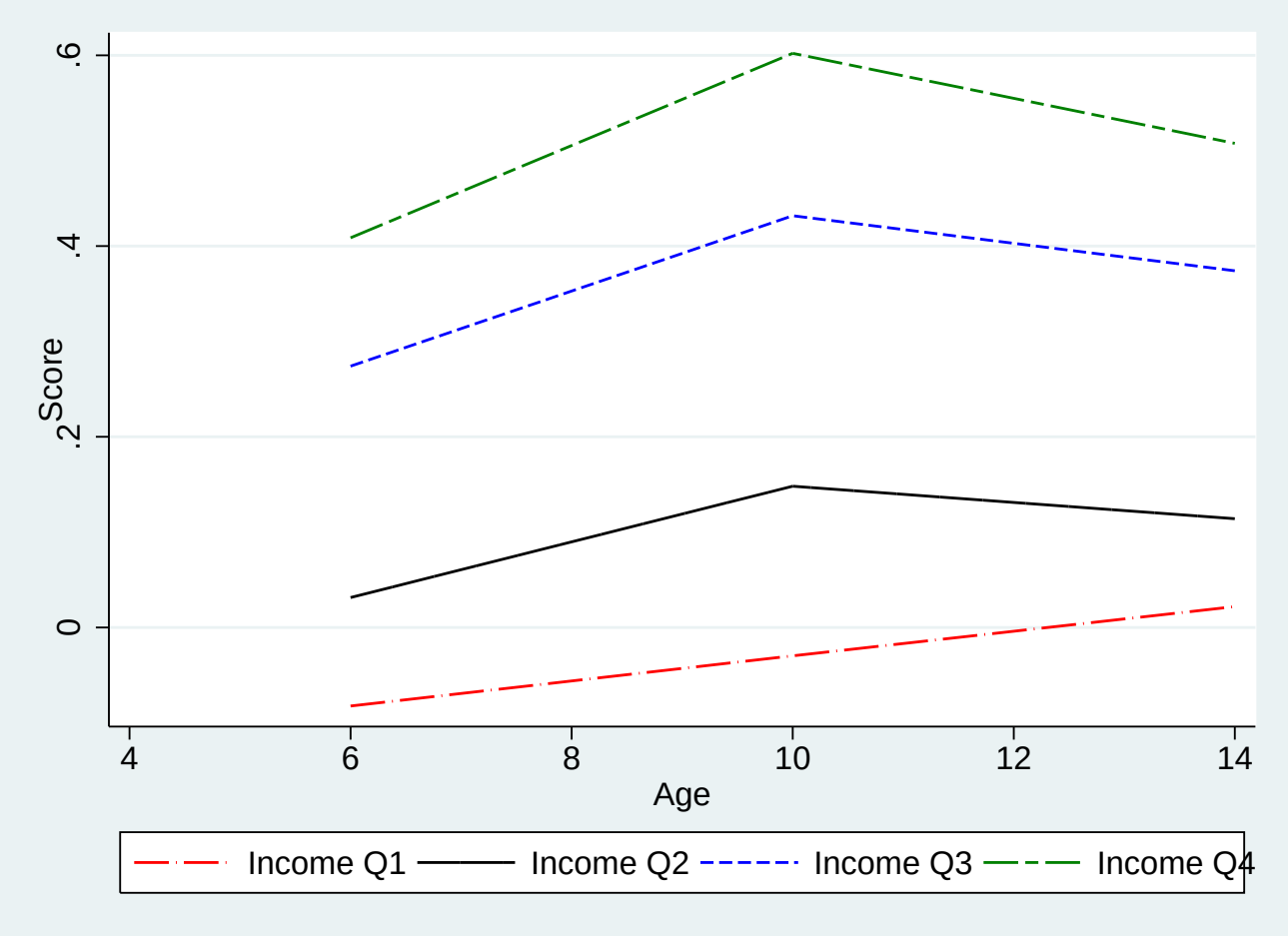
Figure 17: Parental Investment over Childhood among Whites by Mother's Education: Emotional Support



Data: A balanced panel from Children of National Longitudinal Survey of Youth 1979.

Source: Moon (2012).

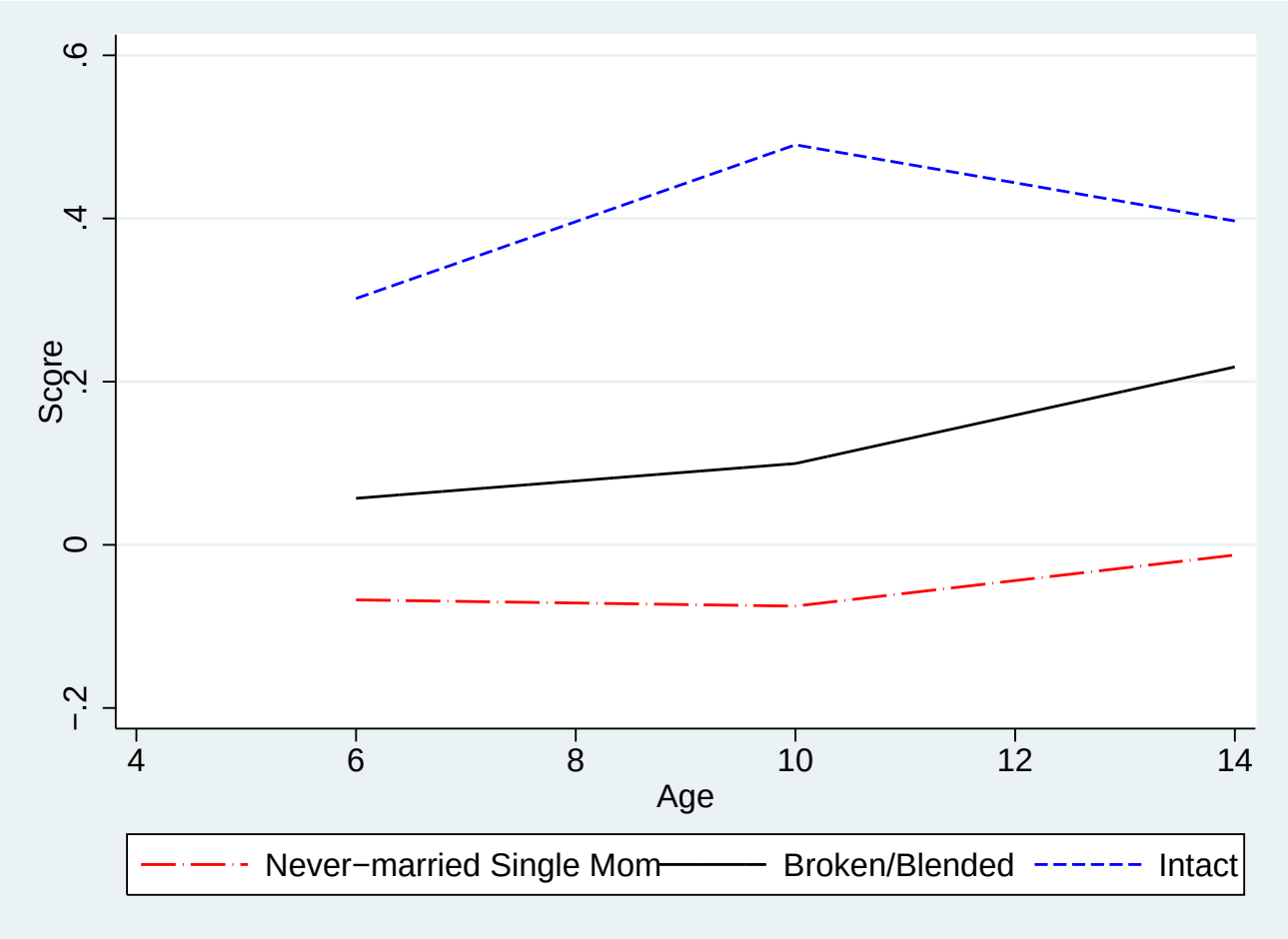
Figure 18: Parental Investment over Childhood among Whites by Family Income Quartile: Cognitive Stimulation



Data: A balanced panel from Children of National Longitudinal Survey of Youth 1979.

Source: Moon (2012).

Figure 19: Parental Investment over Childhood among Whites by Family Type: Cognitive Stimulation



Data: A balanced panel from Children of National Longitudinal Survey of Youth 1979.

Source: Moon (2012).

4. Critical and Sensitive Periods

- Sensitive and critical periods have been documented extensively for many organisms.
- Especially clear in biological developmental processes, e.g.,
  i. Cataracts
  ii. Vitamin A deficiencies and blindness
  iii. Iron deficiencies and long-term IQ
  iv. Iodine

Early Life Conditions Matter

- Fetal origins or Barker (2001) hypothesis.
- Fetal environment affects adult outcomes. (Gluckman and Hansen, 2005, 2006)
- Fetal alcohol (Nilsson, 2008); smoking.
- Dutch hunger winter. (Lumey, 2008)
- Related animal evidence. (Meaney and Szyf, 2002; Champagne, 2007)
- See Knudsen et al. (2006)

- But need to be careful.
- Early life conditions are reinforced by (or attenuated by) later-life interventions.

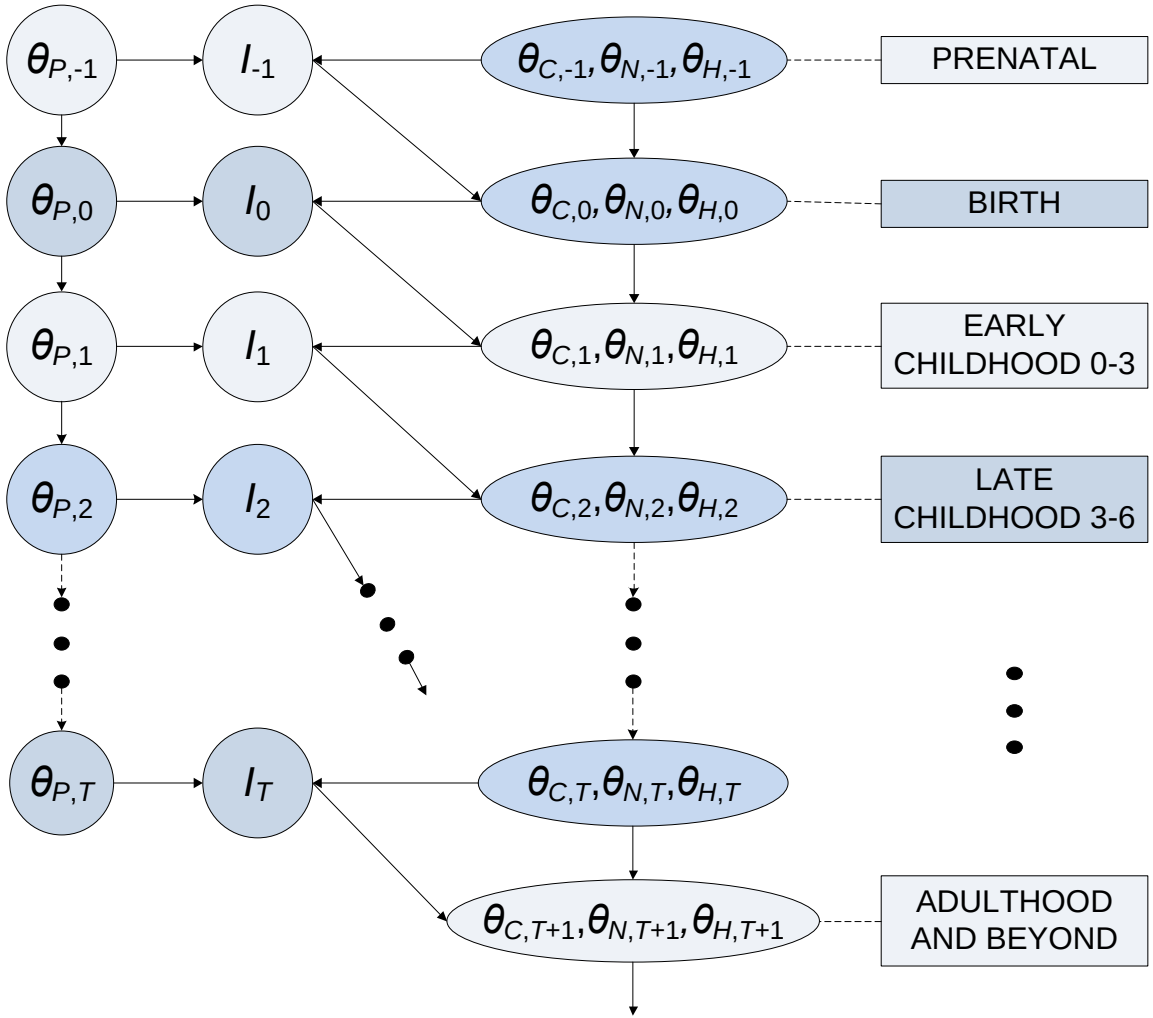
A Life Cycle Framework for Organizing Studies and Integrating Evidence

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

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

I_t: investment at t

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



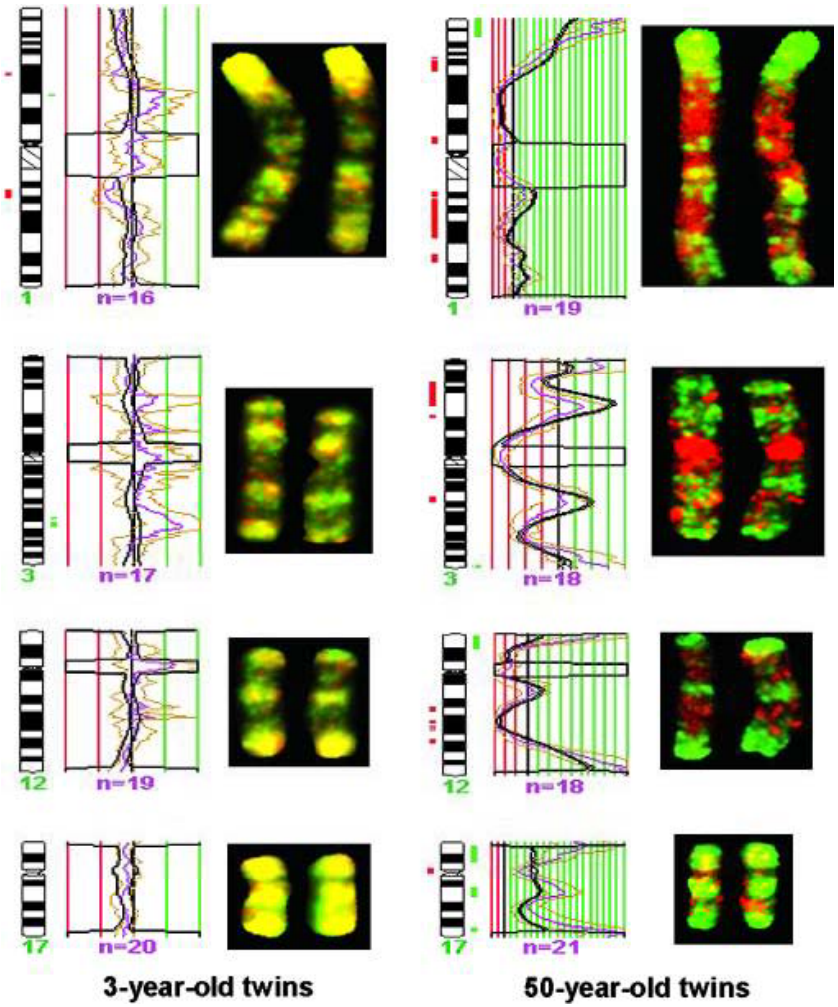
- Few early-life studies control for later-later conditions.

5. Genes, Biological Embedding of Experience and Gene-Environment Interactions

- An emerging literature on embedding of experience in the biology of organisms.

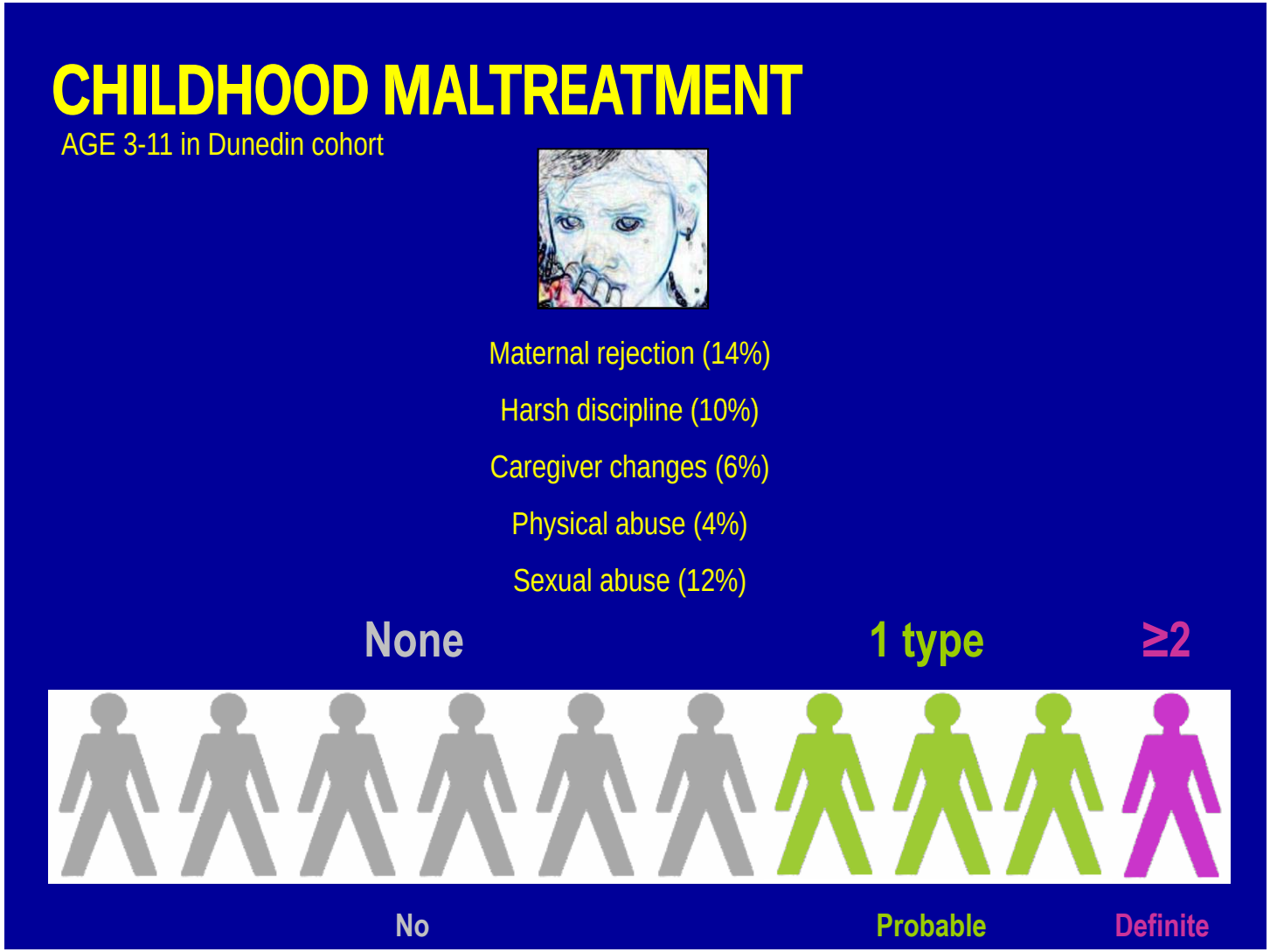
- Evidence of environmental effects on gene expression.
- Traditional linear models that are widely used and attempt to separate genes and environments fail to capture this interaction.
- Estimated "genetic" effects have a strong environmental component.

DNA methylation and histone acetylation patterns in young and old twins

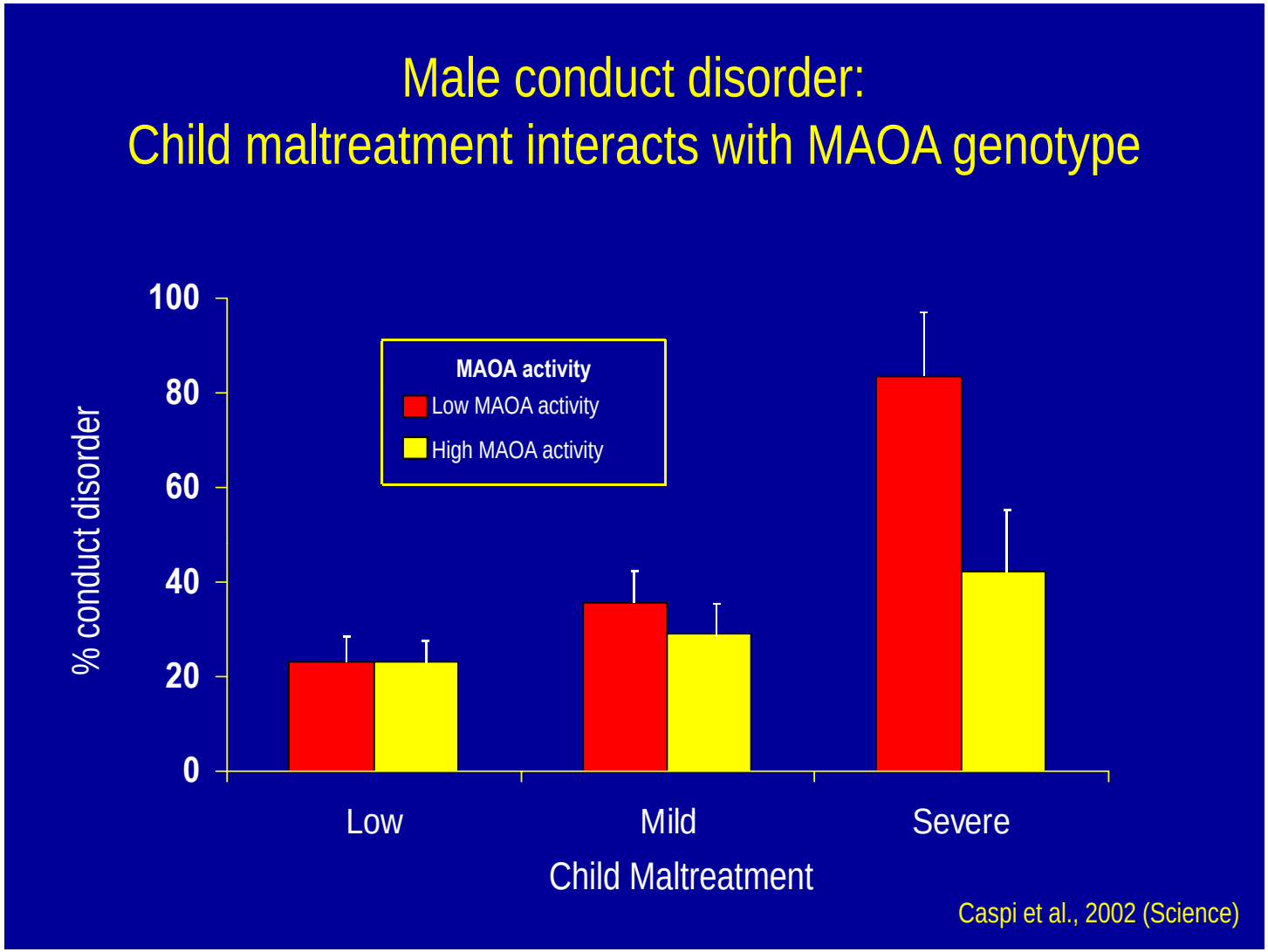


Source: Fraga, Ballestar et al. (2005)

Examples of How Genes are Triggered by Environments



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



Caspi, McClay et al. (2002).

- Evidence, however, is not rock solid.
- Parental genes may affect the selection and creation of environments, so analysis is not completely clean.
- 6 replications and 2 failures to replicate.
- The particular environment and phenotype seem to affect the conclusions.
- Even stronger effects for other genes.
- Child maltreatment and inflammation.
- But what is the quantitative importance of this and related phenomena?

How Do Early Experiences Get Under the Skin?

- Lots of evidence by now that early conditions matter for late life health. *Why?* What is the mechanism?
- Meaney, Suomi, and Szyf (2009): Early peer rearing affects gene expression in 22% of rhesus monkey genes.
- Joint work with Steve Cole, Gabriella Conti and Stephen Suomi investigates the quantitative importance of **epigenetic mechanisms**.
- We show that adversity-related changes in expression of basal leukocyte genes can emerge *early* in life (4-month old rhesus monkeys), and independently of cumulative exposures.
- In a companion paper we also show that the adverse effects of early rearing conditions are *not compensated* by a normal social environment later in life.

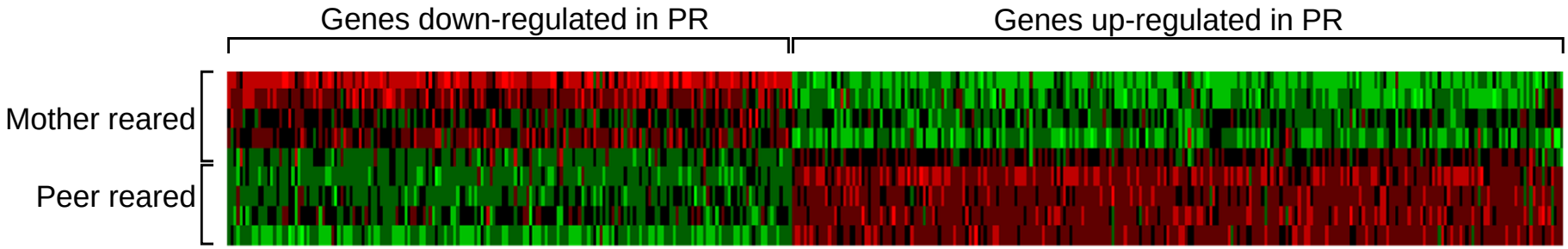
The Rhesus Monkeys Experiment

- At birth, monkeys are randomized into 1 of 3 rearing conditions:
  - Mother Reared (MR): left with their mothers
  - Peer Reared (PR)
  - Surrogate Peer Reared (SPR)
- Last two removed from their mothers at birth, and raised in a nursery until the 37th day of life. After that:
  - PR are placed in groups of 4, and spend 24 hrs a day together in cages;
  - SPR spend 22 hrs a day alone in a cage with a Surrogate mother (hot water bottle hanging in the cage); for 2 hrs a day they play with a peer group of 3 other monkeys.

The Rhesus Monkeys Experiment

- Between 6 months and 1 yr, all monkeys born in the same year are put together in a single mixed social group.
- We analyze the genome-wide transcriptional profile of circulating immune cells in 4-month old infant rhesus macaques.

Differential gene expression in leukocytes from mother-reared vs. peer-reared 4-month-old rhesus macaques

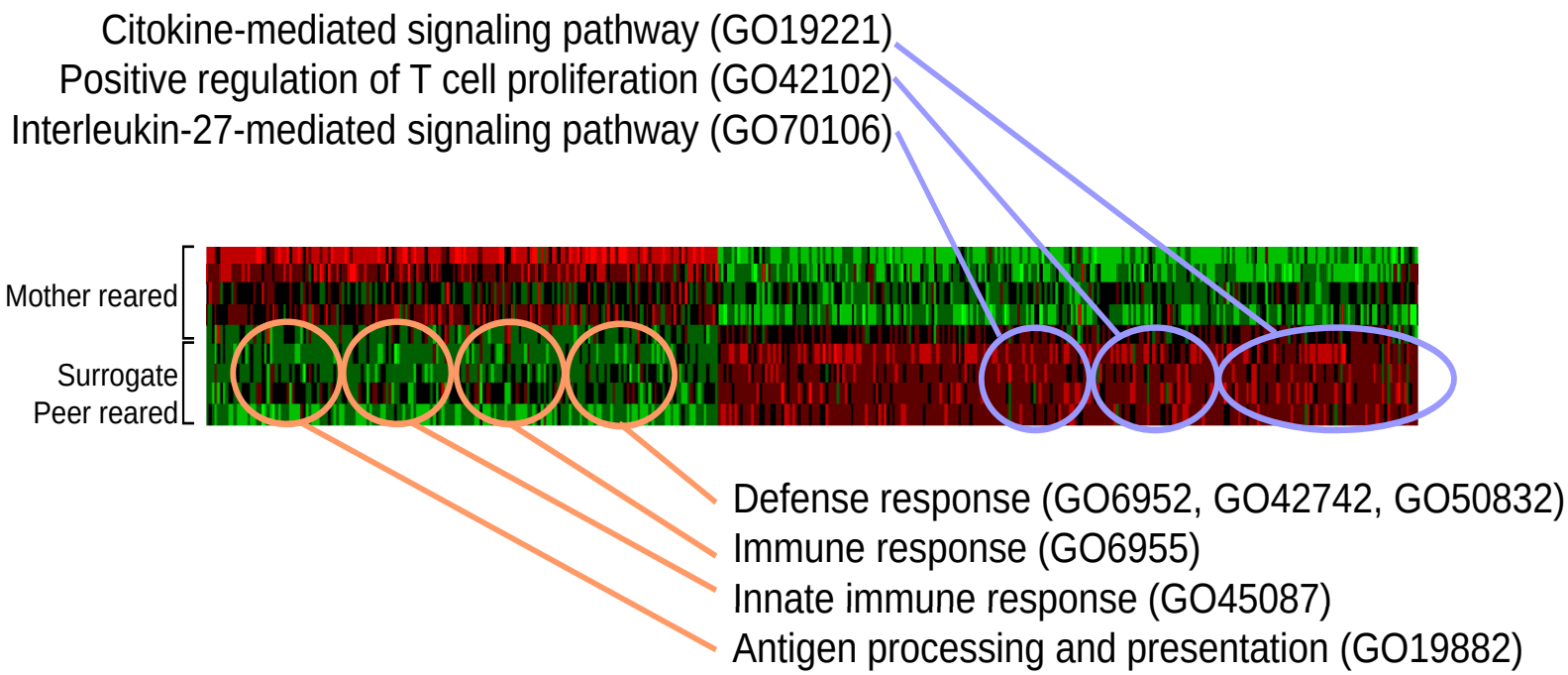


Source: Cole, Conti, Heckman, and Suomi (2011).

Early Life Experiences Change The Way Genes Express Themselves

Up- and Down-Regulated Genes in Rhesus Monkeys

Differential gene expression (GO annotations, biological functions), SPR vs. MR monkeys

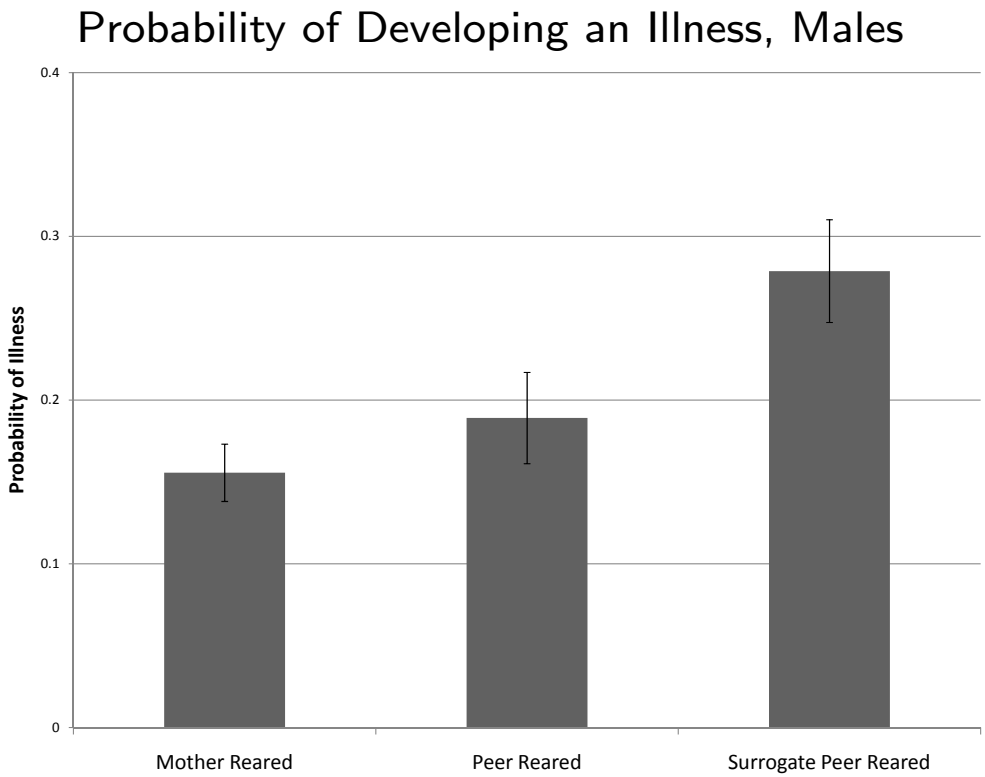


Source: Cole, Conti, Heckman and Suomi.

What Are the Late Life Effects of Early Adverse Rearing Conditions?

- What is the quantitative significance of these epigenetic effects?

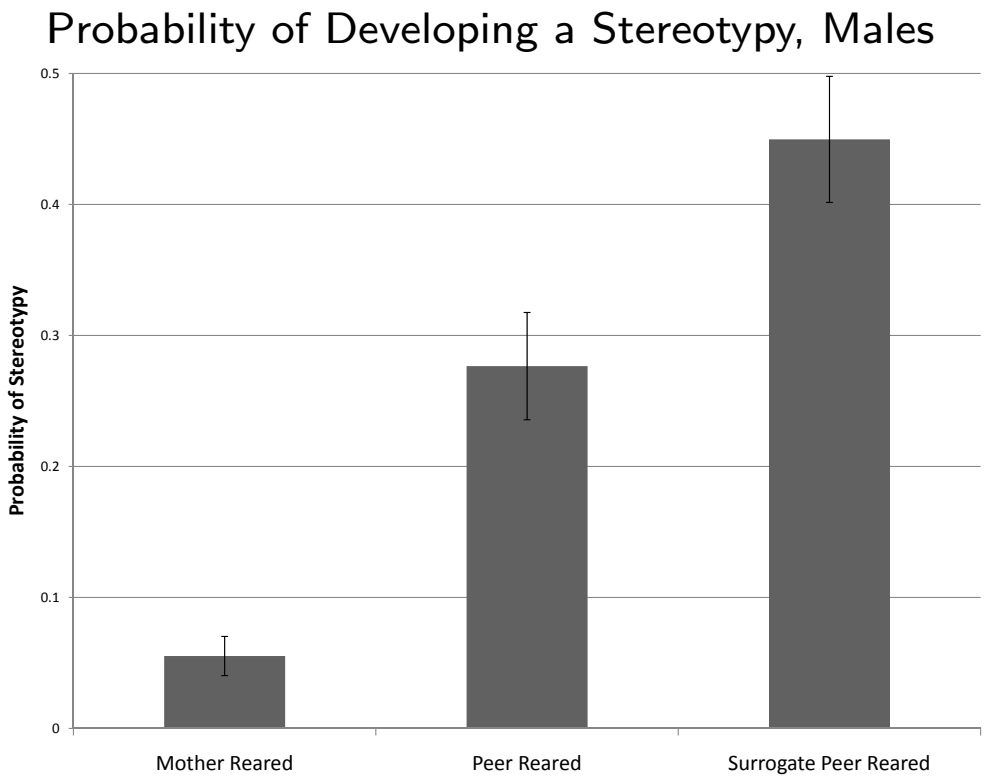
Early Life And Later Physical Health in Rhesus Monkeys



Source: Conti, Hansman, Heckman and Suomi.

- Males show greater susceptibility to early separation: role of cortisol and 5-HIAA.

Early Life And Later Mental Health



Source: Conti, Hansman, Heckman and Suomi.

- We find the same longlasting effect for females.
- **We find no evidence that the detrimental effects of early rearing conditions are compensated by a normal environment later in life.**

6. But Early Life Conditions Are Not the Full Story: Resilience, Recovery, and Repair

- There is also evidence of resilience to adversity and recovery at later ages.
- Early conditions are not fully determinative.
- Later life experiences are also important.
- The central economic question is what is the cost of remediation?
- How important are experiences and investments at various stages of the life cycle?

