The Economics and the Econometrics of Human Development

James J. Heckman

THE UNIVERSITY OF CHICAGO

HCEO Human Capital and Economic Opportunity Global Working Group

Summer School on Socioeconomic Inequality

July 15, 2013

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Inequality and Social Opportunity

- An approach based on building capacities to function: **Pre-distribution** rather than **Redistribution**.

Capabilities—the Capacities to Function

1. Capabilities—skills—are multidimensional.
2. Capabilities—skills—can be created, although there is a strong genetic component.
3. Different capabilities are more easily shaped at different stages of the life cycle. Large gaps in capabilities between advantaged and disadvantaged children open up early, **before children enter school**.
4. Families play an important role in shaping capabilities.
5. Schools matter, but what schools do depends on what parents send them and how parents support children in school.
6. An approach that recognizes the multidimensional aspects of inequality—health, education, crime, social engagement—using a unified framework of dynamic capability formation.

This approach offers both challenges and opportunities that I will discuss today.

- A central finding in the literature is that at least 50% of lifetime inequality in earnings is due to factors that are in place and known by the agent by age 18 (Keane and Wolpin (1997); Cunha et al. (2005); Huggett et al. (2011); Johnson (2010); Navarro (2011)).

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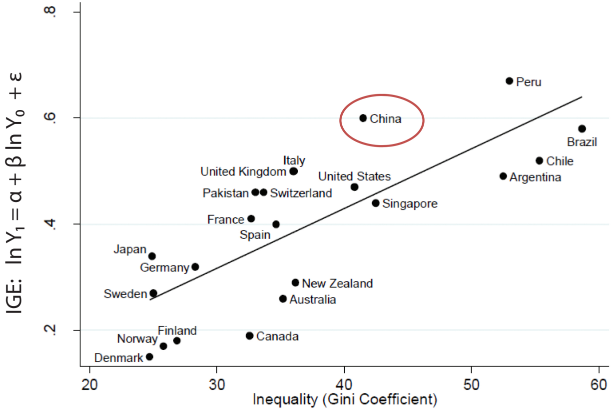
Key Policy Issues

- From the point of view of social policy, the key question is, how easy is it to remediate the effects 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?
- What form should they take?
- Go beyond treatment effects and understand the mechanisms that produce treatment effects to be able to compare very different policies and design new policies.

Intergenerational Mobility and Inequality: The "Gatsby Curve"



Source: Corak 2011, Inequality from generation to generation: the United States in Comparison

- What does income measure in this estimated relationship?

Intergenerational Correlations of Earnings

- Y_1 is income in generation "1"; Y_0 is income in generation "0"

$$\underbrace{\ln(Y_1)}_{\substack{\text{child}\\\text{permanent}\\\text{earnings}}} = \alpha + \beta \underbrace{\log(Y_0)}_{\substack{\text{parent}\\\text{permanent}\\\text{earnings}}} + \underbrace{\xi}_{\text{error term}} \tag{1}$$

- β: the intergenerational elasticity (IGE)

- Becker and Tomes (1979, 1986), Loury (1981), Solon (2004).
- Black and Devereux (2011).

Why the IGE may differ across countries and over time (Solon 2004)

- τ = tax rate
- Family budget constraint:

$$(1-\tau)Y_0 = \underbrace{C_0}_{\text{parental consumption}} + \underbrace{I_0}_{\text{parental investment}} \tag{2}$$

- Human capital of the child (h_1):

$$\underbrace{h_1}_{\substack{\text{human capital}\\\text{of child}}} = \underbrace{\psi}_{\substack{\text{productivity}\\\text{of the}\\\text{transmission}\\\text{process}}} \log(\underbrace{I_0}_{\substack{\text{parental}\\\text{investment}}} + \underbrace{Q_0}_{\substack{\text{governmental}\\\text{investment}}}) + \underbrace{e_1}_{\substack{\text{child initial}\\\text{endowment}}} \tag{3}$$

- Becker-Tomes (1986): more general credit market (limited borrowing against future income)

$$e_1 = \iota + \lambda e_0 + \chi_1 \tag{4}$$

- λ is between 0 and 1 and χ_1 is white noise.
- Earnings equation:

$$\log(Y_1) = \mu + wh_1 \tag{5}$$

- w is the payment to a unit of human capital.

- Family maximizes:
  $U_1 = (1-\delta)\log(C_0) + \delta \log(Y_1)$.
- δ measures the degree of altruism towards the child.
- Parental investment:

$$I_0 = \left[\frac{\delta\psi w}{1-\delta\,(1-\psi w)}\right](1-\delta)Y_0 - \frac{(1-\delta)}{1-\delta(1-\psi w)}Q_0$$

- Provision of governmental goods:
  $Q_0/[(1-\tau)Y_0] = \varphi - \gamma\log(Y_0)$.
- Assumes no lending or borrowing across generations.

$$\log(Y_1) \doteq \mu^* + [(1-\gamma)\psi w] \log(Y_0) + we_1 \tag{6}$$

- e_1 correlated with $\ln(Y_0)$ through common shock e_0.

- In steady state, $\sigma_0 = \sigma_1$

$$\beta = \frac{(1-\gamma)\psi w + \lambda}{1 + (1-\gamma)\psi w \lambda} \quad \uparrow \text{ as } \lambda \uparrow, \psi \uparrow, w \uparrow, \gamma \downarrow .$$

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- Cross section variance of log Y (steady state):

$$\text{Var}(\ln Y) \sim \frac{\text{Var}\,\chi}{1-\beta^2}$$

$$\uparrow \text{ in } \lambda, \psi, w, 1-\gamma$$

- New term not in β is Var(χ) associated with shocks to endowments

Questions:

1. Is income the correct summary of family influence?
2. Are credit constraints as important as this model emphasizes?
3. What form should Q_0 take?
4. How do families transmit their influence?

- A (false) belief that family influence on educational decisions vanishes in the presence of perfect credit markets—but in fact in a richer view of the role of parenting this claim is not true.

How well does this model represent the current state of knowledge about the origins of inequality?

Some relevant findings from the recent literature

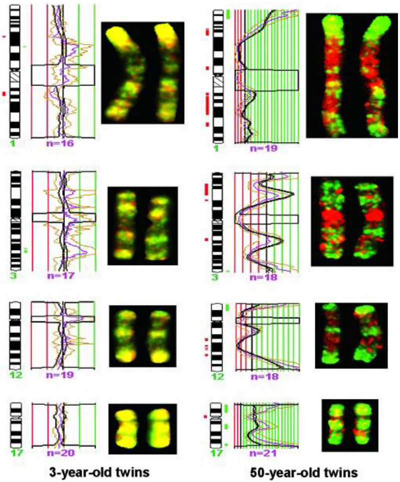
1. *Ability matters*.
2. *Abilities are multiple in nature*.
3. Abilities are created—not solely genetically determined.
4. The nature versus nurture distinction is obsolete (epigenetics).

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

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

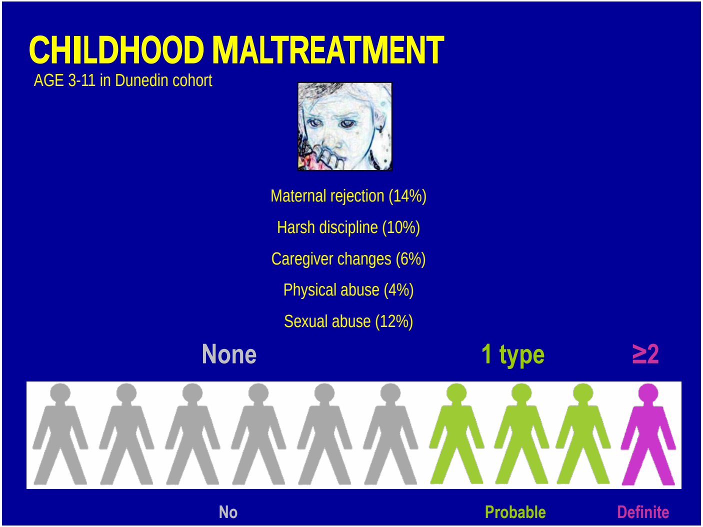
- Evidence of environmental effects on gene expression.
- Traditional linear models that are widely used and attempt to separate genes and environments fail to capture this interaction.
- Estimated "genetic" effects have a strong environmental component.

DNA methylation and histone acetylation patterns in young and old twins

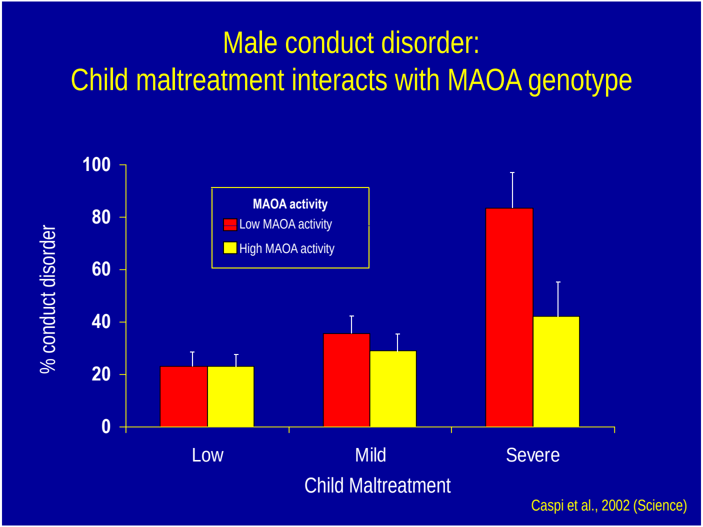


Source: Fraga, Ballestar et al. (2005)

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).

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.

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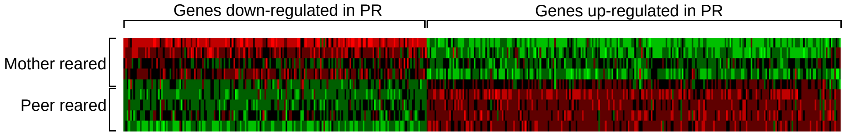
The Rhesus Monkeys Experiment

- 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.

- 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

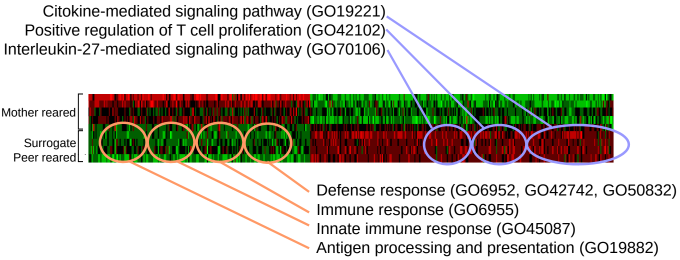


Source: Cole, Conti, Heckman, and Suomi (2012).

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 (2012).

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

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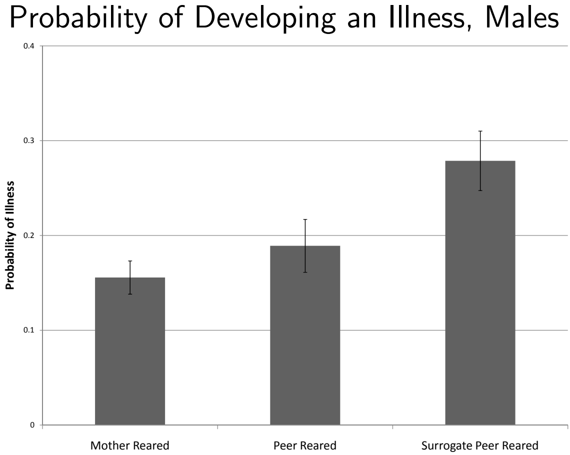
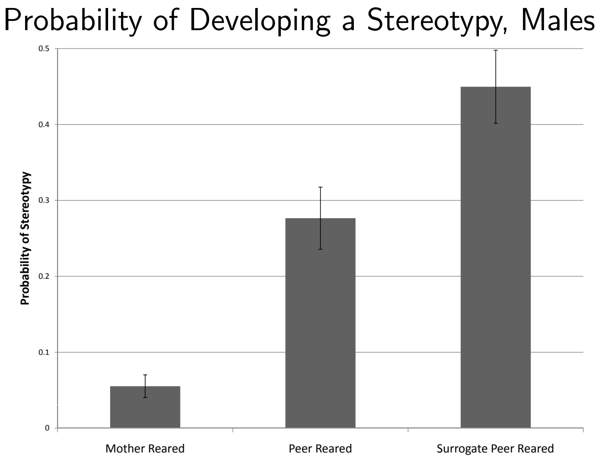


Source: Conti, Hansman, Heckman and Suomi (2012).

- 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 (2012).

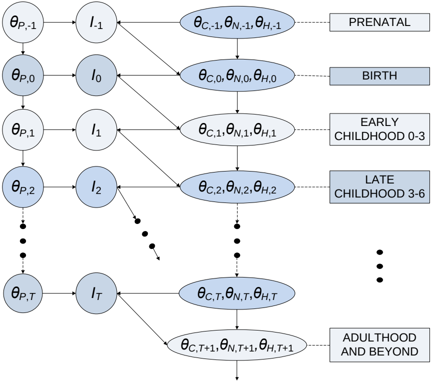
- We find the same long-lasting effect for females.
- **We find no evidence that the detrimental effects of early rearing conditions are compensated by a normal environment later in life.**

1. 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

$$\theta_t = (\theta_C, \theta_N, \theta_H) \text{ capacities at } t$$
$$\theta_{P,t}\text{: parental traits at } t$$
$$I_t\text{: investment at } t$$
$$Q_t\text{: kept implicit}$$
$$\theta_{t+1} = f_t(\theta_t, I_t, \theta_{P,t})\text{: } \textbf{Technology of Skill Formation}$$



2. 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

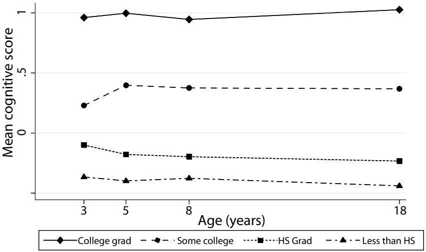
- Any evidence of binding credit constraints is in the early years of childhood.
- Controlling for ability, at the age schooling decisions are made, racial/ethnic socioeconomic gaps in schooling **reverse sign**.
- Family income in the adolescent years plays only a minor role in explaining schooling.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

3. 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 it's 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.

5. *Ability gaps between individuals and across socioeconomic groups open up at early ages for both cognitive and noncognitive skills*.

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).

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

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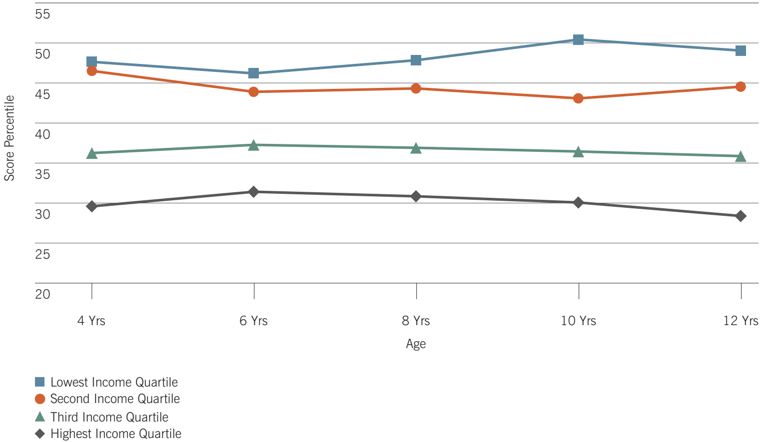


6. *Gaps in capabilities by age across different socioeconomic groups have counterparts in gaps in family investments and environments.*

What is the Role of Families and Environments?

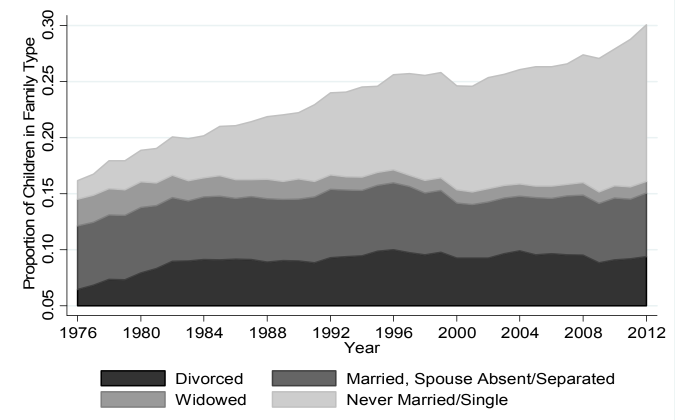
- Which aspects of families and environments are responsible for producing these gaps?
- Genes?
- Family environments and investments? Social interactions?
- The evidence from numerous intervention studies suggests an important role for investments and family environments in determining adult capabilities.

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

Family Environments

- In many 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.

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



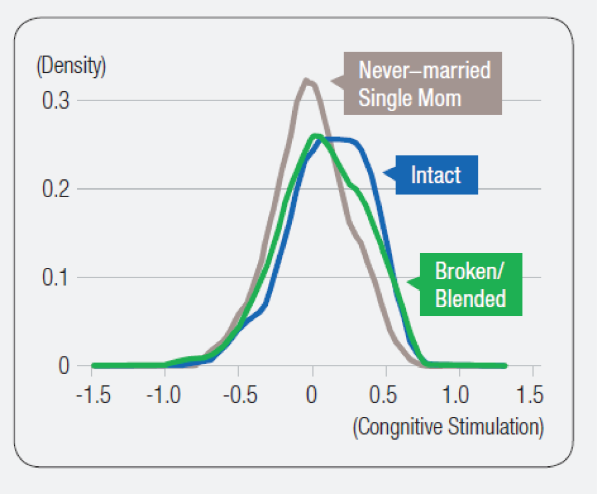
Source: IPUMS March CPS 1976-2012

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

4. 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.

Cognitive Stimulation and Emotional Support by Family Type



Source: Moon (2012)

Cognitive Stimulation and Emotional Support by Family Type

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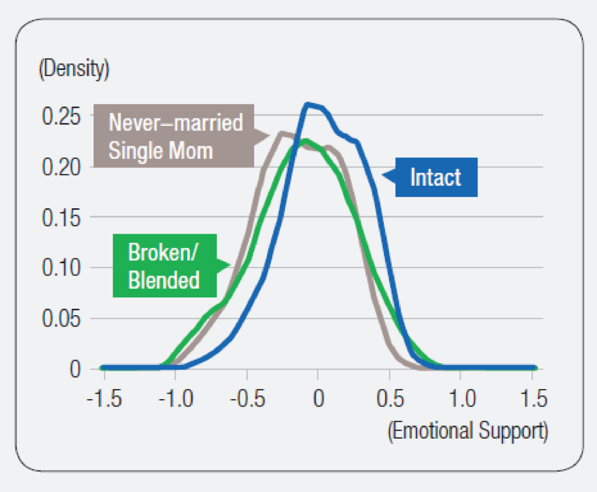
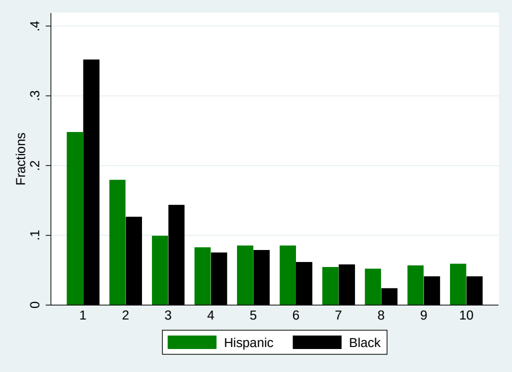


Source: Moon (2012)

Minority Groups' Parental Investment in Deciles of White Distribution: Material Resource, age 0–3

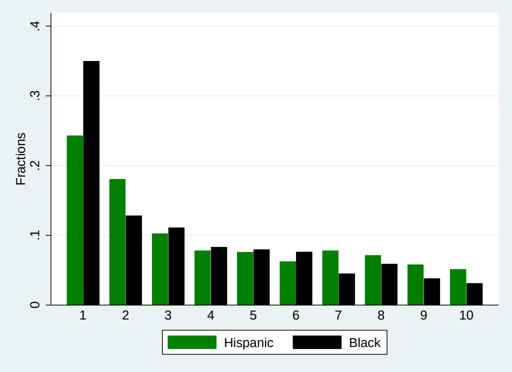


(a) Girls

Note: Intact family, adjusted for mother's education.