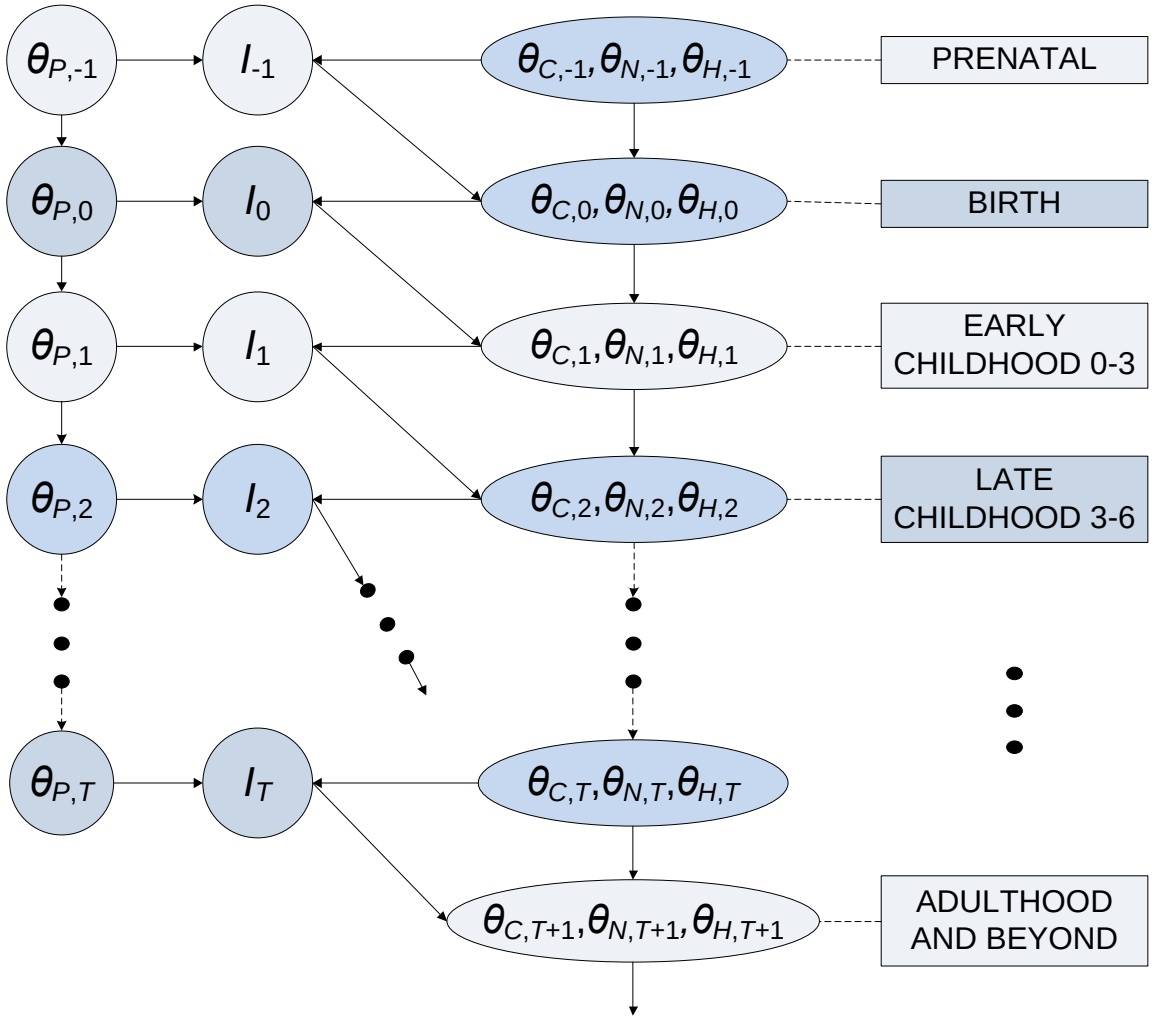
A Life Cycle Framework for Organizing Studies and Integrating Evidence

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

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

I_t: investment at t

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



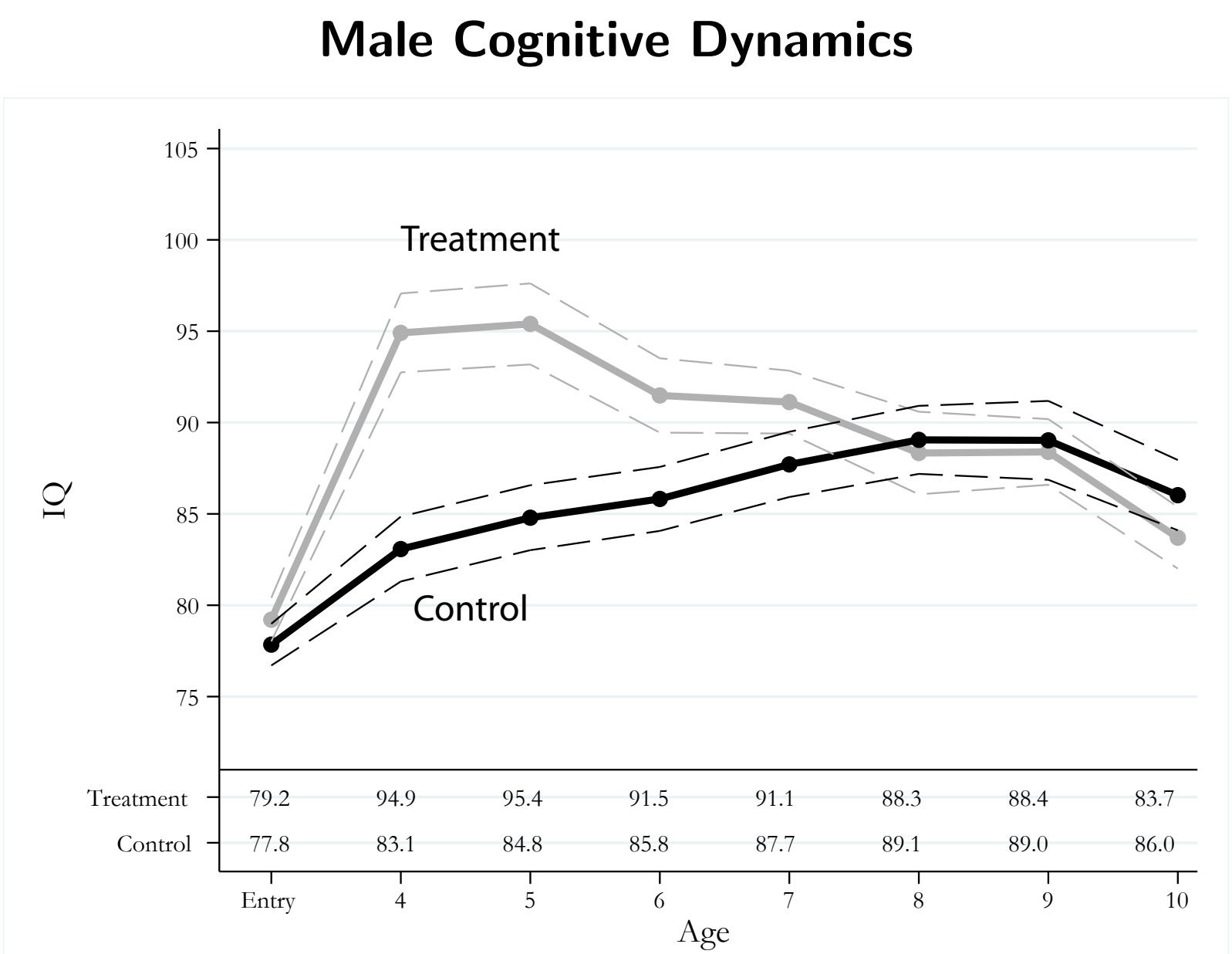
7. The effects of constraints on family resources ("credit constraints") on a child's adult outcomes depend on the age at which they bind for the child's family

- Controlling for ability, at the age schooling decisions are made, racial/ethnic socioeconomic gaps in schooling **reverse sign**.
- Family income in the adolescent years plays only a minor role in explaining schooling.
- Family income in early years shows more effect on adult outcomes than family income in the adolescent years.

8. Enriched Early Environments Compensate In Part For the Risks Arising from Disadvantaged Environments

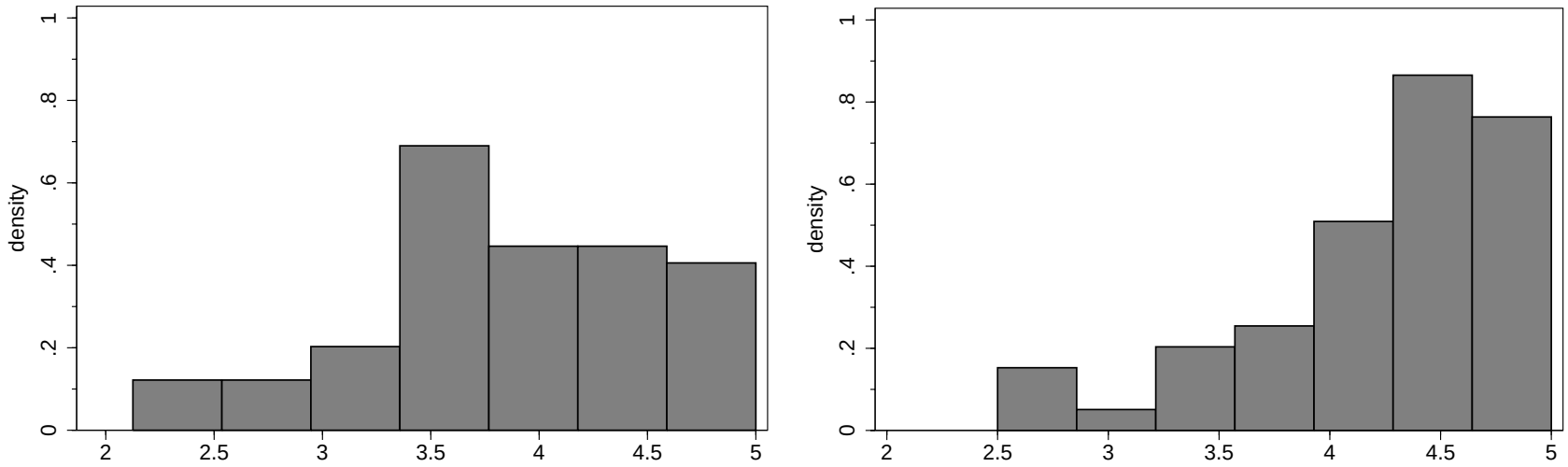
- A main channel through which these interventions operate is socioemotional skills.
- In some studies its the only channel.
- The effects on health in early intervention studies is now being investigated.
- Perry Preschool Study.
- Early childhood program that primarily targeted social and emotional skills.

Cognitive Evolution Through Time, Perry Males



- Yet the Perry Program has a statistically significant annual rate of return of around 7–10% per annum—for both boys and girls—above the post World War II stock market returns to equity in U.S. labor market estimated to be 5.8%.

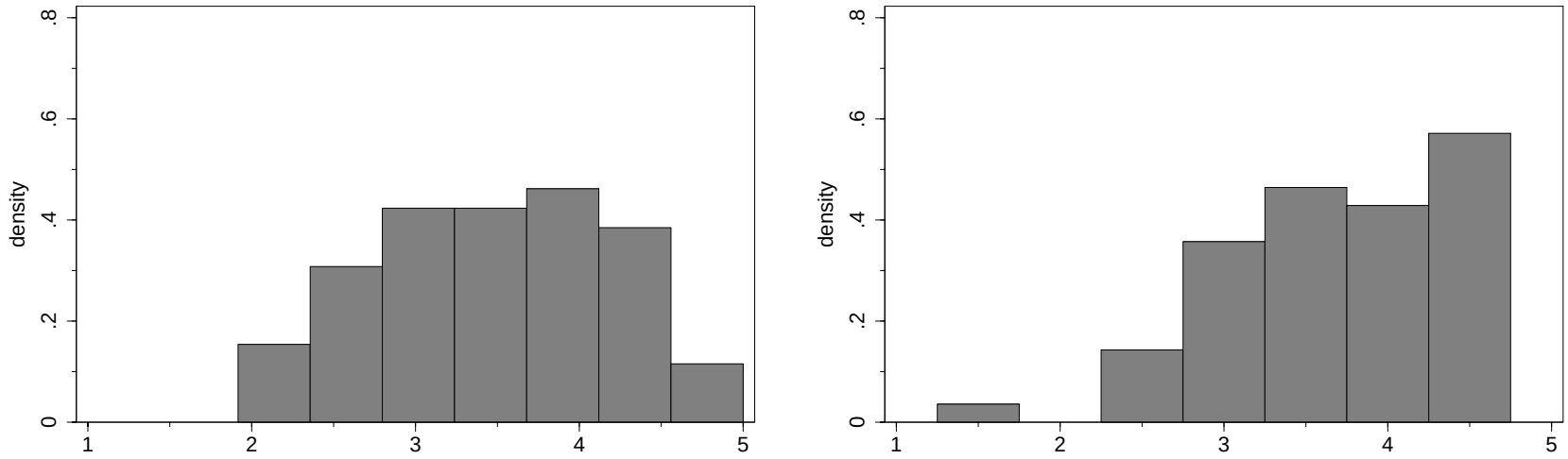
Figure 20: Personal Behavior Index by Treatment Group



(a) Control

(b) Treatment

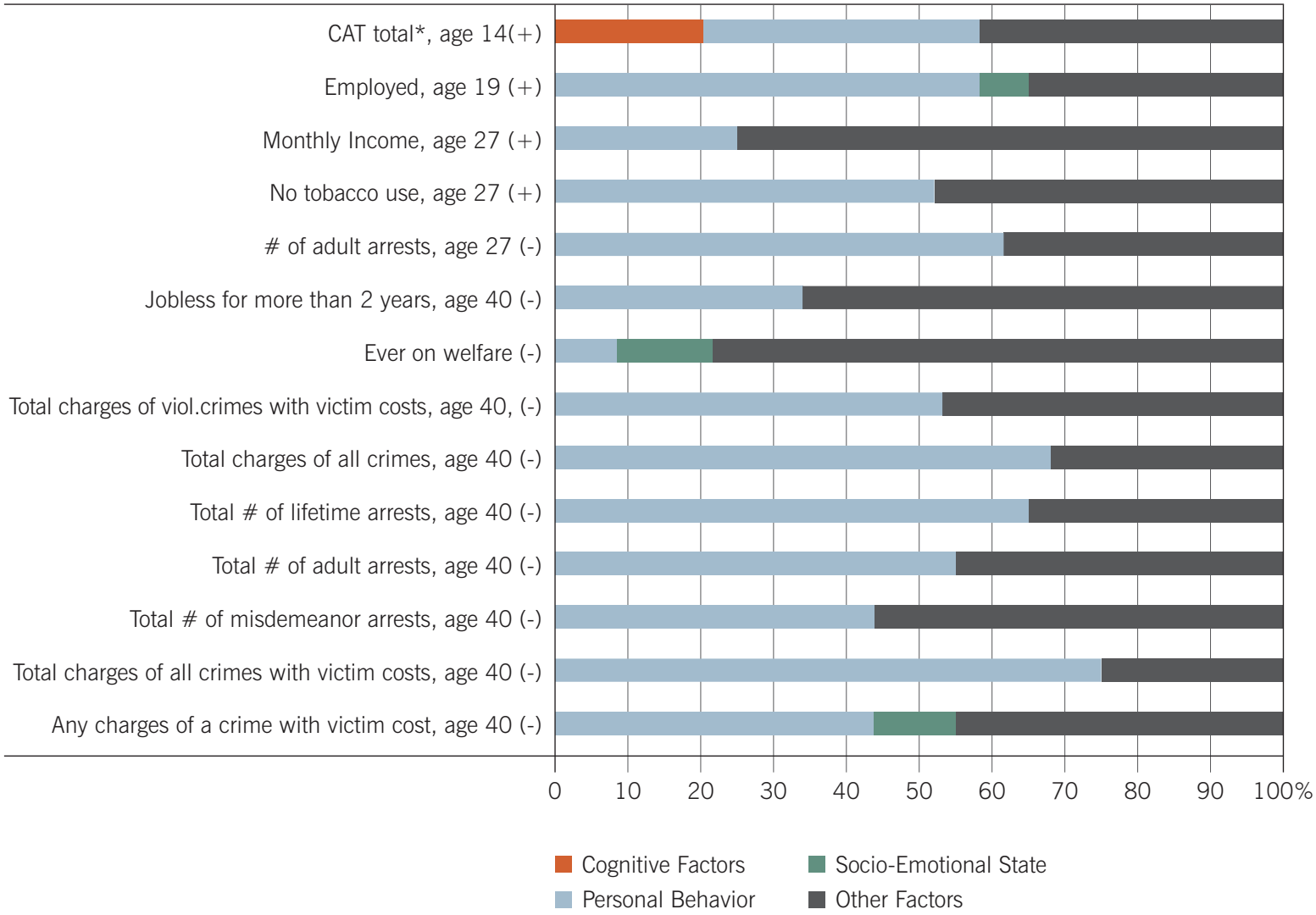
Figure 21: Socio-Emotional Index by Treatment Group



(a) Control

(b) Treatment

Decomposition of Treatment Effects, Males

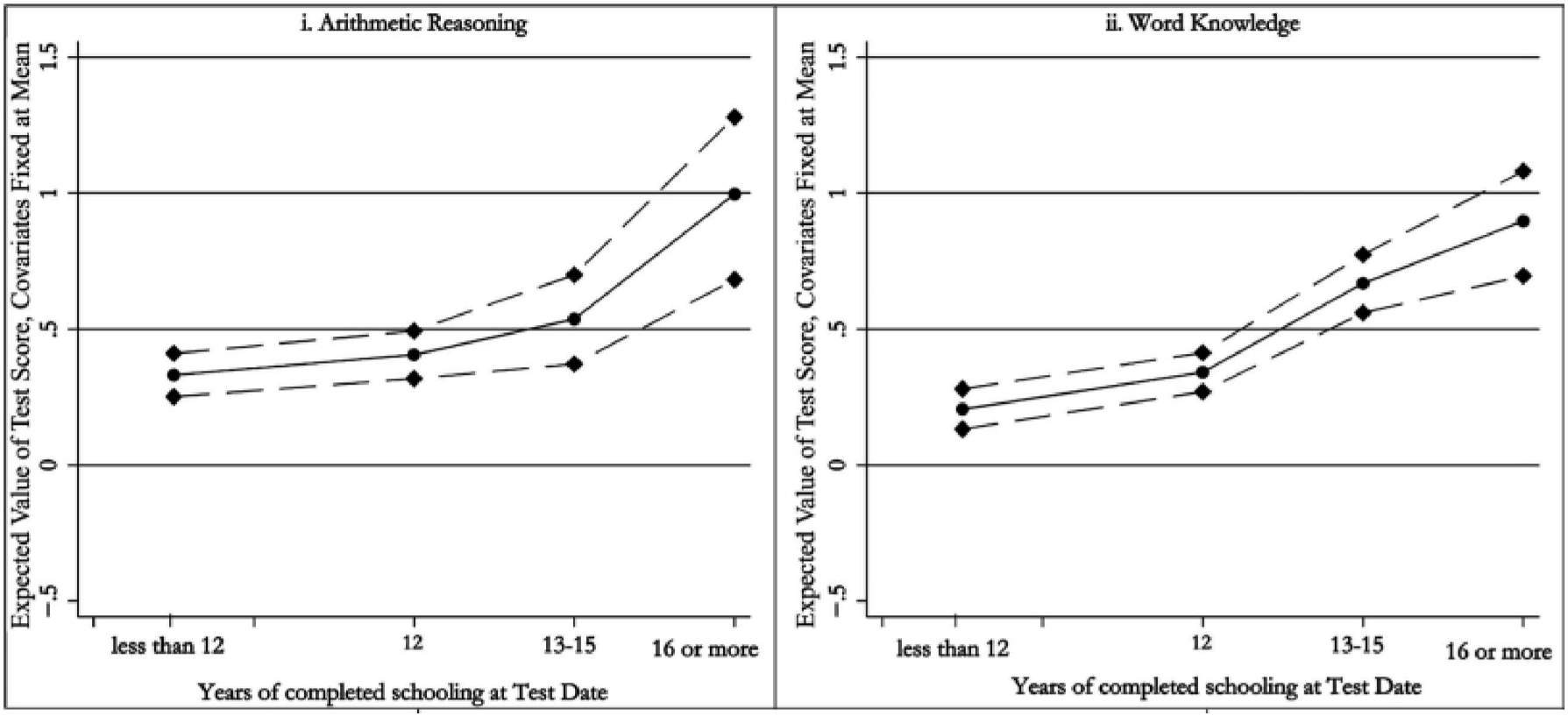


Schooling in Adolescent Years Also Promotes Capabilities That Matter

Causal Effects of Education on Capabilities

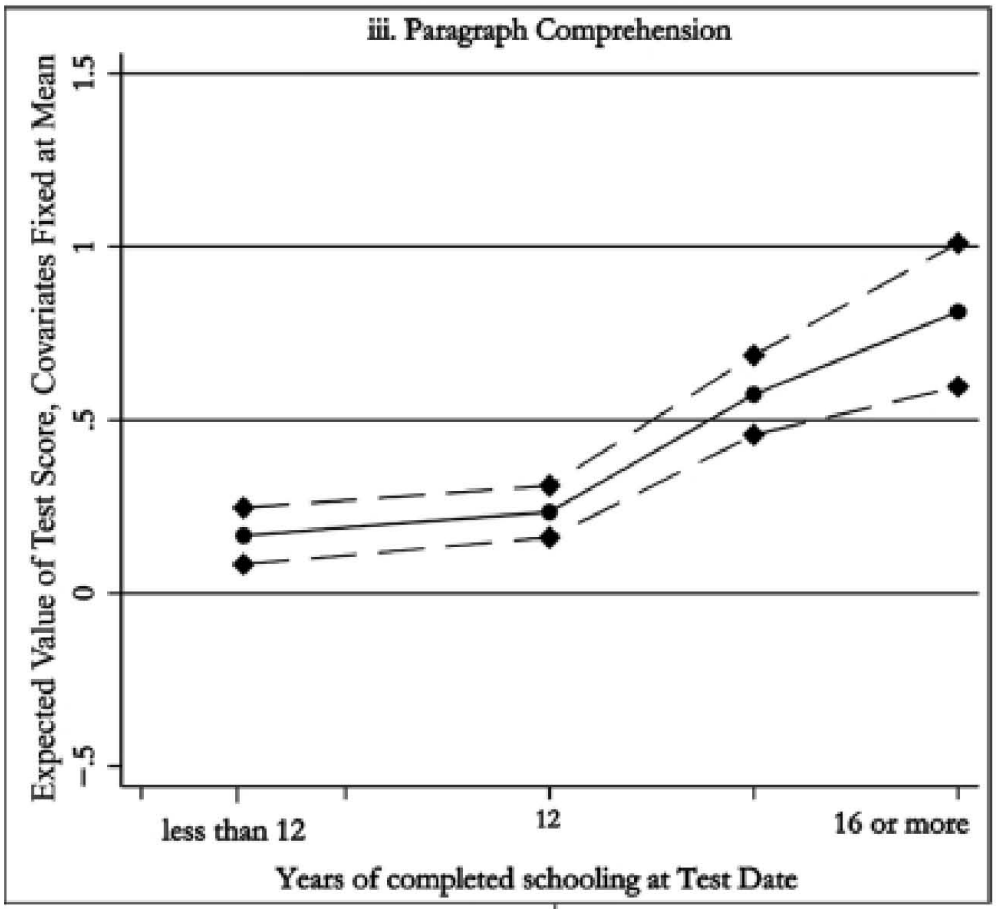
- Perry Study (previously discussed and to be discussed further this afternoon) uses experimental variation and shows how early education boosts some capabilities.
- One can also use observational data.
- Exploit panel design. (Heckman, Stixrud, and Urzua, 2006)
- Study a random sample of people at different schooling **at the date of the interview** all of whom complete the same final schooling.
- The variation in schooling at the date of the interview on measures of capabilities **conditioning on final schooling attained (as a measure of control for selection)** can be interpreted as the causal effect of schooling.

Figure 22: 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 22: Causal Effect of Schooling on ASVAB Measures of Cognition



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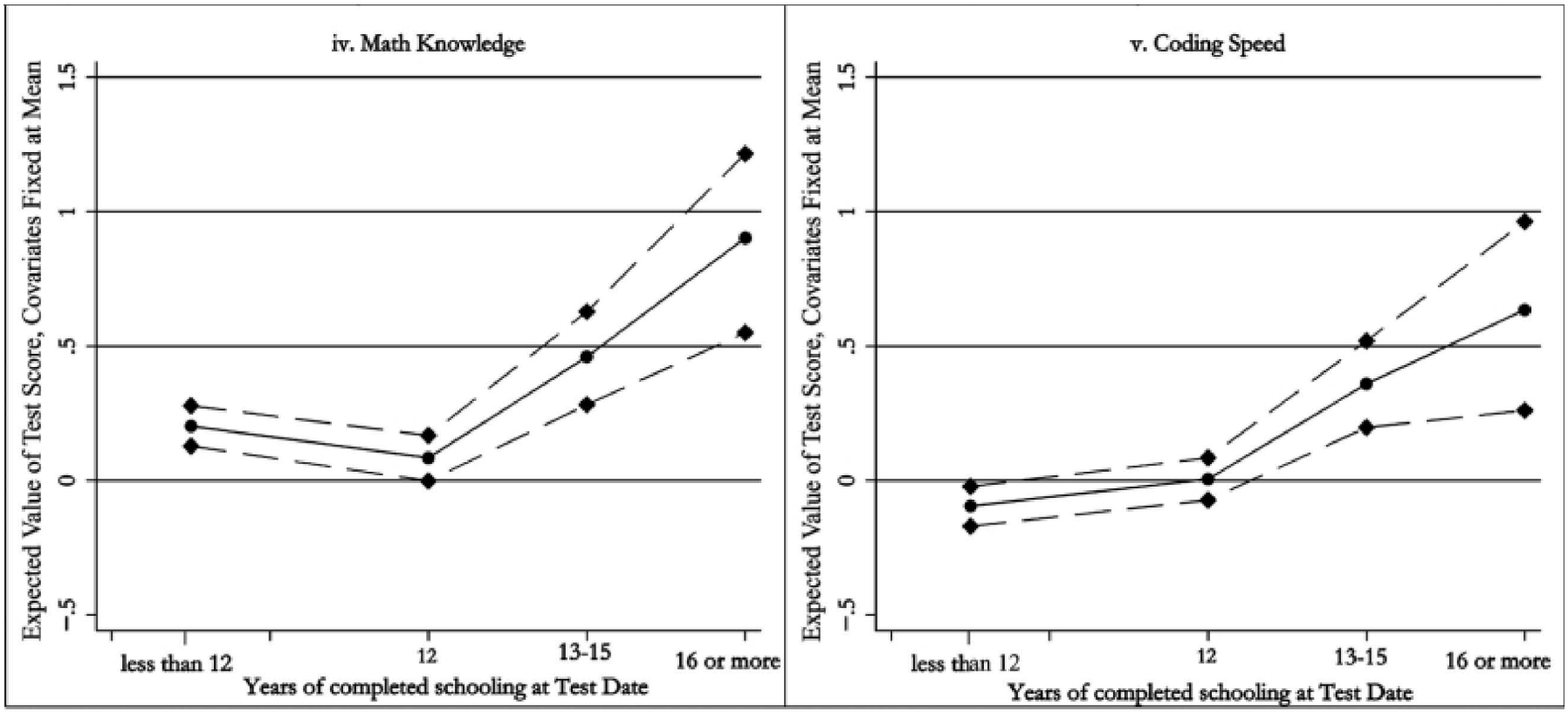

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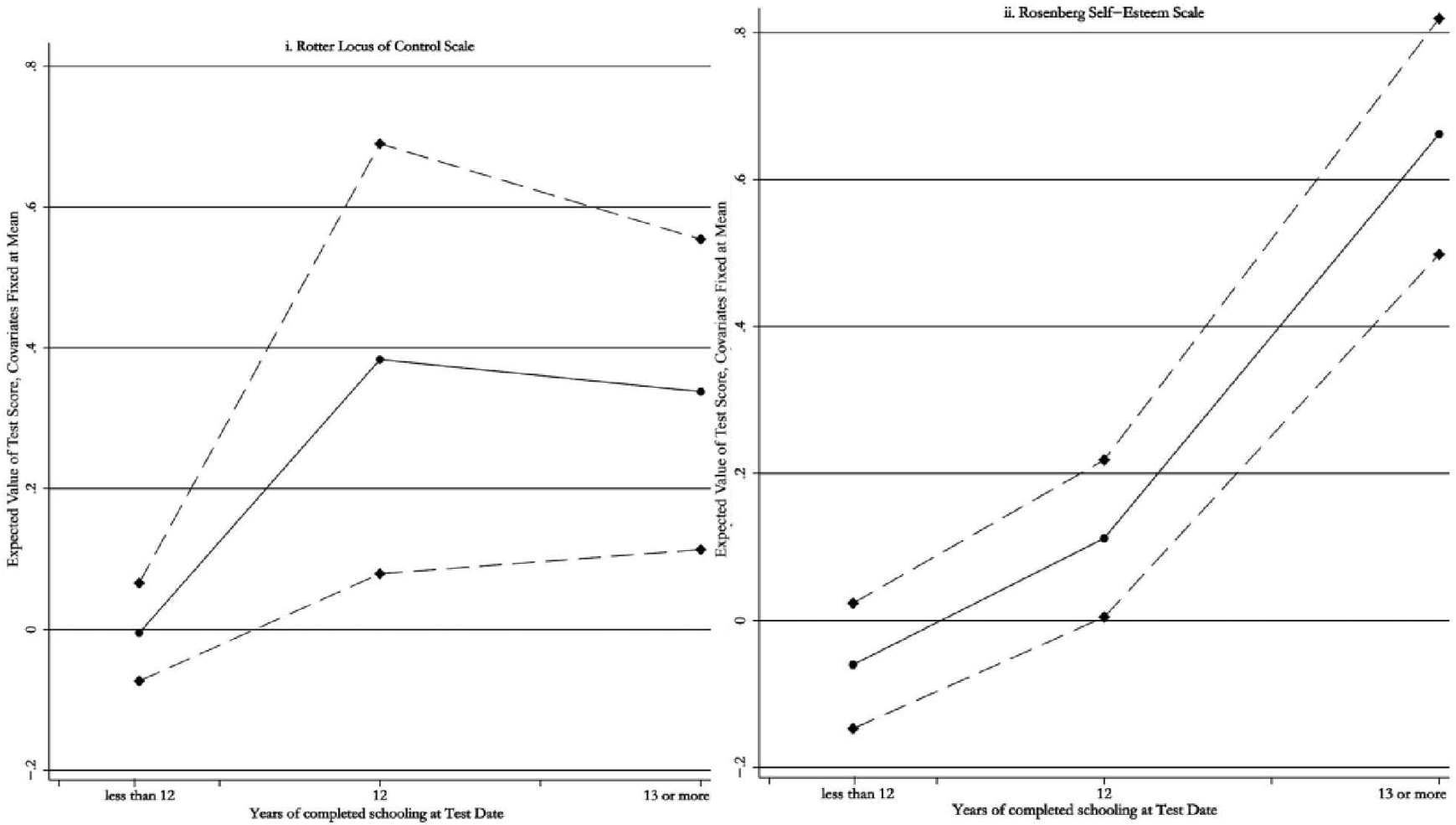
Source: Heckman, Stixrud and Urzua [2006, Figure 4].

Figure 23: Causal Effect of Schooling on Two Measures of Personality



Source: Heckman, Stixrud and Urzua [2006, Figure 5].

9. Later Remediation is Costly and Often Ineffective

- As **currently implemented**, most adolescent remediation efforts, especially those targeted toward raising adolescent cognitive abilities targeted **toward the disadvantaged** have low returns.
  a. Active labor market programs
  b. Class size reductions (reducing class size by five pupils per classroom)
  c. Adult literacy programs
  d. Public job training programs
  e. Tuition reduction policy

- Pattern: returns on later life programs are **higher** for the more able.
- Lower returns for the less able adolescents (both cognitive and socioemotional).
- However, motivational programs—programs that build social skills and promote social behavior—seem to be effective in the adolescent years.
- Returns are very high for the most able / motivated college children (returns of 20% or more)
- Very low for less motivated / less able children
- Recent Dynarski et al. paper (2011) apparently contradicts this substantial body of evidence
- Confuses the discussion by not controlling for ability in evaluating rates of return

10. Key Policy Issues

- From the point of view of social policy, the key question is how easy is it to remediate the effect of early disadvantage?
- How costly is delay in addressing early disadvantage? How critical are the early years and for what traits?
- What is the optimal timing for intervention in different capacities?
- To address these problems, a clearly articulated empirical framework is useful.

A Framework For Integrating the Evidence and Guiding Policy

Becker and Tomes (1986):

- An early paper that *loosely* guides recent research
- Features
  a. Parental Preferences (altruism),
  b. Intergenerational credit markets and bequests,
  c. Parental investment in child skills,
  d. Genetic mechanisms
- A one period-one skill model of childhood with ability transmitted solely genetically.

Recent research in the economics of the family

- Cunha et al. (2006, 2007, 2008, 2009, 2010)
- Moon (2008)
- Bernal and Keane (2009)
- Todd and Wolpin (2007)
- Del Boca, Flinn, and Wiswall (2010)
- Tartari (2010)
- Conti et al. (2010)
- Akabayashi (1995, 2000)
- Weinberg (2006)
- Cosconati (2009)
- Caucutt and Lochner (2011)

1. Multiple stages of childhood and adulthood
2. Moves beyond "schooling" as *the* investment to allow economists to address the benefits and costs of different types of investments at different stages of the life cycle:
   a. Schooling
   b. Training
   c. Preschool and early childhood investments
3. Recognizes the modern literature on the biology and psychology of skill formation and the literature on critical and sensitive periods in development

4. Multiple capabilities (cognitive, noncognitive, and biological capabilities)
5. Child preference formation and emergence of decision making (transition from child to adult)
6. Interactions between child and parents in shaping investment (principle-agent problems)
7. Recognizes the importance of within generation (within lifecycle) budget constraints

Review and apply the framework sketched at the start of this lecture.

Modeling Human Capability Formation

- An agent at age t is characterized by a vector of capabilities

$$\theta_t = (\theta_{C,t}, \theta_{N,t}, \theta_{H,t}),$$

where

- $\theta_{C,t}$ is a vector of cognitive abilities (e.g., IQ) at age t,
- $\theta_{N,t}$ is a vector of socioemotional abilities at age t (e.g., patience, self control, temperament, risk aversion, and neuroticism), and
- $\theta_{H,t}$ is a vector of health stocks for mental and physical health at age t.

- The model has four ingredients:
  (a) outcome functions that show how capabilities, effort and incentives affect outcomes;
  (b) dynamic technologies for producing capabilities;
  (c) parental (and social) preferences; and
  (d) constraints reflecting access to financial markets, as well as genetic endowments.

Formal models of child outcomes and investment in children

- The *outcome from activity k at age t* is Y_t^k, where

$$Y_t^k = \psi_k \left(\theta_{C,t}, \theta_{N,t}, \theta_{H,t}, e_{k,t}\right), \quad k \in \{1, \ldots, K\} \tag{5}$$

where $e_{k,t}$ is effort devoted to activity k at time t where the effort supply function depends on rewards and endowments:

$$e_{k,t} = \delta_k \left(R_t^k, A_t\right) \tag{6}$$

where R_t^k is the reward per unit effort in activity k and A_t represents other determinants of effort which might include some or all of the components of θ_t.

- Captures needs to standardize measures for incentives and context.

- Parental preferences for child outcomes
  - Parental altruism.
  - Alternative: merit goods: Parents value specific outcomes, not necessarily child utility.
  - $V^P(V^C)$: the valuation by parents of child value function.
  - V^P = Parental Preference.
  - V^C = Child Preference.
  - Models of Preference Formation.
  - Models of Parent-Child Interactions

Capability Formation Process

- The capability formation process is governed by a multistage technology.
- Each stage corresponds to a period in the life cycle of a child.

A Life Cycle Framework for Organizing Studies and Integrating Evidence

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

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

I_t: investment at t

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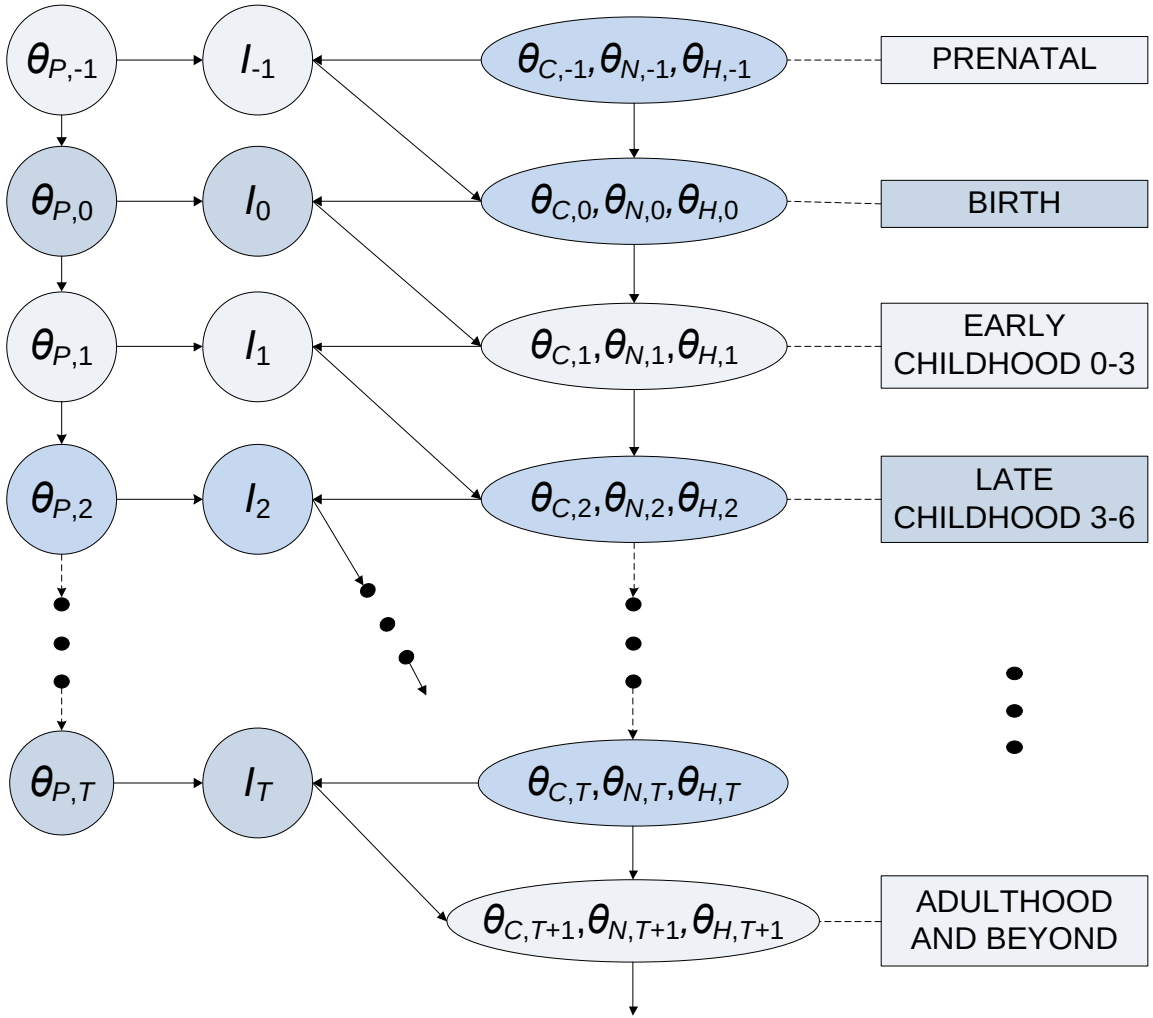

- Agent born with initial conditions: θ_0.
- This can be influenced by family investment (also has genetic component).
- The **technology of production of skill** when the child is t years-old:

$$\theta_{t+1} = f_t(\theta_t, I_t, \theta_{P,t}), \qquad t = 1, \ldots, T. \tag{7}$$

$\uparrow$

parental environmental variables

affect productivity of investment

- *Dynamic complementarity* arises when

$$\frac{\partial^2 f_t\left(\theta_t, I_t, \theta_{P,t}\right)}{\partial \theta_t \partial I_t'} > 0.$$

- Two distinct ideas:
  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*:

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

- This includes own and cross effects.
(*Cross complementarity of capabilities*)

- This technology describes learning in rodents and macaques as documented, respectively, by Meaney (2001), Cameron (2004), and Knudsen (2006).
- Early parental emotional environments encourage the animals to explore (and learn) more.
- This technology also captures the critical and sensitive periods in humans and animals.

1. Critical and sensitive periods for investment:
   - i. If
   $$\frac{\partial f_t(\theta_t, I_t, \theta_{P,t})}{\partial I_t} = 0 \qquad \text{for } t \neq t^*$$
   t^* is the critical period for that investment.
   - ii. 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.

- Special cases of the technology:
  - Ontogenic models:

$$\theta_{t+1} = f_t(\theta_t, I_t, \theta_{P,t}) = f_t(\theta_{P,0}, \theta_0), \quad \forall t \geq 0$$

    (initial conditions fully determinative, no investment, no feedback, Nagin-Tremblay).
  - Initially-determined trajectories fully determine life cycle evolution ("Types" as in Keane and Wolpin, 1997).
  - More general models feature adaptive responses of parents and environments to current states facing agents.

- It is important for policy purposes to know at which stage of the life cycle which interventions are the most effective.
- To account for the full life cycle of skill formation not just focus on one stage.
- To move beyond correlations between early life and later life events — to understand the mechanisms of capability formation.

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

I_t: investment at t

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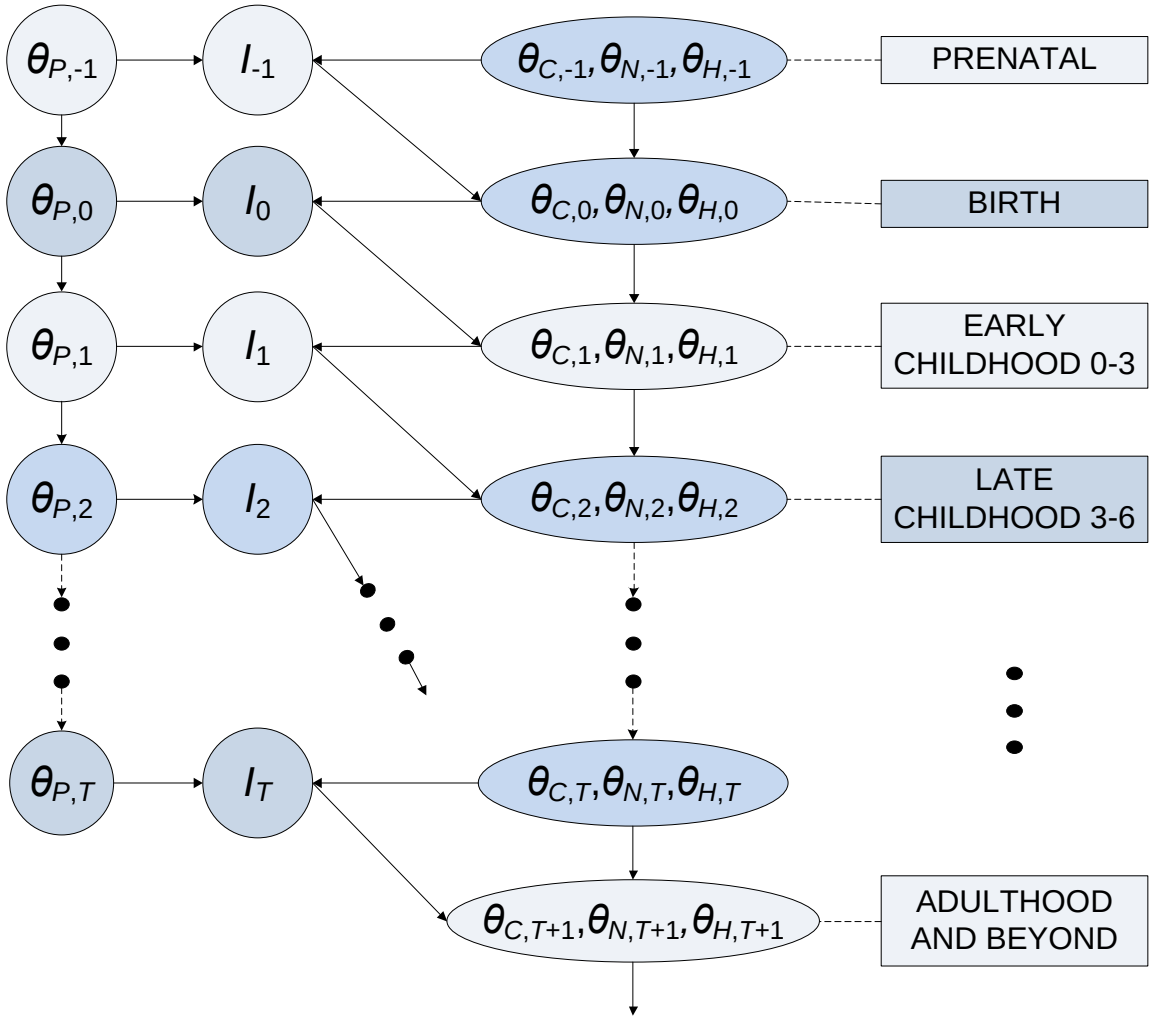


Stylized Model of Parental Investment

Cunha and Heckman (2007, 2009)

- One child families
- Multiple periods as adults and as children
- Parental altruism over child and adult outcomes
- Parents face different constraints
  - i Inability of the family to borrow against future income of child
  - ii Inability of parents to borrow against their own future income
- Consider a model with 2 periods of childhood
- Let I_1, I_2 be parental investment in period 1 (early childhood) and period 2 (later childhood)
- Let θ_t be a scalar
- Solve technology recursively

- *Final Form* of the Model of the Evolution of Skills

$$\theta_3 = M_2(\underbrace{I_2, \quad I_1}_{\substack{\text{investments} \\ \text{(determined} \\ \text{by parents)}}}, \quad \underbrace{\theta_0}_{\substack{\text{initial} \\ \text{conditions} \\ \text{of child}}})$$

- Two polar cases:
  - A Perfect substitutes

$$\theta_3 = M_2\left(\gamma I_1 + (1-\gamma) I_2, \theta_0\right)$$
$$0 \leq \gamma \leq 1$$

    Becker-Tomes case implicitly assumes this case with $\gamma = \frac{1}{2}$.

  - B Perfect complements

$$\theta_3 = M_2\left(\min(I_1, I_2), \theta_0\right)$$

Dual Face of Complementarity

- Complementarity has a dual face.
- It is essential to invest early to get satisfactory adult outcomes.
- But it is also essential to invest late to harvest the fruits of the early investment.

- More General Case

$$\theta_3 = M_2\left(\left[\gamma I_1^{\phi} + (1-\gamma)(I_2)^{\phi}\right]^{\frac{1}{\phi}}, \theta_0\right) \qquad \phi \leq 1, 0 \leq \gamma \leq 1$$

- γ is a *skill multiplier* (How early investments percolate through life)
- $\sigma = \frac{1}{1-\phi}$ is a measure of how easy it is to substitute between I_1 and I_2 (A measure of the cost of compensation for early disadvantage)
- Technology explains why returns to education are in adolescent years for disadvantaged (low I_1)

Optimal Investment Strategies for $\phi = 1$ (perfect substitutes)

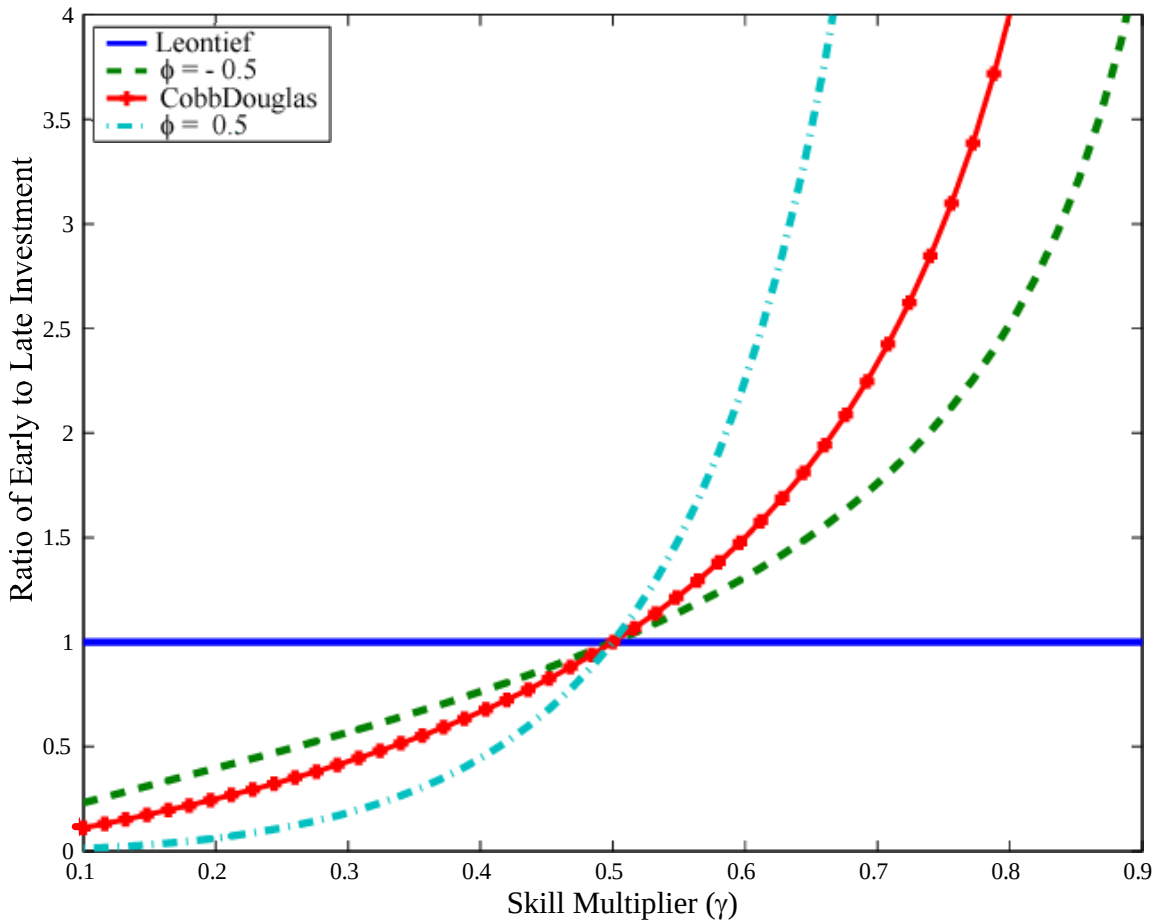
- When $\phi = 1$, early and late investments are perfect CES substitutes, the optimal investment strategy is straightforward.
- The price of early investment is \$1.
- The price of late investment is $\$1/(1 + r)$.
- Productivity of early investment: γ; late investment $(1 - \gamma)$.
- Invest early if $\gamma > (1 - \gamma)(1 + r)$

General Case

- For $-\infty < \phi < 1$, the first-order conditions are necessary and sufficient given concavity of the technology in terms of I_1 and I_2.
- $-\infty < \phi < 1$:

$$\frac{I_1}{I_2} = \left[\frac{\gamma}{(1-\gamma)(1+r)}\right]^{\frac{1}{1-\phi}}. \tag{8}$$

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, 2009).

Alternative Market Environments (Analyzed in Cunha and Heckman, 2007, AER)

- Parents cannot borrow against future income of children.
  - i Reduces I_1 and I_2, but by a common proportion.
  - ii Does not affect optimal I_1/I_2.
- Parents cannot borrow against their own future income.
  - i Reduces I_1 and I_2.
  - ii Affects I_1/I_2, in a fashion consistent with the evidence under investment in I_1 relative to I_2 in disadvantaged families.
  - iii Can be undone (over a range) by parental substitution of their own consumption over time.

Estimating and Interpreting the Estimates of the Technology of Skill Formation

- Cunha and Heckman (2008) and Cunha, Heckman, and Schennach (2010) estimate versions of the technology of skill formation. (Dynamic state space models)
- Can identify the technology under many different credit market structures.

- Econometric challenges in analyzing longitudinal data sets of child interventions and child quality
  - a. Multiplicity of measured inputs and measured outputs: need to summarize
  - b. Measurement error in inputs and outputs (we only have proxies)
  - c. Endogeneity of Investment and hence stocks of skills
  - d. Omitted inputs
  - e. Need to go beyond the linear technology to capture the notion of substitution between early and late.
  - f. Output as measured by test scores is meaningless.
    - i. Any monotonic function of a test score is still a test score.
    - ii. "Value-added" measures, widely used, are arbitrarily and potentially very misleading.
    - iii. Need to *anchor* outcomes in real behavior.

Findings from Nonlinear Model (Cunha et al., 2010)

- The major findings from analyses of models with two skills that control for measurement error and endogeneity of inputs are:
  a. Self-productivity becomes stronger as children become older, for both cognitive and noncognitive skill formation (i.e., $\frac{\partial \theta_{t+1}}{\partial \theta_t} \uparrow t$).
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- (c) ($\sigma_C \doteq 0.3$) It is more difficult to compensate for the effects of adverse environments on cognitive endowments at later ages than it is at earlier ages. This pattern of the estimates helps to explain the evidence on ineffective cognitive remediation strategies for disadvantaged adolescents.
- (d) Complementarity between noncognitive skills and investments becomes slightly *weaker* as children become older.

- It is easier (less costly) at *later* stages of childhood to remediate early disadvantage using investments in noncognitive skills.
- Noncognitive traits promote the accumulation of cognitive traits (but not vice versa).
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- 34% of the variation in educational attainment in the sample is explained by the measures of cognitive and noncognitive capabilities.
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- 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.

The Importance of Early Life Conditions in Explaining the Variability in Adult Outcomes: Role of Luck in Adult Life

- Big role for "*luck*."
- But big role for investment and family influence.
- 50-60% of the variance in lifetime income determined by factors present at the time college-going decisions are being made (Cunha et al., 2005; Hoffman, 2010; Yaron et al., 2010)

Integrating Family Intervention Studies With Family Influence Studies: Beyond Treatment Effects

- Understanding mechanisms producing treatment effects
- Understanding how interventions supplement, complement, or substitute for family investments
- Many experiments that target early childhood—some long running (e.g., Perry Preschool)
- Evidence that they are effective (rate of return is 7–10%), and a primary channel of influence is through noncognitive skills — personality
  (Heckman, Malofeeva, et al., 2008; revised 2011).

- Technology of skill formation allows economists to integrate diverse studies through their effects on θ_t
  a. Can model interaction of parental investment with governmental investments: components may be perfect substitutes or not.
  b. Identify different technologies (public and private) that produce θ_t.

Example:

- I_t^G: government investment
- I_t^F: private (family) investment
- Government technology: $f^G(\theta_t, \theta_t^P, I_t^G, I_t^F, \theta_{P,t})$
- Family technology: $f^F(\theta_t, \theta_t^P, I_t^P, I_t^G, \theta_{P,t})$

One Specification:

- $\theta_{t+1} = f^G(\theta_t, \theta_t^P, I_t^G, I_t^P, \theta_{P,t}) + f^F(\theta_t, \theta_t^P, I_t^P, I_t^G, \theta_{P,t})$
- Family chooses a technology to minimize the cost of achieving a given level of capabilities.

An Alternative Specification:

- Families may have multiple private technologies, as well as government technology, and choose to use least cost envelope of parental technologies.
- Studies under way doing this (Moon, Pinto, et al., 2011)
- Can establish the channels through which government (external) investment promotes capabilities.
- Can determine the capabilities that each technology produces

Behavioral Genetics

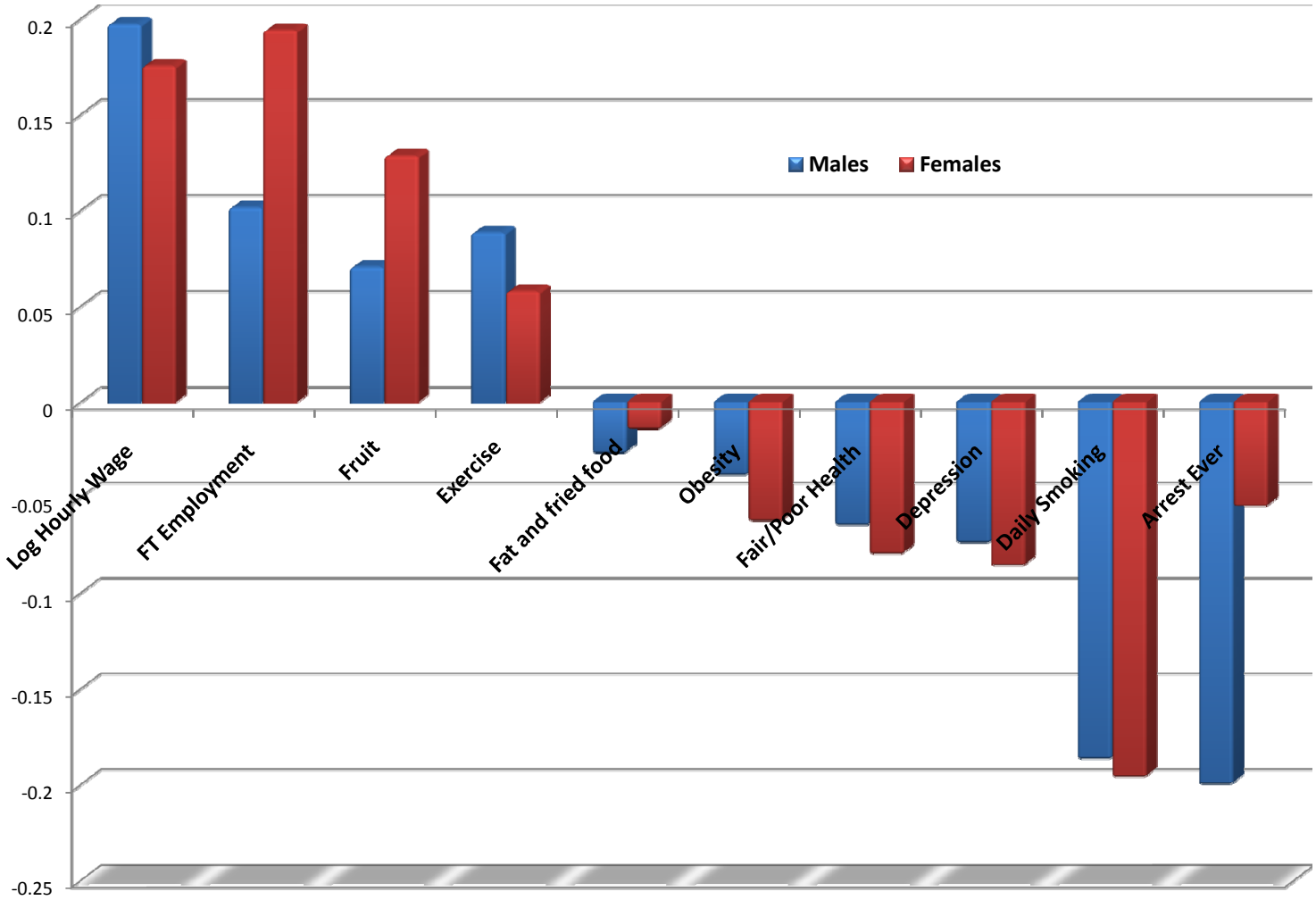
- Does the family do anything besides pass on its genes?
- Epigenetics: Judith Rich Harris, Turkheimer, and beyond
- An influential line of argument that has to be taken seriously because it is so widespread
- Experimental interventions that supplement family life show that we can boost θ_t by interventions (surrogate parenting)
- Kruger (2011)

Evidence from Studies Applying This Framework

Conti, Heckman, and Urzua (2012)

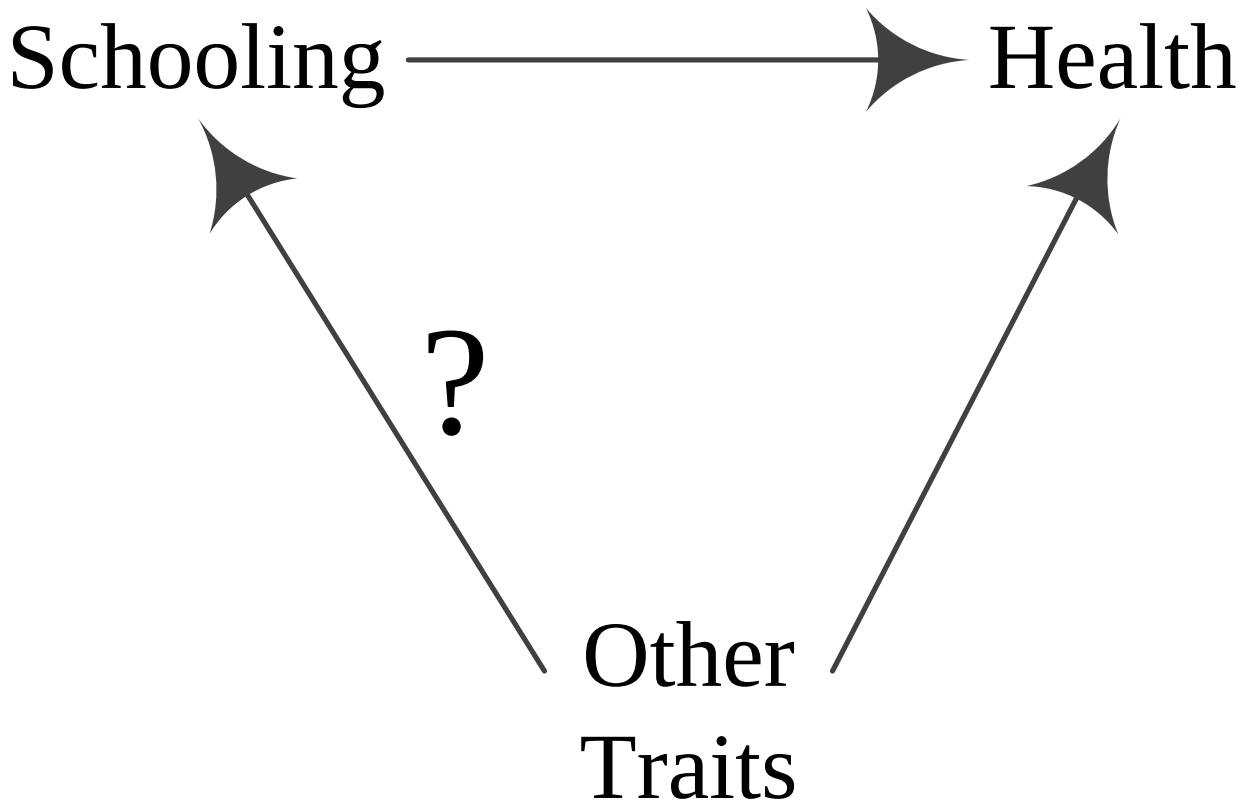
- UK Data

Disparities by Education



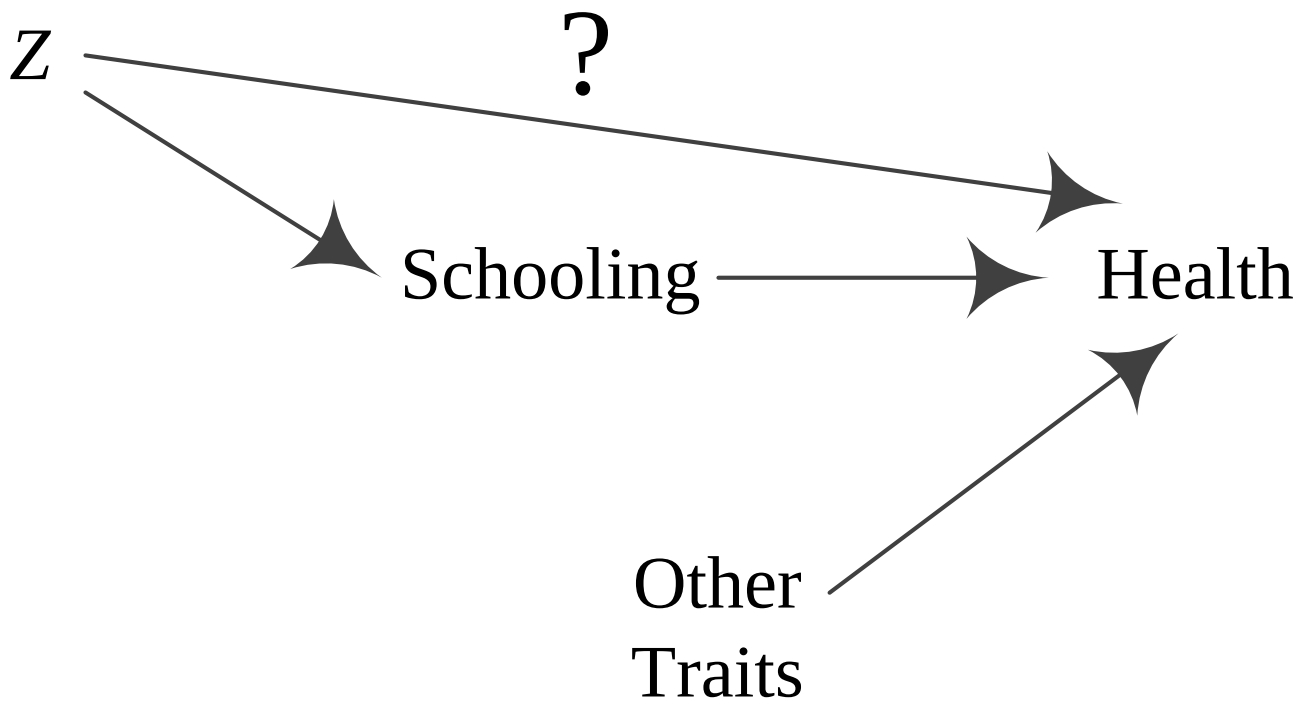
Note: U.K. Data: Authors' calculations using BCS70. The graph shows the raw differentials in the outcomes between individuals with post-compulsory and compulsory level of education. Source: Conti, Heckman and Urzua (2012).

Inferring Causation



Search for causality: Two strategies

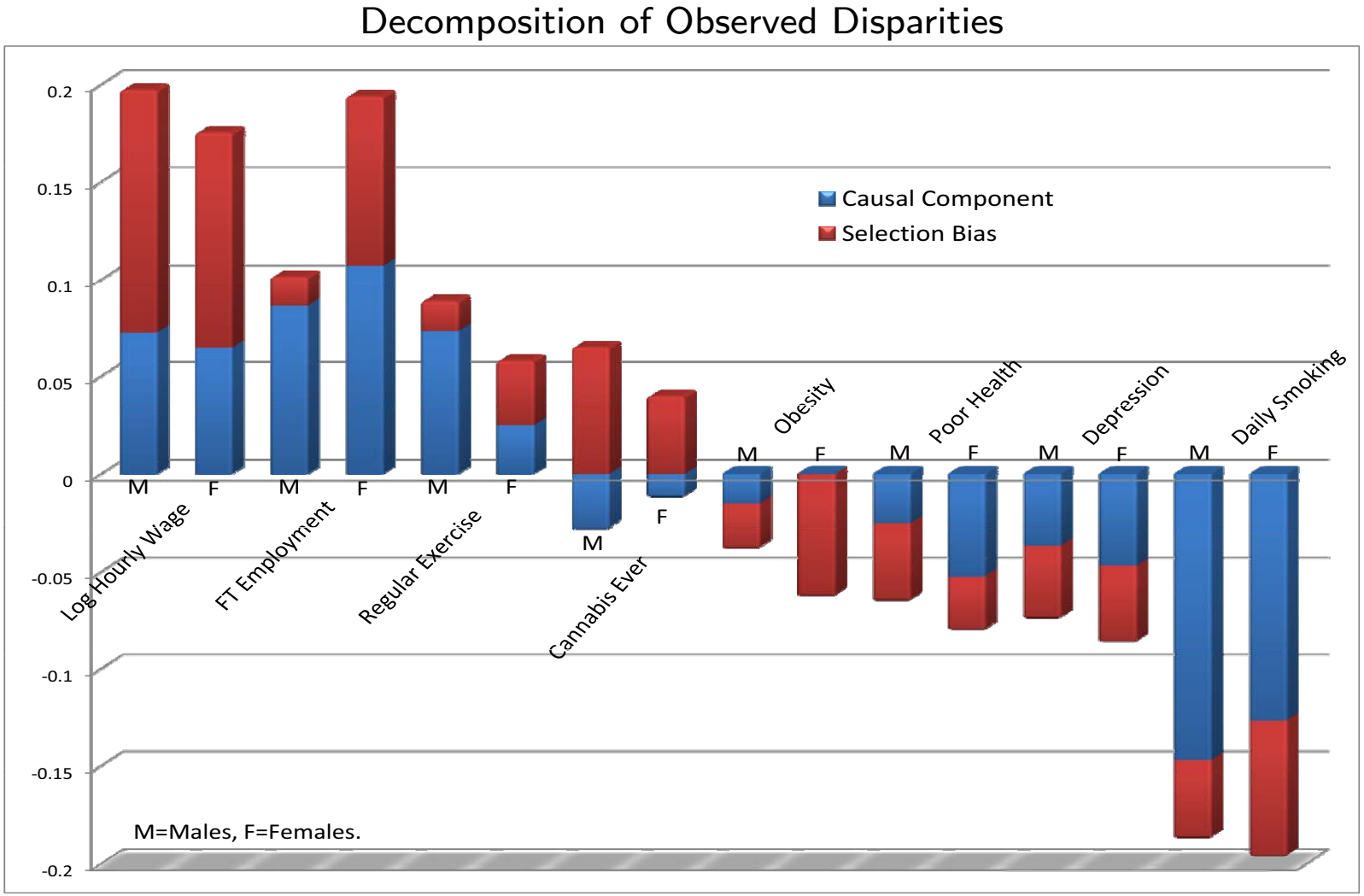
- Instruments Z



Random assignment is an instrument

- Control for "other traits" or proxies for "other traits."
  - Matching assumes we can perfectly proxy the "relevant" other traits (traits that affect schooling and health).
  - Our approach does *not* make the strong assumptions of matching.
  - Allows for matching on mismeasured variables (Heckman, Schennach, and Williams, 2011).

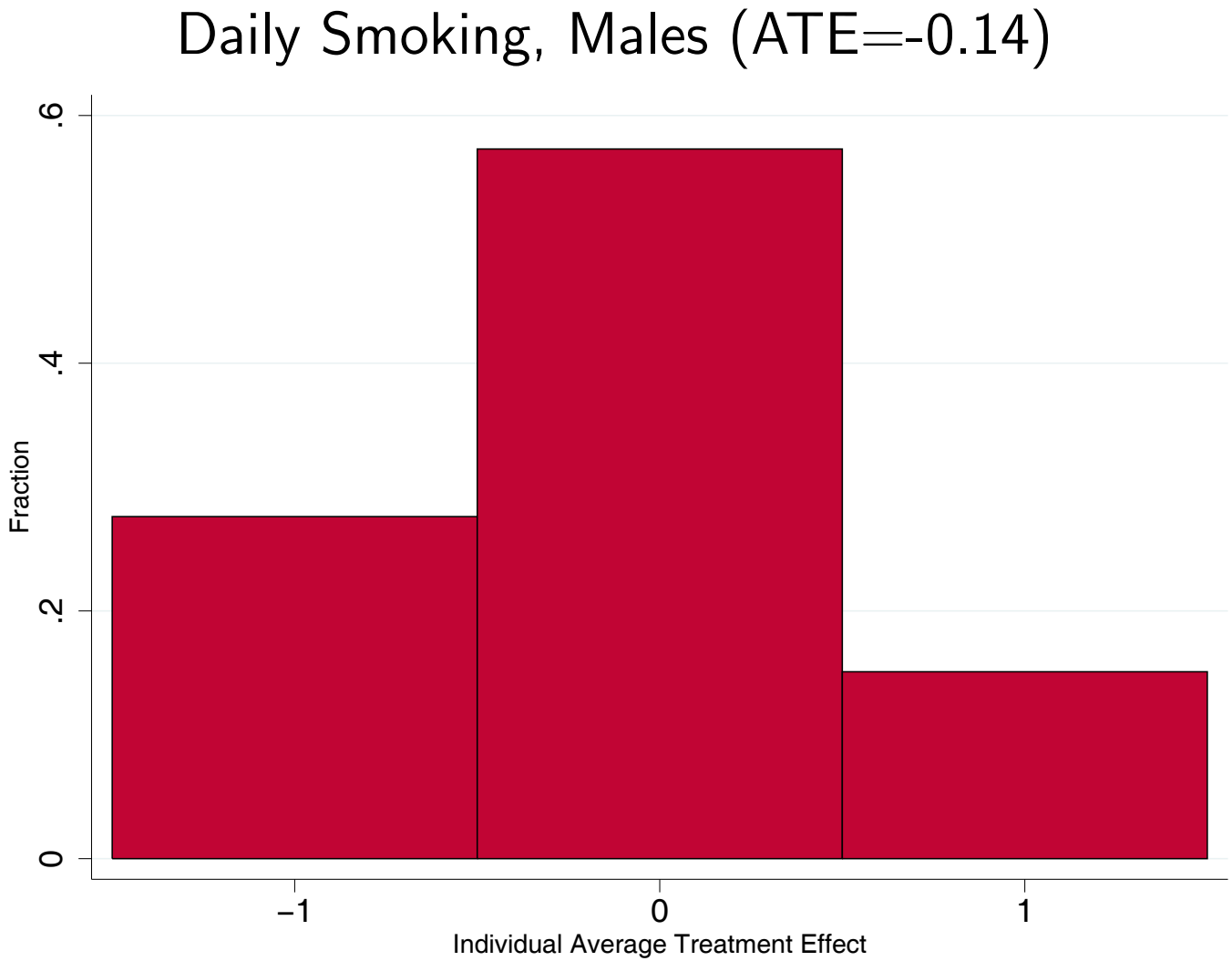
The Causal Effect of Education



Distributional Treatment Effects: Does everybody benefit?

- We also identify **the joint distribution** of the treatment effects.