Source: Moon (2013).

Minority Groups' Parental Investment in Deciles of White Distribution: Material Resource, age 0–3

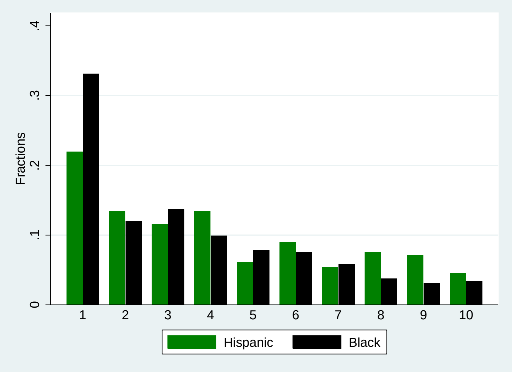


(b) Boys

Note: Intact family, adjusted for mother's education.

Source: Moon (2013).

Minority Groups' Parental Investment in Deciles of White Distribution: Cognitive Stimulation, age 0–3



(c) Girls

Note: Intact family, adjusted for mother's education.

Source: Moon (2013).

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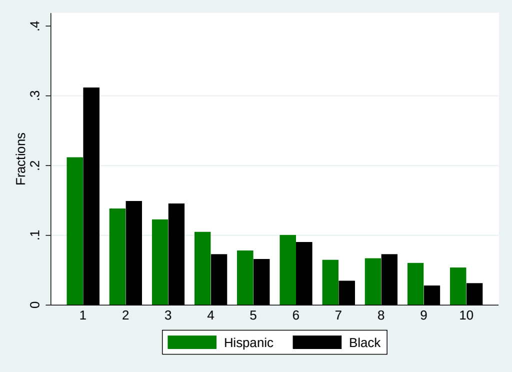
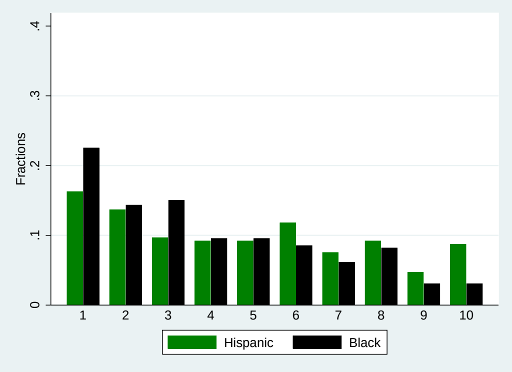


(d) Boys

Note: Intact family, adjusted for mother's education.

Source: Moon (2013).

Minority Groups' Parental Investment in Deciles of White Distribution: Emotional Support, age 0–3

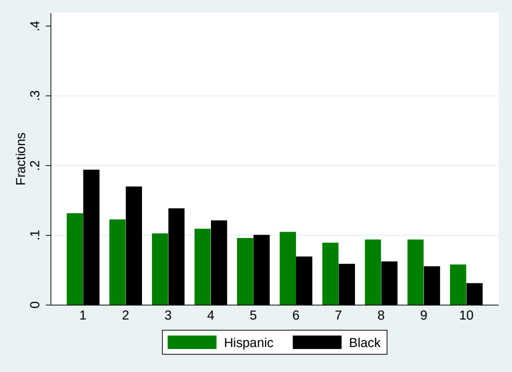


(e) Girls

Note: Intact family, adjusted for mother's education.

Source: Moon (2013).

Minority Groups' Parental Investment in Deciles of White Distribution: Emotional Support, age 0–3

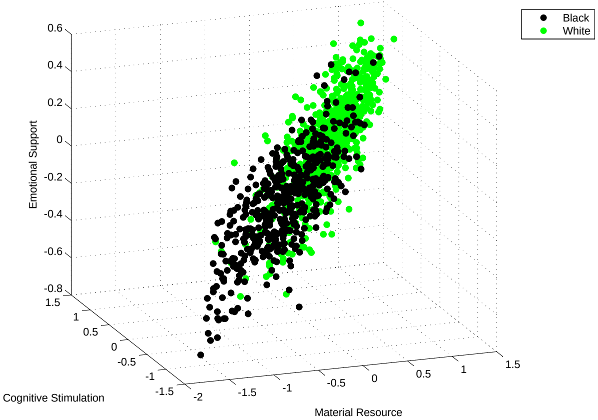


(f) Boys

Note: Intact family, adjusted for mother's education.

Source: Moon (2013).

Joint Distribution of Parental Investments at age 12: Black vs. White



(g) Girls

Source: Moon (2013).

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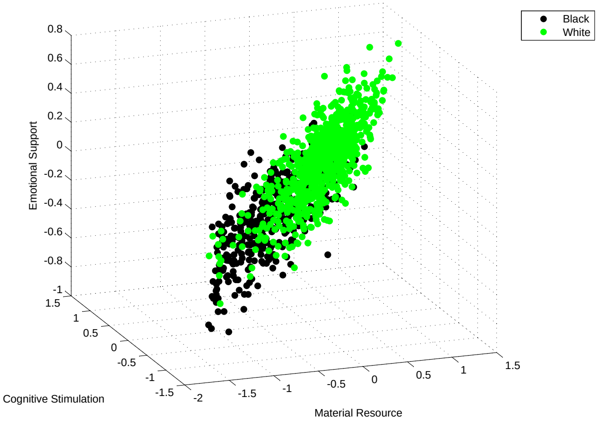
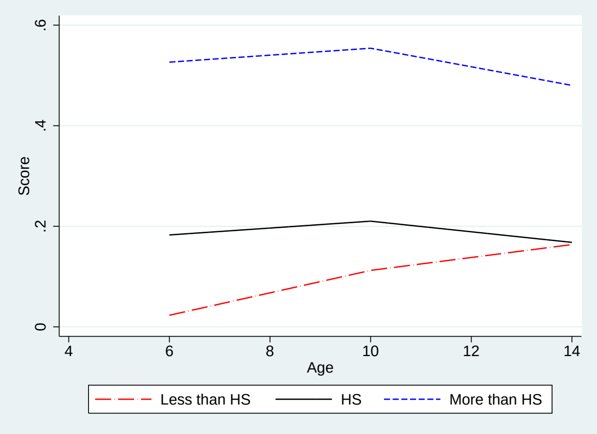


(h) Boys

Source: Moon (2013).

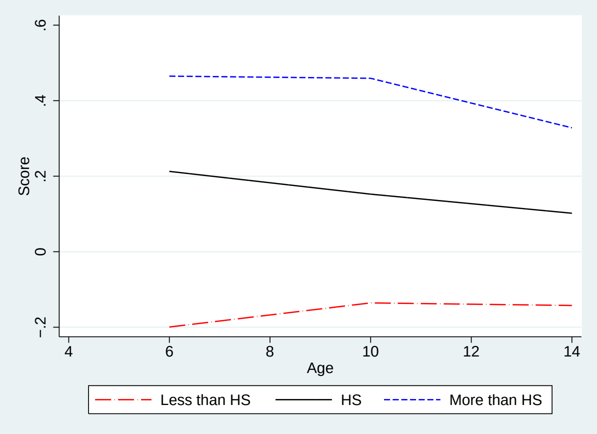
Parental Investment over Childhood among Whites by Mother's Education: Material Resource



(i) Girls

Source: Moon (2013).

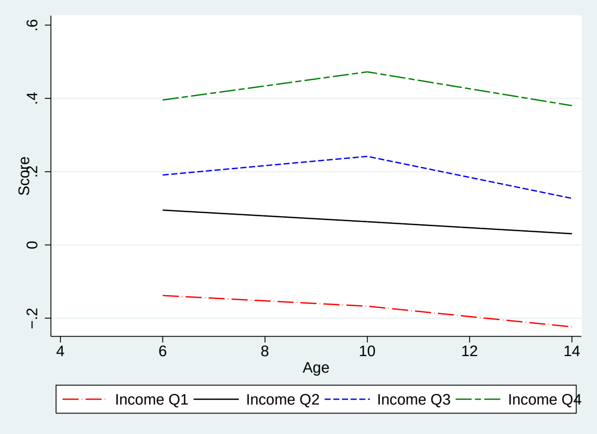
Parental Investment over Childhood among Whites by Mother's Education: Material Resource



(j) Boys

Source: Moon (2013).

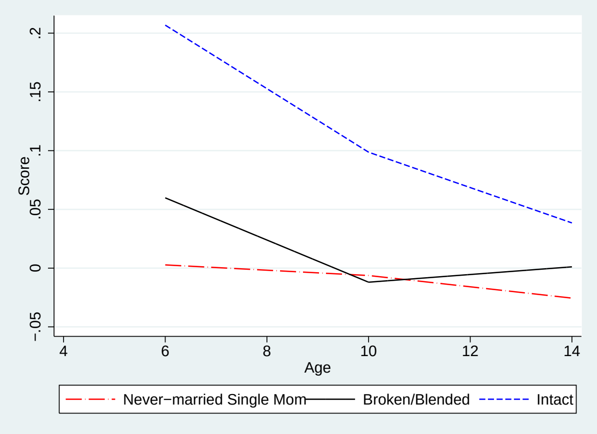
Parental Investment over Childhood among Whites by Family Income Quartile: Cognitive Stimulation



(k) Boys

Source: Moon (2013).

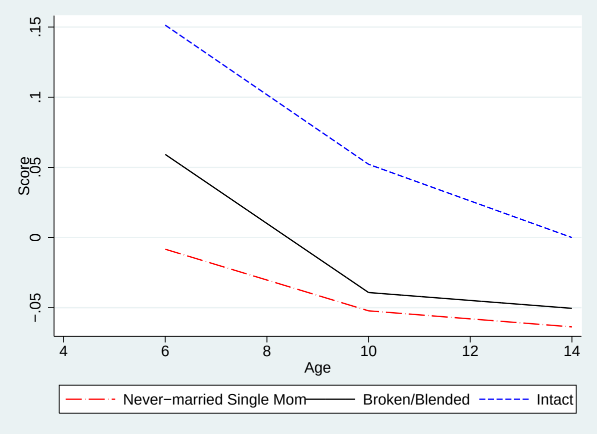
Parental Investment over Childhood among Whites by Family Type: Emotional Support



(l) Girls

Source: Moon (2013).

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



(m) Boys

Source: Moon (2013).

Source of Differences

(a) Information?
(b) Expectations?
(c) Credit constraints? General resources?

- Parental ignorance substantial (Lareu, 2010; Cunha et. al 2012)

  (i) Information about the technology of skill formation
  (ii) Information about the child itself

Hart & Risley, 1995

Children enter school with “meaningful differences“ in vocabulary knowledge.

1. Emergence of the Problem

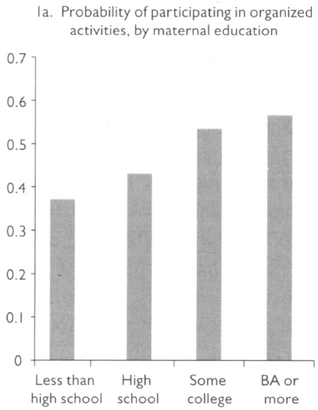
In a typical hour, the average child hears:

Family Status	Actual Differences in Quantity of Words Heard	Actual Differences in Quality of Words Heard
Welfare	616 Words	5 affirmatives, 11 prohibitions
Working Class	1,251 Words	12 affirmatives, 7 prohibitions
Professional	2,153 Words	32 affirmatives, 5 prohibitions

2. Cumulative Vocabulary at Age 3

Cumulative Vocabulary at Age 3	
Children from welfare families:	500 words
Children from working class families:	700 words
Children from professional families:	1,100 words

Effects of Maternal Education and Family Income on Children's Participation in Organized Activities: Black Male Child



Source: Lareau (2012), Figure 1

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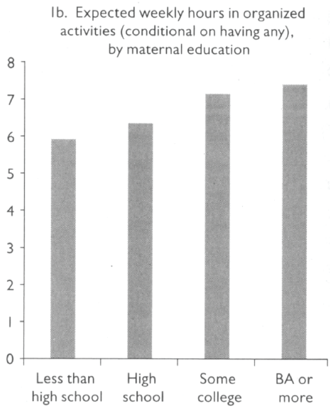

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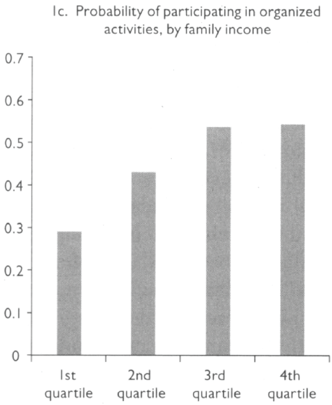

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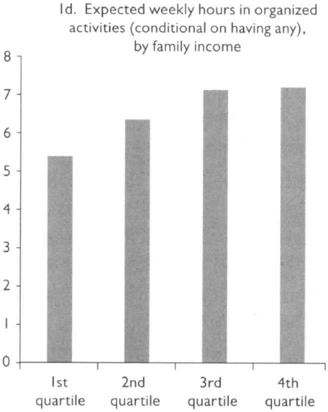

Source: Lareau (2012), Figure 1

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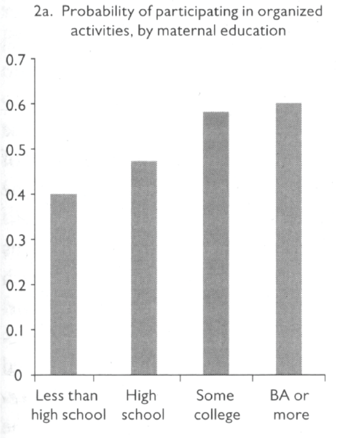
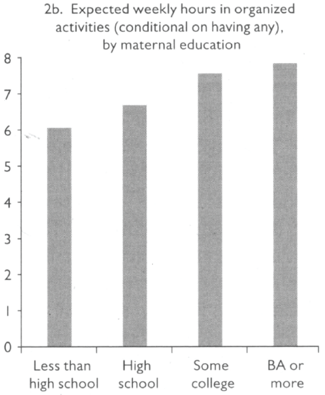
Effects of Maternal Education and Family Income on Children's Participation in Organized Activities: White Female Child



Source: Lareau (2012), Figure 2

Effects of Maternal Education and Family Income on Children's Participation in Organized Activities: White Female Child



Source: Lareau (2012), Figure 2

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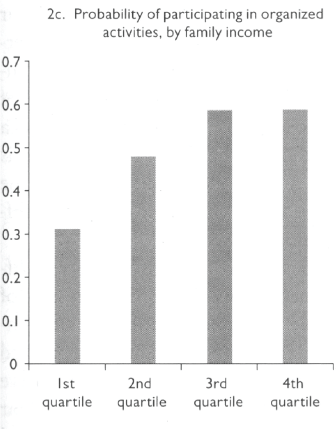

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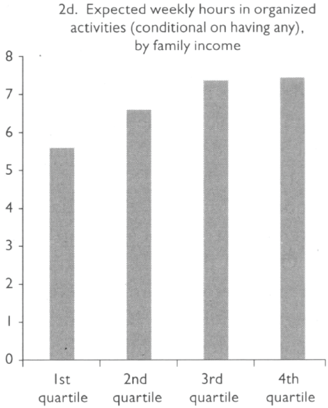


Source: Lareau (2012), Figure 2

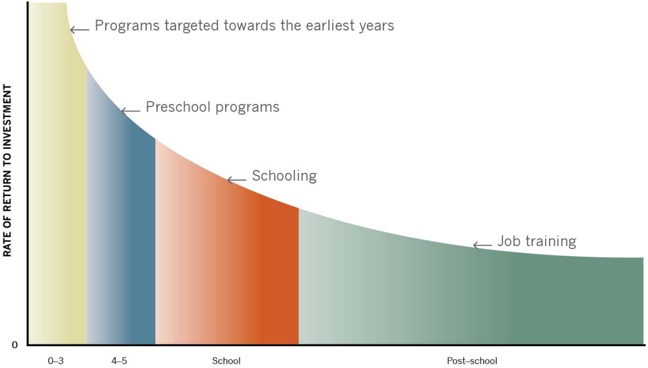
Note: Based on coefficients from a tobit regression. These computations assume a reference child who is white and female; whose family wealth is in the second quartile; whose father works and whose mother does not; who has the sample mean values of age and number of siblings; and whose time diaries were collected on Wednesday and Saturday. For the education charts, income is set to the second quartile; for the income calculations, education is set to high school. Source: Based on author's analysis of PSID-CDS data.

7. *In both animal and human species, there is compelling evidence of critical and sensitive periods in the development of the child*.
8. *Early life conditions are not the full story: resilience, recovery, and repair*.
9. *As currently configured, many public job training programs and adult literacy and educational programs that attempt to remediate years of educational and emotional neglect among disadvantaged individuals have a low economic return and produce meager effects for most people.*

- 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

10. *Despite the low returns to interventions targeted toward disadvantaged adolescents, the empirical literature shows high economic returns for remedial investments in young disadvantaged children*.

Returns to a Unit Value Invested



Source: Heckman (2008)

11. *If early investment in disadvantaged children is not followed up by later investment, its effect at later ages is lessened*.
12. *The effects of credit constraints on a child's outcomes when the child reaches adulthood depend on the age at which they bind for the child's family. Credit constraints operating in the* ***early*** *years have effects on adult ability and schooling outcomes. Carneiro and Heckman (2003) show that controlling for family permanent income reduces the estimated effect of early income on child outcomes. Permanent income has a strong effect on child outcomes. The strongest evidence for an effect of the timing of parental income for disadvantaged children is in their early years. Holding ability constant, family income plays no role in adolescent schooling choice.*

13. *Socioemotional (noncognitive) skills foster cognitive skills and are an important product of successful families and successful interventions in disadvantaged families*.
14. *Parental knowledge of the production technology of children is very limited, especially among disadvantaged parents (Cunha et al., 2012, 2013, Lareau, 2001).*
15. *Early life factors play an important role in shaping adult health (Barker, 1993; Gluckman and Hansen 2005; Conti et al., 2012).*
16. *Multiple treatment effects reported in the literature have a well established causal bases. The mechanisms producing the effects are much less clearly established.*

- Literature is long on treatment effects, short on understanding mechanisms

- Mechanisms needed for policy and interpretation

Dynastic Model of Parental Investment that Emphasizes the Interaction of Dynamic Complementarity and Credit Markets

Cunha and Heckman (2007, 2009) and Cunha (2007); Heckman and Mosso (2013)

- One child families
- **Multiple periods** as adults and as children
- Allows for critical and sensitive periods
- Parental altruism over child and adult outcomes
- Parents face different constraints
  1. Inability of the family to borrow against future income of child
  2. **Inability of parents to borrow against their own future income**
- Children cannot choose their parents (accident of birth)
- Retain h as a scalar ("human capital")

Which features of the list of facts are captured by the model?

- Abilities created ($\equiv$ human capital)
- Silent on genetics
- Explains emergence of ability gaps
- Relates to gaps in family investments
- Critical and sensitive periods
- Explains why later life interventions may not be as effective as early life interventions
- High returns for disadvantaged children
- Why early investment should be followed by later investment
- Why early credit constraints have bigger effects on child outcomes than later constraints
- It captures empirically important mechanisms of family influence that are present even when credit constraints are absent: parental influence on IGE and educational choices even when credit markets are perfect

- 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 she is $2T$ years old, just before her child's child is born.

- Parents invest in their children because of altruism.
- I_t: parental investments in child skill when the child is t years old, where $t = 1, 2, \ldots, T$.

- Retain scalar human capital but there are critical and sensitive periods. For generation g in period t:

$$h_{t+1}^{g} = f_t(\underbrace{h_t^g}_{\text{self-productivity}}, \overbrace{I_t^g}^{\text{parental investment}}, \underbrace{h_t^{g-1}}_{\substack{\text{parental}\\ \text{human}\\ \text{capital}}}, \underbrace{Q_t^g}_{\substack{\text{governmental}\\ \text{investment}}}, \underbrace{\varepsilon_t^g}_{\text{shocks}})$$

- f_t increasing in all arguments
- h_0^g: initial condition (can depend on parental investment and parental human capital)

Complementarity/Substitutability

Static Complementarity/Substitutability:

$$\frac{\partial^2 h^g_{t+1}}{\partial I^g_t \partial h^g_t} \gtrless 0; \quad \frac{\partial^2 h^g}{\partial I^g_t \partial h^{g-1}_t} \gtrless 0$$

Dynamic Complementarity/Substitutability:

$$\frac{\partial^2 h^g_{t+j}}{\partial I^g_t \partial I^g_{t+j}} \gtrless 0; \quad j \geq 1$$

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_0^g, from $J(\theta_0^g)$, which they can influence through investment.
- Drop "g" superscript to simplify notation.

- 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:

$$\underbrace{C_1 + I_1 + \frac{C_2 + I_2}{(1+r)} + \frac{b'}{(1+r)^2}}_{\text{Parental choice variables}} = wh + \frac{wh}{(1+r)} + b. \tag{7}$$

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

$$V(h, b, \theta_0) = \max \left\{ \eta(C_1) + \beta\eta(C_2) + \beta^2 \delta E\left[V(h', b', \theta_0')\right] \right\}. \tag{8}$$

A Special Case

- Assume h_0, I_1, I_2 are scalars.
- The child's adult stock of skills, h':

$$h' = m_2\left(h, \theta_0, I_1, I_2\right). \tag{9}$$

- Conventional specification of technology (9) implicit in one-period models:

$$h' = m_2\left(h, \theta_0, \gamma I_1 + \left(1-\gamma\right) I_2\right) \tag{10}$$
$$\gamma = 1/2.$$

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

- Polar opposite:

$$h' = m_2\left(h, \theta_0, \min\left\{I_1, I_2\right\}\right). \tag{11}$$

- More general technology:

$$h' = m_2\left(h, \theta_0, \left[\gamma\left(I_1\right)^{\phi} + (1-\gamma)\left(I_2\right)^{\phi}\right]^{\frac{1}{\phi}}\right), \tag{12}$$

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

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

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

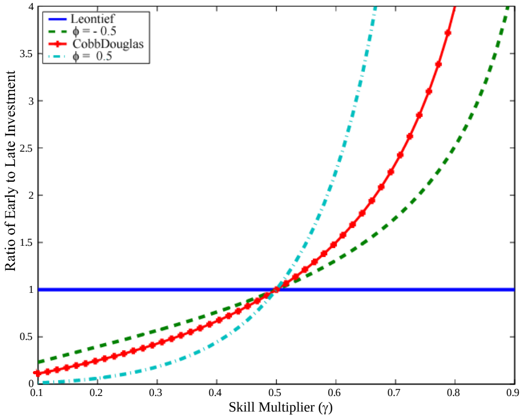
- When $\phi = 1$, early and late investments are perfect CES substitutes, the optimal investment strategy is straightforward.
- The price of early investment is \$1.
- The price of late investment is $\$1/(1+r)$.
- Productivity of early investment: γ; late investment $(1-\gamma)$.
- Invest early if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

General Case

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

$$\frac{I_1}{I_2} = \left[\frac{\gamma}{(1-\gamma)(1+r)} \right]^{\frac{1}{1-\phi}}. \tag{13}$$

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.
- Generalizes Becker-Tomes.
- From the point of view of the child, this is a *market failure due to the accident of birth* (cannot insure against "bad" parents).

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 (8) subject to (7), the technology (12), and the liquidity constraint:

$$b' \geq 0. \tag{14}$$

- 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).**

Parents Themselves Face Lifetime Liquidity Constraints

- Cunha (2007); 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:

$$C_1 + I_1 + \frac{s}{(1+r)} = wh + b \tag{15}$$

$$C_2 + I_2 + \frac{b'}{(1+r)} = w\left(1+\alpha\right)h + s \tag{16}$$

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

- Suppose $\eta(C) = \left(C^{\lambda} - 1\right)/\lambda$:

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

$$= \left[\frac{\gamma}{(1-\gamma)(1+r)}\right]^{\frac{1}{1-\phi}} \underbrace{\left[\frac{C_1}{\beta C_2}\right]^{\frac{1-\lambda}{1-\phi}}}_{\leq 1}.$$

- 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 *relative* investment.

- Cunha et al. (2006) and Cunha and Heckman (2007) discuss the evidence in support of the importance of early credit constraints.
- Recent empirical work by Caucutt and Lochner (2012) confirms the findings reported in previous research. See Lochner and Monge-Naranjo (2012) for a survey.
- Evidence consistent with relative unimportance of family income on adult human capital, except possibly at early years.
- Ineffectiveness of adolescent interventions

- Question: Does this analysis support a social Darwinist point of view?
- Depends on the complementarity/substitutibility between I_1 and I_2
- Three different notions:
- $\theta_1 = f^1(\theta_0, I_1)$ $\qquad f^1_{12} < 0$ or $f^1_{12} > 0$
- $\theta_2 = f^2(\theta_1, I_2)$ $\qquad f^2_{12} < 0$ or $f^2_{12} > 0$
- $\theta_2 = g(I_1, I_2, \theta_0)$ $\qquad g_{12} < 0$ even if $f^2_{12} > 0$ (this seems to be the case)

Limitations of Analysis

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(A) One-dimensional focus on inequality as *income inequality*. Yet other dimensions: education, health, crime

(B) Places focus on credit market failures as a principal source of inequality

(C) But does broaden the role of family in producing inequality in investment and income

(D) Scalar ability: there are multiple abilities

(E) Scalar investments: yet multiple investments at indifferent stages of the life cycle

(F) Efficiency units model of labor market—yet there is evidence of comparative advantage in the labor market and other tasks in life. Huge literature on multiple skills with different pricing of skills and trends of prices

(G) No clear way to interpret a large and growing body of evidence on treatment effects from different policies.

(H) How to integrate family investments and government policies?

The Capability Approach to Inequality and Human Development

- 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.

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

8. Many early childhood interventions operate primarily through boosting noncognitive capabilities—IQ barely budged—if at all—by many interventions.
9. Adolescent remediation is largely ineffective especially for cognitive interventions.
10. 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.

The framework has five main ingredients:

1. **Age-Specific Outcome Functions** that show how capabilities, effort, incentives and purchased inputs determine outcomes of **functionings**;
2. **Dynamic Technologies** for producing capabilities;
3. **Parental Preferences**:
   - 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;
4. **Social Influences, and Government Policies** that help to shape investments in skills. Parental preferences for child outcomes;
5. **Information and Constraints** reflecting access to credit markets, time constraints, and constraints arising from social interactions and access to information.

Functionings

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

$$Y_{j,t} = \psi_{j,t}\left(\underbrace{\theta_{C,t}, \theta_{N,t}, \theta_{H,t}}_{\theta_t}, e_{j,t}, X_{j,t}\right), \quad j \in \underbrace{\{1, \ldots, J_t\}}_{\substack{\text{set of}\\ \text{available}\\ \text{activities}}} \tag{17}$$

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

$$e_{j,t} = \delta_j\left(R_{j,t}, A_t\right) \tag{18}$$

- $R_{j,t}$ 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, as well as purchased goods.
- $X_{j,t}$ is purchased inputs that affect functionings.

Dynamic Complementarity and the 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, 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), parental environments $(\theta_{P,t})$, and government investment Q_t:

$$\theta_{t+1} = f_t(\theta_t, I_t, \theta_{P,t}, Q_t). \tag{19}$$

- 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:*

$$\frac{\partial^2 f_t(\theta_t, I_t, \theta_{P,t}, Q_t)}{\partial\theta_t \partial I_t'} \geq 0. \tag{20}$$

- *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 (19) determines period $t+1$ capabilities (θ_{t+1}).
- This generates complementarity between investment in period t and investment in period s, $s > t$.
- Substitutability replaces "≥ 0" with "≤ 0."

- 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.

A Life Cycle Framework for Organizing Studies and Integrating Evidence

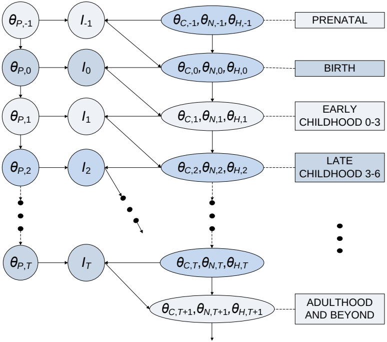
$\theta_t = (\theta_C, \theta_N, \theta_H)$ capacities at t

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

I_t: investment at t

Q_t: kept implicit

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



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Estimating and Interpreting the Distribution of Capabilities, the Maps Between Capabilities and Functionings and the Technology of Capability Formation

1. Rich panel data—multiple measurements on proxies for capabilities, functionings, and investment.
2. Need to condense data into interpretable summaries.
3. Linear production systems do not capture dynamic complementary; *Nonlinearity is fundamental*.
4. Measurements are often item scores: i.e. measurement system is nonlinear.
5. Need a robust approach that does not depend on specific functional forms: *nonparametric approach*.
6. Test scores do not have a natural metric. Any monotonic function of a test score is a test score. "Value added" measures widely used are meaningless unless anchored in meaningful outcomes.

7. Anchor test scores in adult outcomes of interest.
8. The data on inputs and outputs are characterized by considerable measurement error, and models are nonlinear.
9. Investments are chosen by parents who have more information than econometricians. Address and solve the problem of endogeneity in nonlinear systems.
10. Low dimensional factors ("capabilities") generate a high dimensional set of functionings.
11. Dimension and factor structures selected through a novel Bayesian procedure—Avoids arbitrary methods in Exploratory Factor Analysis.
12. Nonparametric state space and measurement system.

- Adult outcome j in period t, $Y_{j,t}$, is produced by a combination of different end of period T skills:

$$Y_{j,t} = \psi_{j,t}\left(\theta_t, e_{j,t}, X_{j,t}\right), \quad j \in \{1, \ldots, J\}. \tag{21}$$

- Outcomes include test scores, wages, achievement in an occupation, hours worked, criminal activity, teenage pregnancy, etc.
- θ_T has different effects in different tasks in the labor market and in other areas of social performance.

Technologies

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-
$$\theta_{k,t+1} = f_{s,k}\left(\theta_t, I_{k,t}, \theta_{P_t}, \theta_{Q_t}, \eta_{k,t}\right) \tag{22}$$
for $k \in \{C, N, H\}$, $t \in \{1, 2, \ldots, T\}$, and $s \in \{1, \ldots, S\}$.
- $\eta_t = (\eta_{C,t}, \eta_{N,t}, \eta_{H,t})$ denotes shocks and/or unobserved inputs.

Identification of the Technology of Skill Formation

- To estimate the technology of skill formation: Have to solve three problems.

1. Don't observe $(\theta_t, I_{k,t}, \theta_{P,t})$ directly, but have many measurements on it. **Measurement error in nonlinear systems.**
2. Don't know which scale to use to measure components of θ_t. **Anchor test scores on adult outcomes.**
3. Investment $I_{k,t}$ may be chosen by parents based on information that may be unobserved by the econometrician $(\eta_{k,t})$. **Endogeneity of investment.**

- Key idea is use of multiple proxies for unobserved components (MIMIC; Jöreskog and Goldberger, 1975).
- *Extend MIMIC to a nonlinear model*
- Allow for nonclassical measurement error

Identification of a General Measurement Error Model

- Generalize linear factor models:

$$Z_j = a_j\left(\theta, \varepsilon_j\right) \text{ for } j \in \{1, \ldots, M\} \tag{23}$$

- $M \geq 3$
- Indicator Z_j is observed while the latent factor θ and the disturbance ε_j are not.
- Cunha, Heckman, and Schennach (2010, Econometrica)

Nonparametric Identification of the Technology of Capability Formation

- Nonparametrically identify technology:

$$\theta_{k,t+1} = f_{t,j}\left(\theta_t, I_{k,t}, \theta_{P,t}, \theta_{Q_t}, \eta_{k,t}\right).$$

- Normalize $\eta_{j,t}$ to have a uniform density on $[0,1]$.
- Any of the other normalizations suggested by Matzkin (2003, 2007) could also be used.
- Assuming $\eta_{k,t}$ is uniform $[0,1]$, $f_{t,k}$ is nonparametrically identified.

Proof:

- Can identify:

$$\Pr\left[\theta_{k,t+1} \leq \bar{\theta} | \theta_t, I_{k,t}, \theta_{P,t}\right] \equiv G\left(\bar{\theta} | \theta_t, I_{k,t}, \theta_{P,t}\right).$$

- $$f_{s,k}\left(\theta_t, I_{k,t}, \theta_{P,t}\right) = G^{-1}\left(\eta_{k,t} | \theta_t, I_{k,t}, \theta_{P,t}\right)$$

- $G^{-1}\left(\eta_{k,t} \mid \theta_t, I_{k,t}, \theta_{P,t}\right)$ denotes the inverse of $G\left(\bar{\theta} \mid \theta_t, I_{k,t}, \theta_{P,t}\right)$ with respect to its first argument: i.e. the value $\bar{\theta}$ such that $\eta_{k,t} = G\left(\bar{\theta} \mid \theta_t, I_{k,t}, \theta_{P,t}\right)$.

Anchoring Skills in an Interpretable Metric

- It is common in the empirical literature on child development, schooling, investment and on value added models for test scores to measure capabilities—"ability"—by test scores.
- However, test scores are arbitrarily scaled.
- Any monotonic function of a test score is a test score.
- To gain a better understanding of the relative importance of cognitive and noncognitive skills and their interactions and the relative importance of investments at different stages of the life cycle, it is important to anchor skills in a common scale.

Three Step Estimation Procedure

Step 1

For a given set of dedicated measurements, and choice of the number of factors, we estimate a factor model using measurement system:

Measures associated with factor j:

$$\text{Measures} : M^j_{m^j} = \nu^j_{m^j} + \varphi^j_{m^j}\theta^j + \eta^j_{m^j},\ j \in \mathcal{J}_p,\ m^j \in \mathcal{M}^j. \quad (24)$$

- Keep covariates $\boldsymbol{X}$ implicit. Parameters $\nu^j_{m^j}$ are measure-specific intercepts.
- Parameters $\varphi^j_{m^j}$ are factor loadings. The $\eta^j_{m^j}$ are mean-zero error terms assumed to be independent of $\boldsymbol{\theta}$, and of each other. The factor structure is characterized by the following equations:

$$\text{Factor Means} : \mathrm{E}[\theta^j] = \mu^j,\ j \in \mathcal{J}_p \quad (25)$$

$$\text{Factor Covariance} : \mathrm{Var}[\boldsymbol{\theta}] = \boldsymbol{\Sigma}_{\boldsymbol{\theta}}. \quad (26)$$

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Step 2

- Use the measures and factor loadings estimated in the first step to compute a vector of *factor scores* for each participant i. We form unbiased estimates of the true vector of skills $\boldsymbol{\theta}_i = (\theta_i^j; j \in \mathcal{J}_p)$ for agent i. The factor measure equations contain $\boldsymbol{X}$ which we suppress to simplify the expressions.
- Represent the measurement system for agent i as

$$\underbrace{\boldsymbol{M}_i}_{|\mathcal{M}|\times 1} = \underbrace{\boldsymbol{\varphi}}_{|\mathcal{M}|\times|\mathcal{J}_p|} \underbrace{\boldsymbol{\theta}_i}_{|\mathcal{J}_p|\times 1} + \underbrace{\boldsymbol{\eta}_i}_{|\mathcal{M}|\times 1}, \tag{27}$$

where φ represents a matrix of the factor loadings estimated in first step and $\boldsymbol{M}_i$ is the vector of stacked measures for participant i subtracting the intercepts $\nu_{m^j}^j$ of equation (24).

- The error term for agent i, $\boldsymbol{\eta}_i$, has zero mean and is independent of the vector of skills $\boldsymbol{\theta}_i$. $\mathrm{Cov}(\boldsymbol{\eta}_i, \boldsymbol{\eta}_i) = \boldsymbol{\Omega}$.
- The most commonly used estimator of factor scores is based on a linear function of measures: $\boldsymbol{\theta}_{S,i} = \boldsymbol{L}'\boldsymbol{M}_i$. Unbiasedness requires that $\boldsymbol{L}'\boldsymbol{\varphi} = \boldsymbol{I}_{|p|}$, where $\boldsymbol{I}_{|p|}$ is a $|p|$-dimensional identity matrix.
- To achieve unbiasedness, $\boldsymbol{L}$ must satisfy $\boldsymbol{L}' = (\boldsymbol{\varphi}'\boldsymbol{\Omega}^{-1}\boldsymbol{\varphi})^{-1}\boldsymbol{\varphi}'\boldsymbol{\Omega}^{-1}$.

- The unbiased estimator of the factor is:

$$\boldsymbol{\theta}_{S,i} = \boldsymbol{L}'\boldsymbol{M}_i = (\boldsymbol{\varphi}'\boldsymbol{\Omega}^{-1}\boldsymbol{\varphi})^{-1}\boldsymbol{\varphi}'\boldsymbol{\Omega}^{-1}\boldsymbol{M}_i.$$

- Factor score estimates can be interpreted as the output of a *GLS* estimation procedure where measures are taken as dependent variables and factor loadings are treated as regressors.
- By the Gauss-Markov theorem, for a known $\boldsymbol{\varphi}$ the proposed estimator is the best linear unbiased estimator of the vector of skills $\boldsymbol{\theta}_i$.

Step 3

- The use of factor scores instead of the true factors to estimate outcome equations generates biased estimates of outcome coefficients.
- Even though estimates of $\boldsymbol{\theta}_i$ are unbiased, there is still a discrepancy between the true and measured $\boldsymbol{\theta}_i$ due to estimation error.
- To correct for the bias, implement a bias-correction procedure. Because we estimate the variance of $\boldsymbol{\theta}$ and the variance of the measurement errors in the first step of our procedure, we can eliminate the bias created by the measurement error.

- Consider the outcome model for agent i :

$$Y_i = \boldsymbol{\alpha}\boldsymbol{\theta}_i + \boldsymbol{\gamma}\boldsymbol{Z}_i + \boldsymbol{\epsilon}_i, \tag{28}$$

  where $(\boldsymbol{\theta}_i, \boldsymbol{Z}_i) \perp\!\!\!\perp \boldsymbol{\epsilon}_i$ and $E(\boldsymbol{\epsilon}_i) = 0$.