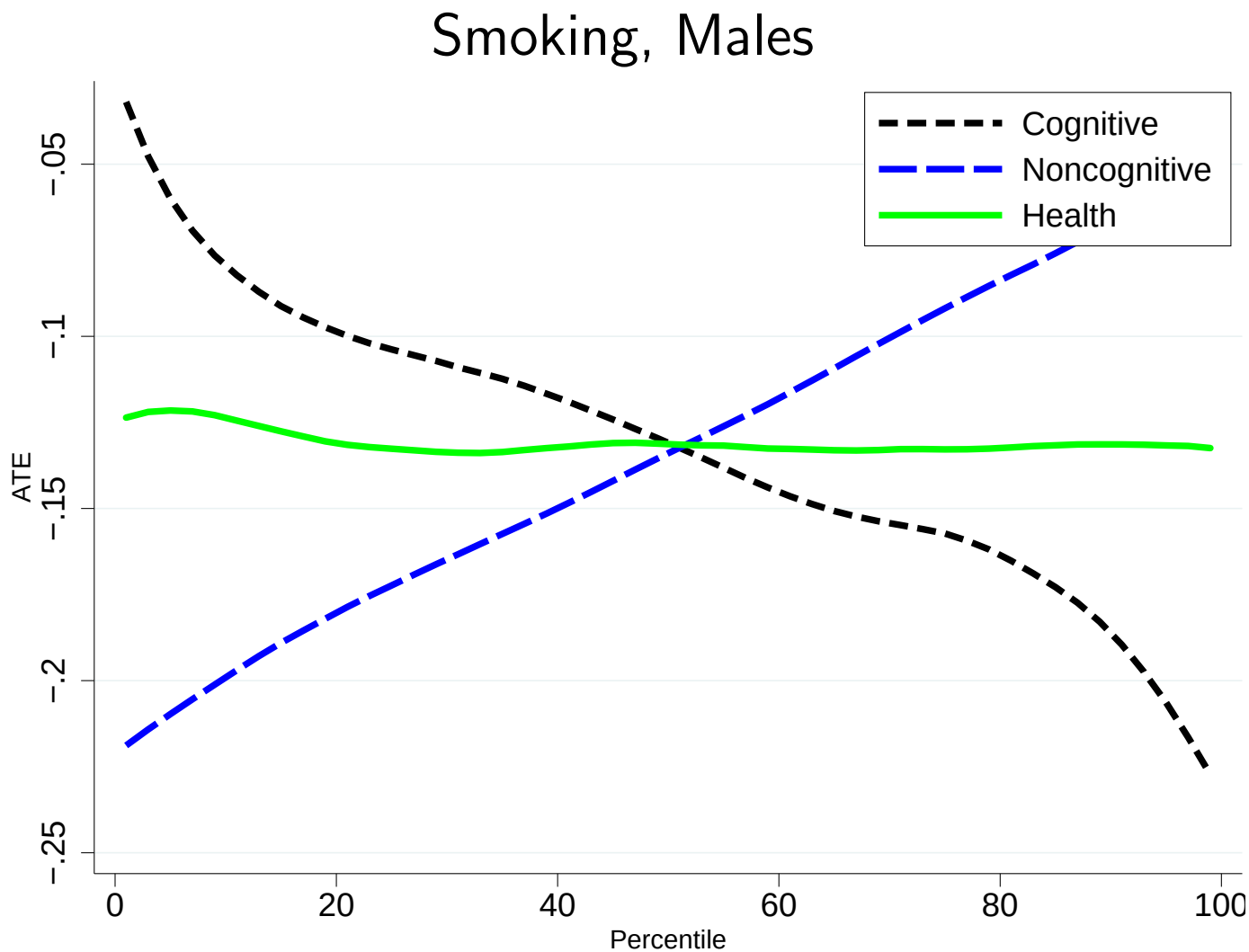
Distribution of Average Treatment Effects



- Behind the ATE, there are gains and losses for different individuals.

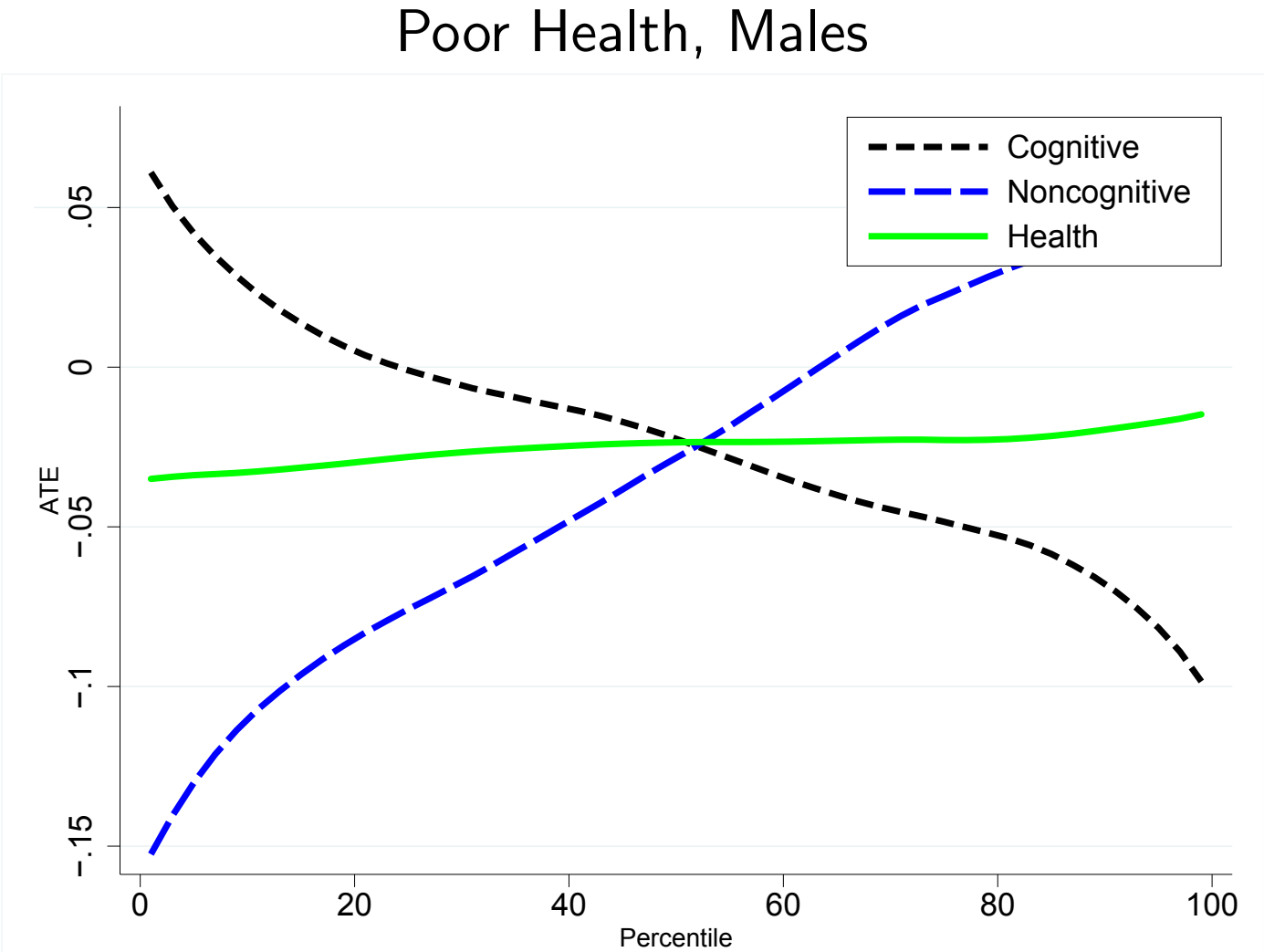
Who benefits?

Treatment Effect Heterogeneity



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

Treatment Effect Heterogeneity

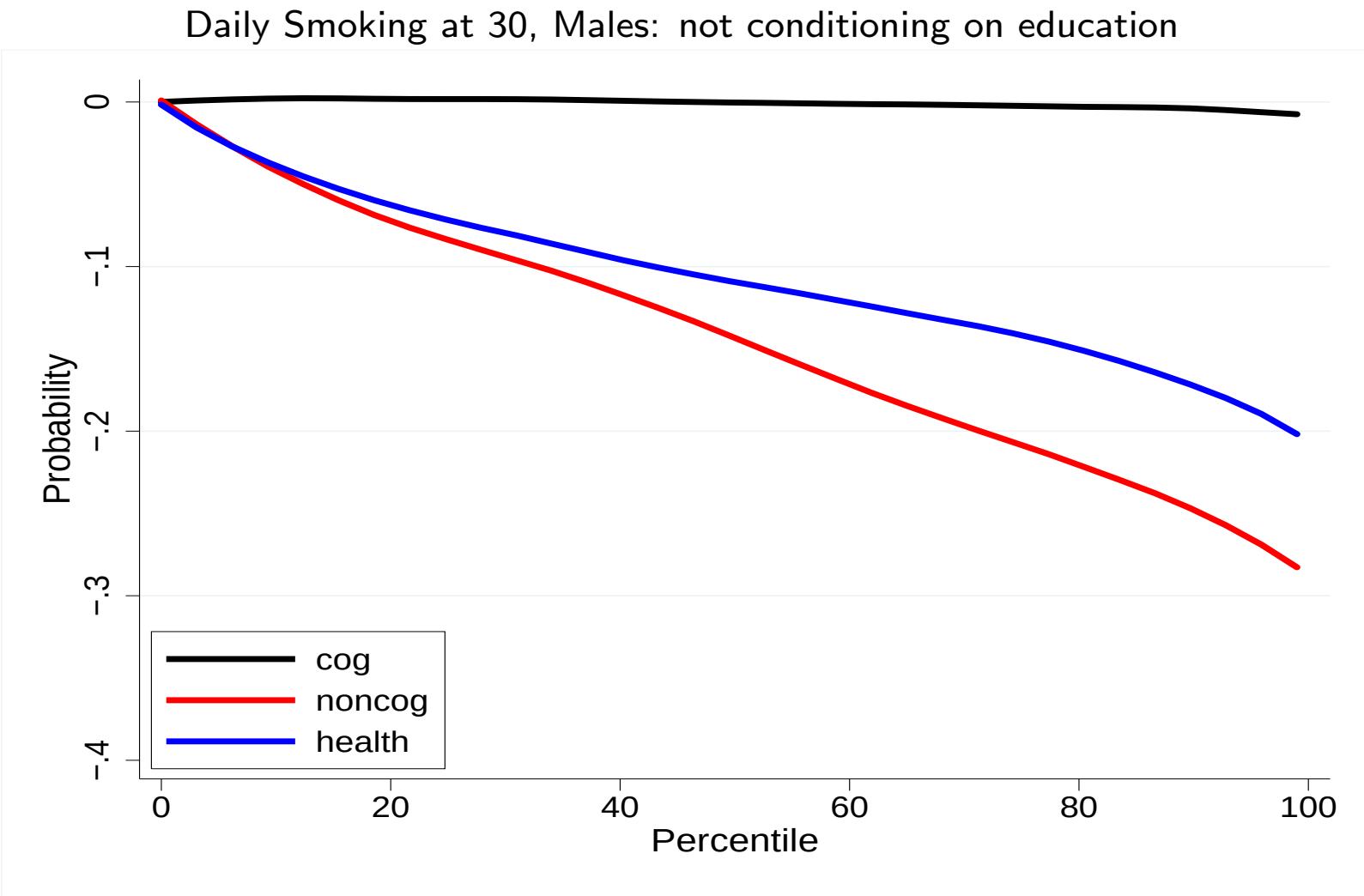


- Education compensates for low early noncognitive endowments and reinforces high early cognitive endowments.

The Role of Factors up to Age 10

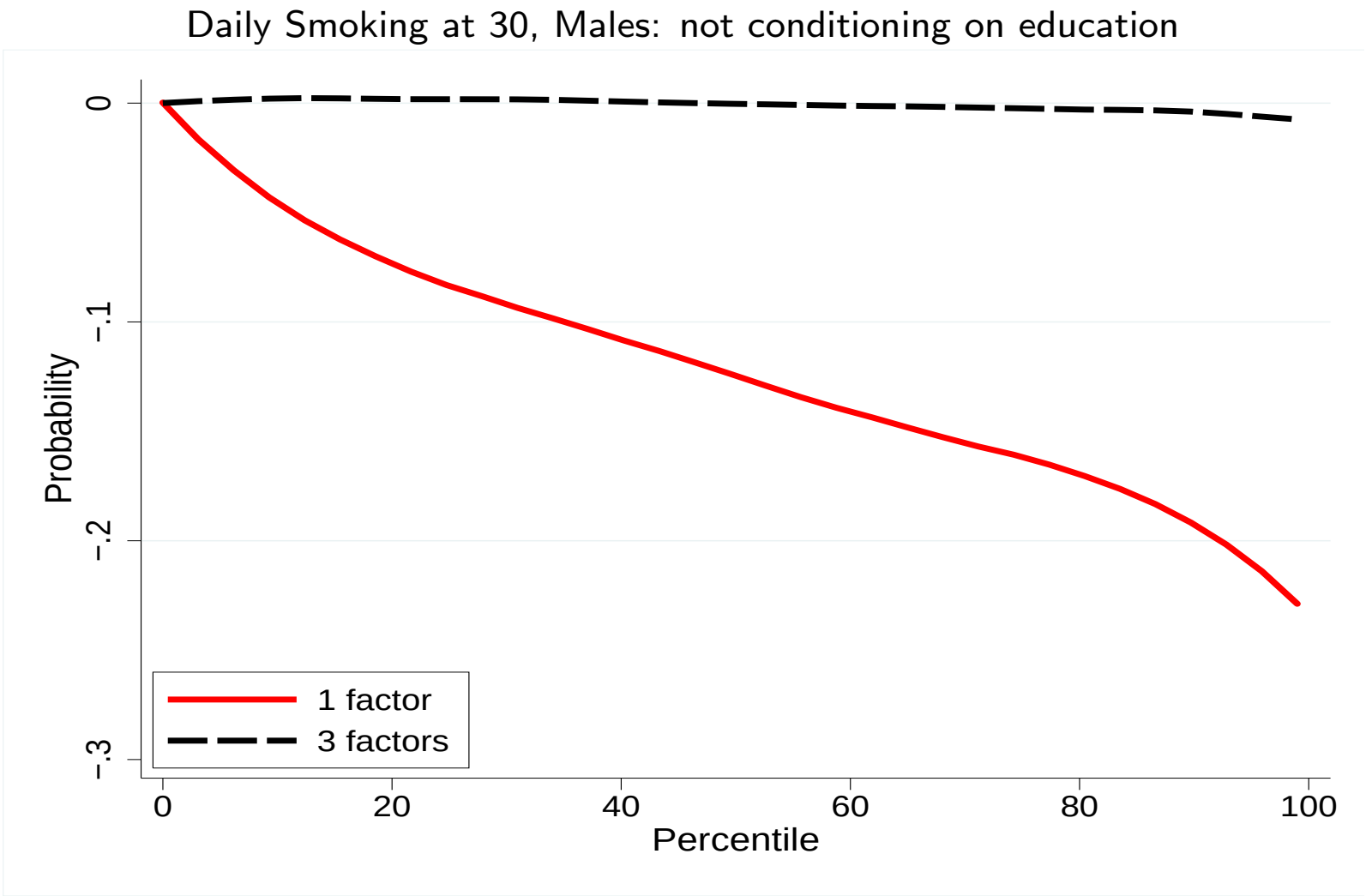
- Cognitive ability has a significant effect on health and health behaviors if self-regulation is not included in the model.

The Role of Factors up to Age 10



- Both self-regulation and physical health are equally important determinants of smoking.

The Role of Factors up to Age 10

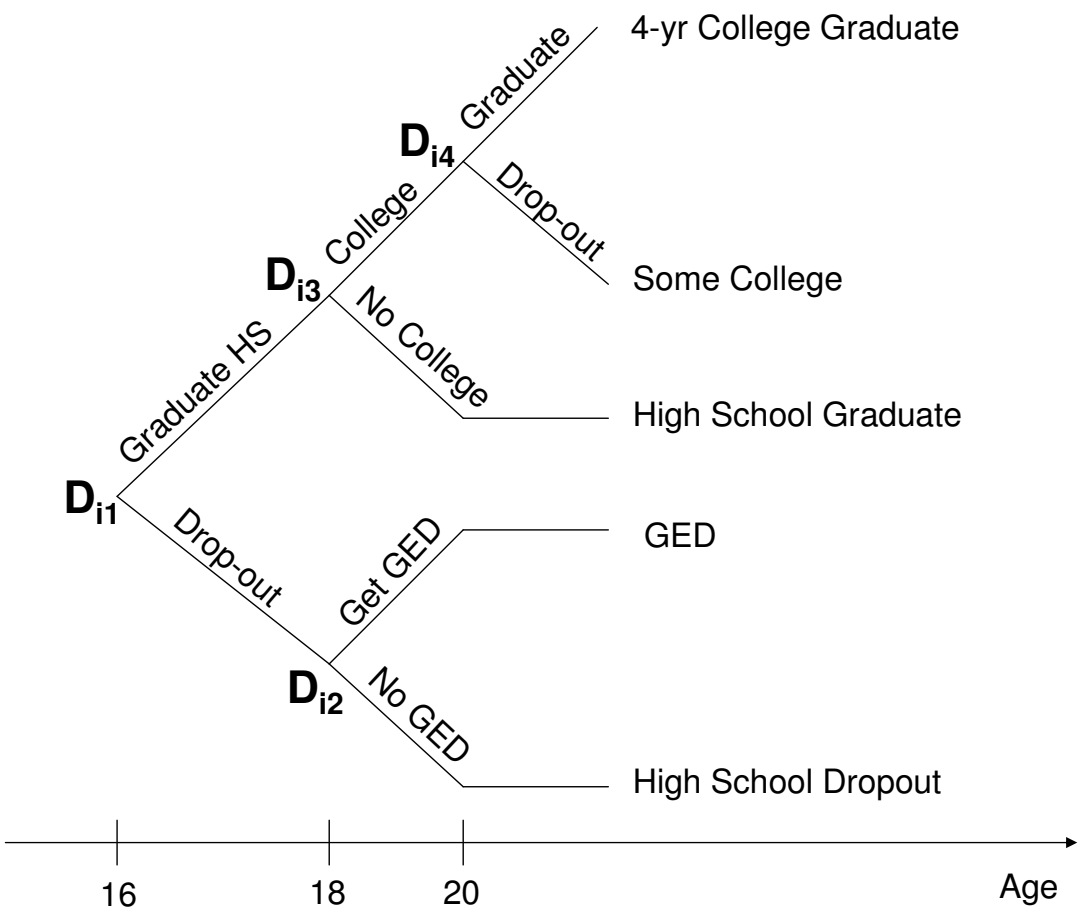


- But not accounting for them *overestimates* the importance of cognition.

Data: The National Longitudinal Survey of Youth (NLSY79) (Heckman, Humphries, Urzua, and Veramendi, 2011)

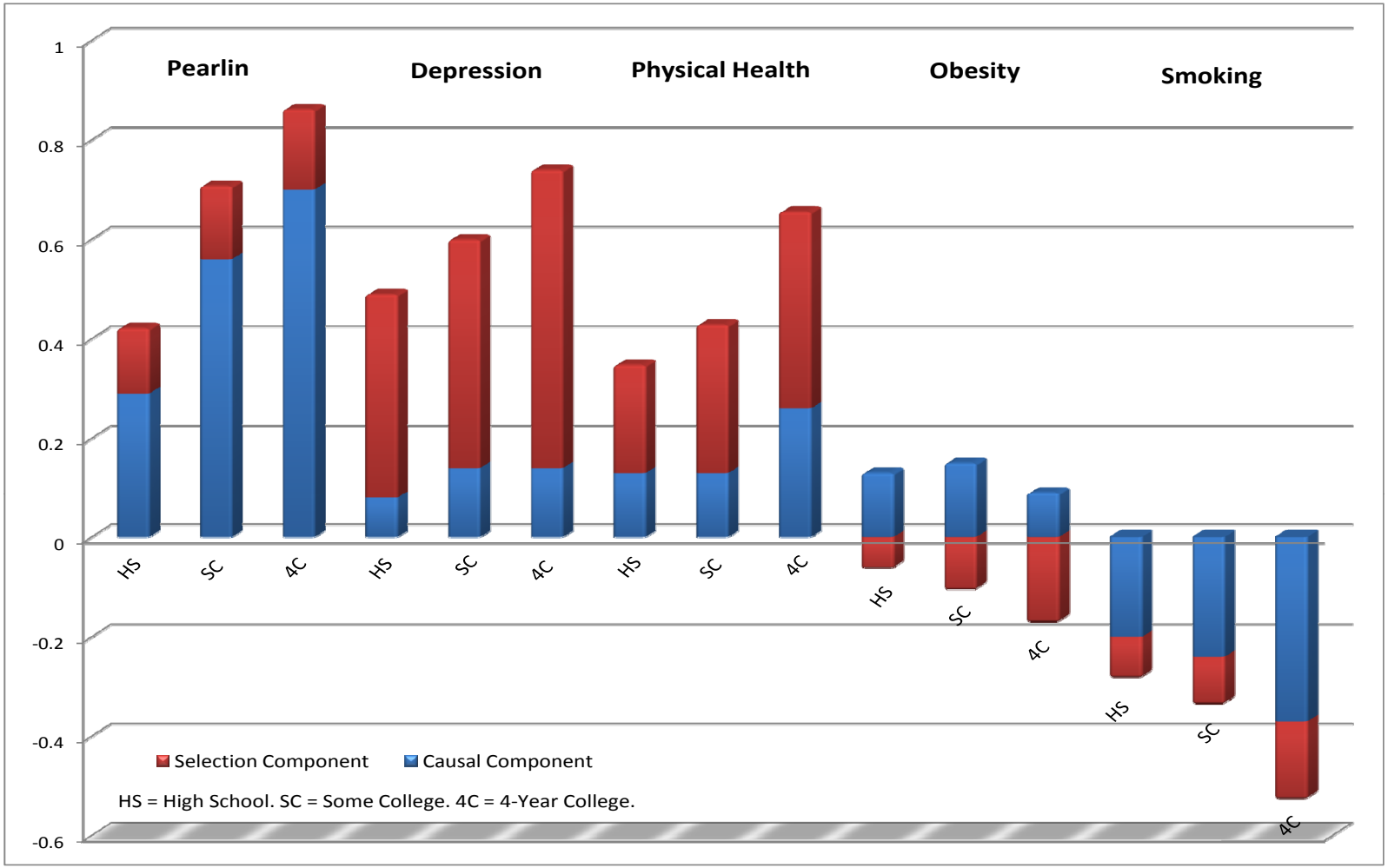
- U.S. Data
- Nationally representative sample of men and women aged 14-22 when first interviewed in 1979.
- Education: sequential model with five final schooling levels: high school dropout, GED, high school graduate, some college, four year college degree.
- Outcomes (age 30):
  1. labor market (wages and employment)
  2. health status (obesity, PCS-12 scale, MCS-12 scale, Pearlin, CESD)
  3. health behaviors (smoking, regular exercise, drinking)
- Measurements (age 14-15):
  1. θ_C: ASVAB components of the AFQT
  2. θ_N: 9^{th} grade GPA in reading social studies, science and math, as well as early measured behaviors.

Figure 24: Sequential model for schooling decisions.



Decomposition of Mean Differences

Pairwise comparisons of a terminal education level to being a dropout



Heckman, Humphries, Urzua, and Veramendi (2011).

Summary

1. Multiple capabilities matter in producing successful lives.
2. Gaps in capabilities across socioeconomic groups open up early — before school starts
3. Capabilities not set in stone or solely genetically determined. They interact with investment to create future capabilities.
4. Evidence of the effectiveness of different interventions at different stages of the life cycle.
5. Early conditions matter but are not fully determinative.
6. Resilience to early life adversity.

7. Compensation partly effective.
8. Multiple sources of data helpful.
9. Longitudinal data — whether experimental or not are essential.
10. No primacy of methodology — experiments not necessarily the "gold standard".
11. Need to go beyond treatment effects to understand mechanisms.
12. Technology of capability formation is a vehicle for doing so.

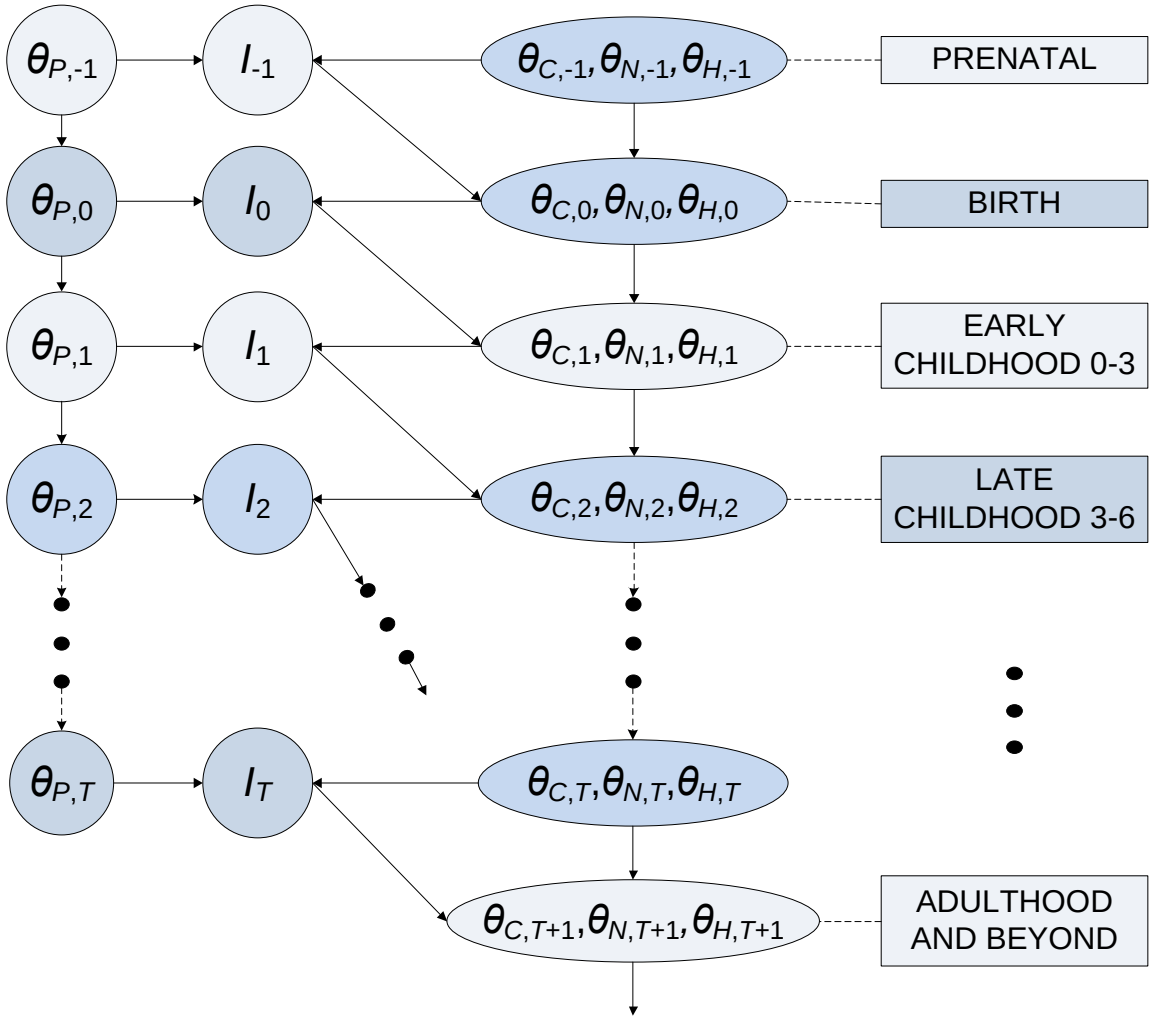
A Life Cycle Framework for Organizing Studies and Integrating Evidence

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

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

I_t: investment at t

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



Appendix

Example From Cunha et al. (2007, 2009)

- Individual lives $2T$ years. $(T \geq 2)$
- The first T years, the individual is a child of an adult parent.
- From age $T+1$ to $2T$ the individual lives as an adult and is the parent of a child.
- The individual dies at the end of the period in which he is $2T$ years-old, just before his child's child is born.

- A household consists of an adult parent and his child.
- Parents invest in their children because of altruism.
- I_t: parental investments in child skill when the child is t years-old, where $t = 1, 2, \ldots, T$.
- The output of the investment process is a skill vector.

Preferences and the Optimal Life-Cycle Profile of Investments

- Assume $T = 2$; stationary environment. (Two periods of childhood)
- w: wage rate
- r: interest rate
- At the beginning of adulthood, the parents draw the initial level of skill of the child, θ_1, from $J(\theta_1)$, which they can influence through investment.

- On reaching adulthood, parents receive bequest b.
- 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 life cycle of the child.
- The budget constraint is:

$$c_1 + I_1 + \frac{c_2 + I_2}{(1+r)} + \frac{b'}{(1+r)^2} = wh + \frac{wh}{(1+r)} + b. \qquad (9)$$

- β: discount factor
- δ: measure of parental altruism toward the child.
- $\eta(\cdot)$ is the one period utility function.
- Problem of the parent:

$$V(h, b, \theta_1) = \max \left\{ \eta(c_1) + \beta \eta(c_2) + \beta^2 \delta E \left[V\left(h', b', \theta_1'\right) \right] \right\}. \tag{10}$$

An Informative Special Case

- Assume θ_1, I_1, I_2 are scalars.
- The child's adult stock of skills, h':

$$h' = m_2\left(h, \theta_1, I_1, I_2\right). \tag{11}$$

- Conventional specification of technology (11) implicit in one-period models:

$$\begin{aligned} h' &= m_2\left(h, \theta_1, \gamma I_1 + (1-\gamma) I_2\right) \qquad (12) \\ \gamma &= 1/2. \end{aligned}$$

- Adult stocks of skills do not depend on how investments are distributed over different periods of childhood.

- Polar opposite:

$$h' = m_2 \left(h, \theta_1, \min \left\{ I_1, I_2 \right\} \right). \tag{13}$$

- Adult stocks of skills critically depend on how investments are distributed over time.
- If investments in period one are zero, $I_1 = 0$, then it does not pay to invest in period two.
- If late investments are zero, $I_2 = 0$, it does not pay to invest early.

Dual Face of Complementarity

- Complementarity has a dual face.
- It is essential to invest early to get satisfactory adult outcomes.
- But it is also essential to invest late to harvest the fruits of the early investment.

- More general technology:

$$h' = m_2\left(h, \theta_1, \left[\gamma\left(I_1\right)^{\phi} + \left(1-\gamma\right)\left(I_2\right)^{\phi}\right]^{\frac{1}{\phi}}\right), \tag{14}$$

  for $\phi \leq 1$ and $0 \leq \gamma \leq 1$.
- The CES share parameter γ is *a skill multiplier*.
- It arises from the productivity of early investment not only in directly boosting h' (through self-productivity) but also in raising the productivity of I_2 by increasing θ_2 through first period investments.
- Thus I_1 directly increases θ_2 which in turn affects the productivity of I_2 in forming h'.
- γ captures the net effect of I_1 on h' through both self-productivity and direct complementarity.

- Elasticity of substitution $1/(1-\phi)$ is a measure of how easy it is to substitute between I_1 and I_2.
- ϕ represents the degree of complementarity (or substitutability) between early and late investments in producing skills.
- When ϕ is small, low levels of early investment I_1 are not easily remediated by later investment I_2 in producing human capital.
- The other face of CES complementarity is that when ϕ is small, high early investments should be followed with high late investments if the early investments are to be harvested.
- In the extreme case when $\phi \to -\infty$, (14) converges to (13).

- This technology explains why returns to education are low in the adolescent years **for disadvantaged** (low h, low I_1, low θ_2) adolescents but are high in the early years.
- In the one-period model of childhood, inputs at any stage of childhood are perfect substitutes.
- Application of the one period model supports the widely held but empirically unsupported intuition that diminishing returns make investment in less advantaged adolescents *more* productive.

Optimal Investment Strategies for $\phi = 1$ (perfect substitutes)

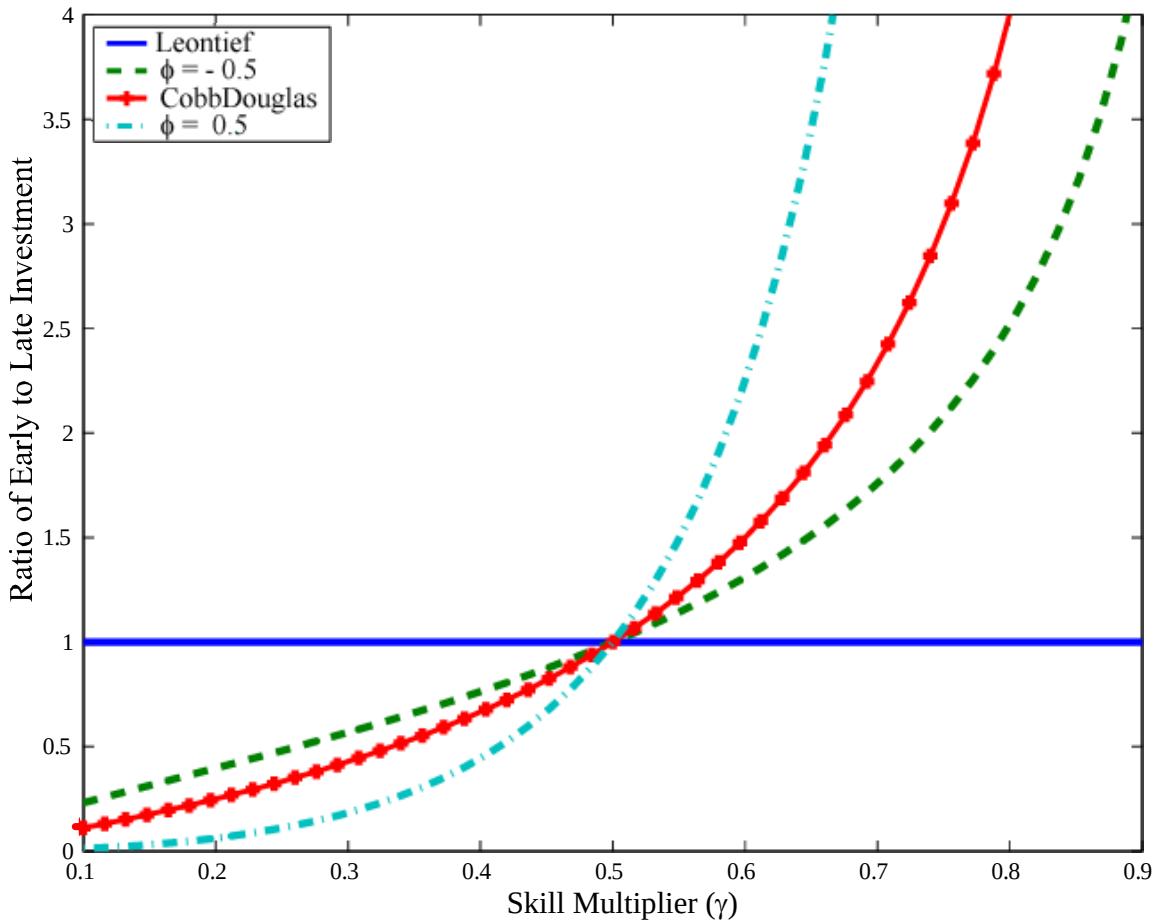
- When $\phi = 1$, early and late investments are perfect CES substitutes, the optimal investment strategy is straightforward.
- The price of early investment is \$1.
- The price of late investment is $\$1/(1 + r)$.
- Productivity of early investment: γ; late investment $(1 - \gamma)$.
- Invest early if $\gamma > (1 - \gamma)(1 + r)$

General Case

- For $-\infty < \phi < 1$, the first-order conditions are necessary and sufficient given concavity of the technology in terms of I_1 and I_2.
- $-\infty < \phi < 1$:

$$\frac{I_1}{I_2} = \left[\frac{\gamma}{(1-\gamma)(1+r)}\right]^{\frac{1}{1-\phi}}. \tag{15}$$

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, 2009).

Alternative Market Environments

- In a complete-market model, optimal investment levels do not depend on the parental permanent shocks to wages or endowments or the parameters that characterize the utility function $\eta(\cdot)$.
- Even in this "perfect" credit market setting, parental investments depend on parental skills, h, because these characteristics affect the returns to investment.
- (But not other features of the model.)
- This generalizes Becker-Tomes (1980) and shows the fundamental role of parental influence.
- From the point of view of the child, this is a market failure due to the accident of birth.

Constraints on Borrowing Across Generations

- Suppose parents cannot borrow against child's future earnings. (Becker-Tomes, 1986)
- A second credit constraint: the parental bequests must be non-negative and parents only have access to of a risk-free bond, and not to contingent claims.
- The problem of the parent is to maximize (10) subject to (9), the technology (14), and the liquidity constraint:

$$b' \geq 0. \tag{16}$$

- If binding, realized investment $\hat{I}_j$ less than optimal I_j^*
  $\hat{I}_1 \leq I_1^*$ (unconstrained), $\hat{I}_2 \leq I_2^*$ (unconstrained)
- Under liquidity constraints actual investment $\hat{I}_1 < I_2^*$ is lower than the early investment under the perfect credit market model, I_1^*, and $\hat{I}_2 < I_2^*$.
- Under this formulation of market incompleteness, underinvestment in skills starts at early ages and continues throughout the life cycle of the child.
- **Lower investment in both periods $does\ not$ affect $ratio$ of investments** (I_1/I_2)**.**

- Both early and late investments depend on parental initial wealth b for the families for whom the constraint (16) binds.
- Children who come from constrained families with lower b will have lower early *and* late investments.
- Interventions that occur at early stages would exhibit high returns, especially if they are followed up with resources to supplement late investments.

Parents Themselves Face Lifetime Liquidity Constraints

- Cunha and Heckman (2007).
- Parents are subject to lifetime liquidity constraints and constraints that prevent the parents from borrowing against their own future labor income, which may affect their ability to finance investments in the child's early years.
- Assume that parents' productivity grows exogenously at rate α.

- s: parental savings.
- Parents face a sequence of constraints at each stage of the life cycle of the child:

$$c_1 + I_1 + \frac{s}{(1+r)} = wh + b \tag{17}$$

$$c_2 + I_2 + \frac{b'}{(1+r)} = w(1+\alpha)h + s, \tag{18}$$

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

- The restriction $s \geq 0$ says that parents cannot borrow income from their old age to finance consumption and investment when the child is in the first stage of the life cycle.
- Some parents may be willing to do this, especially when α is high.
- In the case when $s \geq 0$ and $b' \geq 0$ bind, and investments are not perfect substitutes, early income matters.