- For brevity of notation, use $\boldsymbol{Z}_i$ to denote pre-program variables, treatment status indicators, and the intercept term of equation (28).
- From equation (27), the factor scores $\boldsymbol{\theta}_{S,i}$ can be written as the skills $\boldsymbol{\theta}_i$ plus a measurement error $\boldsymbol{V}_i$, that is,

$$\boldsymbol{\theta}_{S,i} = \boldsymbol{\theta}_i + \boldsymbol{V}_i \text{ such that } (\boldsymbol{Z}_i, \boldsymbol{\theta}_i) \perp\!\!\!\perp \boldsymbol{V}_i \text{ and } E(\boldsymbol{V}_i) = 0. \tag{29}$$

- Replacing $\boldsymbol{\theta}_i$ with $\boldsymbol{\theta}_{S,i}$ yields $Y_i = \boldsymbol{\alpha}\boldsymbol{\theta}_{S,i} + \boldsymbol{\gamma}\boldsymbol{Z}_i + \boldsymbol{\epsilon}_i - \boldsymbol{\alpha}\boldsymbol{V}_i$.

- The linear regression estimator of $\boldsymbol{\alpha}$ and $\boldsymbol{\gamma}$ is inconsistent:

$$\operatorname{plim}\begin{pmatrix}\hat{\boldsymbol{\alpha}}\\ \hat{\boldsymbol{\gamma}}\end{pmatrix} = \tag{30}$$

$$\underbrace{\begin{pmatrix}\mathsf{Cov}(\boldsymbol{\theta}_S,\boldsymbol{\theta}_S) & \mathsf{Cov}(\boldsymbol{\theta}_S,\boldsymbol{Z})\\ \mathsf{Cov}(\boldsymbol{Z},\boldsymbol{\theta}_S) & \mathsf{Cov}(\boldsymbol{Z},\boldsymbol{Z})\end{pmatrix}^{-1}\begin{pmatrix}\mathsf{Cov}(\boldsymbol{\theta},\boldsymbol{\theta}) & \mathsf{Cov}(\boldsymbol{\theta},\boldsymbol{Z})\\ \mathsf{Cov}(\boldsymbol{Z},\boldsymbol{\theta}) & \mathsf{Cov}(\boldsymbol{Z},\boldsymbol{Z})\end{pmatrix}}_{\boldsymbol{A}}\begin{pmatrix}\boldsymbol{\alpha}\\ \gamma\end{pmatrix}.$$

- Multivariate version of the standard one-variable attenuation bias formula.
- All covariances in $\boldsymbol{A}$ can be computed directly except for the terms that involve $\boldsymbol{\theta}$.
- The covariance $\text{Cov}(\boldsymbol{\theta}, \boldsymbol{\theta})$ is estimated in step 1.
- Using equation (29), we can compute $\text{Cov}(\boldsymbol{Z}, \boldsymbol{\theta}_S) = \text{Cov}(\boldsymbol{Z}, \boldsymbol{\theta})$.
- Thus, $\boldsymbol{A}$ is identified.

- Our bias-correction procedure consists of pre-multiplying the least squares estimators $(\hat{\alpha}, \hat{\gamma})$ by $\boldsymbol{A}^{-1}$,
- Produces consistent estimates of $(\boldsymbol{\alpha}, \boldsymbol{\gamma})$.
- A one-step maximum likelihood procedure, while less intuitive, directly estimates the parameters without constructing the factors and accounts for measurement error.
- It is justified in large samples under standard regularity conditions.
- It produces estimates very close to those obtained from the three-step procedure, but with smaller standard errors.
- Heckman, Pinto, and Savelyev (2010, AER)

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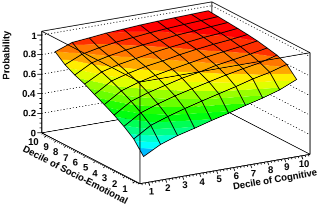
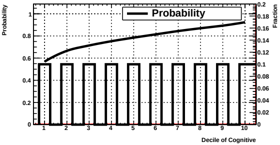
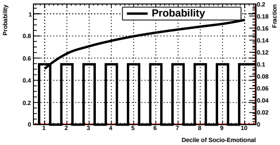
Estimating Functionings and Extracting Factors Multiple Capabilities Shape Human Achievement Across a Variety of Dimensions

$$Y_{j,t} = \psi_j \left(\underbrace{\theta_{C,t}, \theta_{N,t}, \theta_{H,t}}_{\theta_t}, e_{j,t}, X_{j,t} \right), \quad j \in \underbrace{\{1, \ldots, J_t\}}_{\substack{\text{set of} \\ \text{available} \\ \text{activities}}} \tag{31}$$

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

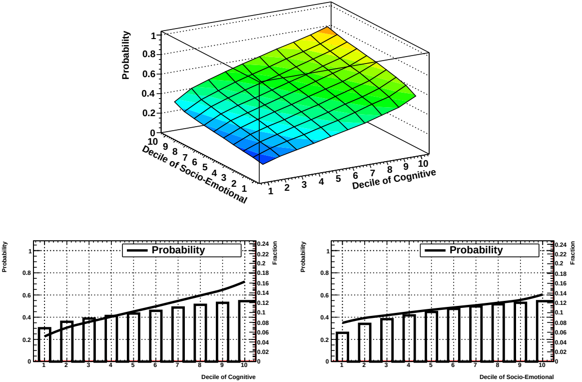






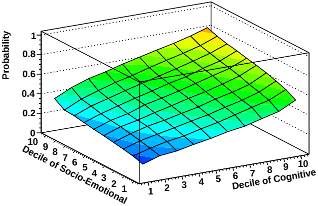
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

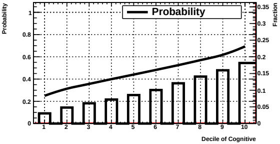
The Probability of Educational Decisions, by Endowment Levels, **HS Graduate** vs. College Enrollment

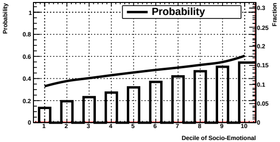


Source: Heckman, Humphries, Urzua, and Veramendi (2011).

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

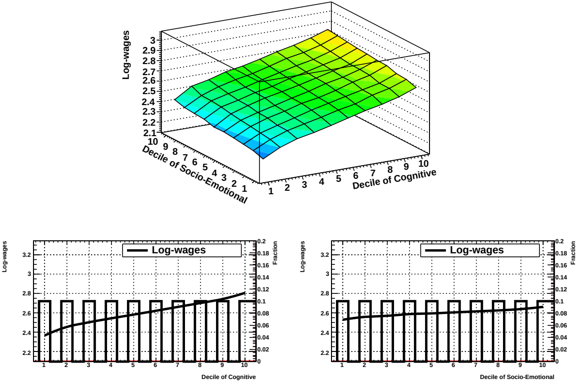






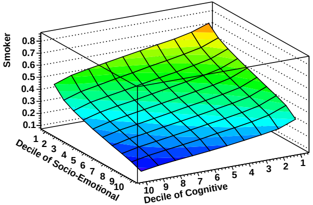
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

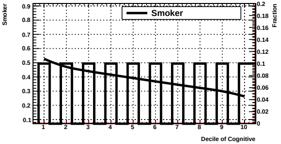
The Effect of Cognitive and Socio-emotional endowments, (log) Wages

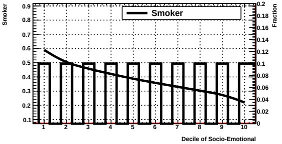


Source: Heckman, Humphries, Urzua, and Veramendi (2011).

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

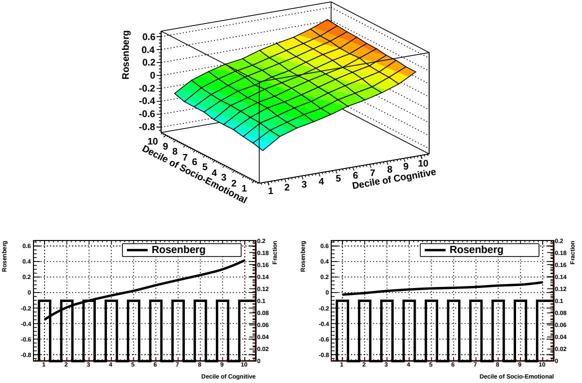






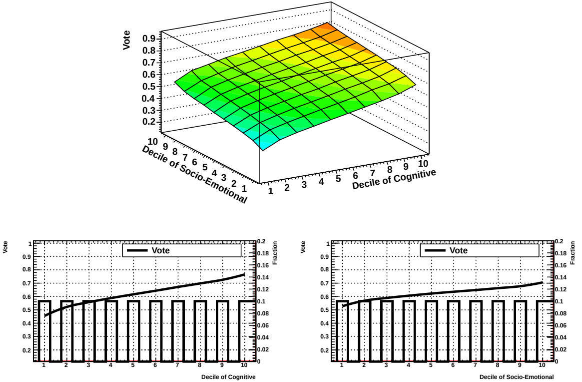
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

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



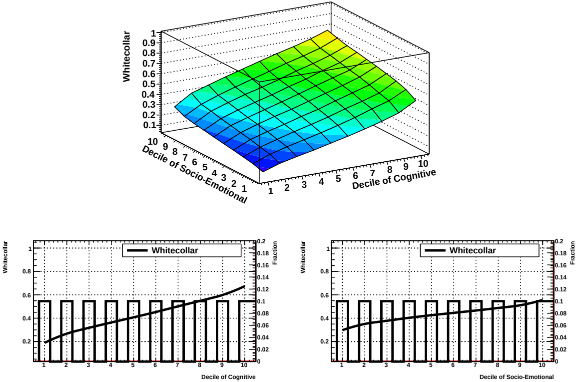
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

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



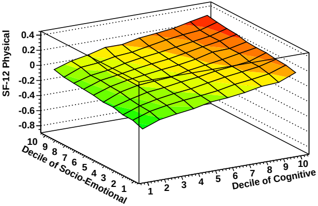
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

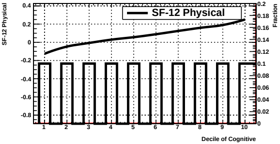
The Effect of Cognitive and Socio-emotional endowments on Probability of White-collar occupation (age 30)

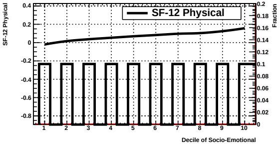


Source: Heckman, Humphries, Urzua, and Veramendi (2011).

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

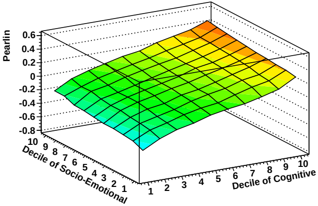


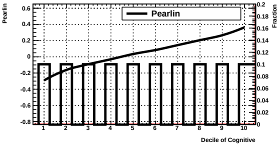


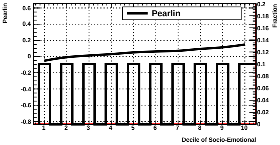


Source: Heckman, Humphries, Urzua, and Veramendi (2011).

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

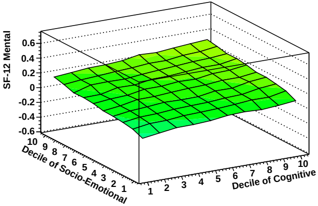


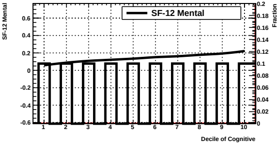


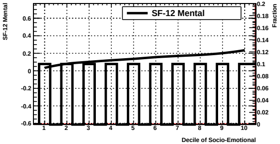


Source: Heckman, Humphries, Urzua, and Veramendi (2011).

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

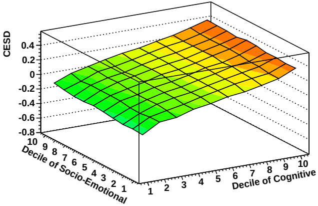


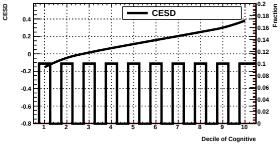


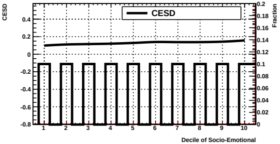


Source: Heckman, Humphries, Urzua, and Veramendi (2011).

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

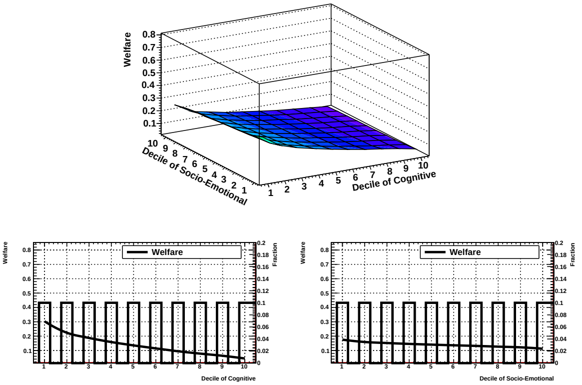






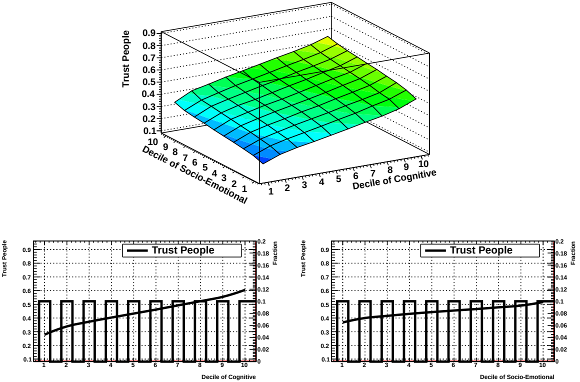
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

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



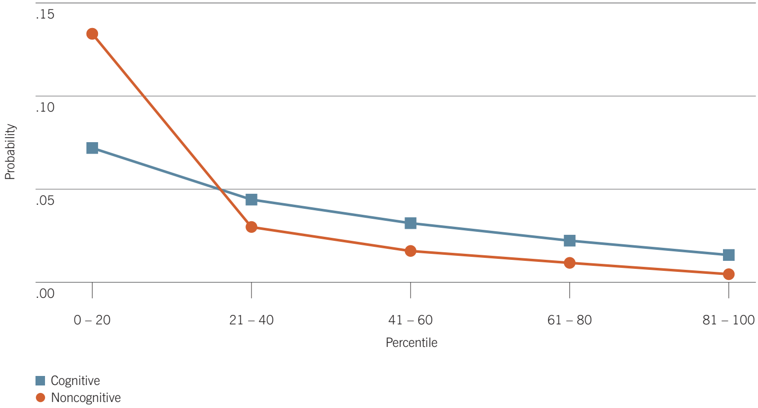
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

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



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

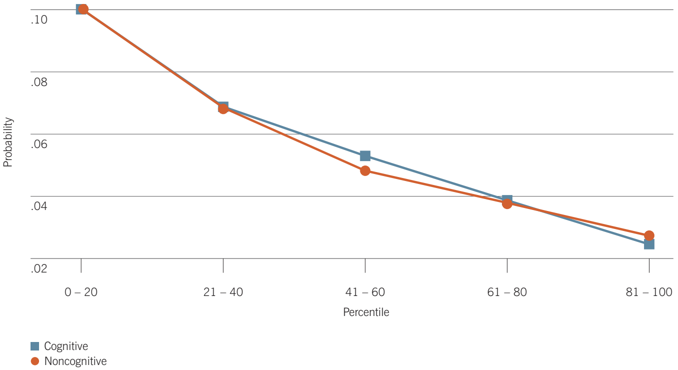
Ever been in jail by age 30, by ability (males)



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).

Estimates of Nonlinear Technologies (Cunha et al., 2010)

Technology estimated by Cunha, Heckman and Schennach (2010)

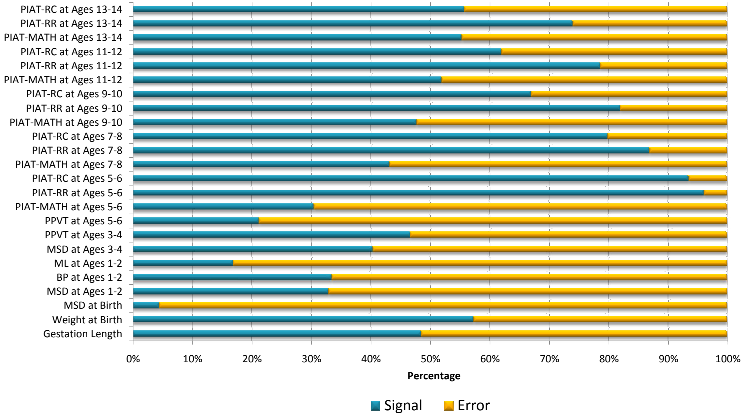
- Use a separable measurement system.
- Ignore health and government investment.
- Technology equations with shocks:

$$\theta_{k,t+1} = \Big[\gamma_{t,k,1}\theta_{C,t}^{\phi_{t,k}} + \gamma_{t,k,2}\theta_{N,t}^{\phi_{t,k}} + \gamma_{t,k,3}I_t^{\phi_{t,k}} + \gamma_{t,k,4}\theta_{C,P}^{\phi_{t,k}} + \gamma_{t,k,5}\theta_{N,P}^{\phi_{t,k}}\Big]^{\frac{1}{\phi_{t,k}}} e^{\eta_{k,t}}, \tag{32}$$

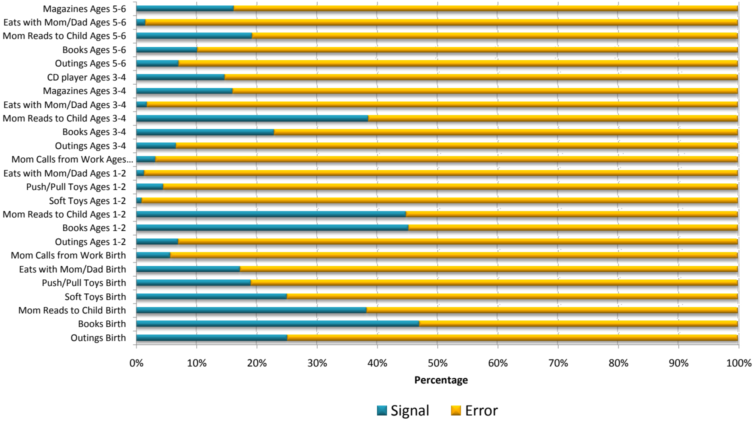
where $\gamma_{t,k,l} \geq 0$ and $\sum_{l=1}^{5} \gamma_{t,k,l} = 1$,

$k \in \{C, N\}, t \in \{1, 2\}$.