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

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

- Now, *ratios* of investment depend on parental preferences and endowments.
- If early income is low with respect to late income, the ratio I_1/I_2 will be lower than the optimal ratio.
- Tug of war between λ and ϕ.
- With sufficiently high λ (e.g. $\lambda = 1$), parental deferred consumption can compensate for early credit constraints.
- Estimates of Cunha, Heckman, and Schennach (2010) suggests $1/(1-\phi) = .\bar{3}$ ($\phi \doteq -2$), and Attanasio and Browning (1995) estimate $\lambda \in [-3, -1.5]$
- $(1-\lambda)/(1-\phi) \in [0.8\bar{3}, 1.\bar{3}]$. Family resource influence on investment.

- This analysis of credit constrained families joined with a low value of ϕ interprets the fact that the timing of family income in the early stages of childhood apparently affects the level of ability and achievement of the children, although there is still some controversy about the empirical importance of this effect.

Estimating and Interpreting the Estimates of the Technology of Skill Formation

- Cunha and Heckman (2008) and Cunha, Heckman, and Schennach (2010) estimate versions of the technology of skill formation. (Dynamic state space models)
- Can identify the technology under many different credit market structures.

- Econometric challenges in analyzing longitudinal data sets of child interventions and child quality
  a. Multiplicity of measured inputs and measured outputs: need to summarize
  b. Measurement error in inputs and outputs (we only have proxies)
  c. Endogeneity of Investment and hence stocks of skills
  d. Omitted inputs
  e. Need to go beyond the linear technology to capture the notion of substitution between early and late.
  f. Output as measured by test scores is meaningless.

Findings from Nonlinear Model (Cunha et al., 2010)

- The major findings from these analyses of models with two skills that control for measurement error and endogeneity of inputs are:
  a. Self-productivity becomes stronger as children become older, for both cognitive and noncognitive skill formation (i.e., $\frac{\partial \theta_{t+1}}{\partial \theta_t} \uparrow t$).
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- It is slightly easier at *later* stages of childhood to remediate early disadvantage using investments in noncognitive skills.
- Noncognitive traits promote the accumulation of cognitive traits (but not vice versa).
- This econometric evidence is consistent with a broad array of evidence from interventions studies on life cycle profile of rates of return.

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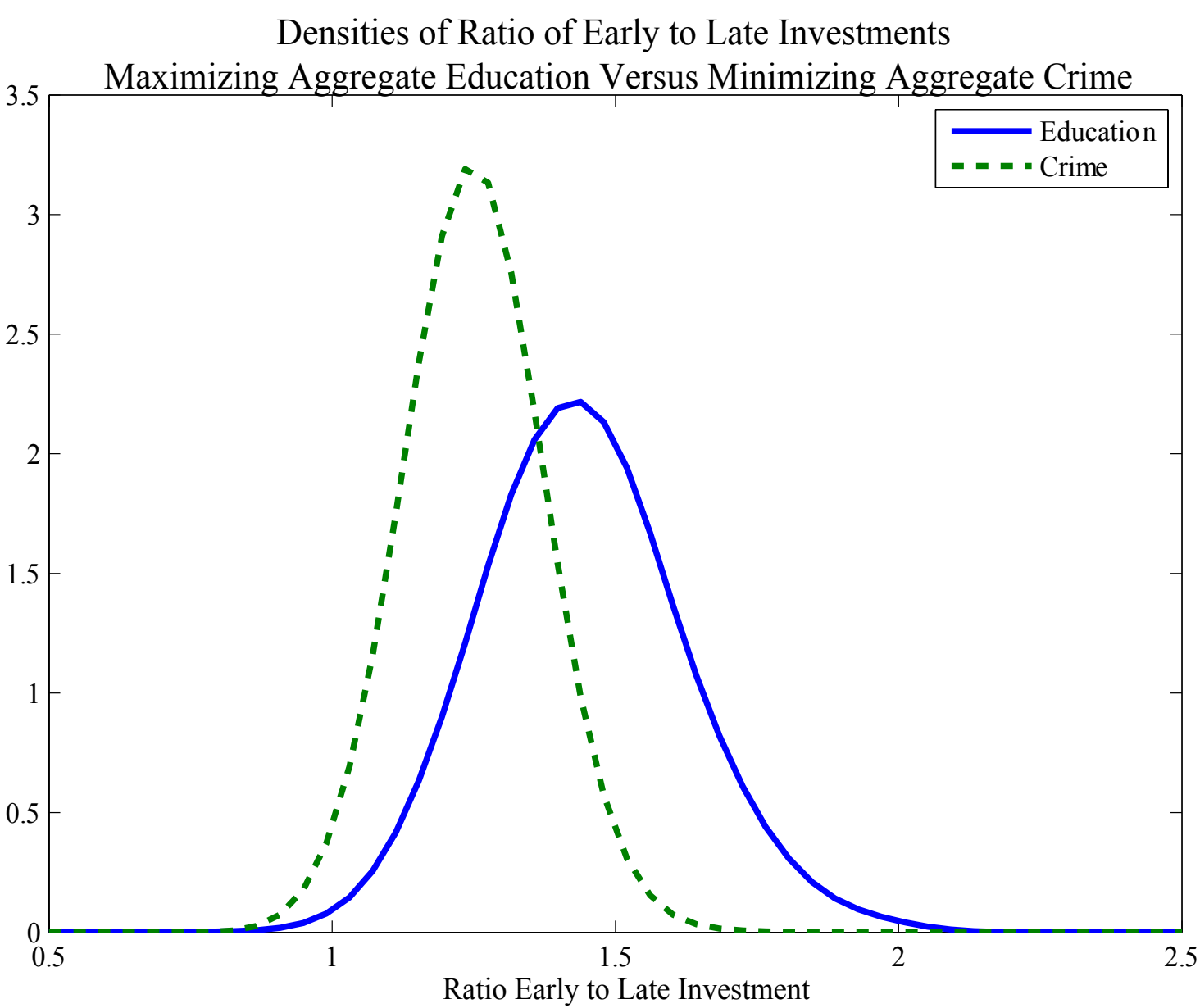
- These estimates suggest that the measures of cognitive and noncognitive capabilities are powerful, but not exclusive, determinants of educational attainment and that other factors, besides the measures of family investment that we use, are at work in explaining variation in educational attainment.

Some Implications for Policy

- Targeted strategies
- Arises 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.
- The opposite is true for cognitive skills.


Densities of Ratio of Early to Late Investments
Maximizing Aggregate Education Versus Minimizing Aggregate Crime
Education
Crime
3.5
3
2.5
2
1.5
1
0.5
0
0.5
1
1.5
2
2.5
Ratio Early to Late Investment

Estimating the Technology of Skill Formation

- Need to account for measurement error.
- Reverse causation and feedback.
- Nonlinear models to account for tradeoffs.
- Monotonic functions of many indicators are also valid indicators (No natural scale for many indicators.)
- Use state space methods

$$\theta_{t+1} = f_t(\theta_t, I_t, \theta_{P,t})$$
$$M^{\theta_t} = \mu_t^{\theta_t}(\theta_t, \epsilon_t^{\theta_t})$$
$$M^{I_t} = \mu_t^{I_t}(I_t, \epsilon^{I_t})$$
$$M^{\theta_{P,t}} = \mu^{\theta_{P,t}}(\theta_{P,t}, \epsilon_t^{\theta_{P,t}})$$

Measurement Error

- The share of error variance for proxies of cognition, personality and investment ranges from 1%–90%.
- Not accounting for measurement error produces downward-biased estimates of self-productivity effects and perverse estimates of investment effects.

Table 1: Share of Residual Variance in Measurements of Cognitive Skills Due to the Variance of Cognitive Factor (Signal) and Due to the Variance of Measurement Error (Noise)

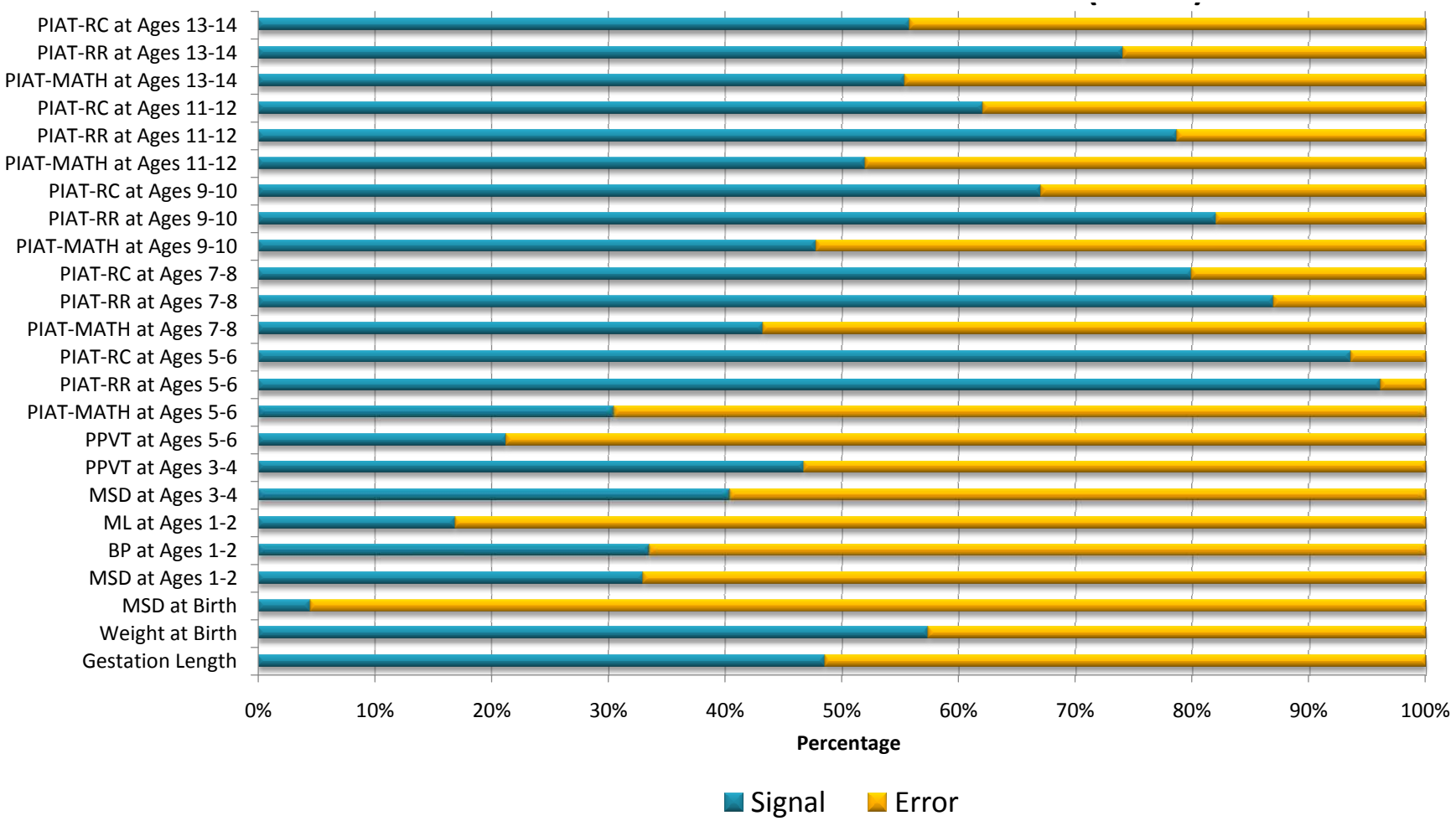
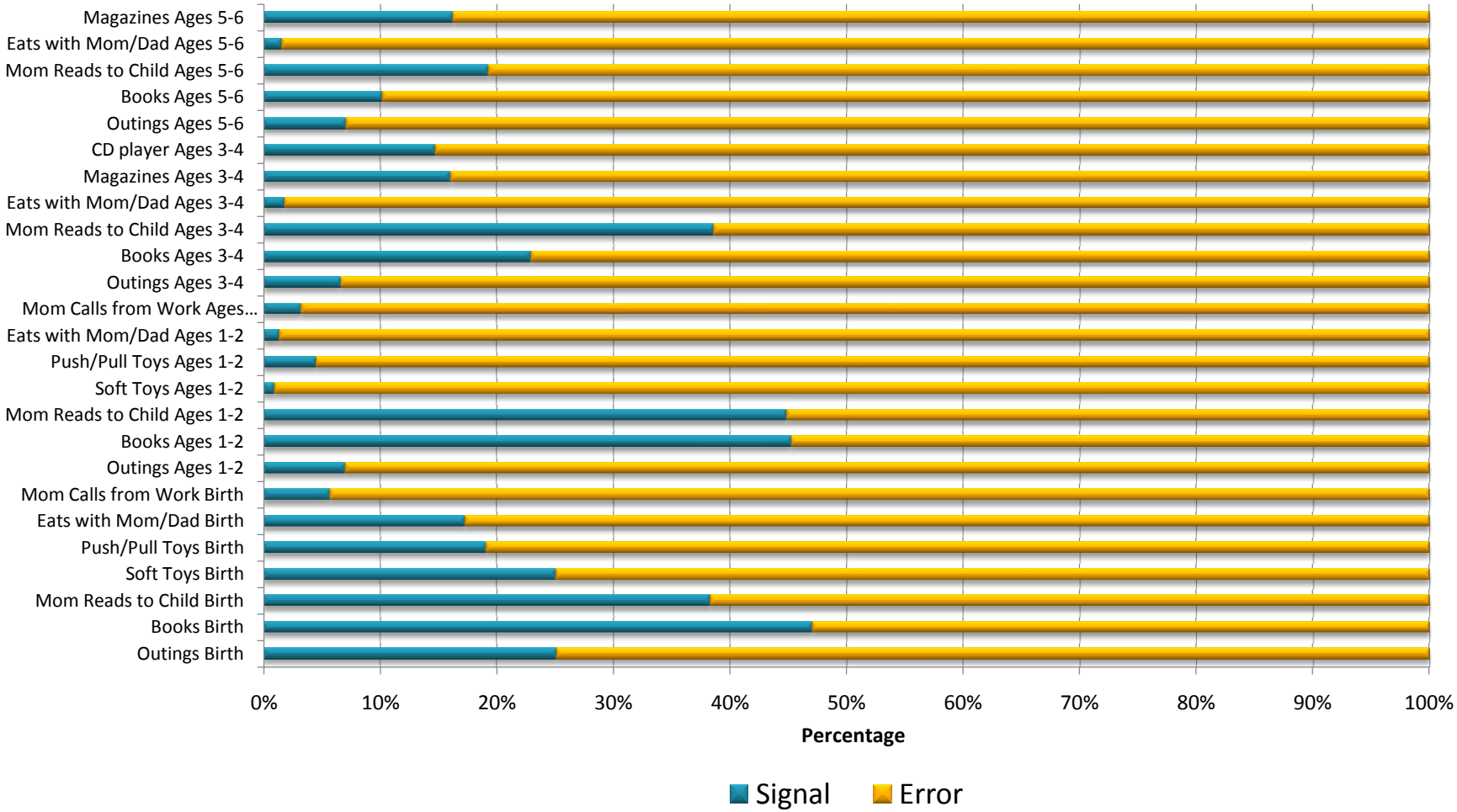


Table 2: Share of Residual Variance in Measurements of Investments Due to the Variance of Investment Factor (Signal) and Due to the Variance of Measurement Error (Noise)



Estimates from Nonlinear Technologies

- Cunha, Heckman, and Schennach (2010) estimate nonlinear technologies to identify key substitution parameters.
- These address the question of whether or not it is possible to remediate from early disadvantage.
- How costly is it to wait to address early disadvantage?

- A two-stage model of childhood ($L = 2$).
- Stage 1 is birth through age 4.
- Stage 2 corresponds to age 5 through 14.

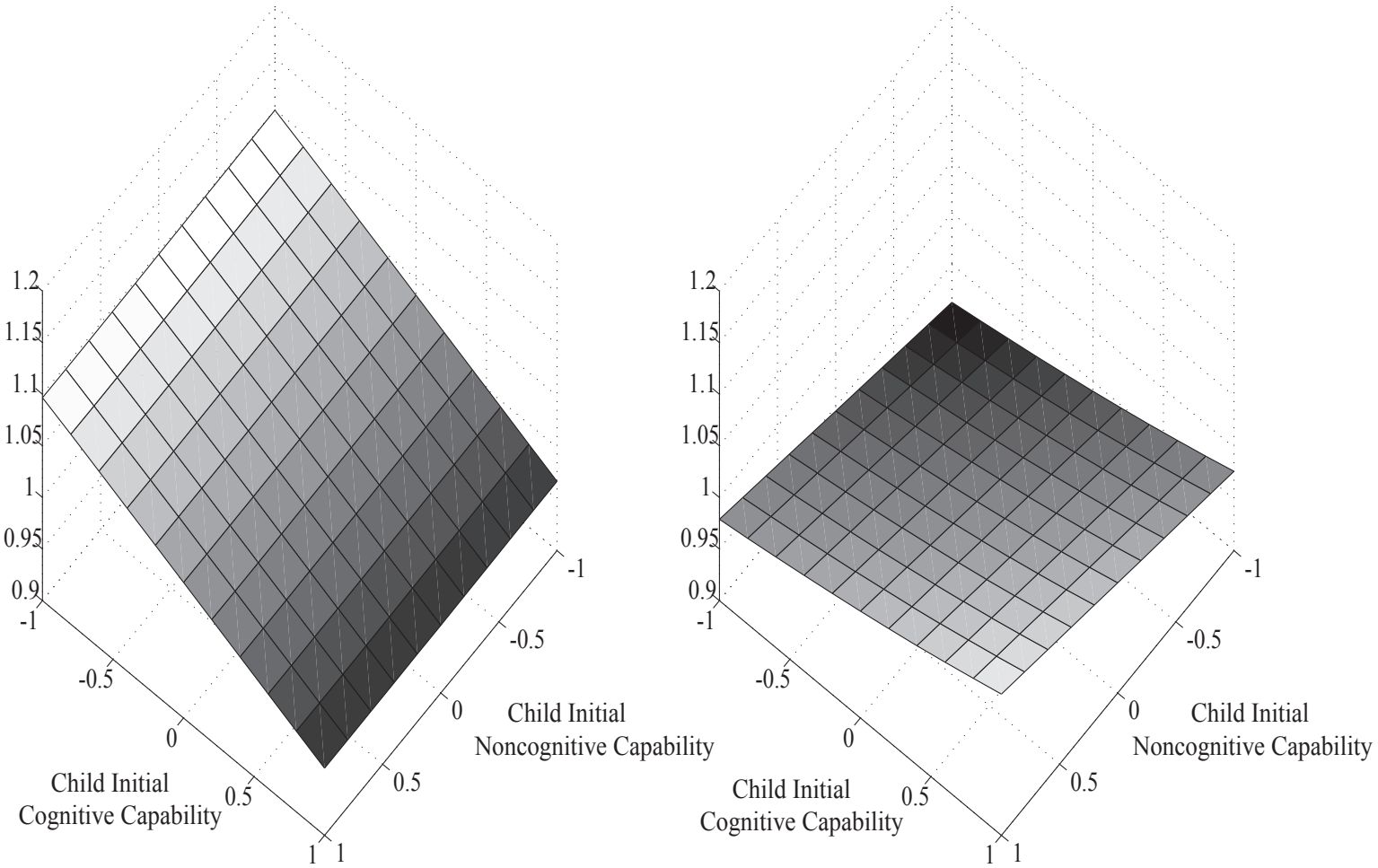
- The major findings are:
  (a) Self-productivity becomes stronger as children become older, for both cognitive and socioemotional capability formation.
  (b) It is more difficult to compensate for the effects of adverse environments on cognitive endowments at later ages than it is at earlier ages. This helps to explain the evidence on ineffective cognitive remediation strategies for disadvantaged adolescents.
  (c) It is **equally easy** to substitute at both stages for socioemotional skills over the life cycle.

- 34% of the variation in educational attainment is explained by the measures of cognitive and socioemotional capabilities that we use.
- Sixteen percent is due to adolescent cognitive capabilities.
- Twelve percent is due to adolescent socioemotional capabilities.
- Measured parental investments account for 15% of the variation in educational attainment.
- This has implications for policy forming capabilities.

The Implications of the Estimates for Policy

- Consider a policy for a social planner to optimize the stock of education in society.
- No consideration of social fairness or equality — just efficiency.
- Yet the optimal policy invests the most in the disadvantaged.

Figure 25: Optimal Early (Left) and Late (Right) Investments by Child Initial Conditions of Cognitive and Socioemotional Capabilities Maximizing Aggregate Education

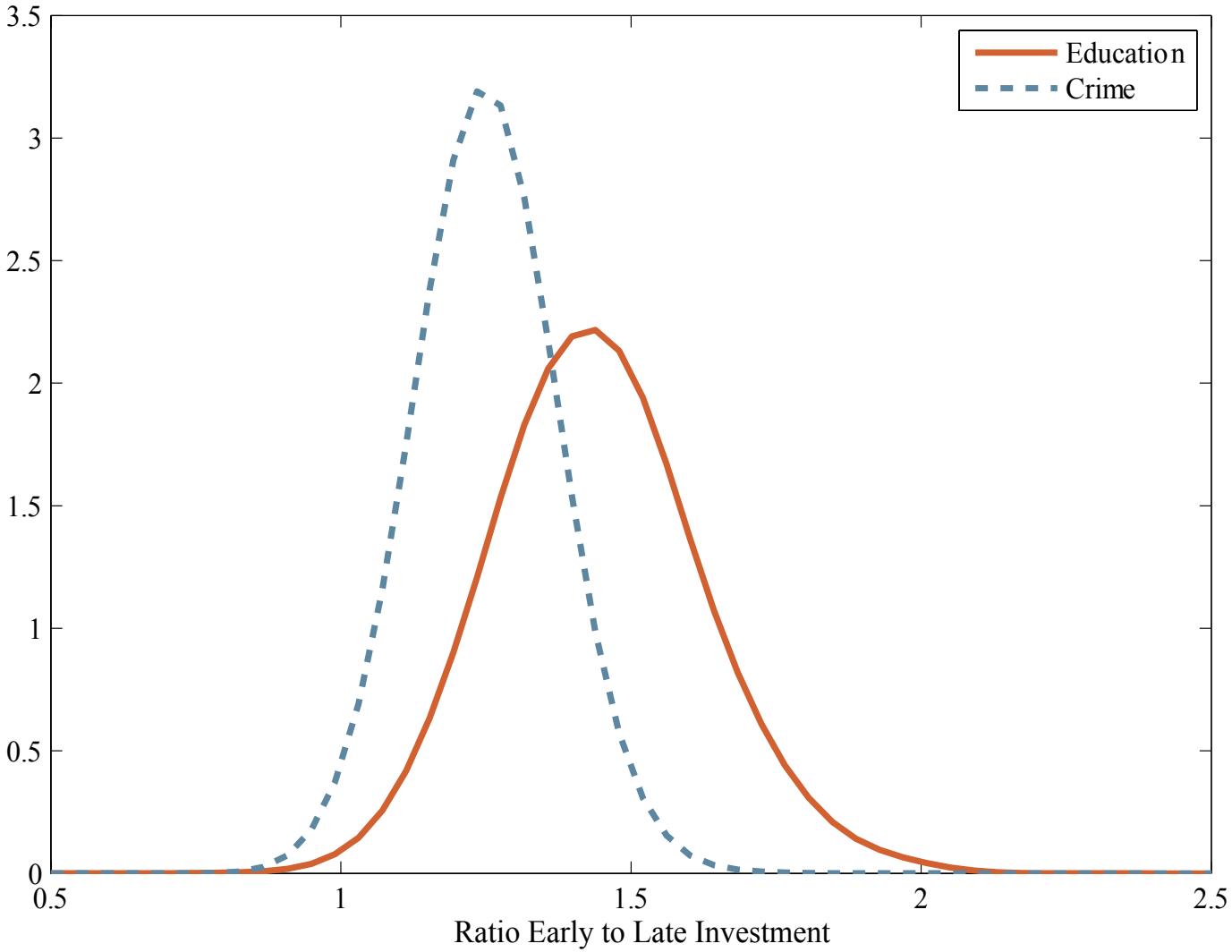


- For the most disadvantaged, the optimal policy is to invest a lot in the early years.

- Second period investment profiles are much flatter and slightly favor more advantaged children.
- This is a manifestation of the dynamic complementarity that produces an equity-efficiency tradeoff that characterizes later stage investment but not early investment.
- It is optimal to invest more in the second period of the lives of advantaged children than in disadvantaged children.
- A similar profile emerges for investments to reduce aggregate crime.

- The optimal ratio of early-to-late investment depends on the desired outcome, the endowments of children and budget B.
- Figure 26 plots the density of the ratio of early-to-late investment for education and crime.
- Crime is more intensive in socioemotional skill than educational attainment, which depends much more strongly on cognitive skills.
- Because compensation for adversity in socioemotional skills is less costly in the second period than in the first period, while the opposite is true for cognitive skills, it is optimal to weight first and second period investments in the directions indicated in the figure.

Figure 26: Densities of Ratio of Early to Late Investments Maximizing Aggregate Education versus Minimizing Aggregate Crime



- These simulations suggest that the timing and level of optimal interventions for disadvantaged children depend on the conditions of disadvantage and the nature of desired outcomes.
- Targeted strategies are likely to be effective especially for different targets that weight cognitive and socioemotional traits differently.

Addressing Health

What Is the Causal Effect of Education on Health?

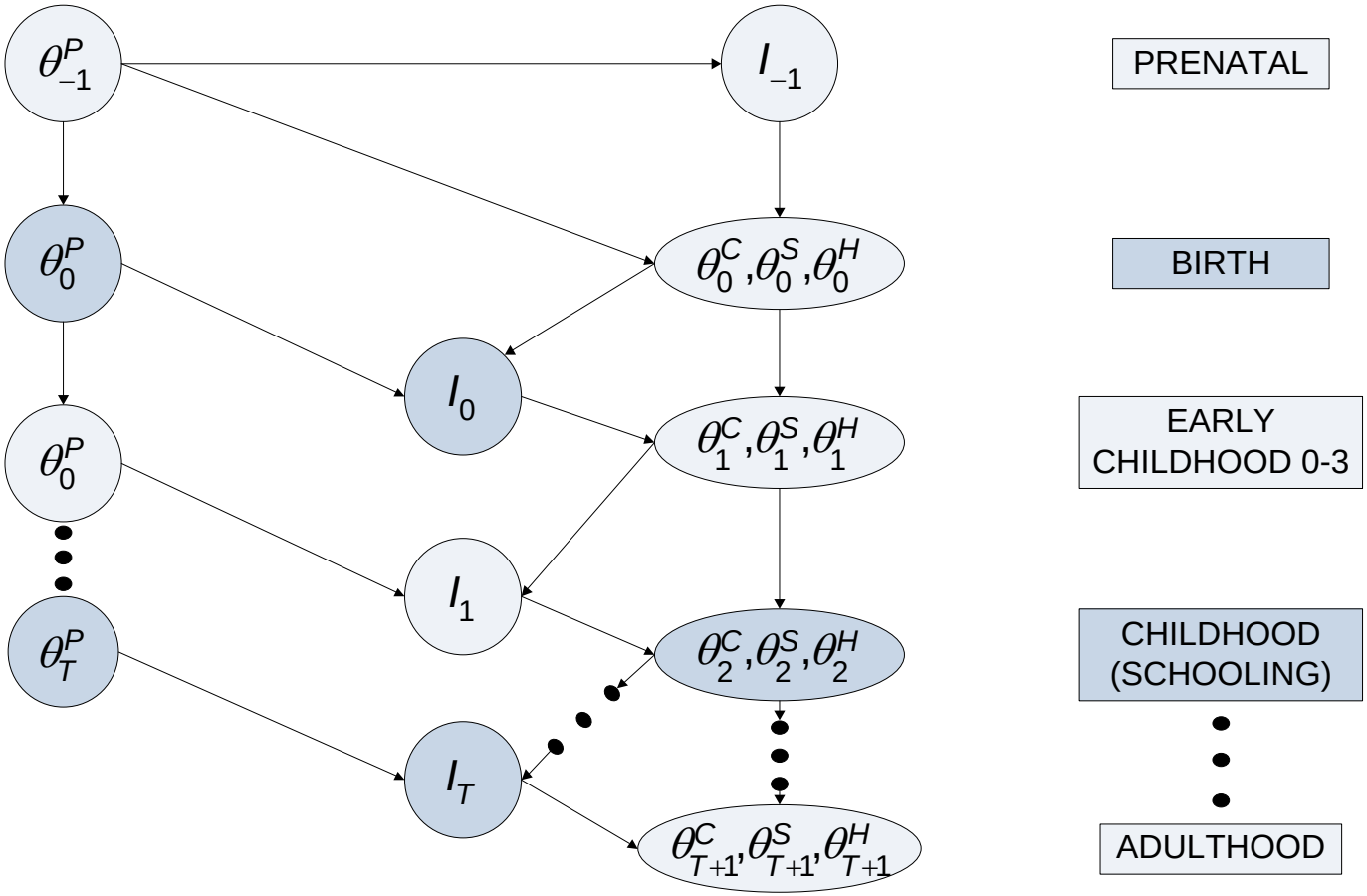
- The life-cycle model is very informative but also very data demanding.
- We typically lack information on all stages of the life cycle.
- Estimating the effect of early life conditions on later life outcomes without accounting for all intermediate stages can be very misleading.

A Life Cycle Framework for Organizing Studies and Integrating Evidence: $T+1$ Periods of Life Cycle

$\theta_t = (\theta_t^C, \theta_t^S, \theta_t^H)$ capacities at t

I_t: investment at t

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



- In the rest of the talk, I focus on one aspect of the general question of how to improve capabilities to promote health and other outcomes.
- Consider interventions in the *adolescent* years.
- Summarize our research on the role of education in promoting health.
- Is an education policy a promising avenue for promoting health?

  Specifically:

  i. What is the causal effect of education on health and healthy behaviors?
  ii. What is the relative effectiveness of education at different levels?
  iii. What is the relative importance of education compared to factors formed before the adolescent years? (Capabilities formed prior to the educational attainment levels studied).

The Literature on the Effects of Education on Health: A Brief Review

First set of studies used family background characteristics as instruments (Z) for education:

- Berger and Leigh [1989], Sander [1995], Leigh and Dir [1997], Adams [2002].
- Found strong effects of education on health.

Second set of studies used features of the schooling system as instruments for education:

- Lleras-Muney for U.S. [2005], Oreopoulos [2006] and Clark and Royer [2010] for U.K. use compulsory schooling laws.
- Kenkel, Lillard and Mathios for U.S. [2006] use high school graduation requirements and GED policies.
- Mixed evidence.

- Two Lines of Research Reported Today:
  1. Conti, Heckman, Urzua (2010a, 2010b) [CHU]:
     "The Education-Health Gradient" and
     "Early, Endowments, Education and Health"
  2. Heckman, Humphries, Urzua, and Veramendi (2011) [HHUV]:
     "The Effects of Schooling on Labor Market and Health Outcomes" (Dynamic sequential model)

- The previous literature investigates the **mean effect** of education on health and healthy behaviors at different margins (educational choice decision).
- Our analyses extend this literature.
  a. We find mean effects that are consistent with the literature when we estimate at the same margins of choice that are used in the empirical literature.
  b. We examine the effect of education at a variety of educational levels, and we estimate dynamic sequential models.
  c. We estimate distributions of treatment effects (what % benefit and lose) and the heterogeneity in response to treatment for people with different endowments.

- We find the following patterns across educational levels:
  1. There is a strong causal relationship of education on healthy behaviors across a variety of schooling levels (fitted one level at a time) and when fitted in a dynamic sequential model (all levels at the same time).
  2. Magnitude of the effects increases with the level of schooling.
  3. Effects depend on the levels of cognitive capabilities and noncognitive capabilities.
     a. Compensatory for noncognitive capabilities
     b. Reinforcing for cognitive capabilities
- These papers offer a consistent picture of the importance of education relative to the importance of factors in place before adolescence begins.

Generalized Roy Model

A Framework of Analysis of Counterfactuals

- A two-outcome model.
- Two potential outcomes for each person i:

$$\left(\underbrace{Y_{0i}}_{\substack{\text{no} \\ \text{schooling}}} , \underbrace{Y_{1i}}_{\text{schooling}} \right)$$

- The potential outcome equation for the treated state is:

$$Y_{1i} = \mu_1(\underbrace{X_i}_{\text{observed}}, \underbrace{U_{1i}}_{\text{unobserved}})$$

- The potential outcome for the untreated state is:

$$Y_{0i} = \mu_0(\underbrace{X_i}_{\text{observed}}, \underbrace{U_{0i}}_{\text{unobserved}})$$

Treatment Choice

- $D_i = 1$ denotes receipt of education (the treatment), $D_i = 0$ compulsory education for person i.
- Observed outcome is:

$$Y_i = D_i Y_{1i} + (1 - D_i) Y_{0i}$$

- Neyman (1923)–Cox (1958)–Quandt (1958)–Rubin (1974) model.
- Key idea introduced into literature in economics is the notion of a selection function (choices made by patients, parents, doctors, etc.).

- We model the choice of education as function of observed and unobserved variables:

$$D_i = \phi_i(\underbrace{Z_i}_{\substack{\text{observed} \\ \text{determinants} \\ \text{of treatment}}}, \underbrace{U_D}_{\text{unobserved}})$$

- We confront the selection problem.
- Some of the traits that generate both schooling and health are not observed, and we cannot condition on them.
- Knowledge of selection function reveals information about the choices of agents and their preferences.

Disparities by Education

- In general, due to uncontrolled unobserved factors

$$\underbrace{E(Y_1 \mid D=1)}_{\text{mean schooled outcome}} - \underbrace{E(Y_0 \mid D=0)}_{\text{mean unschooled outcome}} \neq \underbrace{E(Y_1 - Y_0)}_{\text{mean causal effect of schooling}}$$

- We use a variety of empirical strategies
  i. Instruments
  ii. Proxies for the unobserved traits correcting for proxy measurement error (state space methods)

- Consider a 3 factor model.
- Multiple proxies for C, N, H.
- We have work underway that allows us to choose the dimension of the factors.
- Extends factor analysis to non-normal, non-parametric settings.

Data: The British Cohort Study (BCS70)

- Cohort of all individuals born in one week of April 1970 in the United Kingdom.
- Education: decision to stay in school at age 16.
- Outcomes (age 30):
  1. labor market (wages and employment)
  2. health status (self-reported health, depression and obesity)
  3. health behaviors (smoking, exercise, cannabis use)
- Measurements (age 10):
  1. θ_C: 7 cognitive tests (e.g. British Ability Scales)
  2. θ_N: 6 personality scales (e.g. locus of control)
  3. θ_H: 4 measures (height, head circumference)

Some questions:

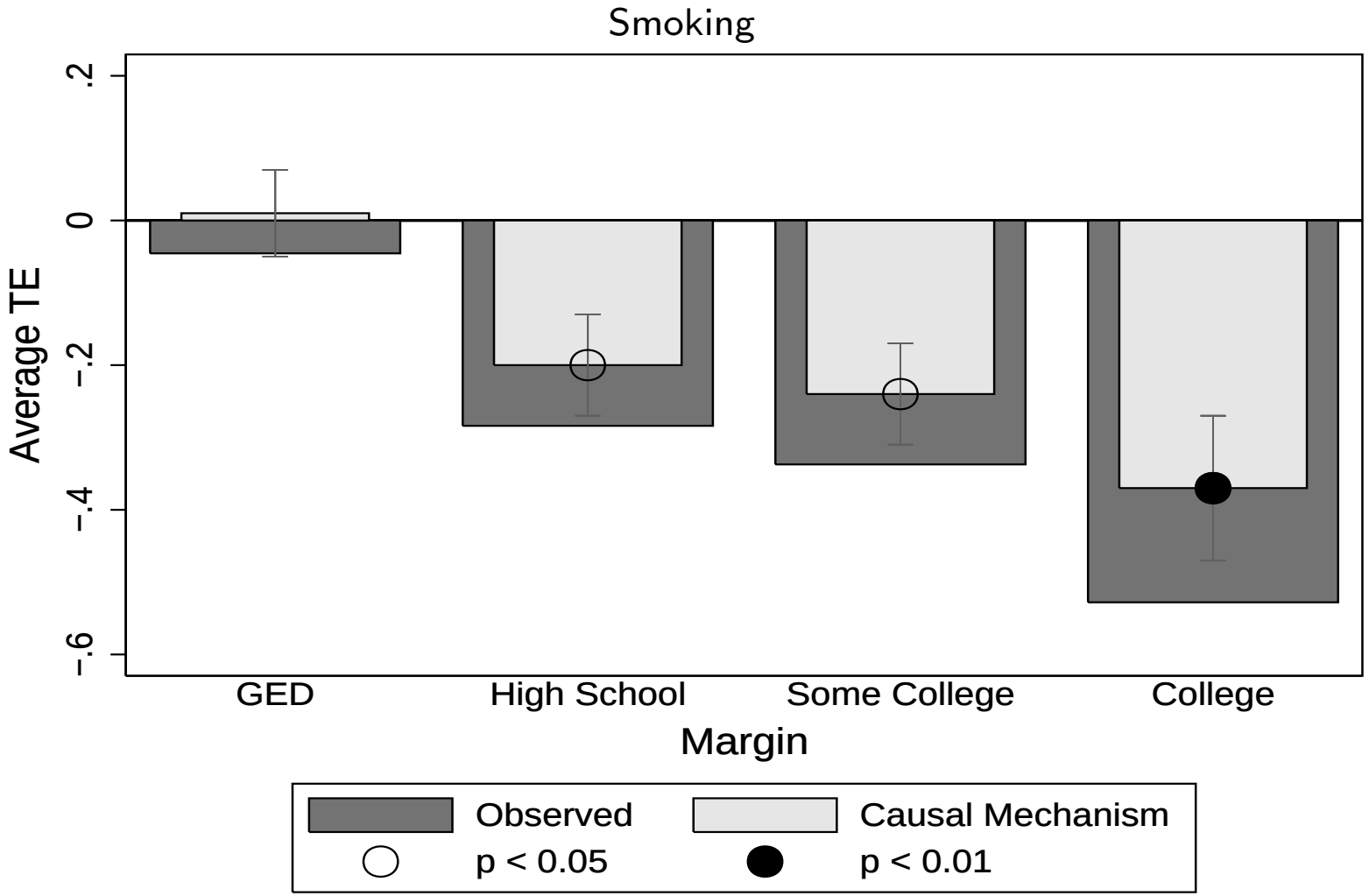
- Do the results from the BCS hold up in other data sets?
- What are the effects on health of other levels of education?