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)

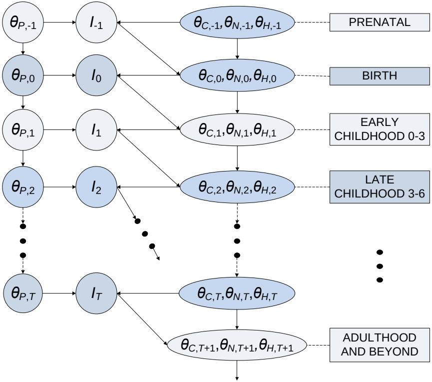


Share of Residual Variance in Measurements of Investments Due to the Variance of Investment Factor (Signal) and Due to the Variance of Measurement Error (Noise)



A Life Cycle Framework for Organizing Studies and Integrating Evidence

$$\theta_t = (\theta_C, \theta_N, \theta_H) \text{ capacities at } t$$
$$\theta_{P,t}\text{: parental traits at } t$$
$$I_t\text{: investment at } t$$
$$Q_t\text{: left implicit}$$
$$\theta_{t+1} = f_t(\theta_t, I_t, \theta_{P,t})\text{: } \textbf{Technology of Skill Formation}$$



The Technology for Cognitive and Noncognitive Skill Formation Estimated Along with Investment Equation with Linear Anchoring on Educational Attainment (Years of Schooling), Factors Normally Distributed

Panel A: Technology of Cognitive Skill Formation (Next Period Cognitive Skills)

	First Stage Parameters	Second Stage Parameters
Current Period Cognitive Skills (Self-Productivity)	0.485	0.884
	(0.031)	(0.013)
Current Period Noncognitive Skills (Cross-Productivity)	0.062	0.011
	(0.026)	(0.005)
Current Period Prenatal Investments	0.261	0.044
	(0.026)	(0.011)
Parental Cognitive Skills	0.035	0.051
	(0.015)	(0.008)
Parental Noncognitive Skills	0.157	0.011
	(0.033)	(0.012)
Complementarity Parameter	0.585	−1.220
	(0.225)	(0.149)
Implied Elasticity of Substitution	2.410	0.450
Variance of Shocks $\eta_{c,t}$	0.165	0.098
	(0.007)	(0.003)

Panel B: Technology of Noncognitive Skill Formation (Next Period Noncognitive Skills)	First Stage Parameters	Second Stage Parameters
Current Period Cognitive Skills (Cross-Productivity)	0.000	0.002
	(0.028)	(0.011)
Current Period Noncognitive Skills (Self-Productivity)	0.602	0.857
	(0.034)	(0.011)
Current Period Prenatal Investments	0.209	0.104
	(0.031)	(0.022)
Parental Cognitive Skills	0.014	0.000
	(0.013)	(0.008)
Parental Noncognitive Skills	0.175	0.037
	(0.033)	(0.021)
Complementarity Parameter	-0.464	-0.522
	(0.263)	(0.214)
Implied Elasticity of Substitution	0.682	0.657
Variance of Shocks $\eta_{N,t}$	0.203	0.102
	(0.012)	(0.003)

- 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., $\frac{\partial \theta_{t+1}}{\partial \theta_t} \uparrow t$).
  b. Complementarity between cognitive skills and investment becomes stronger as children become older. The elasticity of substitution for cognition is *smaller* in second stage production.

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 reported in Cunha et al. (2006).
d. Complementarity between noncognitive skills and investments becomes slightly *weaker* as children become older.

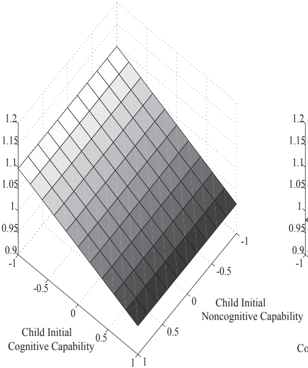
- It is slightly easier at *later* stages of childhood to remediate early disadvantage using investments in noncognitive skills.
- Noncognitive traits promote the accumulation of cognitive traits (but not vice versa).
- This econometric evidence is consistent with a broad array of evidence from interventions studies on life cycle profile of rates of return.

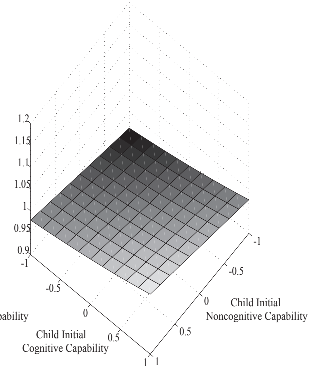
- 34% of the variation in educational attainment in the sample is explained by the measures of cognitive and noncognitive capabilities.
- 16% is due to adolescent cognitive capabilities.
- 12% is due to adolescent noncognitive capabilities.
- Measured parental investments account for 15% of the variation in educational attainment.
- These estimates suggest that the measures of cognitive and noncognitive capabilities are powerful, but not exclusive, determinants of educational attainment and that other factors, besides the measures of family investment that we use, are at work in explaining variation in educational attainment.

The Implications of the Estimates for Design of Policy

- Targeted strategies
- 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.
- As an empirical matter, social justice is enhanced by what is productively efficient.

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.

Why Is It Sometimes Efficient To Invest in the Most Disadvantaged?

Consider a simple model:
θ_1: early endowment (genetics?)
I_1: early investment
I_2: later investment

$$\theta_2 = g(\theta_1, I_1)$$
$$\theta_3 = f(\theta_2, I_2)$$

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Suppose $$\theta_2 = \left(\gamma_1 \theta_1^{a_1} + (1-\gamma_1)(I_1)^{a_1}\right)^{\frac{d_1}{a_1}}$$

$$\theta_3 = \left(\gamma_2 \theta_2^{a_2} + (1-\gamma_2)(I_2)^{\sigma_2}\right)^{\frac{d_2}{a_2}}$$

$$-\infty \leq a_1 \leq 1; \quad -\infty \leq a_2 \leq 1$$

$$0 \leq d_1 \leq 1; \quad 0 \leq d_2 \leq 1$$

$$\sigma_1 = \frac{1}{1-a_1}; \quad \sigma_2 = \frac{1}{1-a_2}$$

$$\frac{\partial^2 \theta_j}{\partial \theta_{j-1} \partial I_{j-1}} = (d_j - a_j)\{+\} \tag{33}$$

Our evidence shows that for cognitive skills:

$$\sigma_1 > 1 \qquad 0 < a_1$$
$$\sigma_2 < 1 \qquad 0 > a_2$$

$$\therefore \quad \frac{\partial^2 g}{\partial \theta_1 \partial I_1} = g_{12} < 0$$

$$\frac{\partial^2 f}{\partial \theta_2 \partial I_2} = f_{12} > 0$$

Three notions of complementarity:

$$\frac{\partial^2 g}{\partial\theta_1 \partial I_1} > 0, \quad \frac{\partial^2 f}{\partial\theta_2 \partial I_2} > 0,$$
$$\text{and } \frac{\partial^2 f(g(\theta_1, I_1), I_2)}{\partial I_1 \partial I_2} > 0.$$

Empirical evidence suggests a switch from substitute to complement for investment at later ages.

Suppose that social planner seeks to maximize the sum of outputs of adult skills for persons A and B:

$$\theta_3^A + \theta_3^B$$

Subject to a resource constraint:

$$P_{I_1}(I_1^A + I_1^B) + P_{I_2}(I_2^A + I_2^B) = M \quad \text{(Budget)} \tag{34}$$

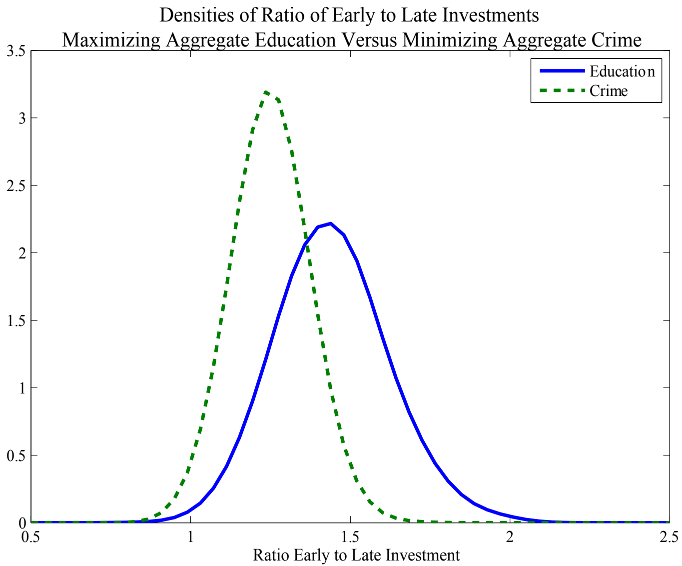
Straightforward to show that (in the absence of any parental compensating responses) if

$$g_{12} < 0, \quad f_{12} > 0 \quad \text{and} \quad \theta_1^A < \theta_1^B,$$

under the stated configuration of parameters,

$$I_1^A > I_1^B.$$

Intuition: compensation for disadvantage is more effective for early investment than for later investment.



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

- Allows us to reconcile two literatures often viewed as in conflict
- Social justice literature (Sen's capabilities approach, 1985)
- Human capital literature based on economic efficiency (Becker, 1964)
- What is fair is also socially efficient.

Beyond Treatment Effects and Meta-Analyses of Treatment Effects

- Recognize that various interventions in early childhood previously implemented differ.
    1. The populations targeted differ.
    2. The objectives and curricula of the programs differ.
    3. The measurement systems of the backgrounds and outcomes of the interventions differ.
    4. The methods of evaluation differ.
    5. Need to integrate the studies of family influence with the intervention studies to understand how interventions affect family life.
    6. Need to compare alternative policies in comparable metrics, i.e. rates of return to policies or cost-benefit analyses.

- 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.

- Understand the mechanisms producing the treatment effects that can be compared across interventions.
- 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.
- 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.

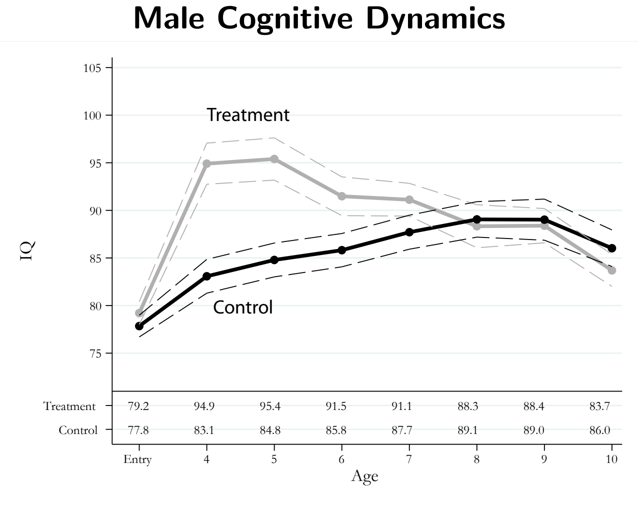
- Technology of skill formation allows economists to integrate these diverse studies through their effects on θ_t
  a. Can model interaction of parental investment with governmental investments: components may be perfect substitutes or not.
  b. Identify different technologies (public and private) that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

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

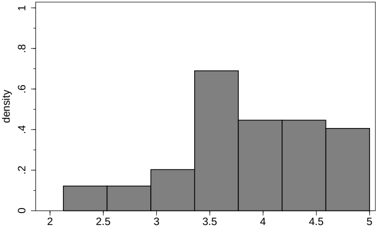
- Evaluated by the method of random assignment.
- Strong effects are found for both boys and girls, although different effects are found at different ages for different outcomes.
- Did not lead to sustained gains in IQ for males, and only slight effect for females.

Cognitive Evolution Through Time, Perry Males

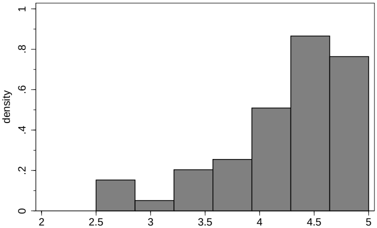


- Yet the Perry Program has a statistically significant annual rate of return of around 7%–10% per annum—for both boys and girls—above the post–World War II stock market returns to equity in U.S. labor market estimated to be 6.9%.

Personal Behavior Index by Treatment Group

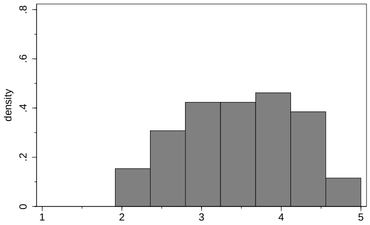


(n) Control

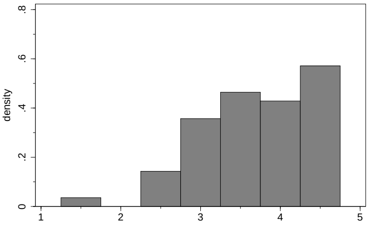


(o) Treatment

Socio-Emotional Index by Treatment Group

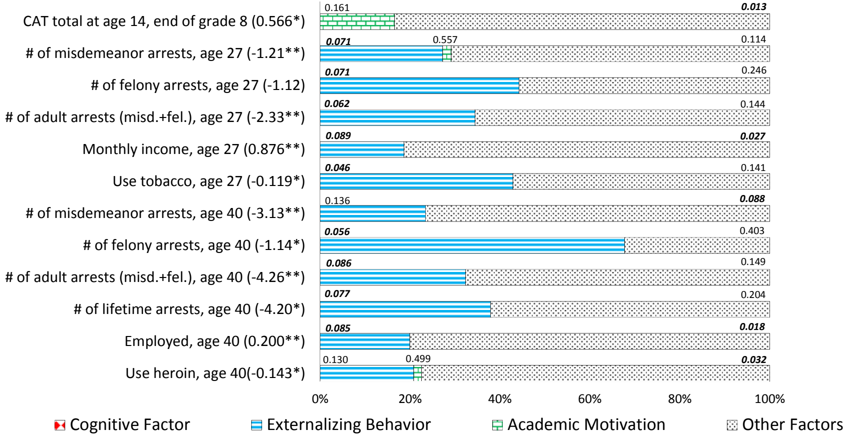


(p) Control

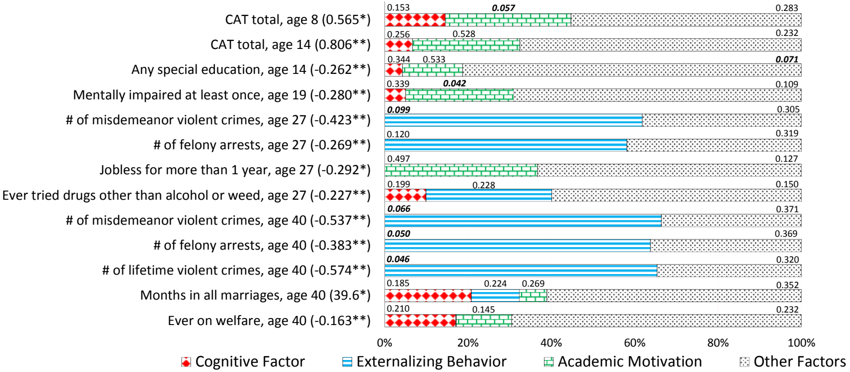


(q) Treatment

Decomposition of Treatment Effects, Males

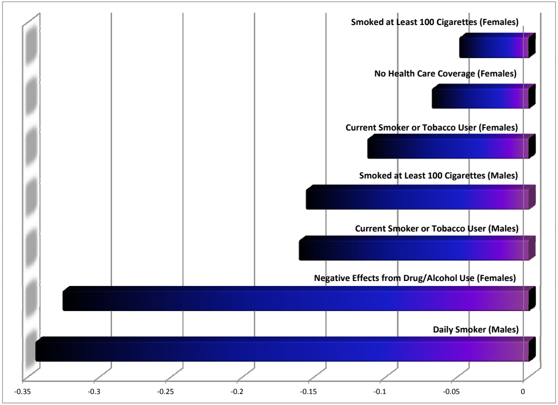


Decomposition of Treatment Effects, Females



Perry Preschool Intervention, Age 40

Treatment Effects



- Early interventions reducing problem behavior can lower the probability of engaging in unhealthy behaviors in adulthood.
- **Benefits can carry over into the next generation.**

Abecedarian Intervention, Health Effects at Age 35

	Treatment Mean	Control Mean	Treatment p-value
Systolic Blood Pressure	125.79	143.33	0.018
Diastolic Blood Pressure	78.53	92.00	0.024
Pre-Hypertension	0.68	0.78	0.235
Hypertension	0.10	0.44	0.011
HDL Cholesterol	53.21	42.00	0.067
Cholesterol/HDL-C	3.89	4.69	0.057
Abdominal Obesity	065	0.87	0.136
Metabolic Syndrome	0.00	0.25	0.009

Source: Conti, Heckman, Moon, Pinto (2012) hceconomics.org

Integrating Experimental Studies with Family Influence Studies

- I_t^G: government investment
- I_t^P: private (family) investment
- Government technology: $f^G(\theta_t^P, I_t^G, I_t^P, h)$
- Private technology: $f^P(\theta_t^P, I_t^P, I_t^G, h)$

- Different (mutually exclusive) programs indexed by k, $k \in \{1, \ldots, K\}$, provide different packages of investment at stage t, $I_{k,t} = (I^C_{k,t}, I^N_{k,t}, I^H_{k,t})$ at cost $C_{k,t}$.
- Discounted costs of program q are C_k.
- The programs affect output θ_{t+1} through production at stage t by technology (19).
- Using estimated structural models, analysts can compare different programs both in terms of their investment content and in terms of their output.

- First stage of adulthood, $T+1$
- Suppose that the goal is to achieve target objective $\bar{Y}^l_{T+1}, l \in \{1,\ldots,L\}$, at $T+1$ by a choice of program k.
- The problem can be formulated for objective k as

$$\min_{k \in \{1,\ldots,K\}} C_k \tag{35a}$$

subject to technology constraints, initial endowments and the output constraint

$$Y^l_{T+1}(\theta_{T+1}, e^l_{T+1}) \geq \bar{Y}^l_{T+1}. \tag{35b}$$

- Some programs may fail to achieve the constraint in (35b).
- They may have high returns but lack the ability to scale adequately to achieve desired targets.

Comparing Perry Intervention to Family Environments

Comparison of Different Investment Strategies

Disadvantaged Children: First Decile in the Distribution of
Cognitive and Non-Cognitive Skills at Age 6

Mothers are in First Decile in the Distribution
of Cognitive and Non-Cognitive Skills at Ages 14-21

	Baseline	Changing initial conditions: moving children to the 4th decile of distribution of skills only through early investments	Adolescent intervention: Moving investments at last transition from 1st to 9th decile	Changing initial conditions and performing a balanced intervention
High School Graduation	0.4109	0.6579	0.6391	0.9135
Enrollment in College	0.0448	0.1264	0.1165	0.3755
Conviction	0.2276	0.1710	0.1733	0.1083
Probation	0.2152	0.1487	0.1562	0.0815
Welfare	0.1767	0.0905	0.0968	0.0259

Note: The adolescent-only and balanced intervention programs cost 35% more than the Perry program.

Source: Cunha and Heckman (2007)

- The same amount of total investment distributed more evenly over the life cycle of the child produces more adult skills than a policy that concentrates attention on only one part of the child's life cycle.

Adolescent Interventions

- Consider interventions in the *adolescent* years.
- Is an education policy a promising avenue for promoting capabilities?

  Specifically:

  i. What is the causal effect of education on capabilities?
  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).

Education is both an input and an output of the dynamic process: A manifestation of the technology of skill formation

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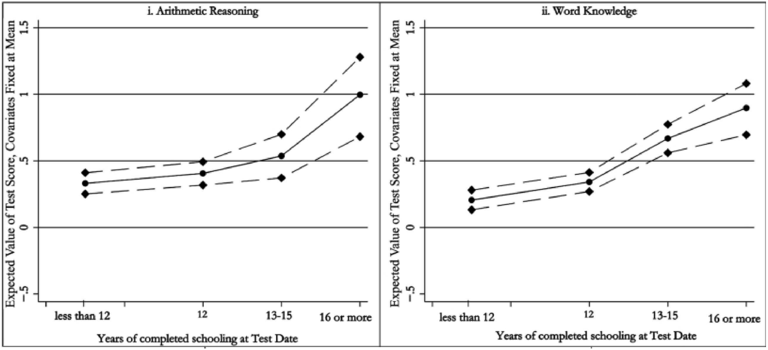
Causal Effects of Education on Capabilities

- Observational data
- Exploit panel design of NLSY79. (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.

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 males with average ability. We standardize the test scores to have within-sample mean zero, variance one. The model is estimated using the NLSY79 sample. Solid lines depict average test scores, and dashed lines, confidence intervals.
Source: Heckman, Stixrud and Urzua [2006, Figure 4].