Evidence from U.S.

- Does education also have a strong impact on health?
- Are pre-education factors also relevant in explaining the education-health gradient?
- Sequential model of educational choice.

Heckman, Humphries, Urzua, and Veramendi (2011) [HHUV]: "The Effects of Schooling on Labor Market and Health Outcomes"

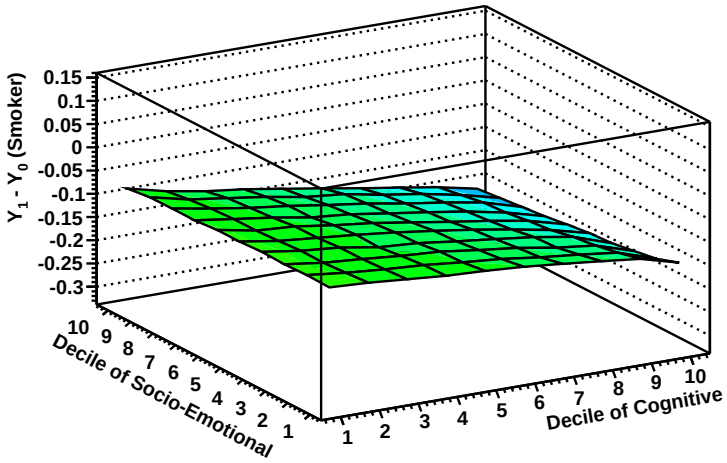
Effects of Education

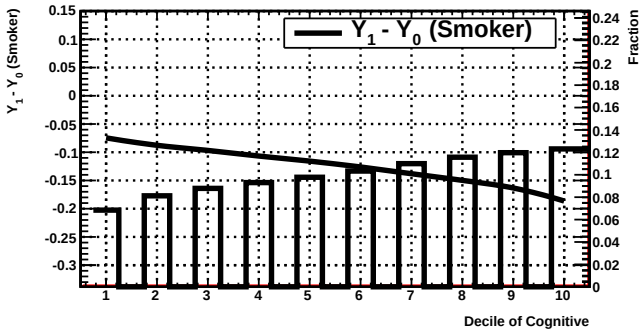


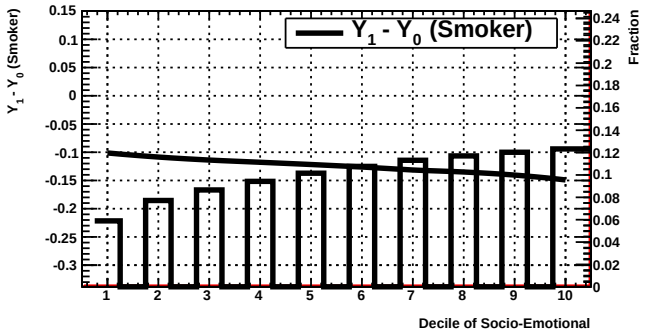
- Like for U.K., the % of the observed disparities in daily smoking due to education is comparable across educational levels (70%).

Treatment Effect Heterogeneity

HS Graduate vs. College Enrollment



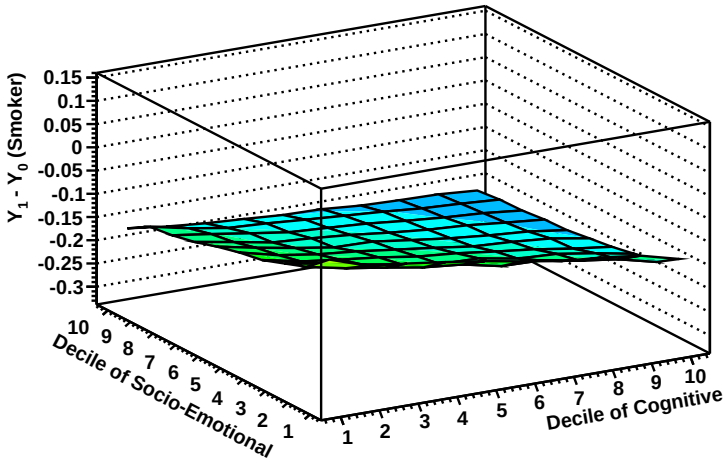


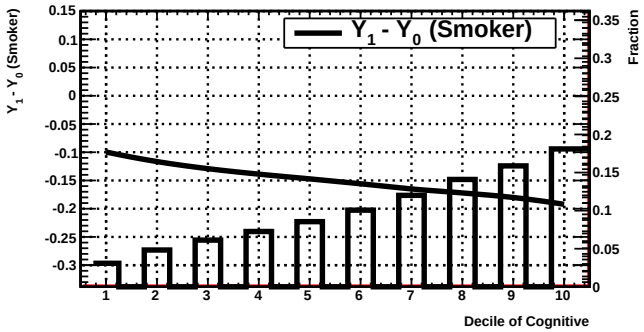


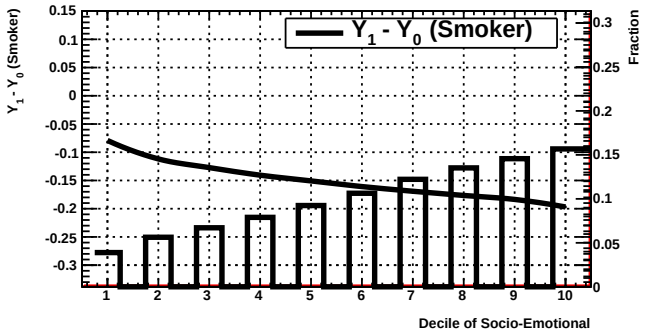
- Education is a complement of both adolescent cognitive and socio-emotional endowments in U.S.

Treatment Effect Heterogeneity

Some College vs. 4-year college degree

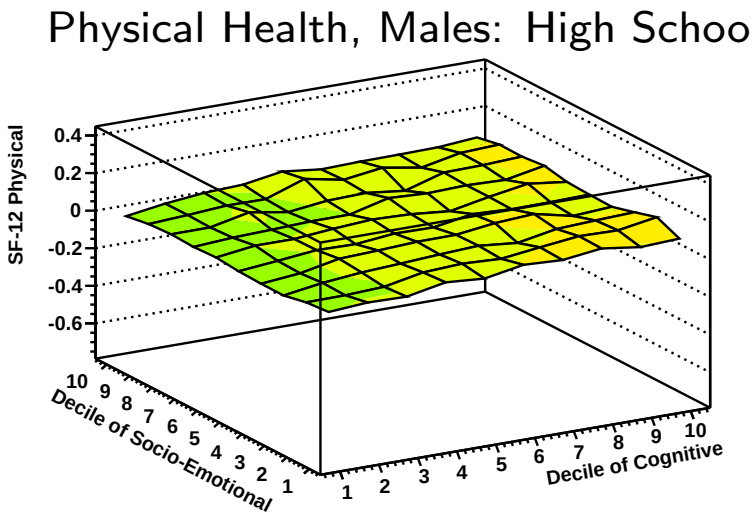


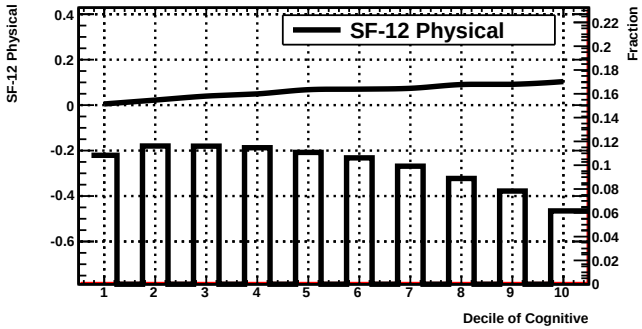


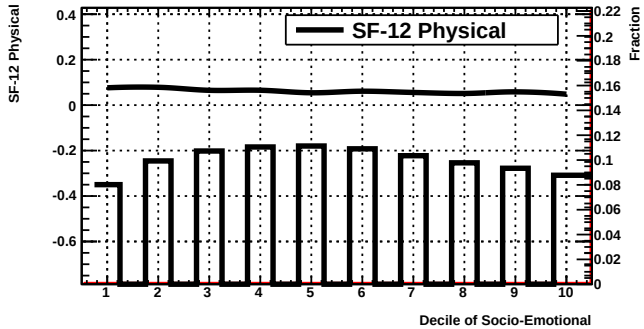


- Education is a complement of both adolescent cognitive and socio-emotional endowments in U.S.

Cognitive and Socioemotional Factors

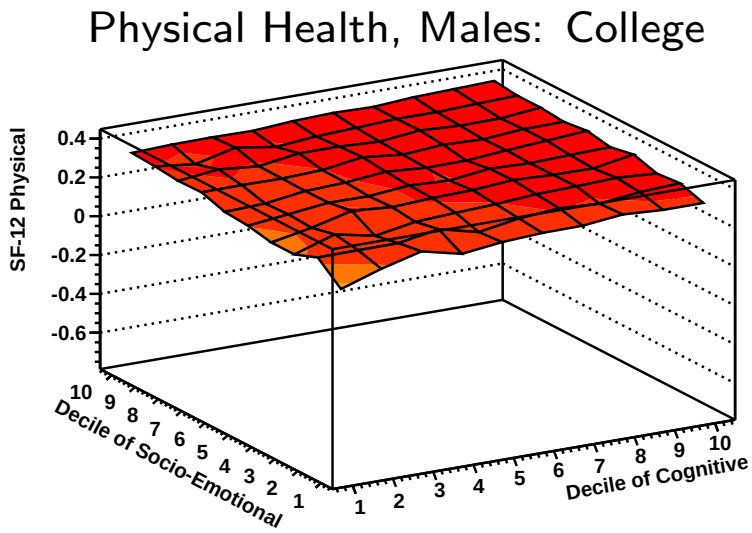


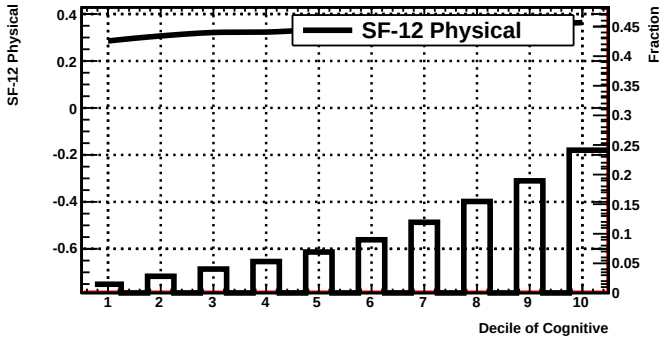


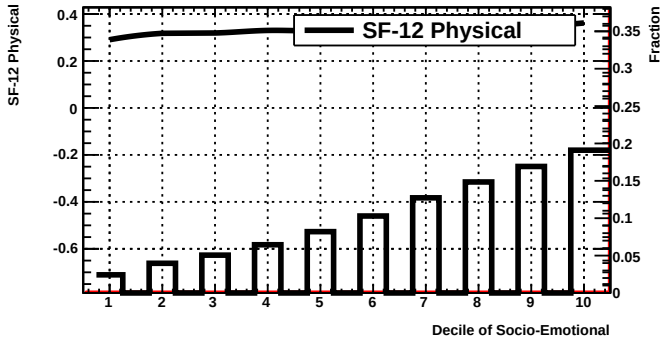


- Not so conditional on education.
- Primary mechanism is through education.

Cognitive and Socioemotional Factors







- ...but not conditional on education.

Table 3: Intergenerational Income elasticities and correlations from Jäntti et al. (2006)

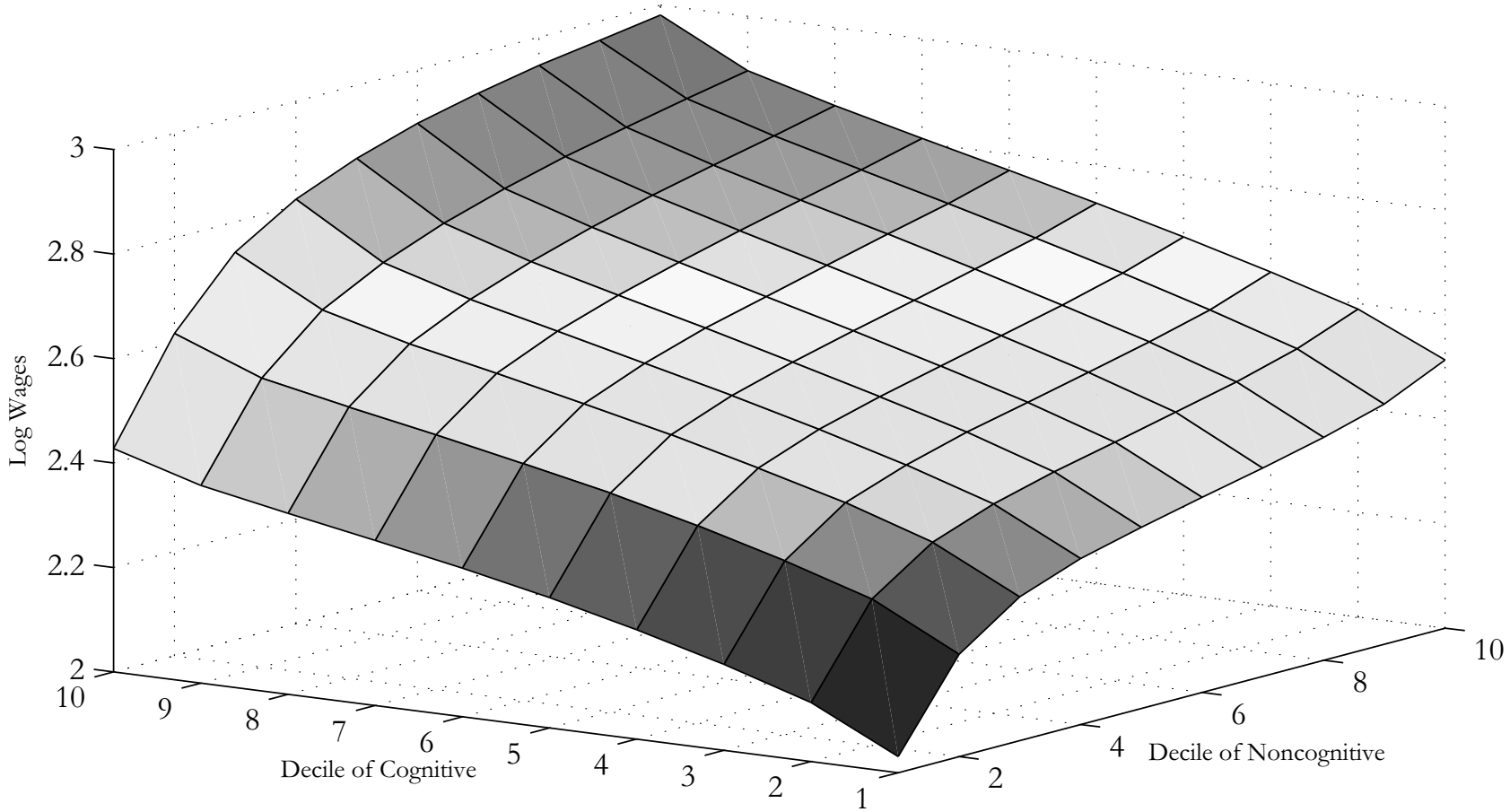
Country	**Elasticity** (β)	**Correlation** (ρ)
Men		
Denmark	0.071	0.089
	[0.064, 0.079]	[0.079, 0.099]
Finland	0.173	0.157
	[0.135, 0.211]	[0.128, 0.186]
Norway	0.155	0.138
	[0.137, 0.174]	[0.123, 0.152]
Sweden	0.258	0.141
	[0.234, 0.281]	[0.129, 0.152]
UK	0.306	0.198
	[0.242, 0.370]	[0.156, 0.240]
US	0.517	0.357
	[0.444, 0.590]	[0.306, 0.409]

Numbers in brackets below the point estimates show the bias corrected 95% bootstrap confidence interval.

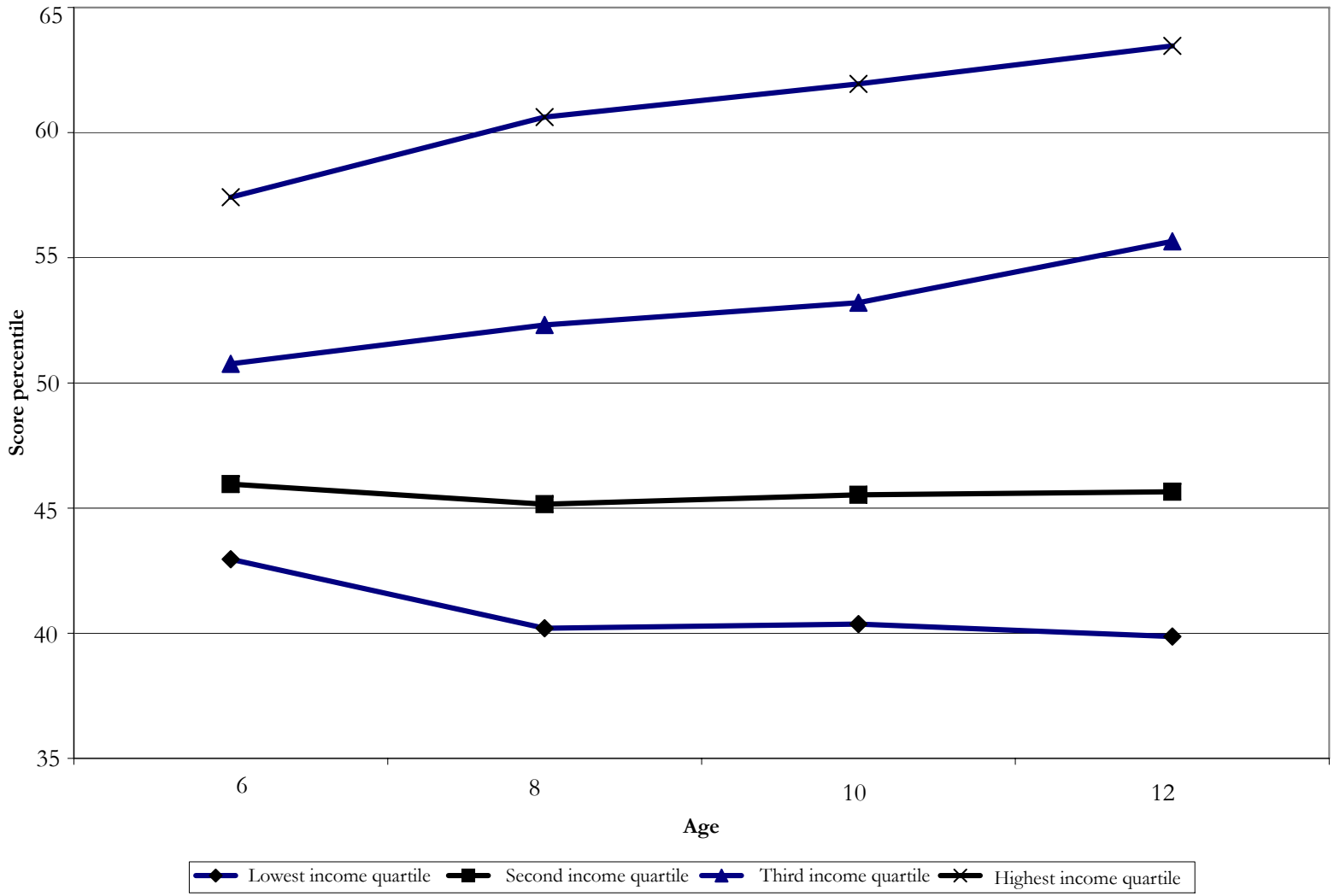
Source: This reproduces much of Table 2 from Jäntti et al. (2006).

Fact 1: Cognitive and Noncognitive Skills Matter

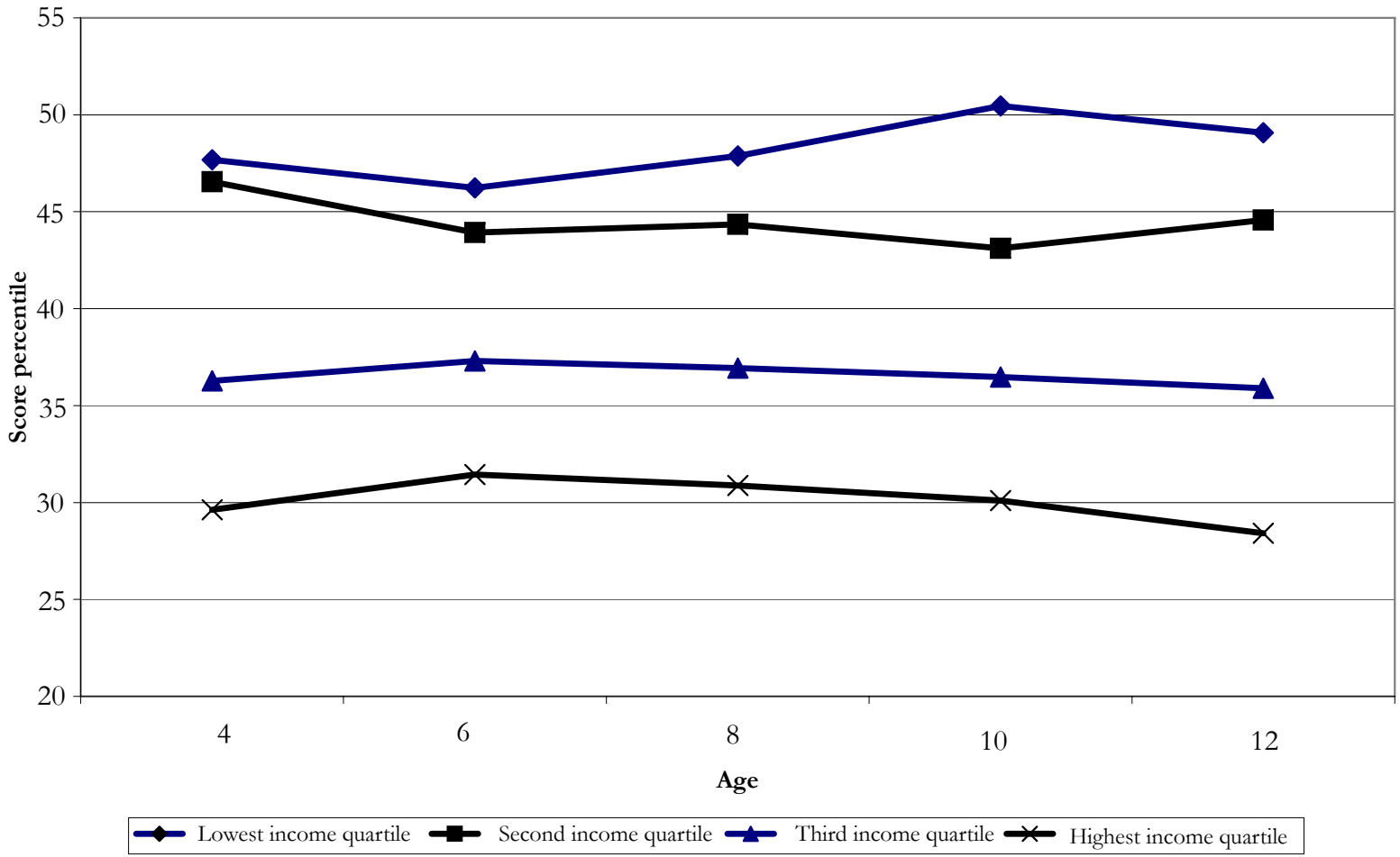
Log Wages at Age 30: Heckman, Stixrud, and Urzua (2006)



Fact 2a: Average percentile rank on PIAT-Math score, by income quartile



Fact 2b: Average percentile rank on anti-social behavior score, by income quartile



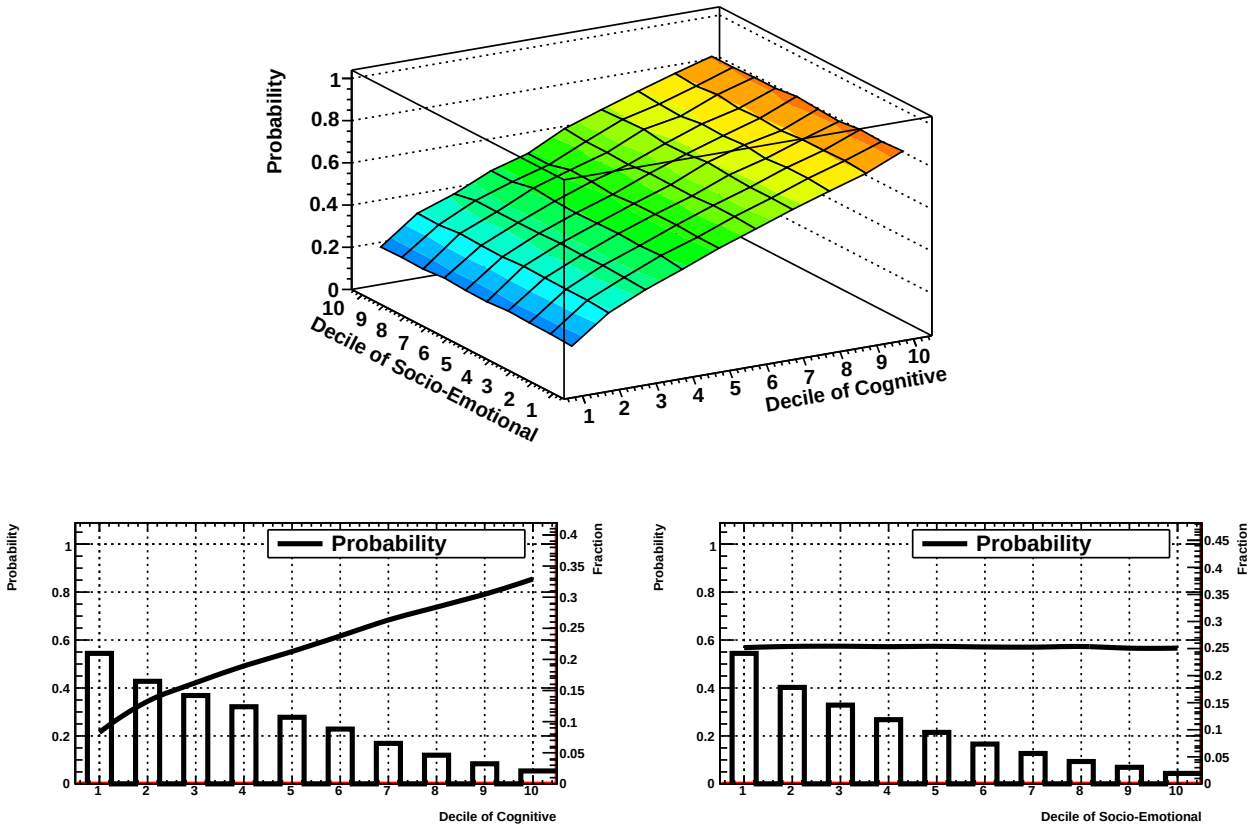
- To estimate the technology of capability formation note that we face the following problems:
  1. Linear production systems do not capture dynamic complementary; Nonlinearity is fundamental.
  2. Measurements are often item scores on achievement tests and personality inventories: i.e. measurement system is nonlinear.
  3. Need a robust approach that does not depend on specific functional forms: nonparametric approach.
  4. Test scores do not have a natural metric. Any monotonic function of a test score is a test score.
  5. We anchor test scores on adult outcomes of interest.
  6. The data on inputs and outputs are characterized by considerable measurement error, and our models are nonlinear.
  7. Investments are chosen by parents who have more information than econometricians. Need to address and solve the problem of endogeneity in nonlinear systems.

Findings Based on Estimates of the Technologies:

Main policy conclusions from our analysis:

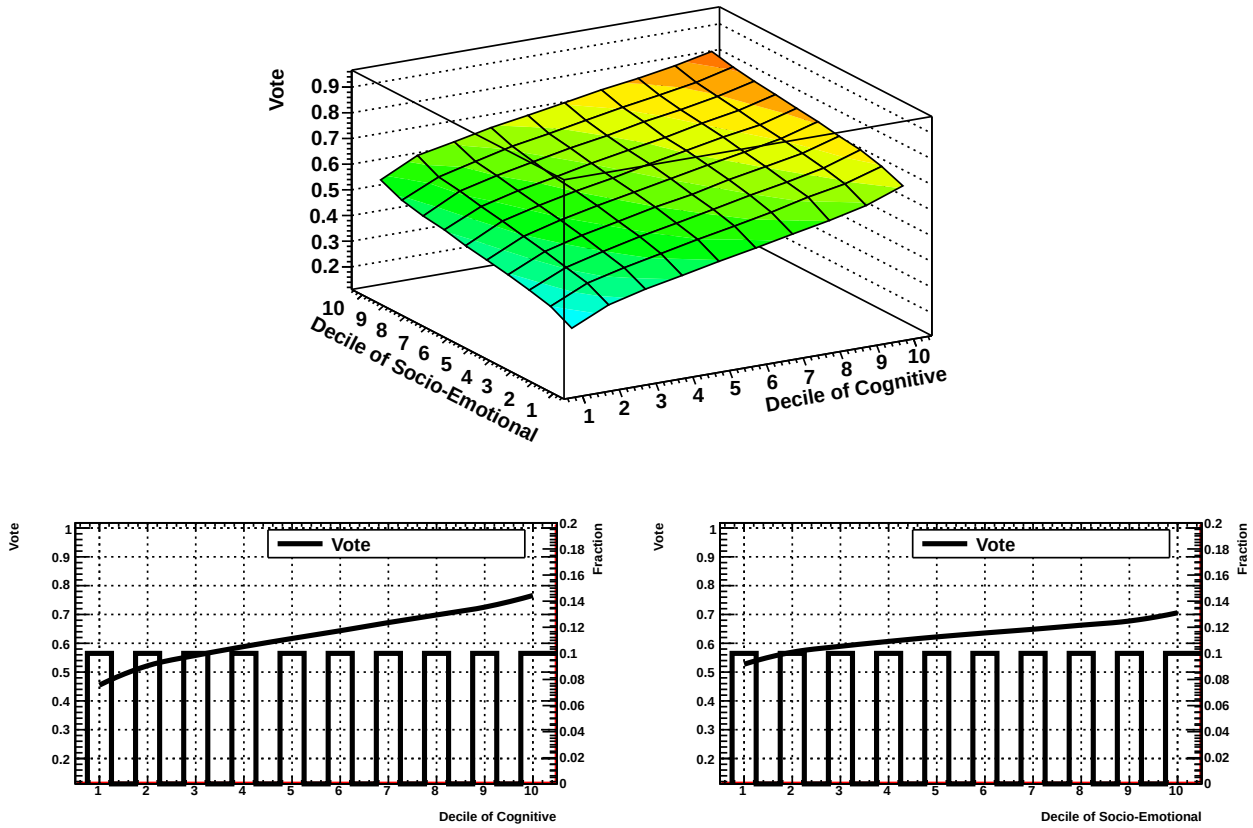
- Public investment directed toward the early years should be targeted to children from disadvantaged backgrounds.
- Investment should be tailored to the particular circumstances of disadvantage.
- The optimal ratio of early to late investment depends on the outcome of interest.
- If remediation does not occur at early stages of childhood, then remediation at later stages should focus primarily on fostering noncognitive skills.

Figure 27: The Probability of Educational Decisions, by Endowment Levels, **HS Dropout** vs. Getting a GED



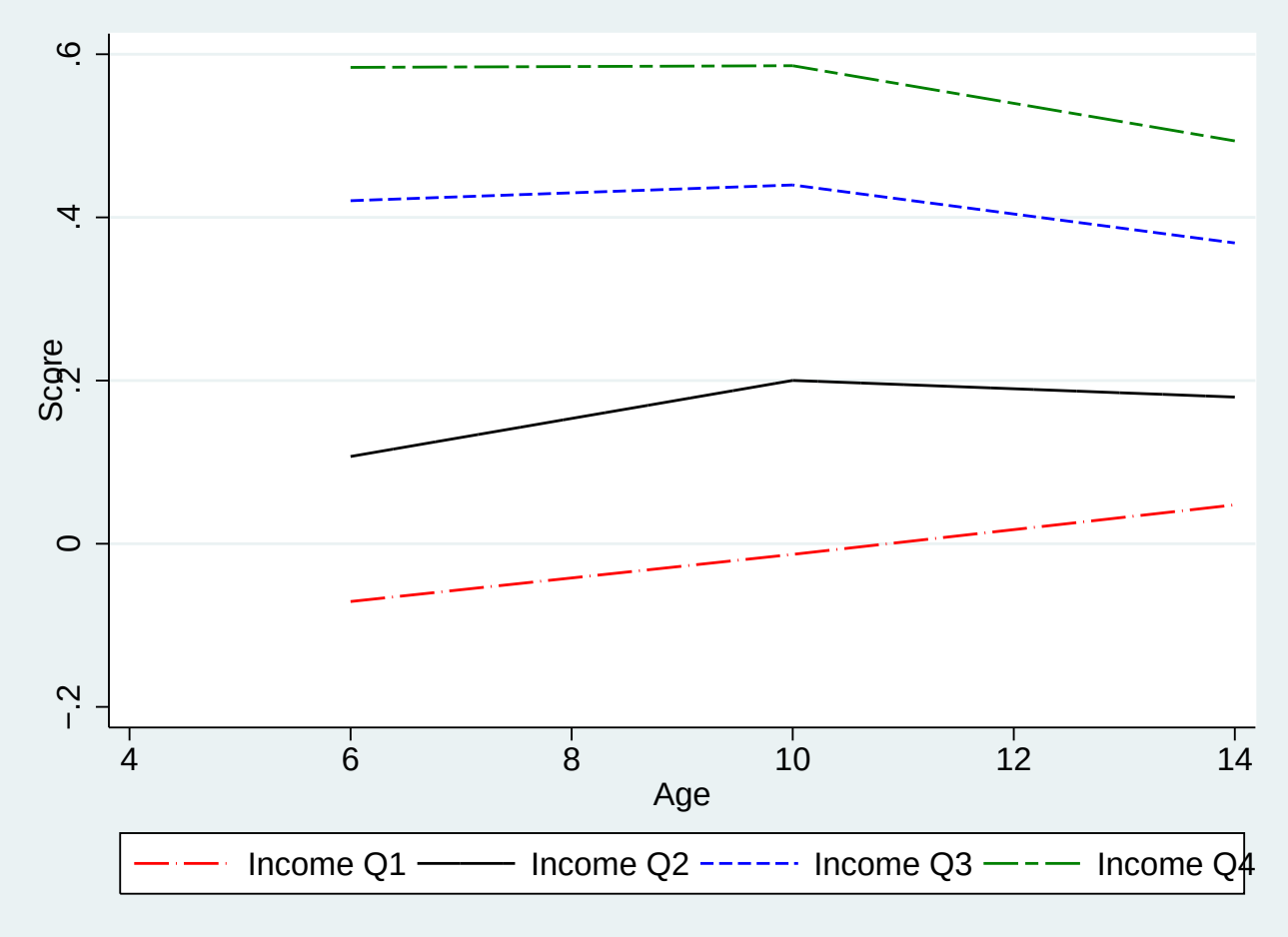
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

Figure 28: The Effect of Cognitive and Socio-emotional endowments on Participation in 2006 Election, All



Source: Heckman, Humphries, Urzua, and Veramendi (2011).