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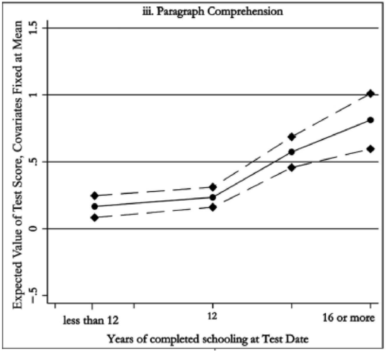

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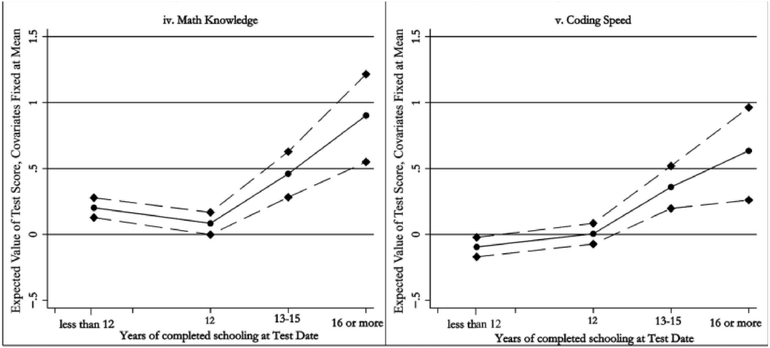

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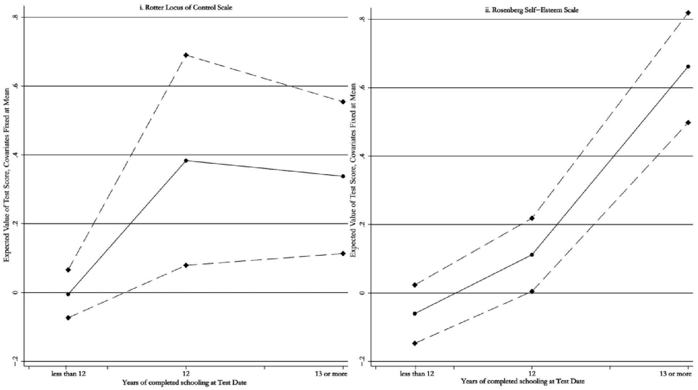
Causal Effect of Schooling on Two Measures of Personality

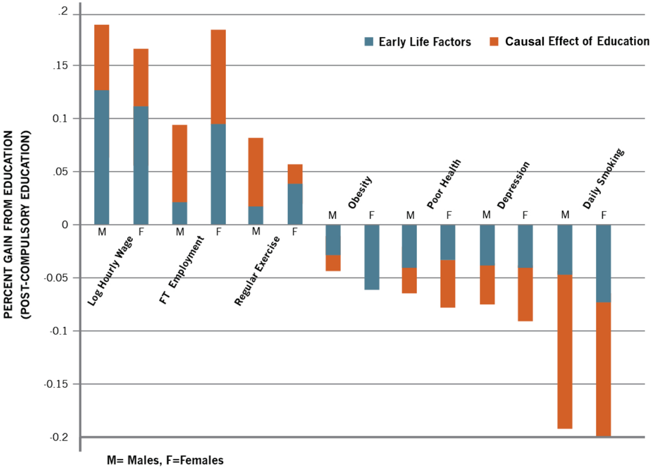


Source: Heckman, Stixrud and Urzua [2006, Figure 5].

Causal Effect of Education on Health: Reconciling Different IV Estimates

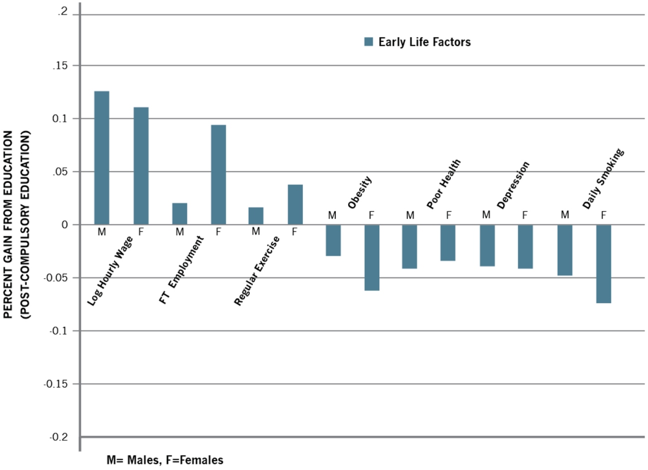
- Mixed evidence.

Disparities by Education (Post-compulsory Education)



Note: Conti and Heckman (2010). Author's calculations using BCS70.

Disparities by Education (Post-compulsory Education)



Note: Conti and Heckman (2010). Author's calculations using BCS70.

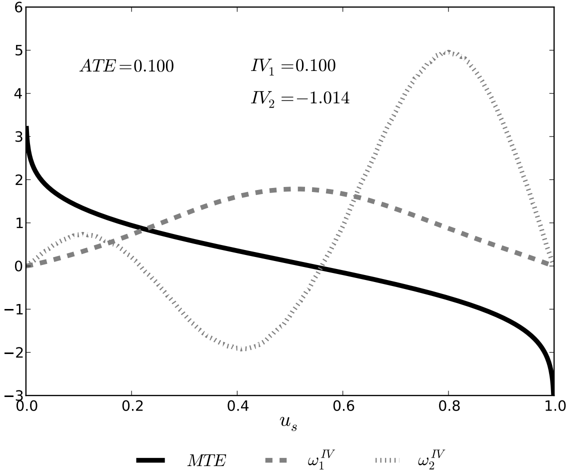
Show Simple Way to Estimate the Factor Model

Interpreting IV Estimates of Compulsory Education on Health

Interpreting IV

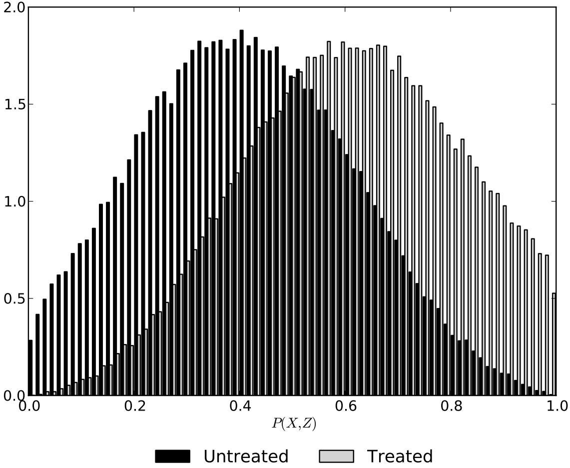
- Apply Heckman and Vytlacil (1999, 2005, 2007a,b, 2010, 2011)
- $Y_1 =$ treated potential outcome
- $Y_0 =$ untreated potential outcome
- MTE $(x, u_d) = E(Y_1 - Y_0 | X = x, U_d = u_d)$
- U_d are the *relevant* unobservables (from the point of view of the economist) in the choice equation that produce dependence between choices and outcomes.
- $U_d = g(\theta)$ if the empirical capability space spans the space of unobservables.
- $\text{LATE}_j = IV_j = \int_0^1 \text{MTE } (u_d)\omega_j(u_d)$
- Weights ω_j for instrument j can be estimated from data
- MTE can be estimated non-parametrically
- *Different instruments identify different segments of MTE*
- Allowing for both instruments and measures allows a test (H_0: IV estimates = factor estimates)

Marginal Treatment Effect and IV Weights



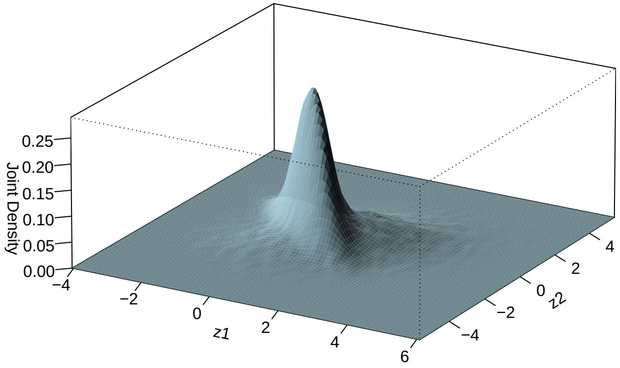
Eisenhauer and Heckman (2013)

Common Support



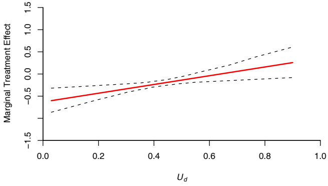
Eisenhauer and Heckman (2013)

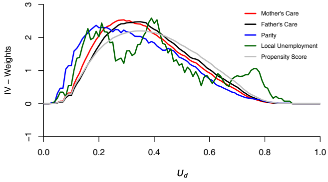
Joint Distribution of Instruments

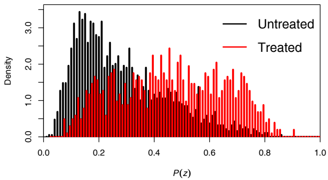


Eisenhauer and Heckman (2013)

IV Example: Diploma, Bad Health, Females (Observables at Mean)







Conti, Eisenhauer, Heckman, and Piatek (2009)

Summary

- Econometrics addresses serious social questions using data, models and statistical tools.
- Illustrated this point of view by considering the origins of inequality and social immobility.
- Econometrics is a cumulative field. It recognizes and builds on previous work.
- All conclusions are necessarily provisional.
- Shown how the new economics and econometrics of human development enable us to advance beyond the standard paradigms of redistribution to **pre-distribution**.

- An empirical framework that synthesizes and expands both the social justice approach of Sen and the human capital approach of Becker.
- Allows us to integrate evidence from diverse studies to devise effective social policies.
- I have presented a more nuanced interpretation of the effectiveness of various strategies over the life cycle and the relative importance of both credit market and parental constraints on inequality and social opportunities.
- Moves emphasis away from income to a broader conception of inequality: how to conceptualize it and how to effectively ameliorate it.

Appendix

Endowments: exogenous and subject to shocks ω_g:

$$e_g = f + \lambda e_{g-1} + \omega_g \tag{36}$$

- No direct effect of parents on transmission of endowments.
- ω_g is iid across generations

Markets:

a. Labor market: efficiency units of homogeneous human capital
   w_g: Reward in generation g (payment per unit human capital)

$$Y_g = \mu + w_g h_g \tag{37}$$

b. Credit market in which agents (parents) can lend and borrow: Imperfect markets across generations. (Parents cannot commit debt to future generations.)

Family Preferences:
C_g is parental consumption

$$U_g = \eta(C_g) + \underbrace{\delta}_{\text{altruism}} U_{g+1} \tag{38}$$

Dynastic form of the utility function:

$$U_g = \sum_{j=0}^{\infty} \delta^j \eta(C_{g+j}) \tag{39}$$

Parents' Problem:
Parents allocate resources between adult consumption C_g and investment in the child I_{g-1} under different market settings.

Causal Effects of Education on Capabilities

- Perry study (previously discussed) 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.

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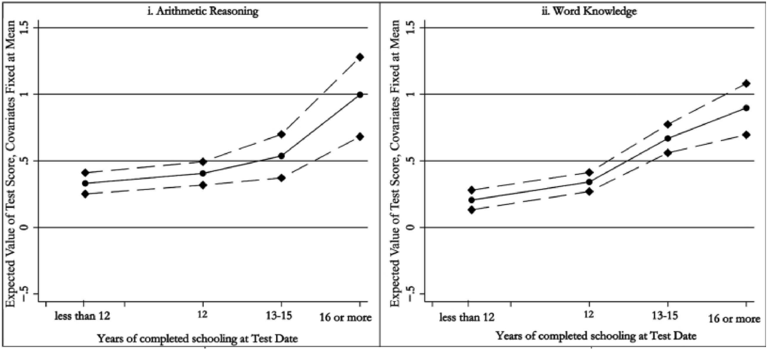

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Causal Effect of Schooling on ASVAB Measures of Cognition

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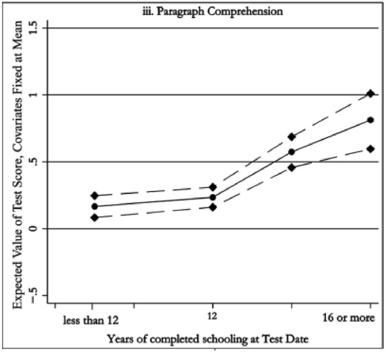

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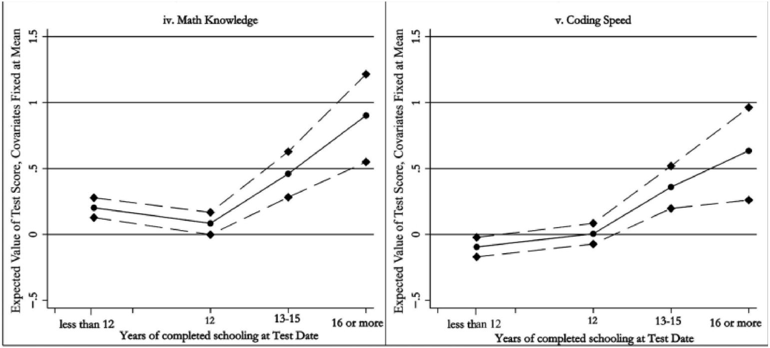

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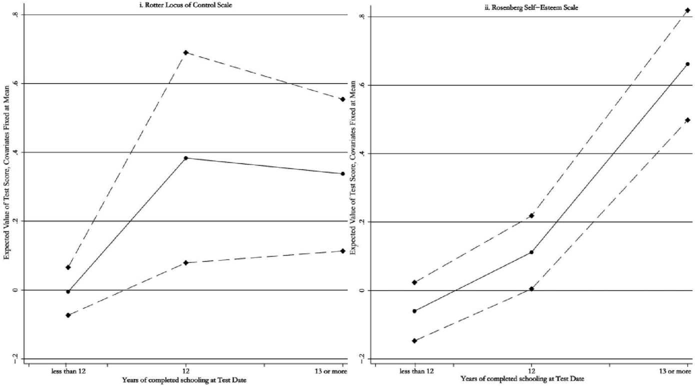
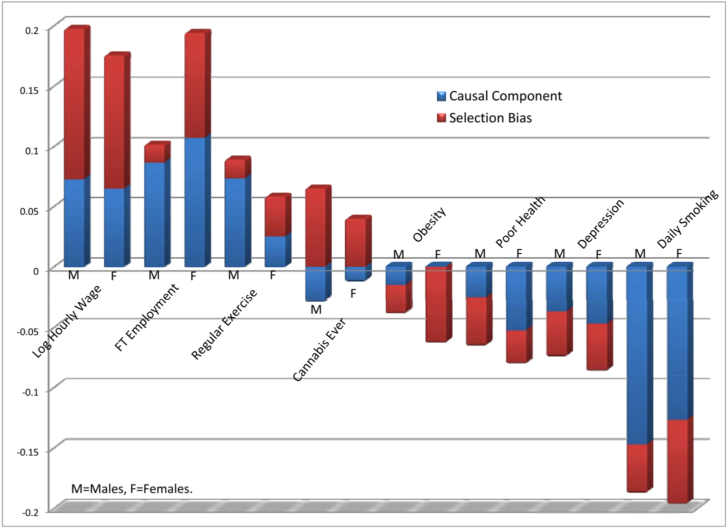
Causal Effect of Schooling on Two Measures of Personality



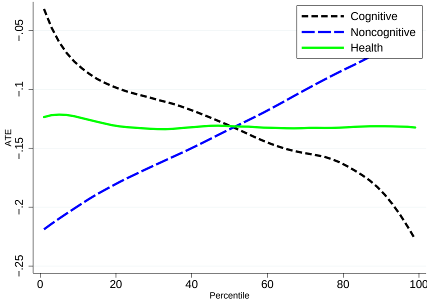
Source: Heckman, Stixrud and Urzua [2006, Figure 5].

The Causal Effect of Education
Decomposition of Observed Disparities



Treatment Effect Heterogeneity

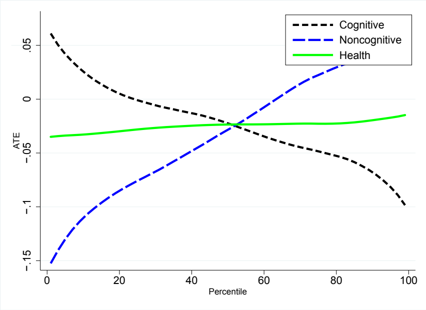
Smoking, Males



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

Treatment Effect Heterogeneity

Poor Health, Males



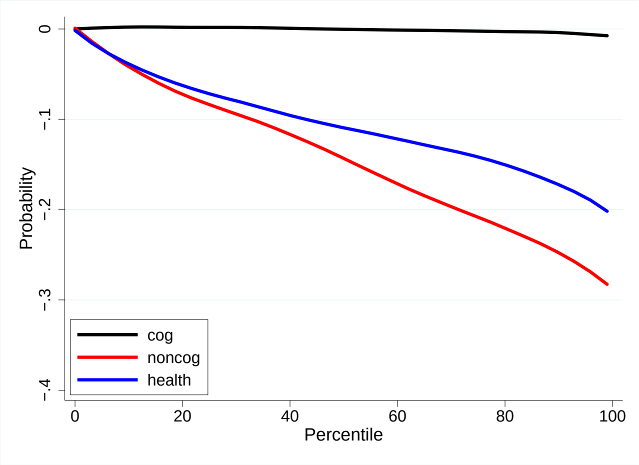
- Education compensates for low early noncognitive endowments and reinforces high early cognitive endowments.

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

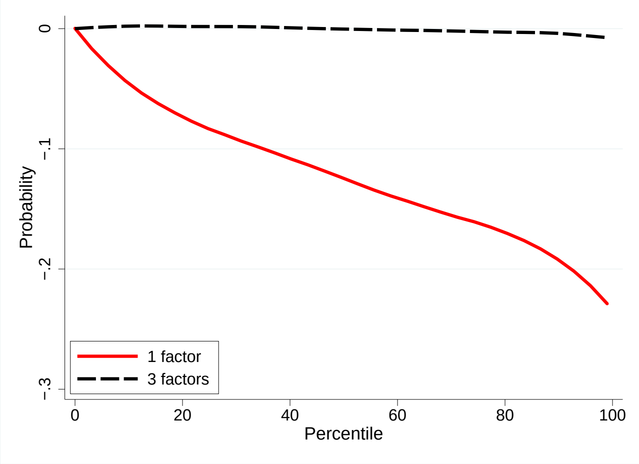
Daily Smoking at 30, Males: not conditioning on education



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

The Role of Factors up to Age 10

Daily Smoking at 30, Males: not conditioning on education



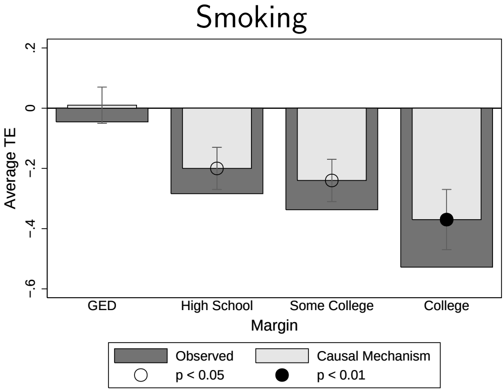
- But not accounting for them *overestimates* the importance of cognition.

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%).

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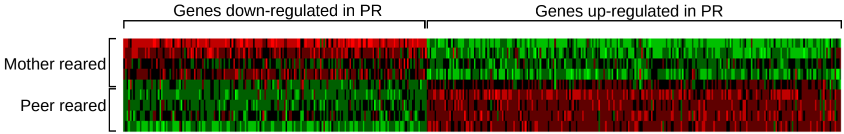
The Rhesus Monkeys Experiment

- 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.

- 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 (2012).