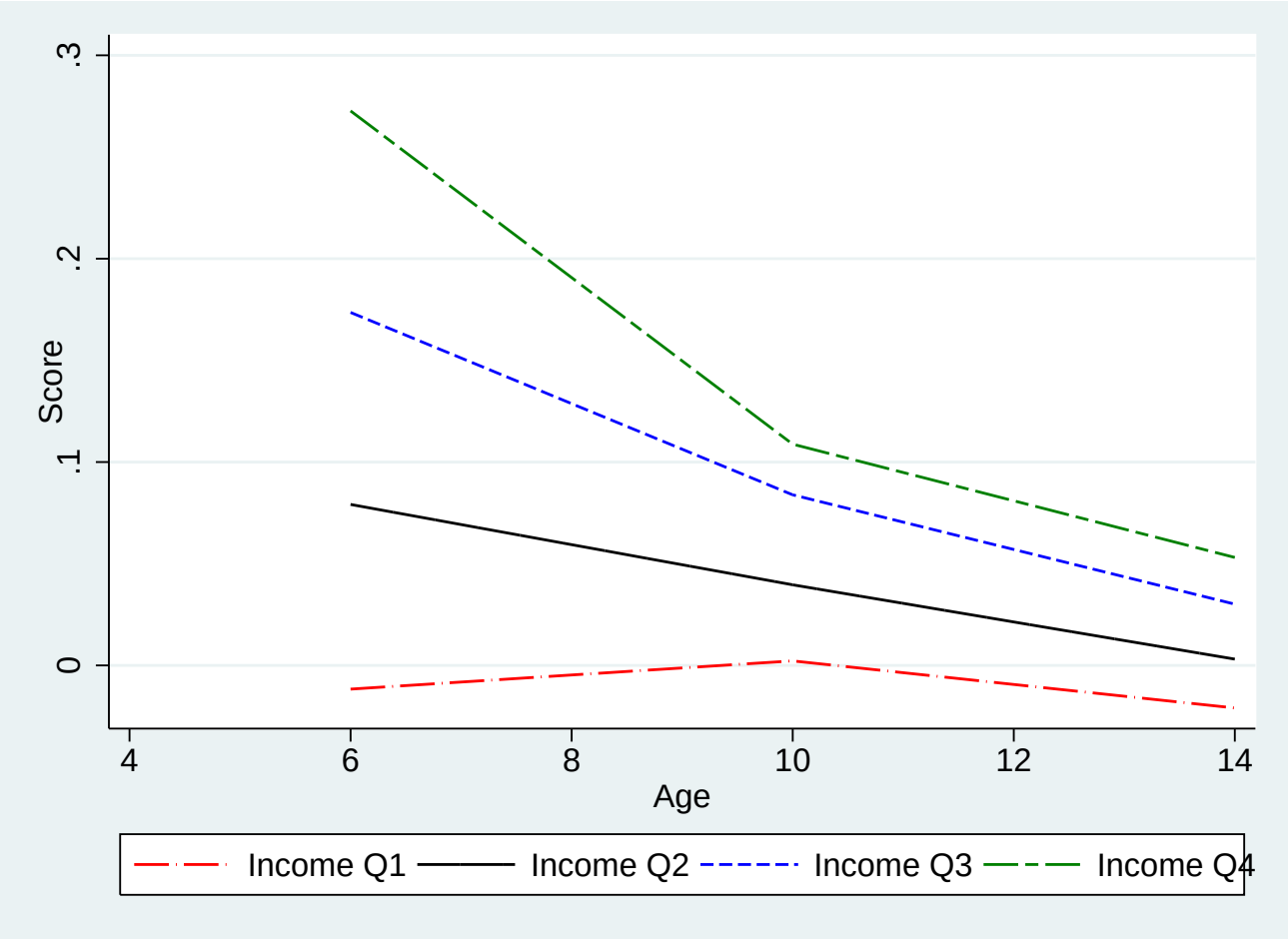
Figure 29: Parental Investment over Childhood among Whites by Family Income Quartile: Material Resource



Data: A balanced panel from Children of National Longitudinal Survey of Youth 1979.

Source: Moon (2012).

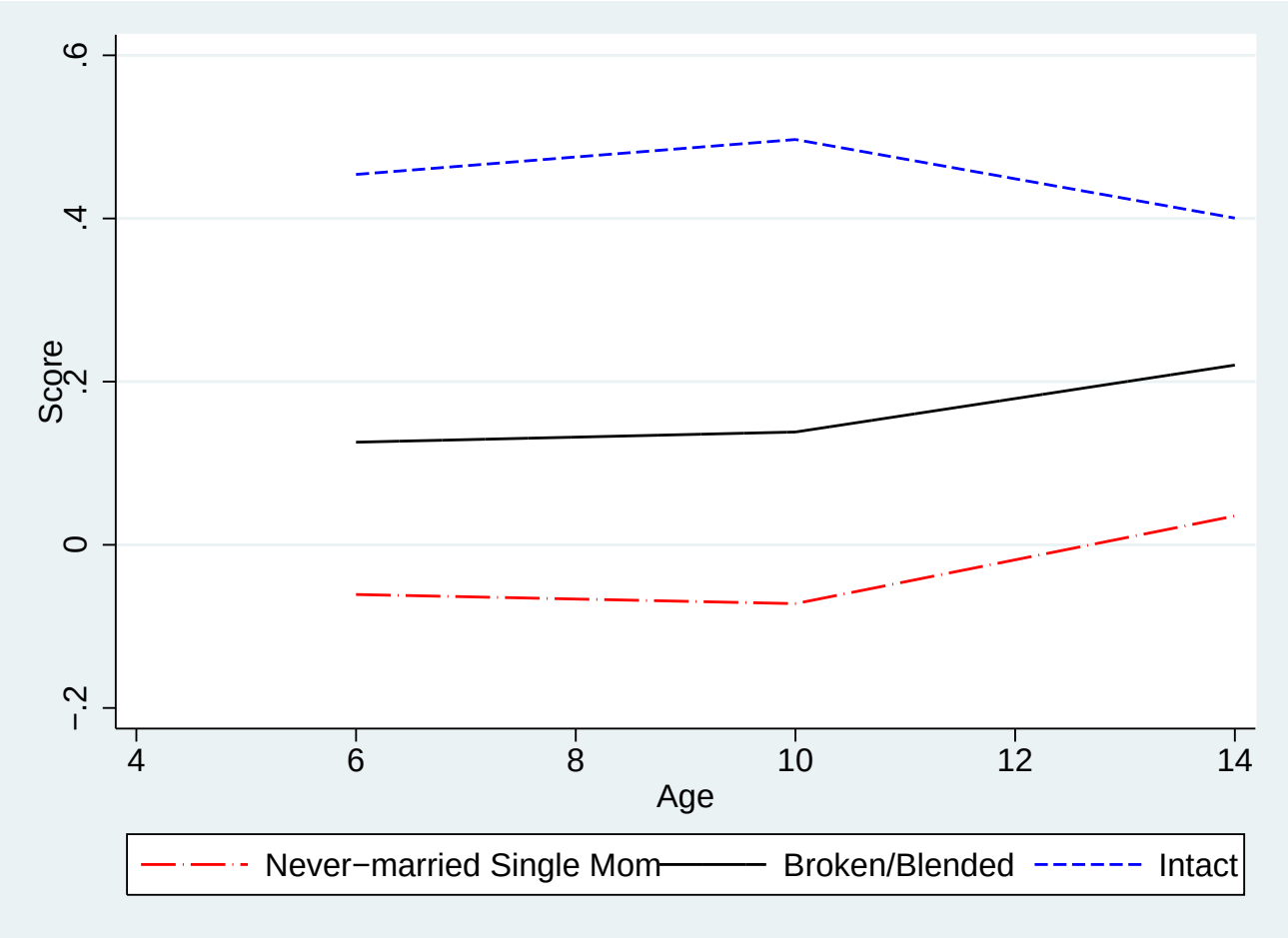
Figure 30: Parental Investment over Childhood among Whites by Family Income Quartile: Emotional Support



Data: A balanced panel from Children of National Longitudinal Survey of Youth 1979.

Source: Moon (2012).

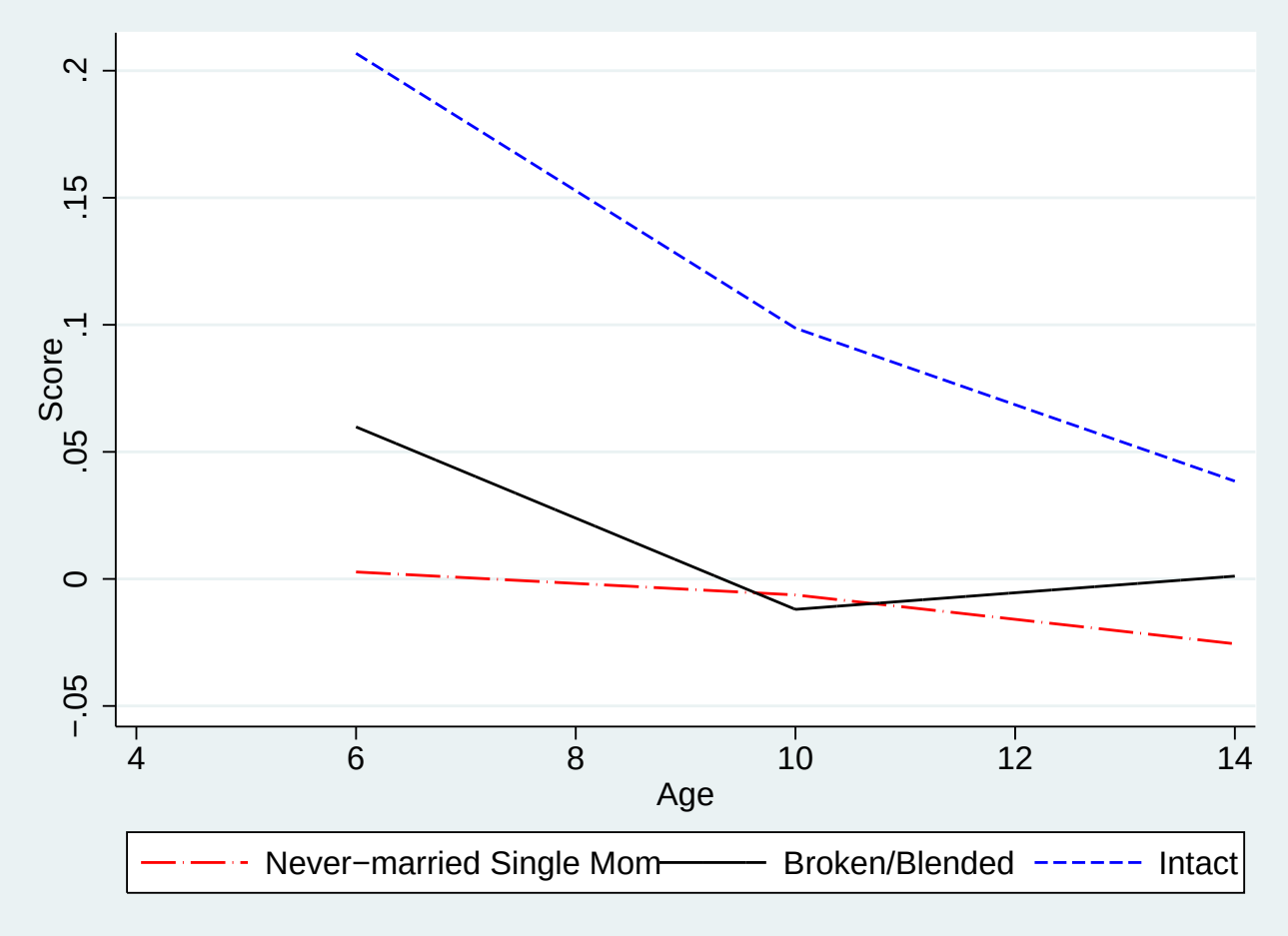
Figure 31: Parental Investment over Childhood among Whites by Family Type: Material Resource



Data: A balanced panel from Children of National Longitudinal Survey of Youth 1979.

Source: Moon (2012).

Figure 32: Parental Investment over Childhood among Whites by Family Type: Emotional Support



Data: A balanced panel from Children of National Longitudinal Survey of Youth 1979.

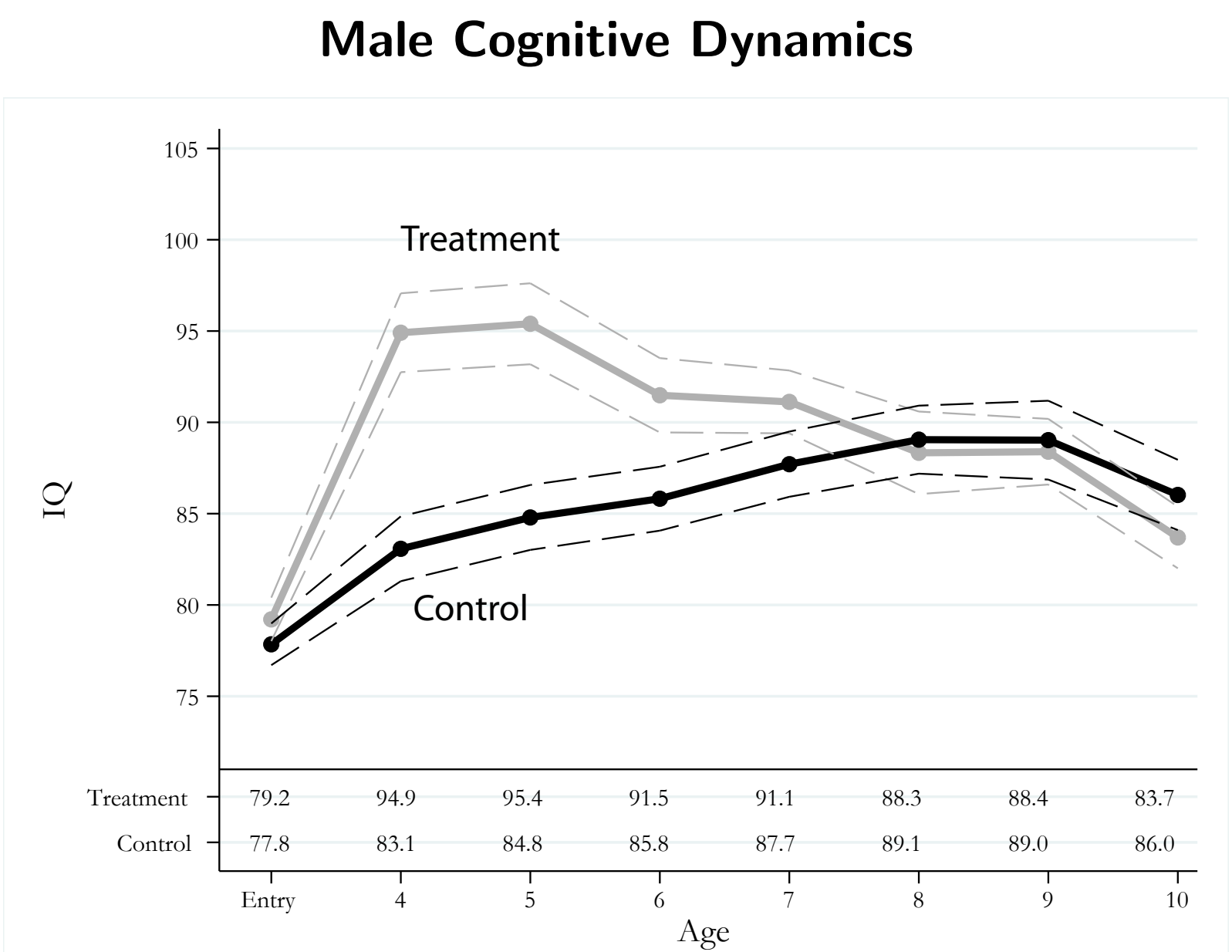
Source: Moon (2012).

High/Scope Perry Preschool Program

- The Perry preschool program enriched the lives of low income black children with initial IQs below 85 at age 3.
  - $2\frac{1}{2}$ hours per day
  - 5 days per week
  - 2 years during each school year (mid-October to May).
  - home visits
  - program stops after two years
  - the program taught planning and persistence as well as social adjustment
  - "Plan, Do, Review": Plan a project, do it, review it collectively

- Evaluated by the method of random assignment.
- Strong effects are found for both boys and girls, although different effects are found at different ages for different outcomes.
- Did not lead to sustained gains in IQ for males, and only slight effect for females.

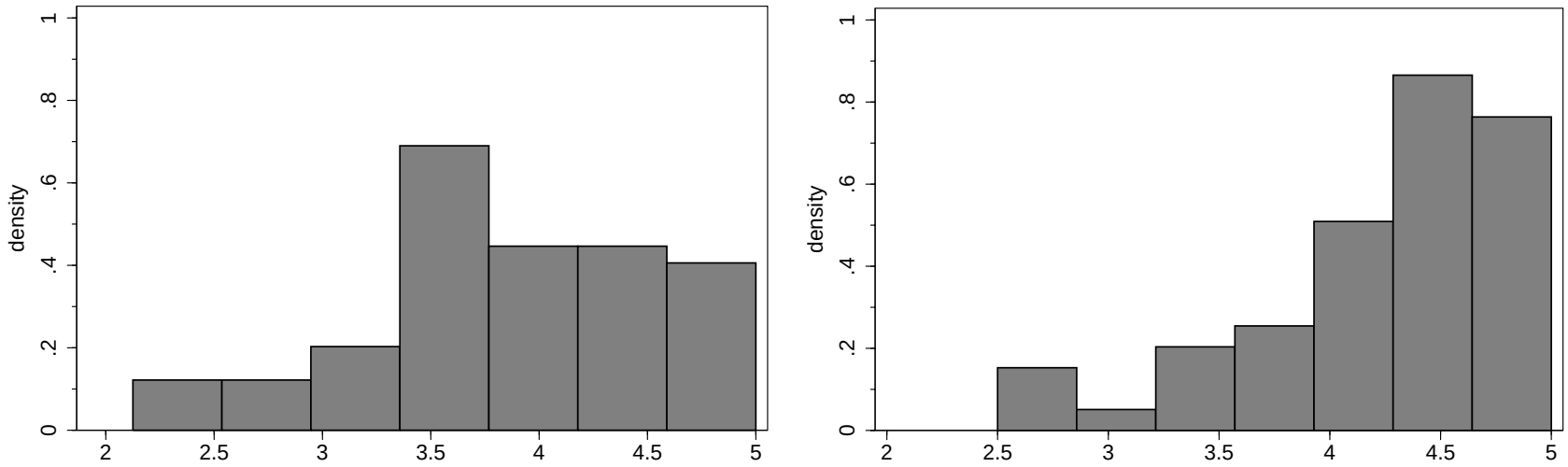
Cognitive Evolution Through Time, Perry Males



- Yet the Perry Program has a statistically significant annual rate of return of around 7–10% per annum—for both boys and girls—above the post World War II stock market returns to equity in U.S. labor market estimated to be 5.8%.

- The Perry Preschool Program worked primarily through socioemotional channels.
- Raises scores on achievement tests but not IQ tests.
- Socioemotional factors and cognitive factors both explain performance on achievement tests (Duckworth, 2006; Borghans et al., 2008; Borghans et al., 2009).

Figure 33: Personal Behavior Index by Treatment Group

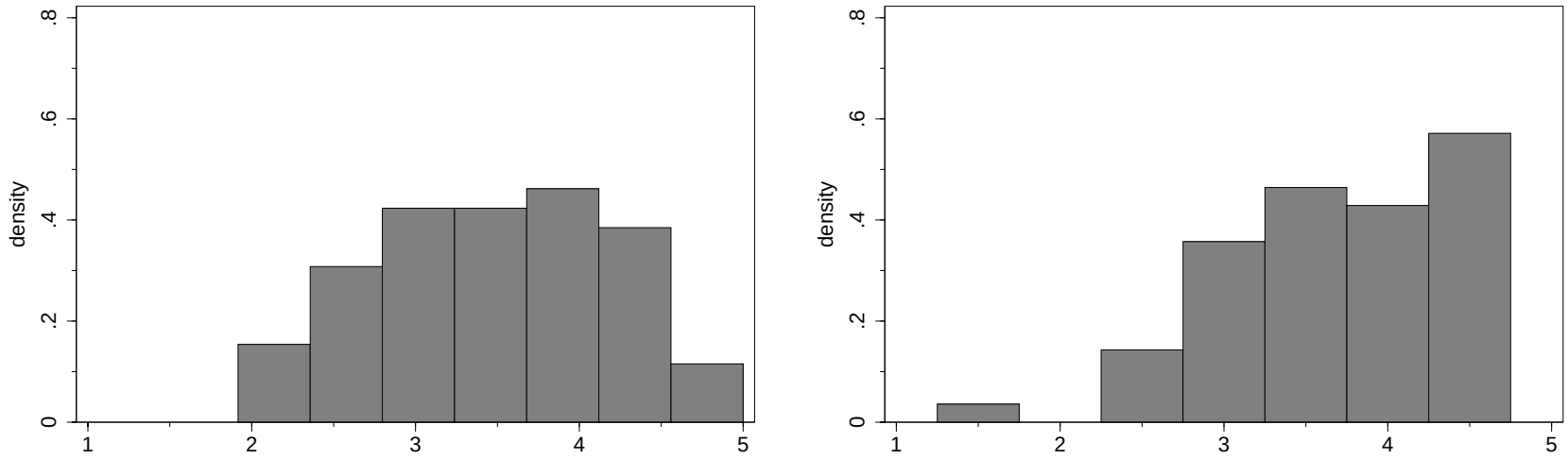


(a) Control

(b) Treatment

- Treatment shifts the distribution upwards (1=bad;...;5=good).
- Statistically significant treatment effect is observed: $p = 0.002$.
- The Personal Behavior Index is an unweighted average of four items: "absences and truancies", "lying or cheating", "steals" and "swears or uses obscene words".

Figure 34: Socio-Emotional Index by Treatment Group



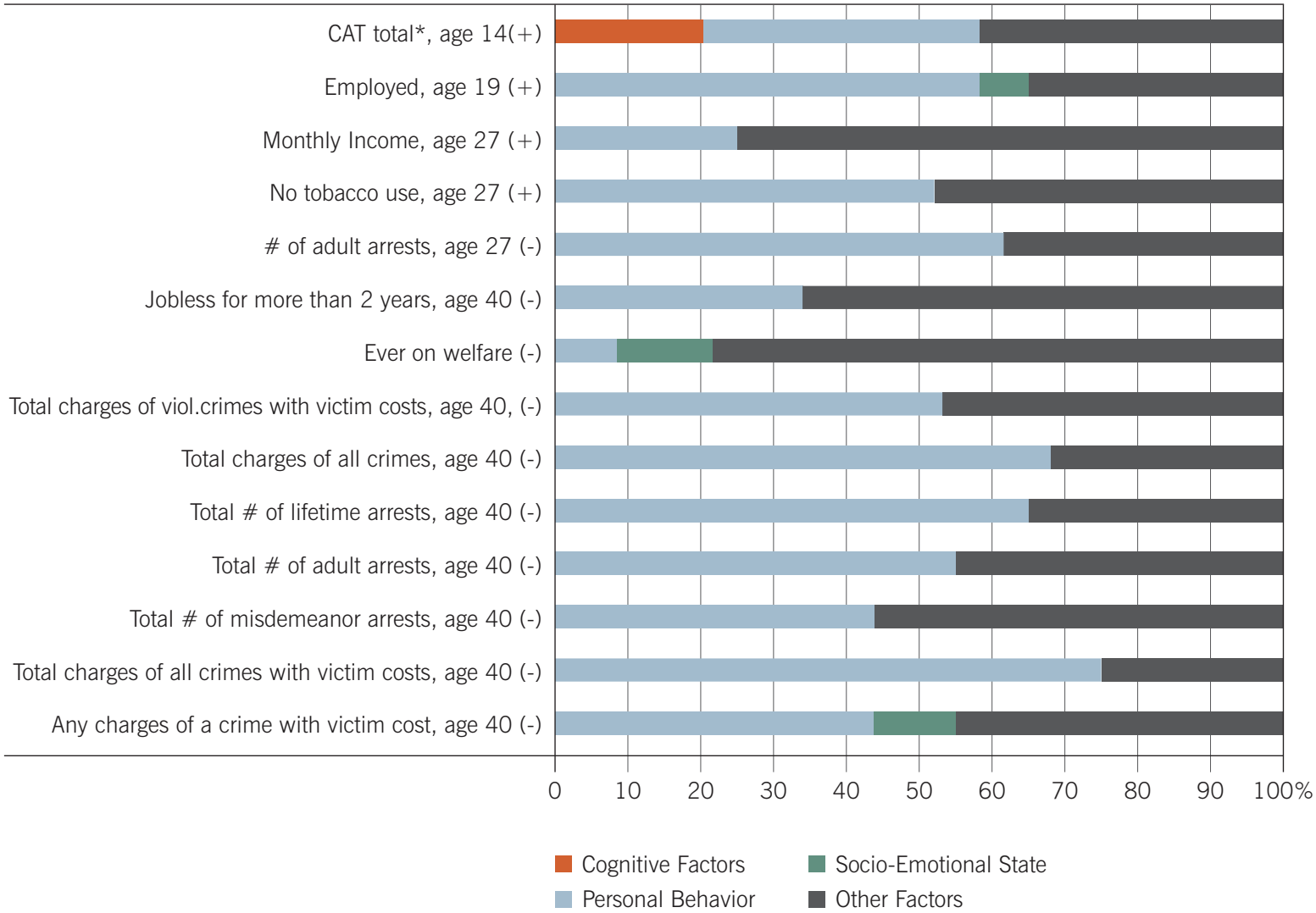
(a) Control

(b) Treatment

- Treatment shifts the mean upwards (1=bad;...;5=good).
- Treatment effect one-sided p-values is 0.096 (borderline statistically significant).
- The Socio-Emotional index is an unweighted average of four items: "appears depressed", "withdrawn and uncommunicative", "friendly and well-received by pupils", and "appears generally happy".

Decomposing Treatment Effects

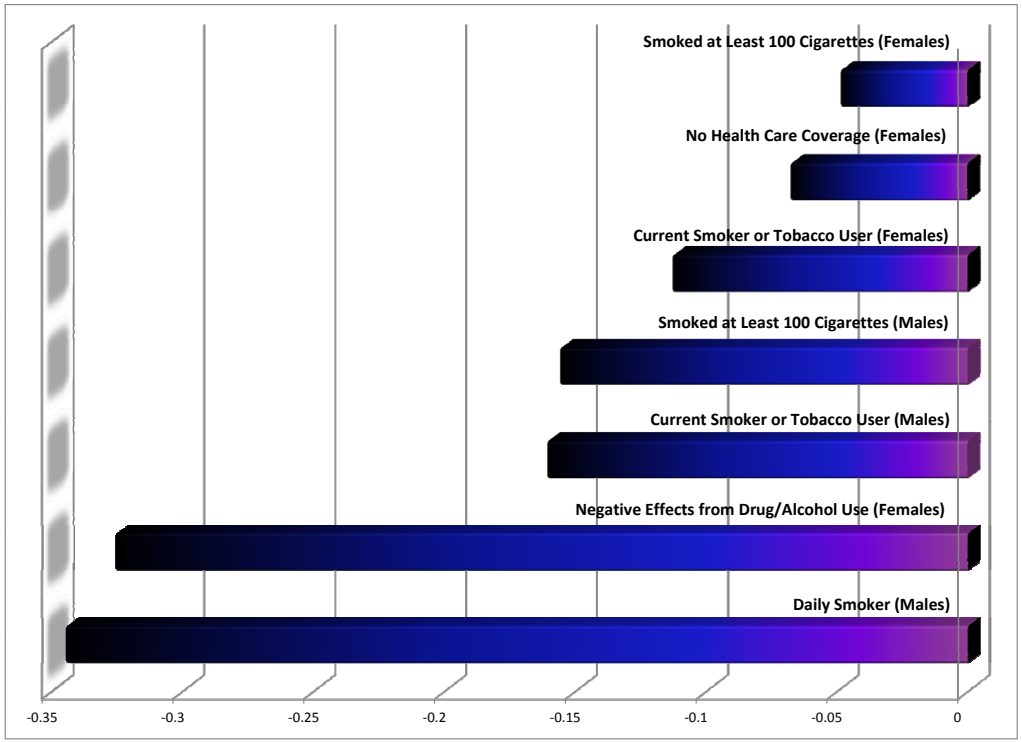
Decomposition of Treatment Effects, Males



Early childhood intervention programs offer a promising avenue for reducing health disparities

Perry Preschool Intervention, Age 40

Treatment Effects



- Early interventions reducing problem behavior can lower the probability of engaging in unhealthy behaviors in adulthood.

$\Longrightarrow$ **Benefits can carry over into the next generation.**

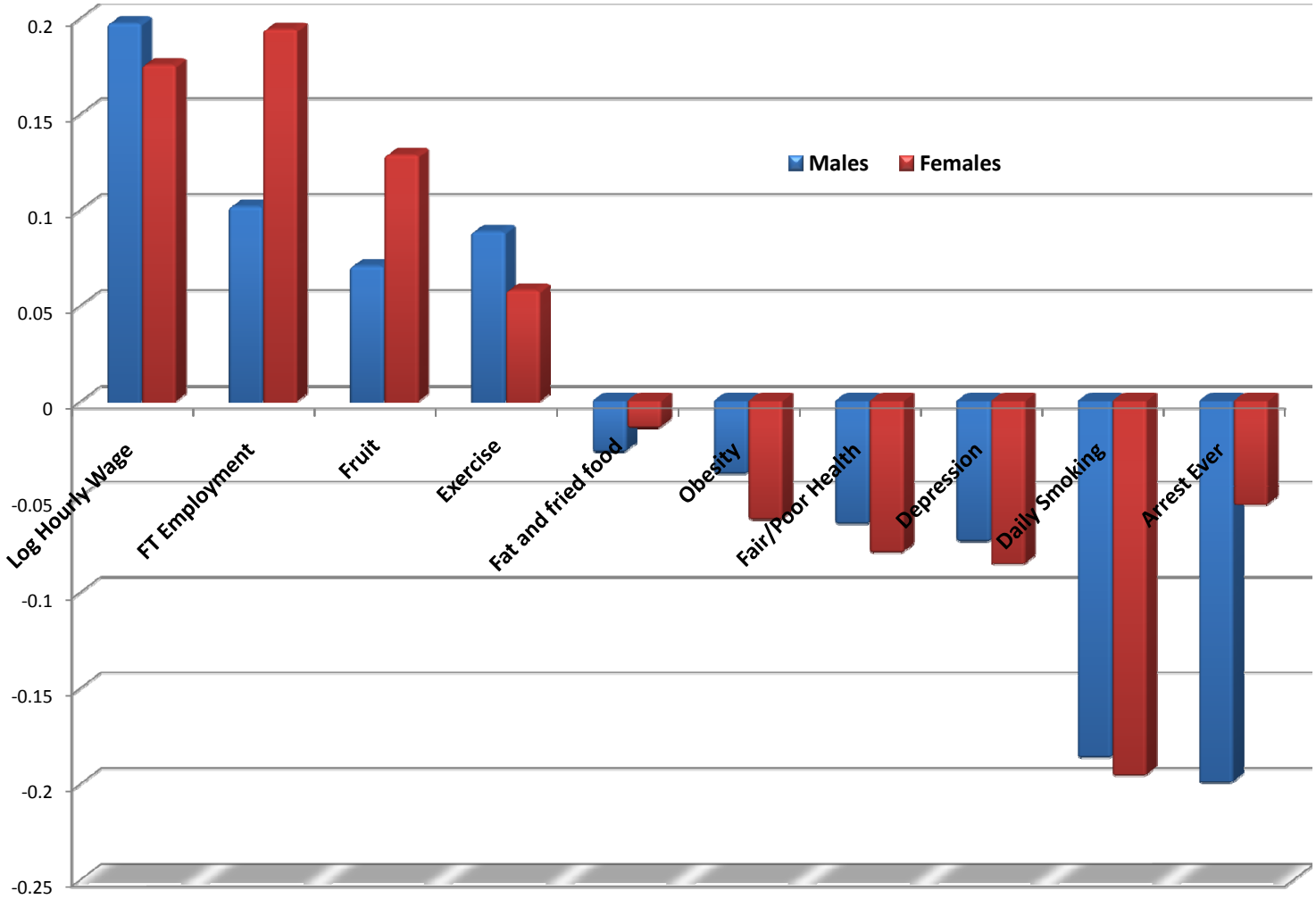
11. Equity-Efficiency Tradeoffs

- Economists often discuss "equity-efficiency" tradeoffs.
- What is economically efficient need not be socially fair.
- **No equity-efficiency tradeoff for early interventions for those born into disadvantage.**
- Substantial tradeoff for the less able for adolescent and young adult interventions, especially those targeted towards fostering cognitive capabilities.

The Effects of Education on Health and Healthy Behaviors

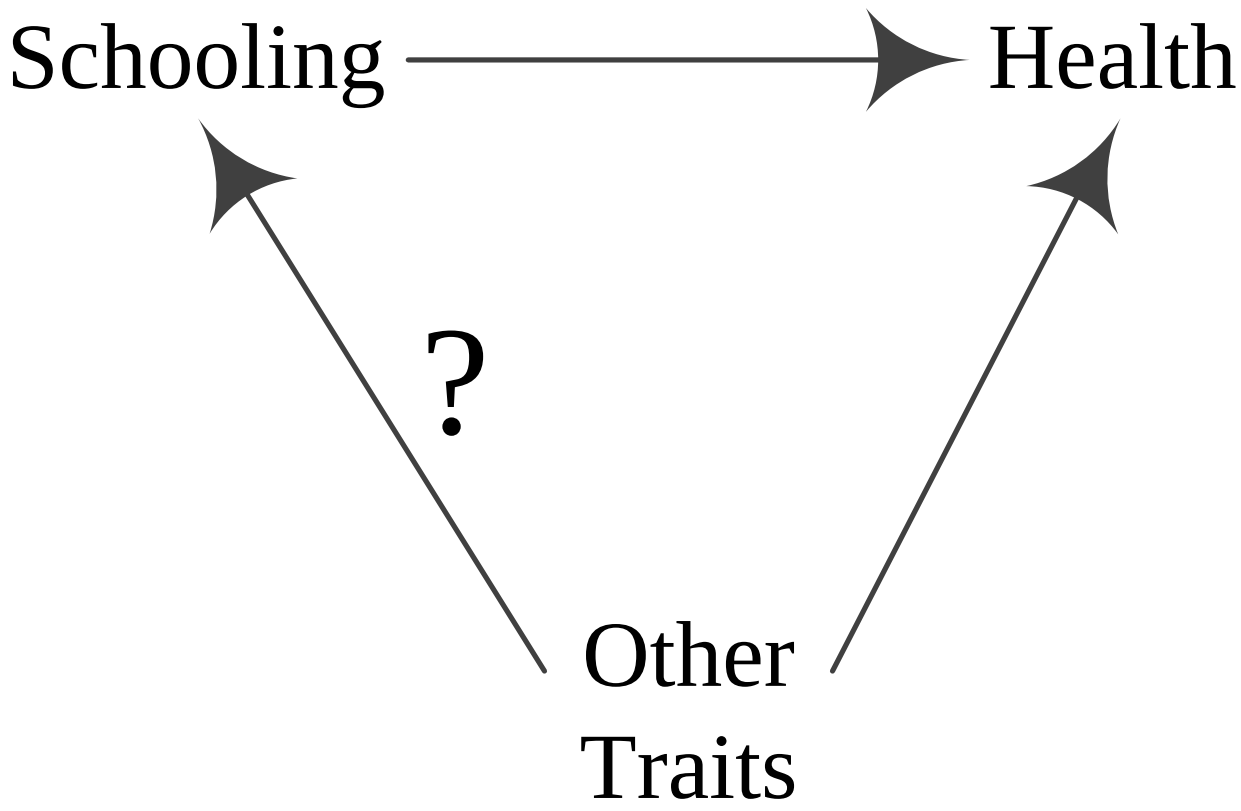
- Use data from the U.S. and U.K. looking at a variety of measures of education.
- Decompose observed effects into causal components.
- First consider U.K. differentials at age 30. (BCS70)
- Effect of completing O-levels.

Disparities by Education



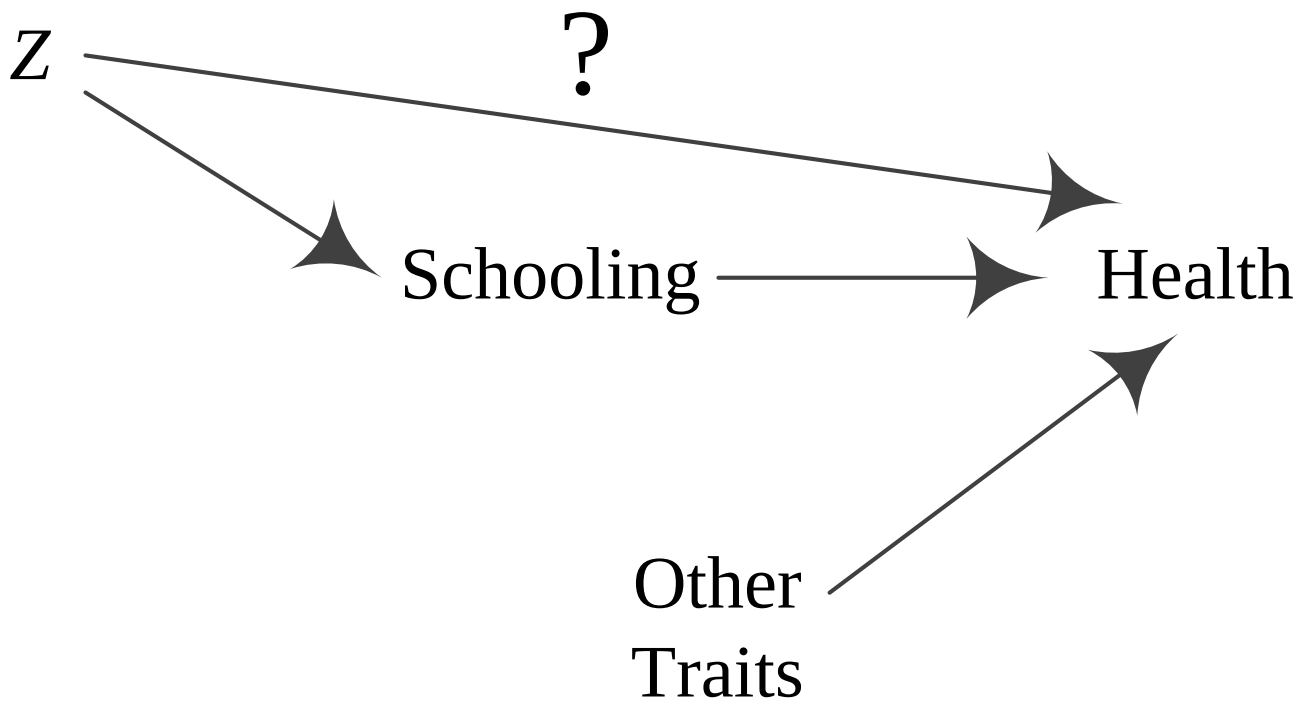
Note: U.K. Data: Authors' calculations using BCS70. The graph shows the raw differentials in the outcomes between individuals with post-compulsory and compulsory level of education. Source: Conti, Heckman and Urzua.