Early Life Experiences Change The Way Genes Express Themselves

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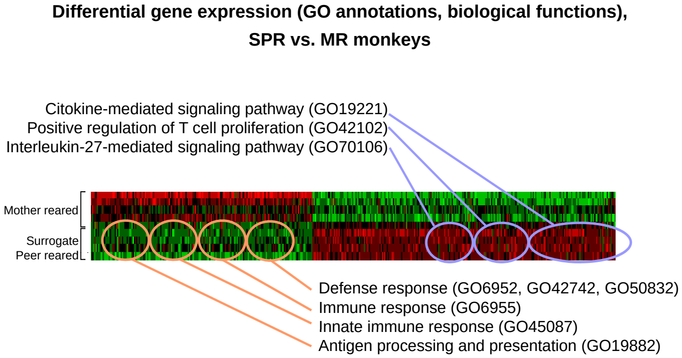
Up- and Down-Regulated Genes in Rhesus Monkeys

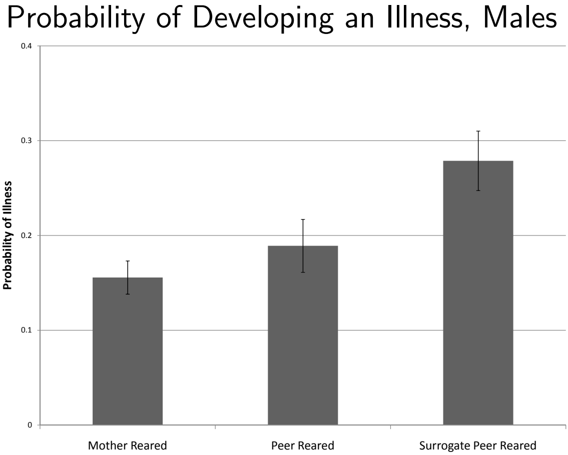


Source: Cole, Conti, Heckman and Suomi (2012).

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

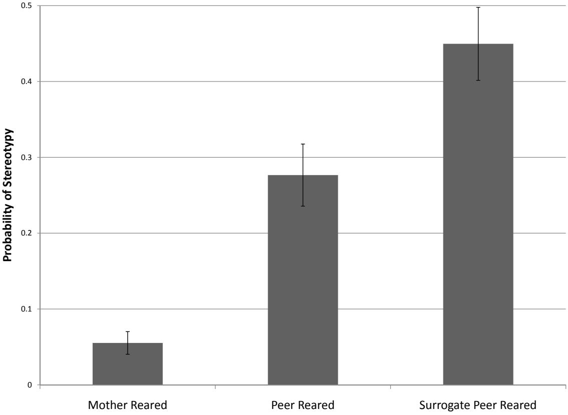


Source: Conti, Hansman, Heckman and Suomi (2012).

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

Early Life And Later Mental Health

Probability of Developing a Stereotypy, Males



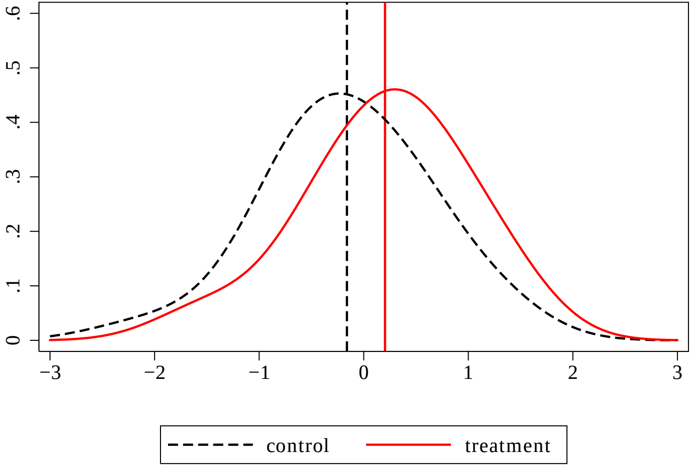
Source: Conti, Hansman, Heckman and Suomi (2012).

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

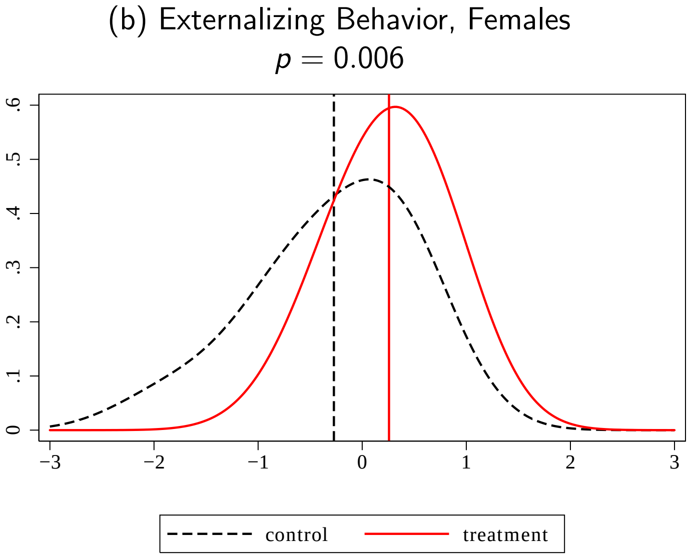
Kernel Densities of Factor Scores

(a) Externalizing Behavior, Males

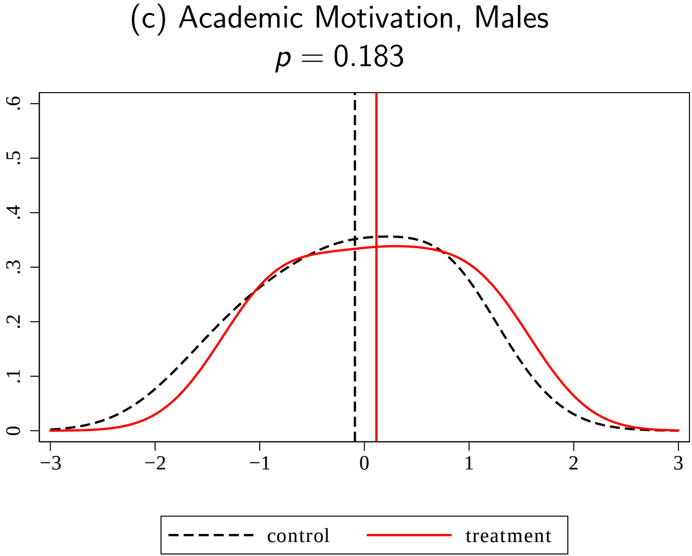
$p = 0.038$



Kernel Densities of Factor Scores



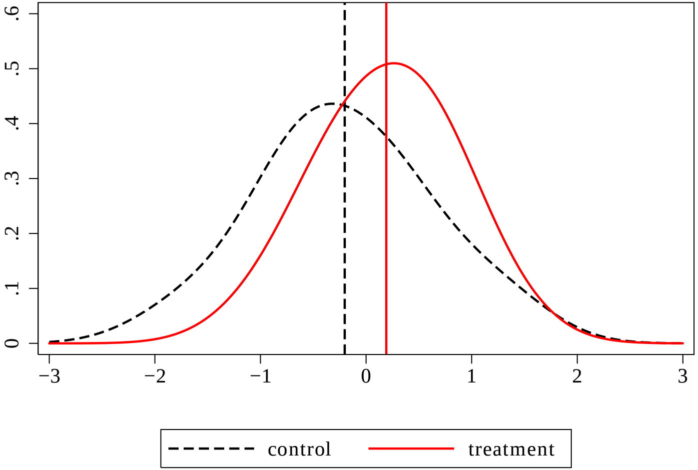
Kernel Densities of Factor Scores



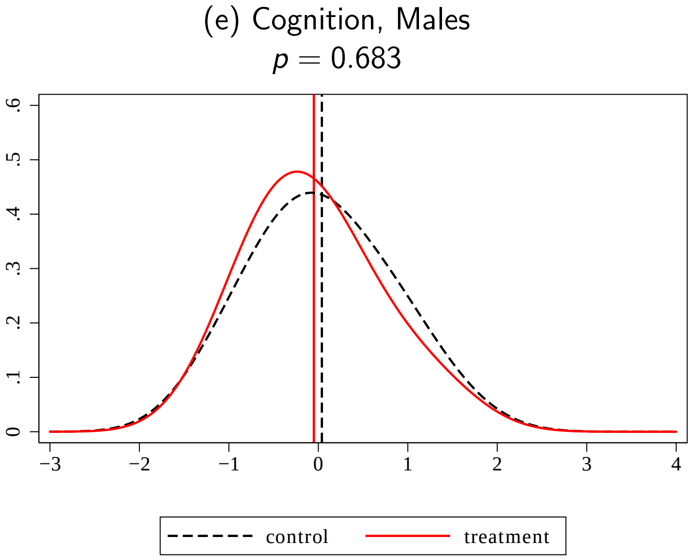
Kernel Densities of Factor Scores

(d) Academic Motivation, Females

$p = 0.048$



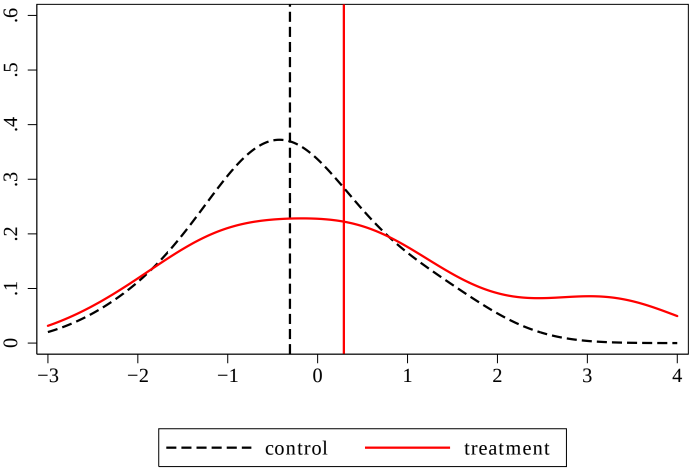
Kernel Densities of Factor Scores



Kernel Densities of Factor Scores

(f) Cognition, Females

$p = 0.095$



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

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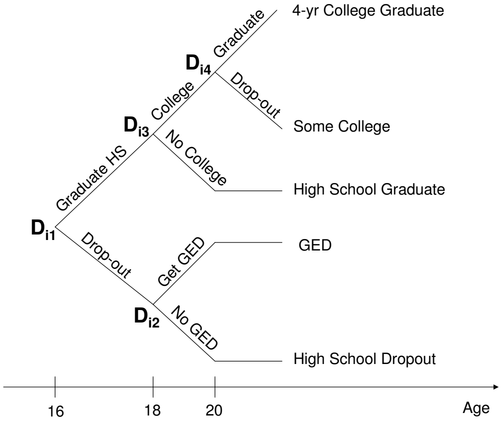
- U.S. Data
- Nationally representative sample of men and women aged 14–22 when first interviewed in 1979.
- Education: sequential model with five final schooling levels: high school dropout, GED, high school graduate, some college, four year college degree.
- Outcomes (age 30):
  1. labor market (wages 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.

Sequential model for schooling decisions.



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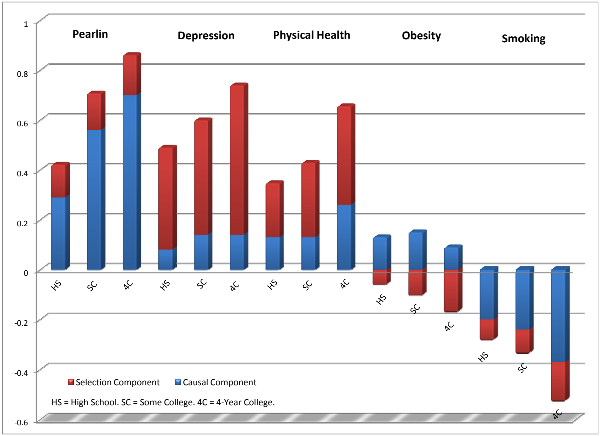
Pairwise comparisons of a terminal education level to being a dropout



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

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

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

- 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.

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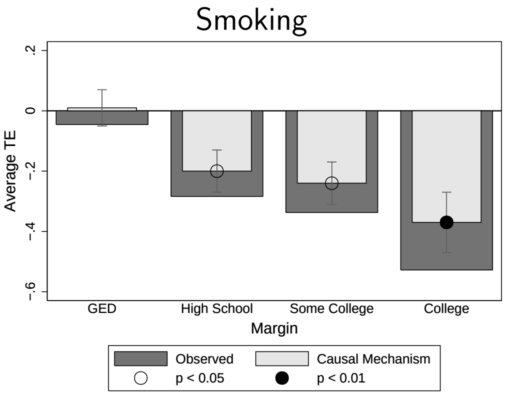
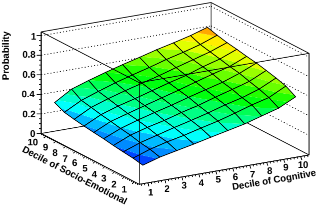
Heckman, Humphries, Urzua, and Veramendi (2011) [HHUV]: "The Effects of Schooling on Labor Market and Health Outcomes"

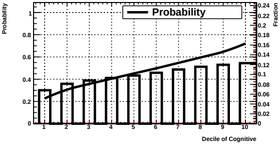
Effects of Education

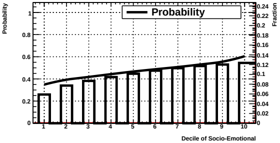


- Like for U.K., the % of the observed disparities in daily smoking due to education is comparable across educational levels (70%).

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



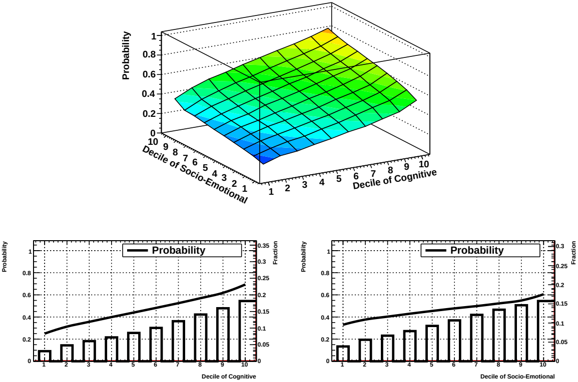




Source: Heckman, Humphries, Urzua, and Veramendi (2011).

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

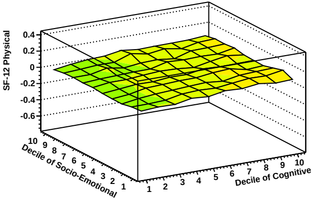
The Probability of Educational Decisions, by Endowment Levels, **Some College** vs. **4-year college degree**

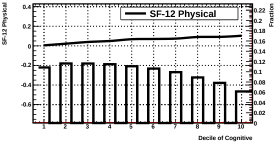


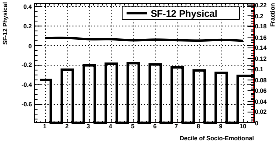
Source: Heckman, Humphries, Urzua, and Veramendi (2011).

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

Physical Health, Males: High School



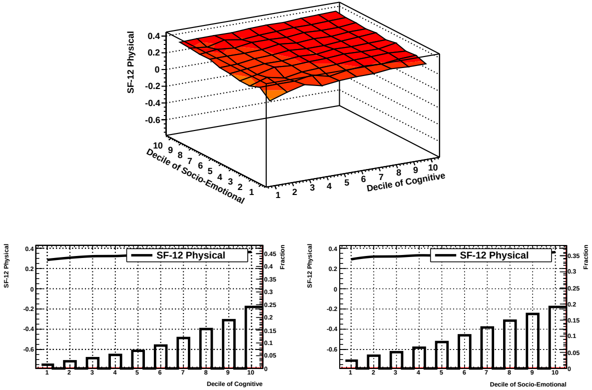




- Not so conditional on education.
- Primary mechanism is through education.

Cognitive and Socioemotional Factors

Physical Health, Males: College



- ...but not conditional on education.

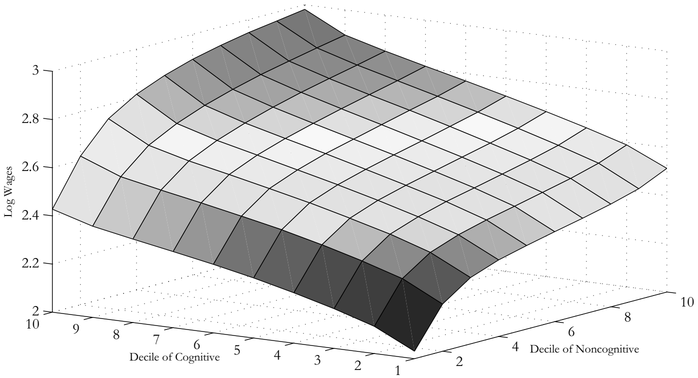
Intergenerational Income elasticities and correlations from Jäntti et al. (2006)

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]

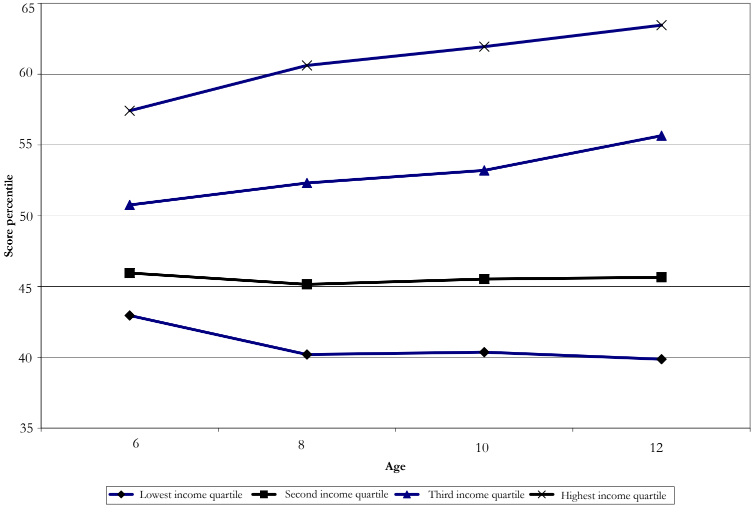
Numbers in brackets below the point estimates show the bias corrected 95% bootstrap confidence interval.

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

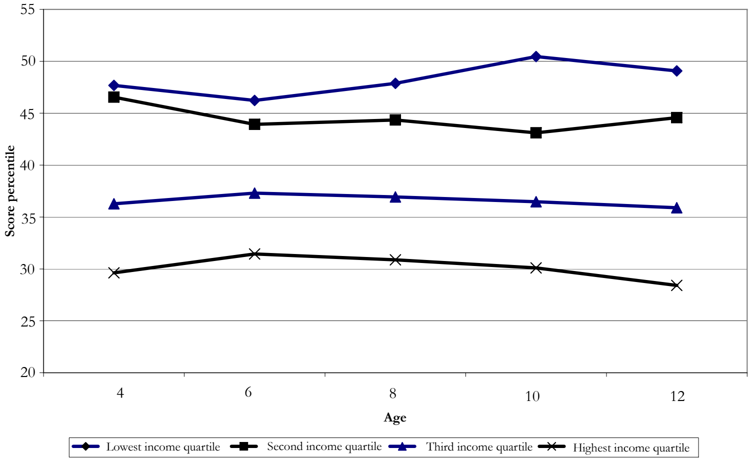
Fact 1: Cognitive and Noncognitive Skills Matter: Log Wages at Age 30: Heckman, Stixrud, and Urzua (2006)



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



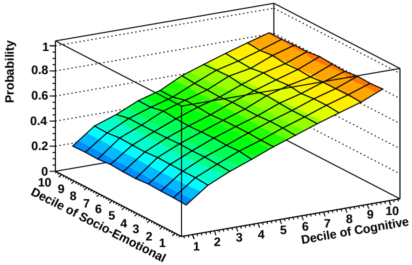
- To estimate the technology of capability formation note that we face the following problems:

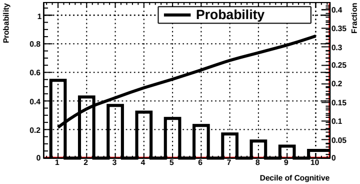
1. Linear production systems do not capture dynamic complementary; Nonlinearity is fundamental.
2. Measurements are often item scores on achievement tests and personality inventories: i.e. measurement system is nonlinear.
3. Need a robust approach that does not depend on specific functional forms: nonparametric 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.