Inferring Causation



Search for causality: Two strategies

- Instruments Z



Random assignment is an instrument

- Control for "other traits" or proxies for "other traits."
  - Matching assumes we can perfectly proxy the "relevant" other traits (traits that affect schooling and health).
  - Our approach does *not* make the strong assumptions of matching.

Is there a causal effect of education on health?

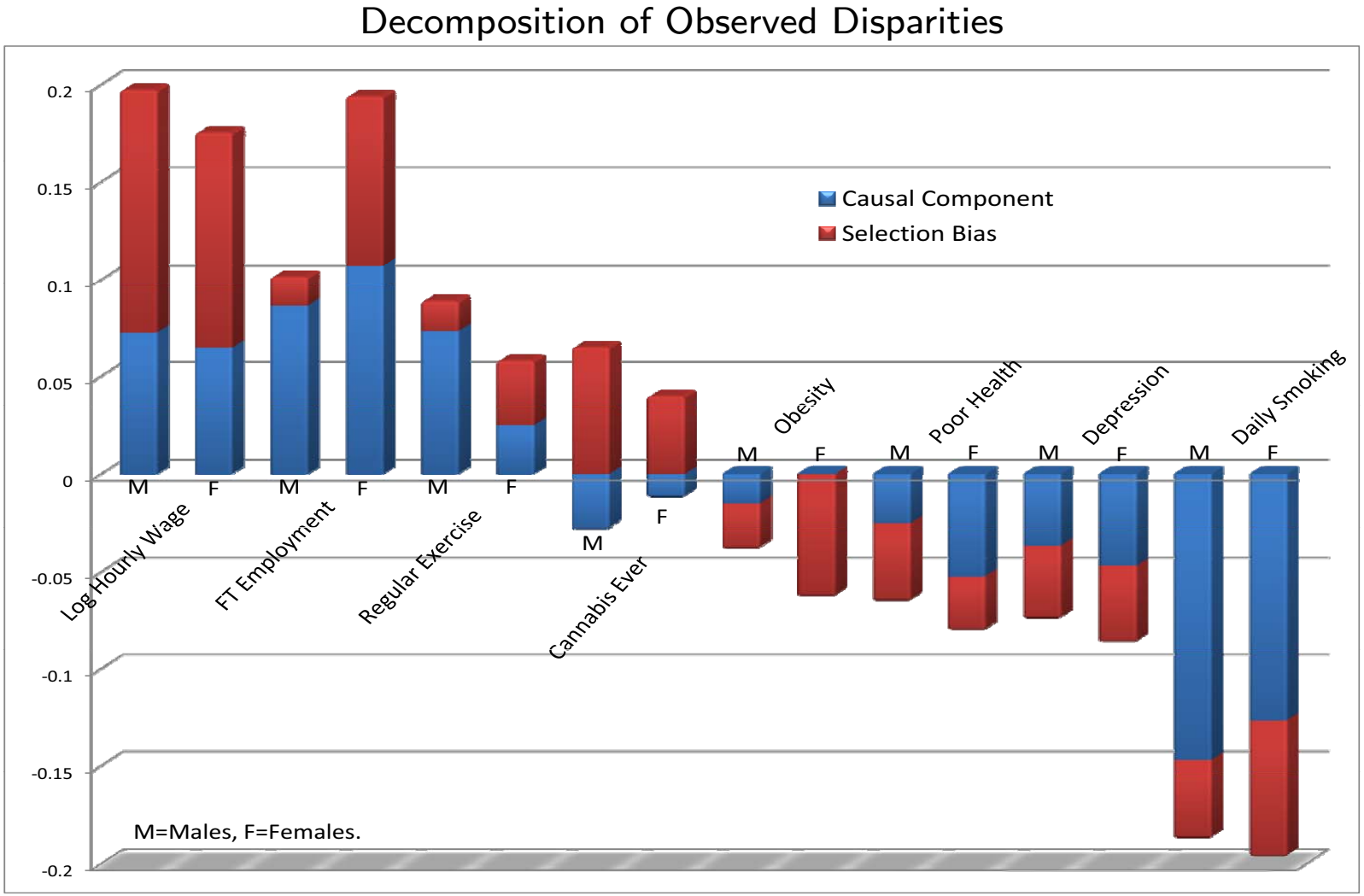
The Causal Effect of Education

- We consistently find that education has a statistically significant effect that is stronger on healthy behaviors than on health.
- We go beyond mean effects to uncover gains and losses for different individuals.
- We find evidence of substantial heterogeneity in the effects of education across the distribution of early endowments.

How much of the correlation between education and health is due to selection on traits in place before the educational levels we study are selected?

- Some of these traits come from early environments before age 10.
- A substantial part of the observed education-health differential is explained by pre-education factors:
  - self-regulation and early health are more important determinants of health and healthy behaviors than cognition, especially for men.
- Nonetheless, education has a statistically significant causal effect on healthy behaviors.

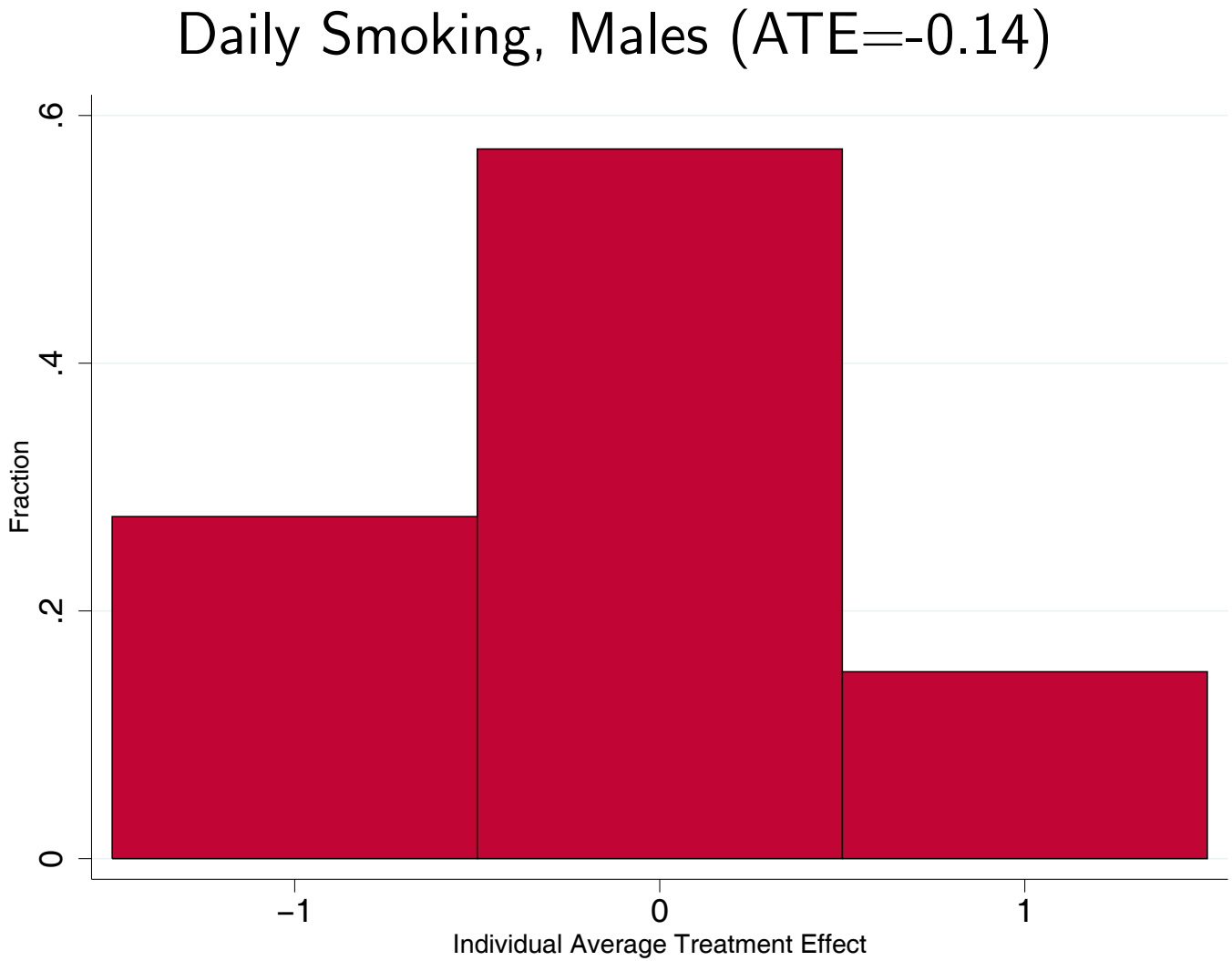
The Causal Effect of Education



Distributional Treatment Effects: Does everybody benefit?

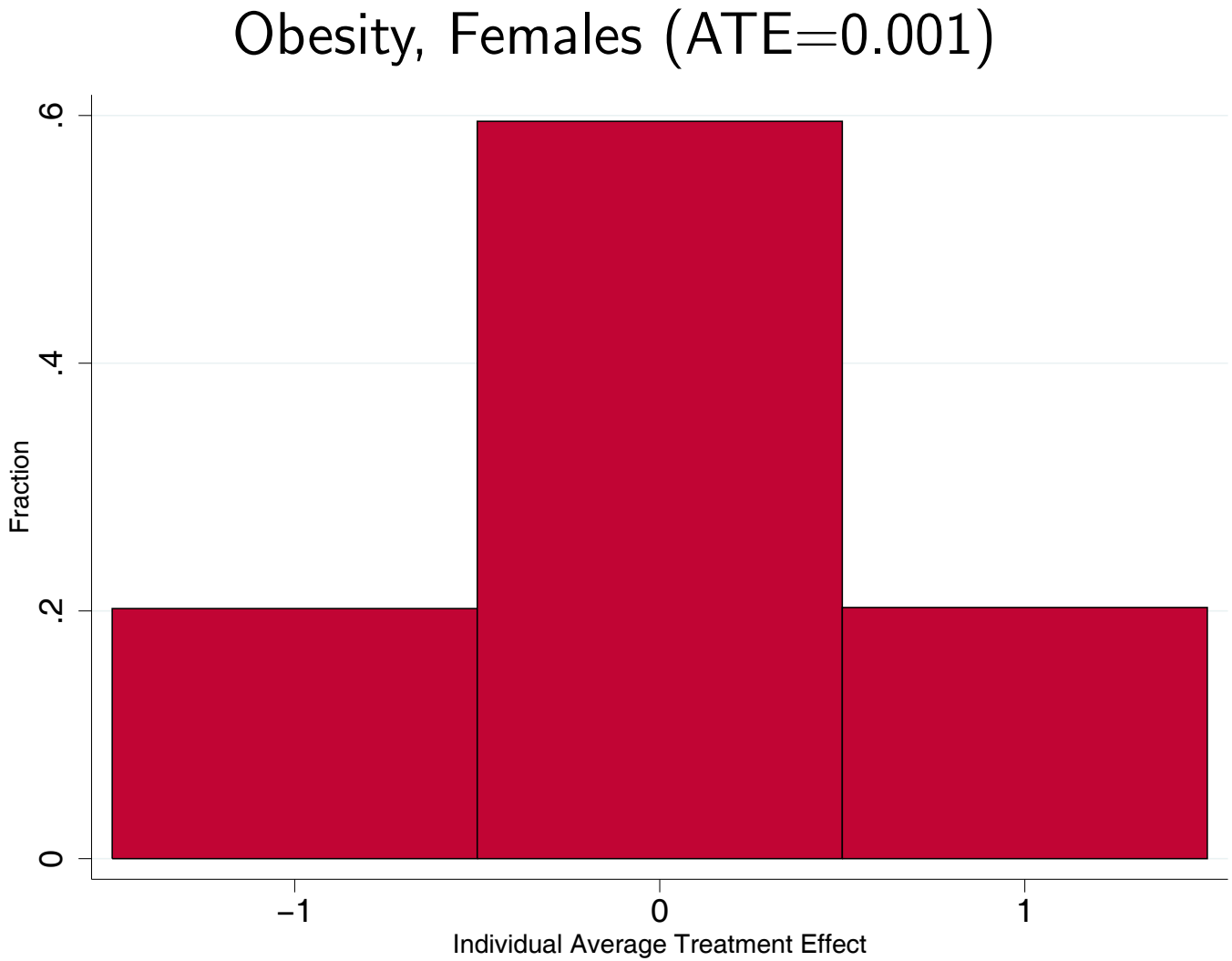
- We also identify **the joint distribution** of the treatment effects.

Distribution of Average Treatment Effects



- Behind the ATE, there are gains and losses for different individuals.

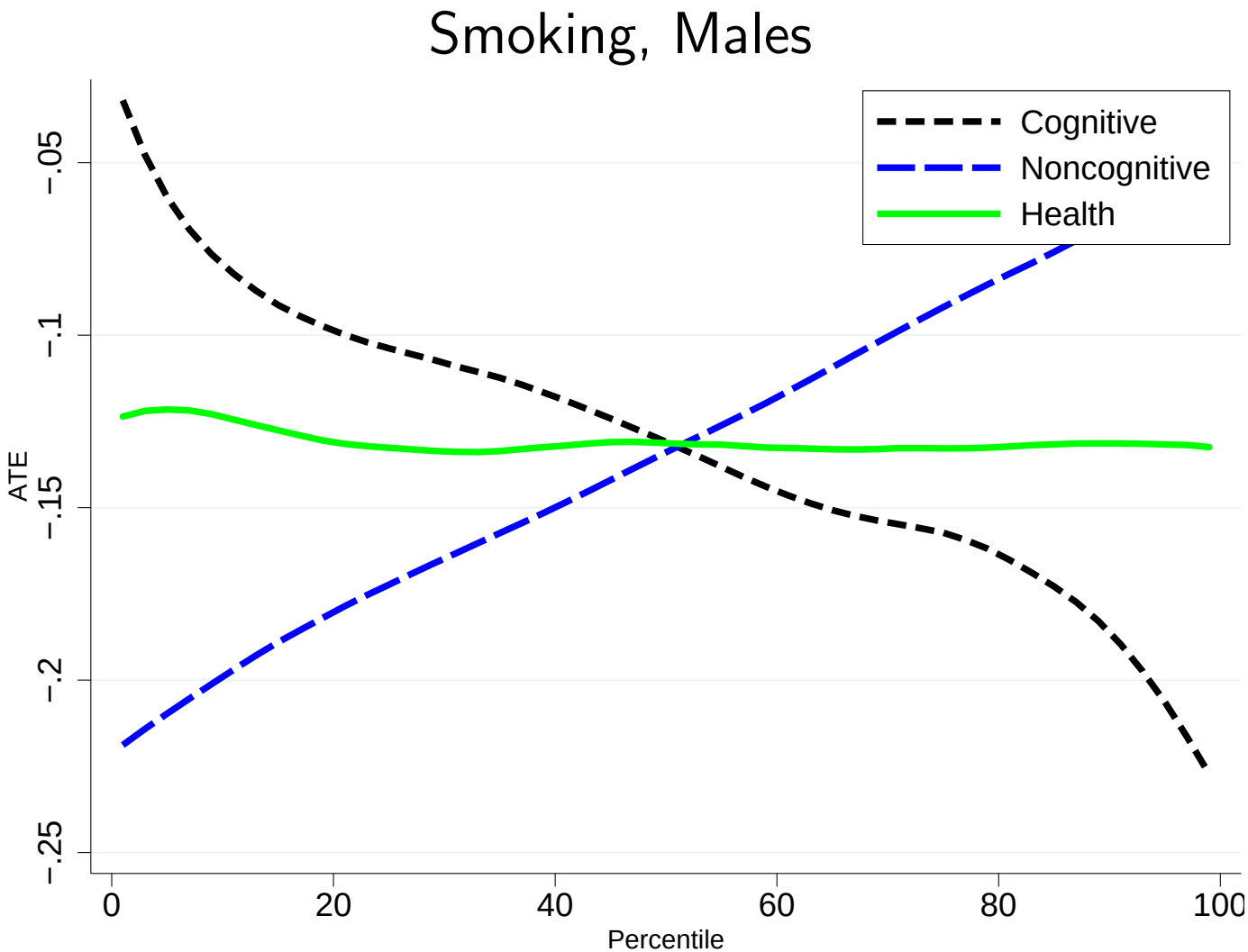
Distribution of Average Treatment Effects



- Which produces essentially a zero average treatment effect.

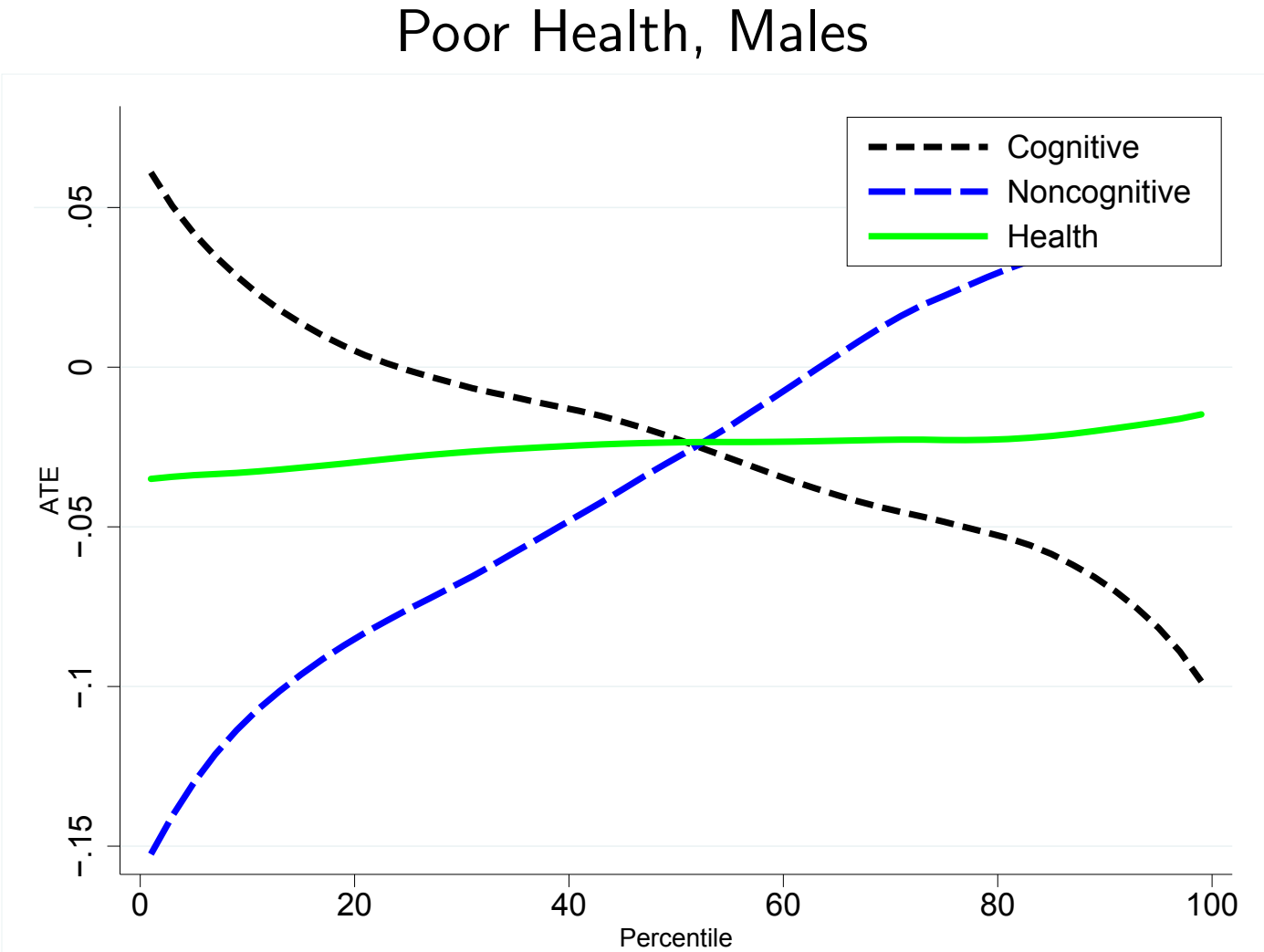
Who benefits?

Treatment Effect Heterogeneity



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

Treatment Effect Heterogeneity

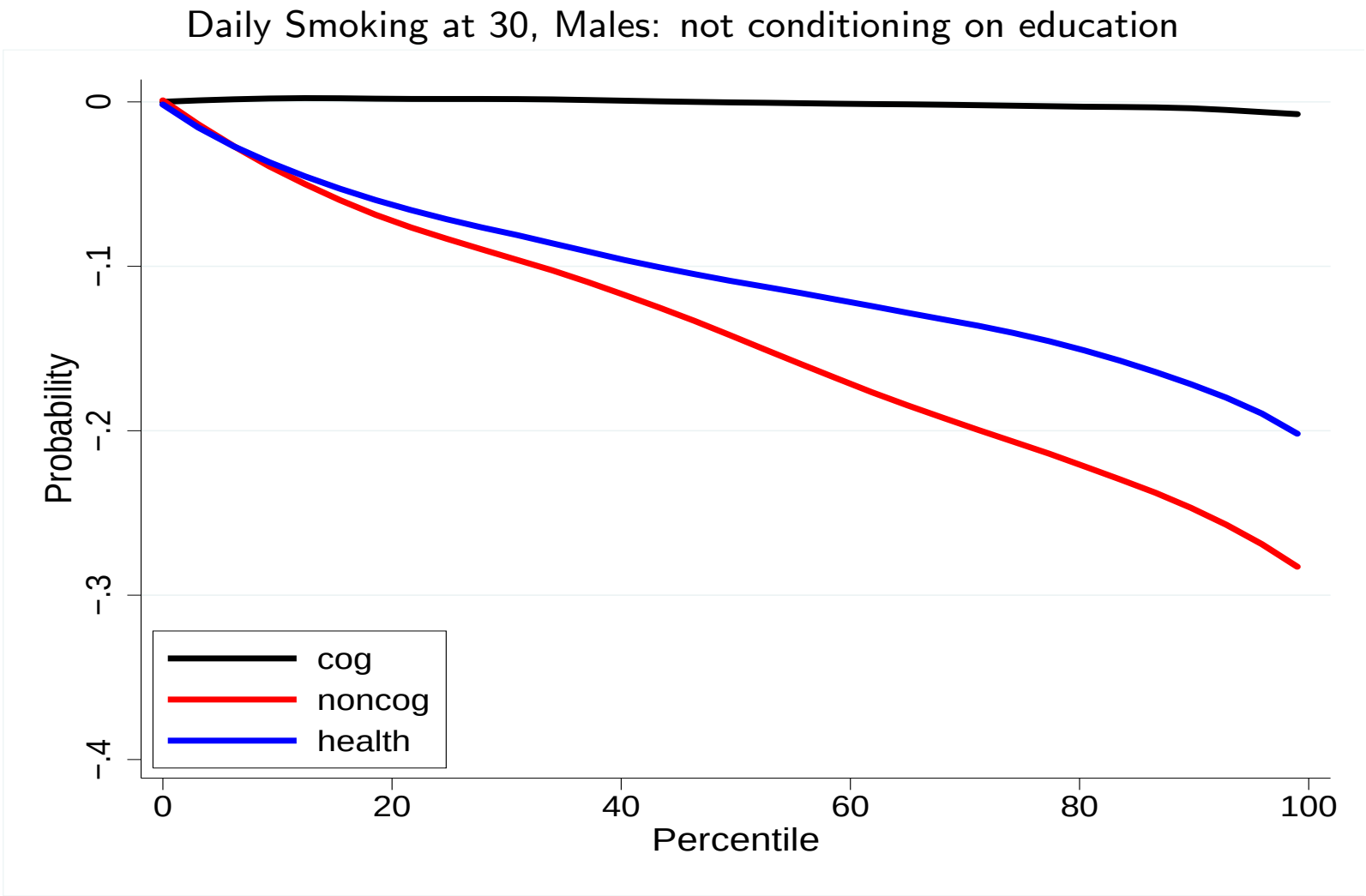


- Education compensates for low early noncognitive endowments and reinforces high early cognitive endowments.

The Role of Factors up to Age 10

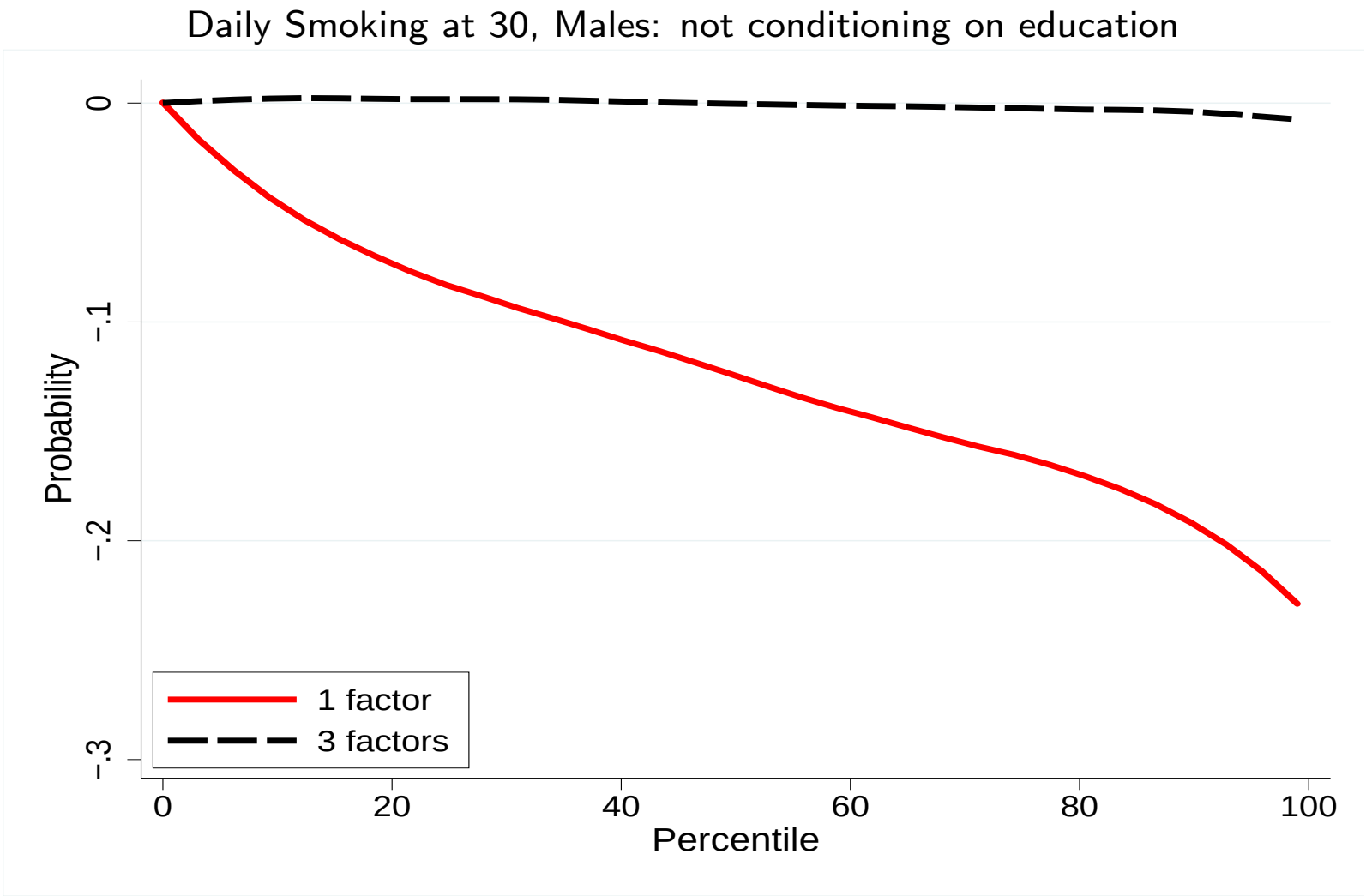
- Cognitive ability has a significant effect on health and health behaviors if self-regulation is not included in the model.

The Role of Factors up to Age 10



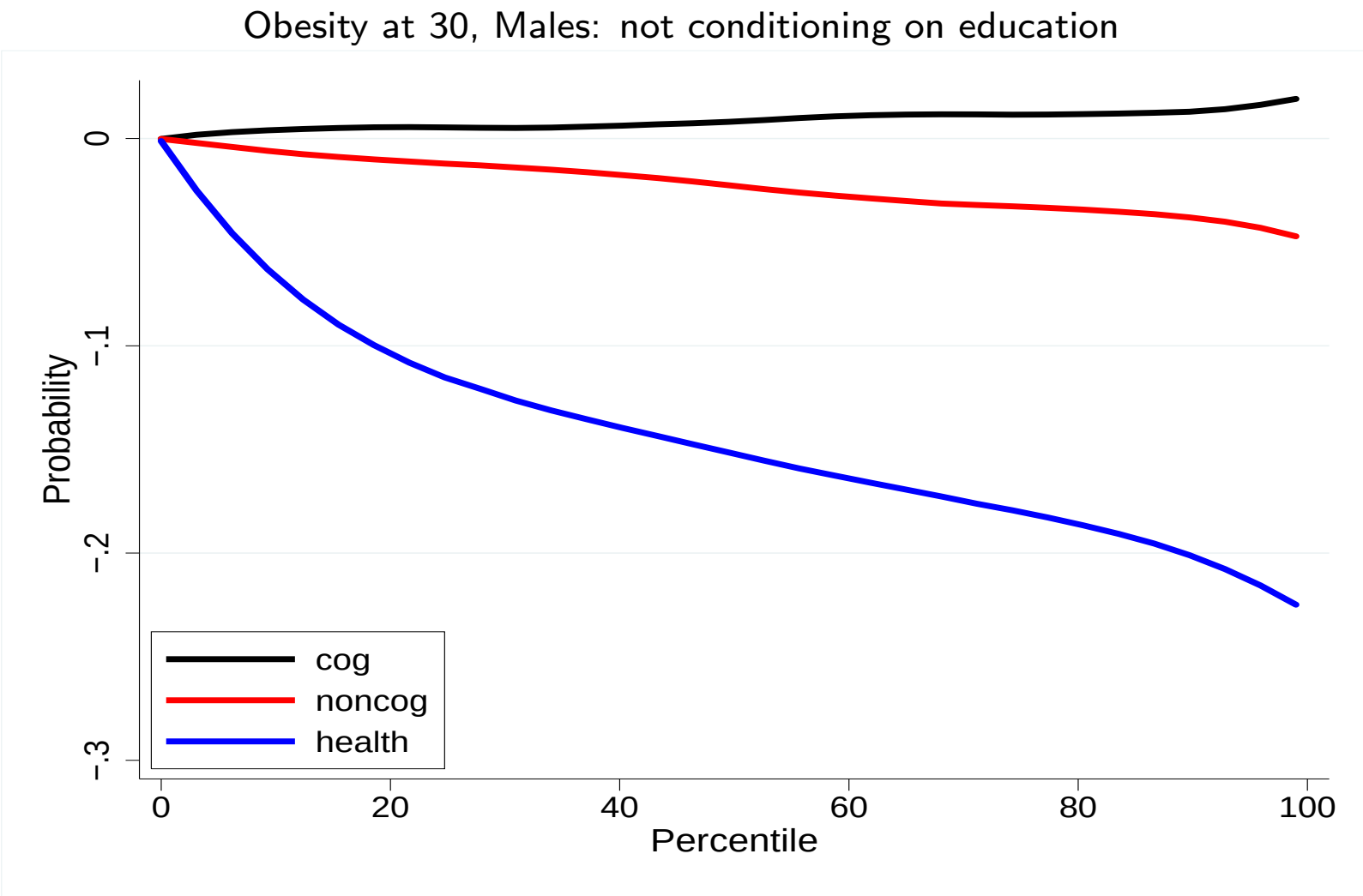
- Both self-regulation and physical health are equally important determinants of smoking.

The Role of Factors up to Age 10



- But not accounting for them *overestimates* the importance of cognition.

The Role of Early Physical Health



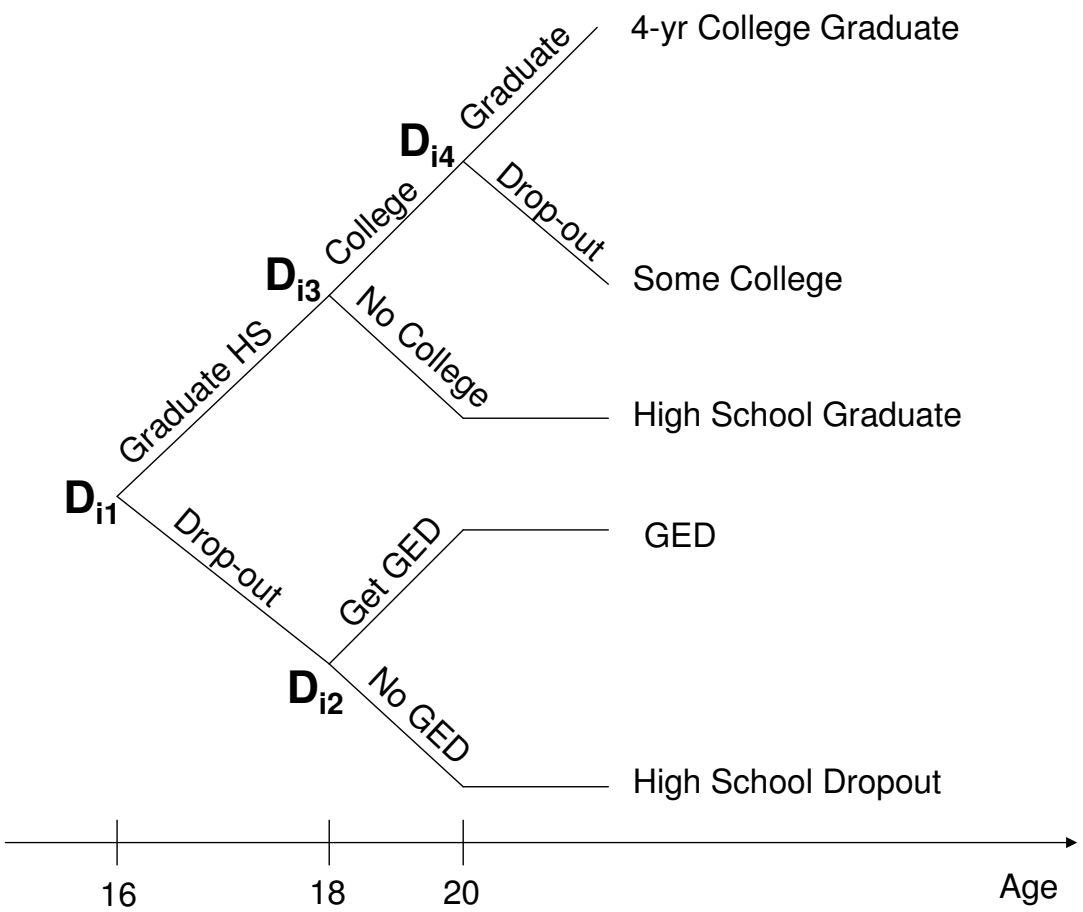
- Early physical health is the most important determinant of obesity for men.

Dynamic Sequential Model

Data: The National Longitudinal Survey of Youth (NLSY79)

- U.S. Data
- Nationally representative sample of men and women aged 14-22 when first interviewed in 1979.
- Education: sequential model with five final schooling levels: high school dropout, GED, high school graduate, some college, four year college degree.
- Outcomes (age 30):
  1. labor market (wages and employment)
  2. health status (obesity, PCS-12 scale, MCS-12 scale, Pearlin, CESD)
  3. health behaviors (smoking, regular exercise, drinking)
- Measurements (age 14-15):
  1. θ_C: ASVAB components of the AFQT
  2. θ_N: 9^{th} grade GPA in reading social studies, science and math, as well as early measured behaviors.

Figure 35: Sequential model for schooling decisions.



Decomposition of Mean Differences