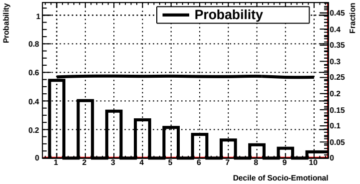
Findings Based on Estimates of the Technologies: **Main policy conclusions from our analysis:**

- 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.

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







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

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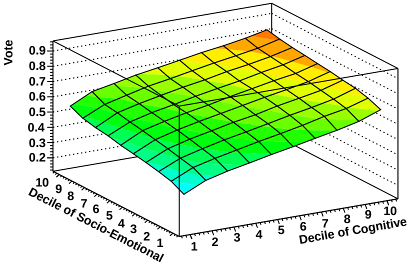
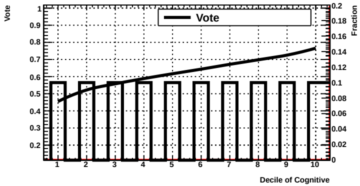
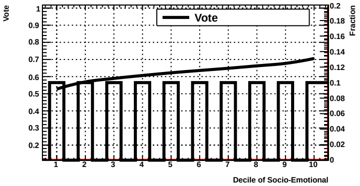
The Effect of Cognitive and Socio-emotional endowments on Participation in 2006 Election, All

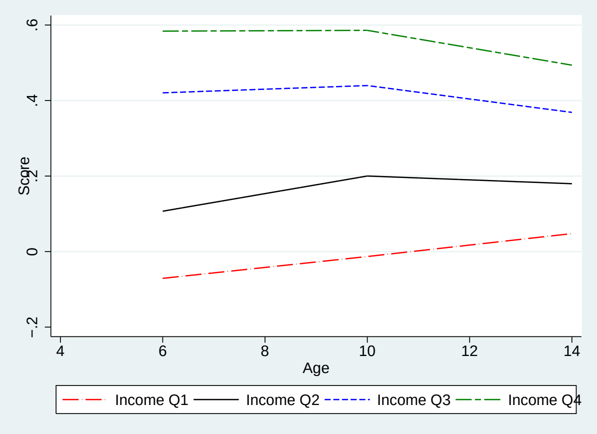






Source: Heckman, Humphries, Urzua, and Veramendi (2011).

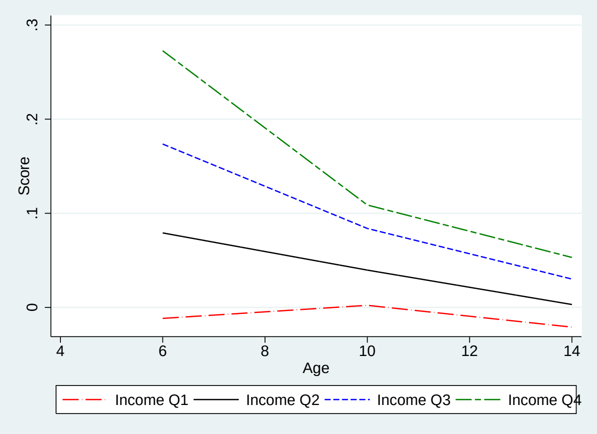
Parental Investment over Childhood among Whites by Family Income Quartile: Material Resource



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

Source: Moon (2012).

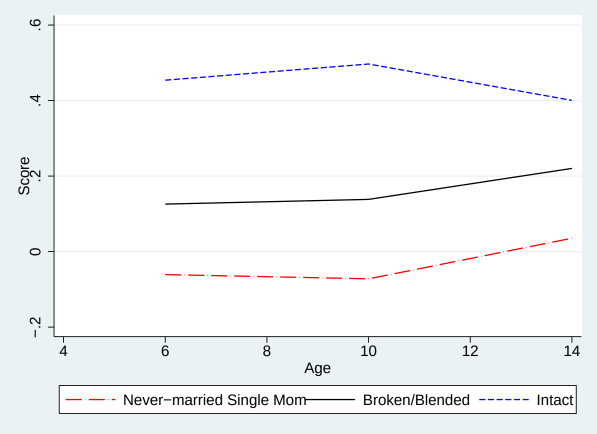
Parental Investment over Childhood among Whites by Family Income Quartile: Emotional Support



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

Source: Moon (2012).

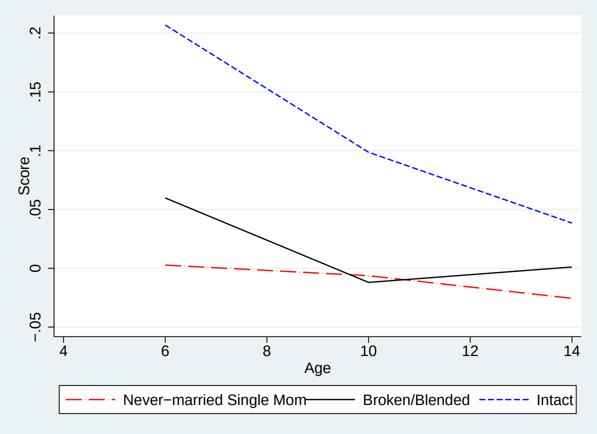
Parental Investment over Childhood among Whites by Family Type: Material Resource



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

Source: Moon (2012).

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

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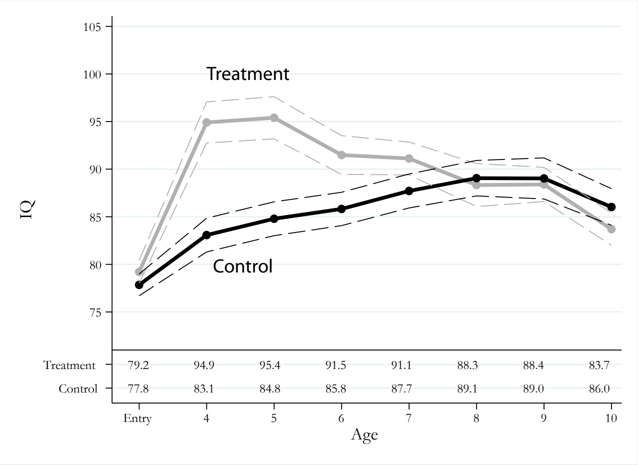
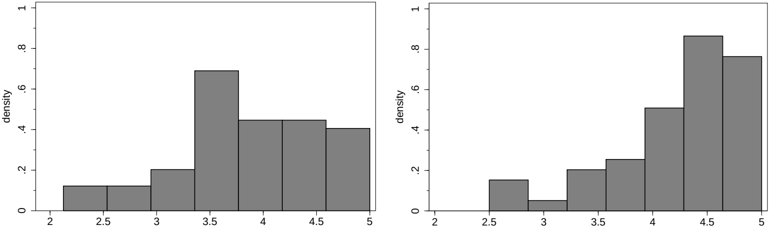
Male Cognitive Dynamics



- 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).

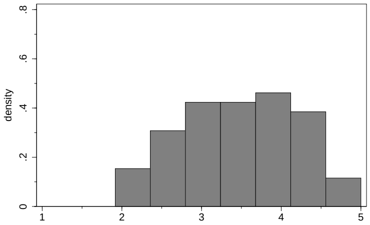
Personal Behavior Index by Treatment Group



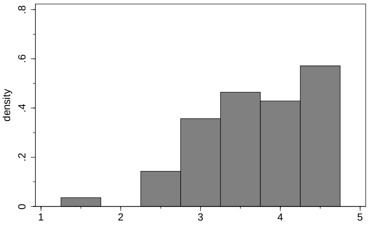
(r) Control (s) Treatment

- 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."

Socio-Emotional Index by Treatment Group



(t) Control



(u) 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

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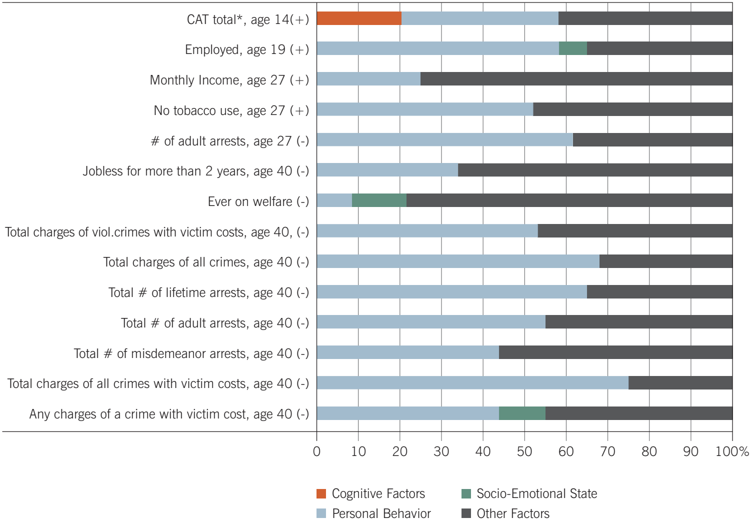

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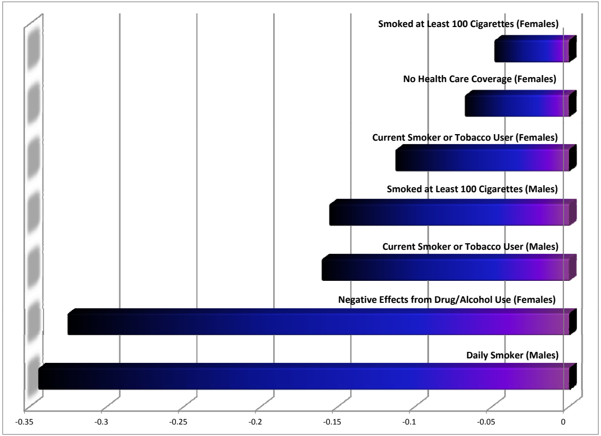
Early childhood intervention programs offer a promising avenue for reducing health disparities

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.**

5. 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.

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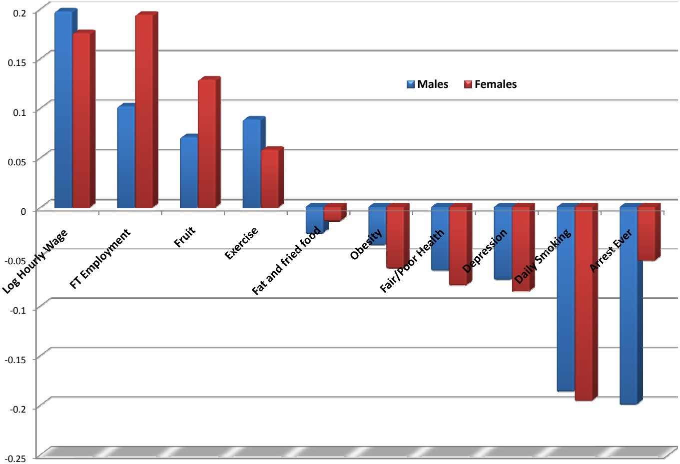
The Effects of Education on Health and Healthy Behaviors

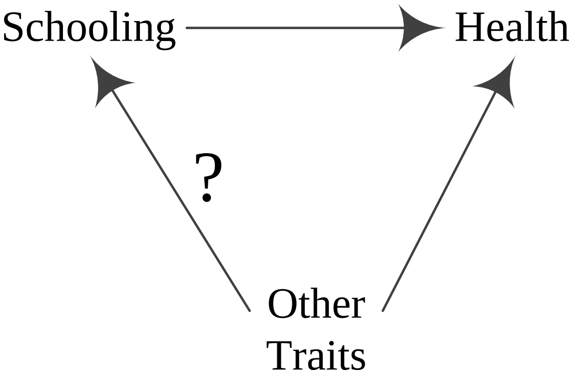
- Use data from the U.S. and U.K. looking at a variety of measures of education.
- Decompose observed effects into causal components.
- First consider U.K. differentials at age 30. (BCS70)
- Effect of completing O-levels.

Disparities by Education



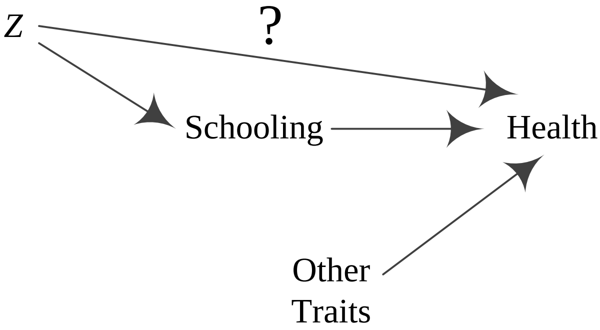
Note: U.K. Data: Authors' calculations using BCS70. The graph shows the raw differentials in the outcomes between individuals with post-compulsory and compulsory level of education. Source: Conti, Heckman and Urzua.

Inferring Causation



Search for causality: Two strategies

a. Instruments Z



Random assignment is an instrument

b. Control for "other traits" or proxies for "other traits."

  b.i Matching assumes we can perfectly proxy the "relevant" other traits (traits that affect schooling and health).

  b.ii Our approach does *not* make the strong assumptions of matching.

Is there a causal effect of education on health?

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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
Decomposition of Observed Disparities

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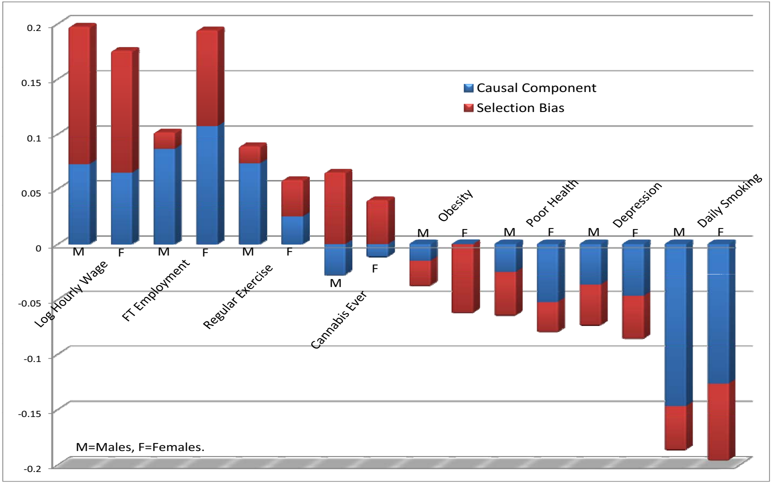

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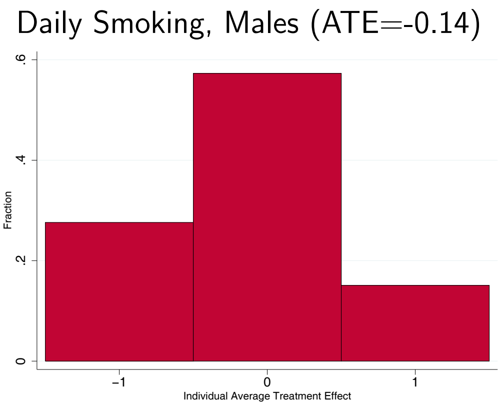
Distributional Treatment Effects:

Does everybody benefit?

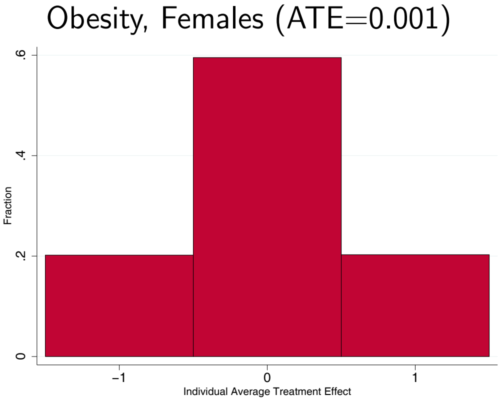
- We also identify **the joint distribution** of the treatment effects.

Distribution of Average Treatment Effects



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

Distribution of Average Treatment Effects

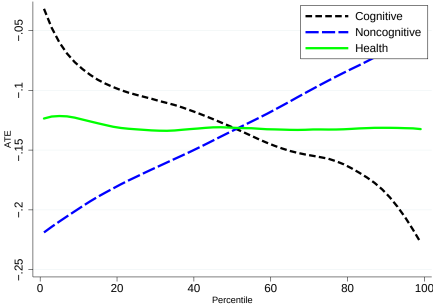


- Which produces essentially a zero average treatment effect.

Who benefits?

Treatment Effect Heterogeneity

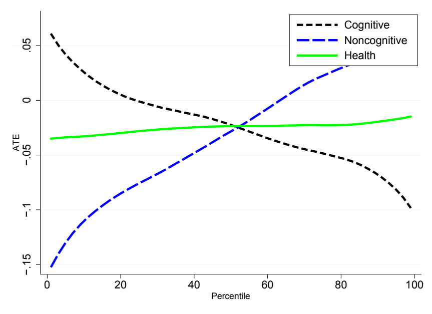
Smoking, Males



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

Treatment Effect Heterogeneity

Poor Health, Males



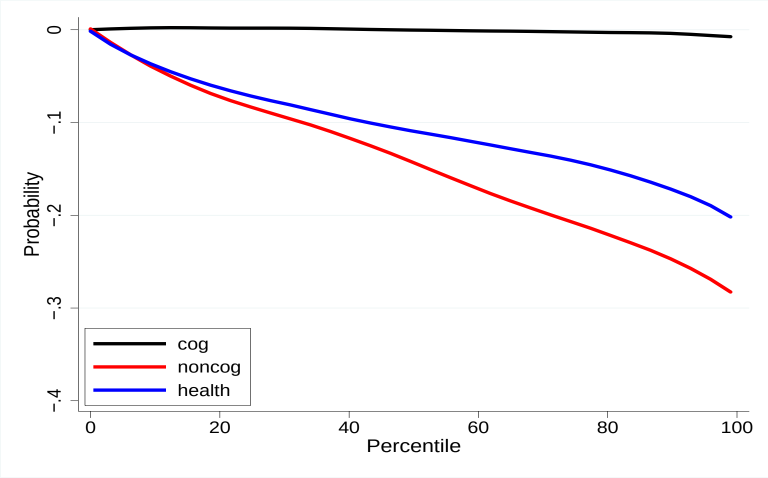
- Education compensates for low early noncognitive endowments and reinforces high early cognitive endowments.

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

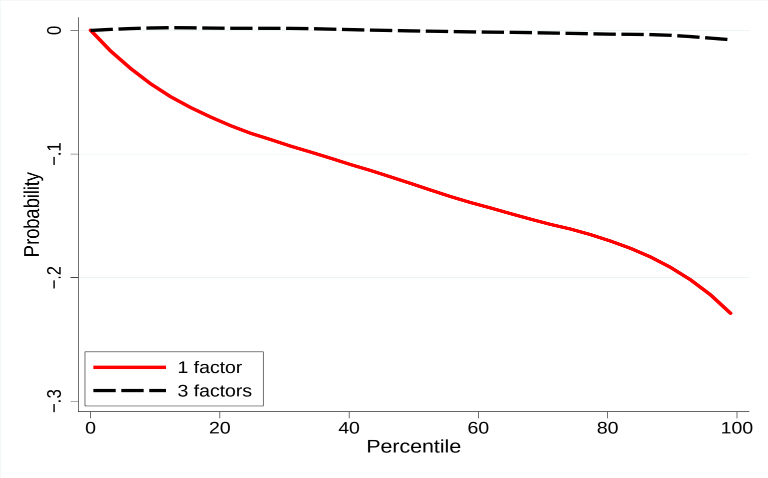
Daily Smoking at 30, Males: not conditioning on education



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

The Role of Factors up to Age 10

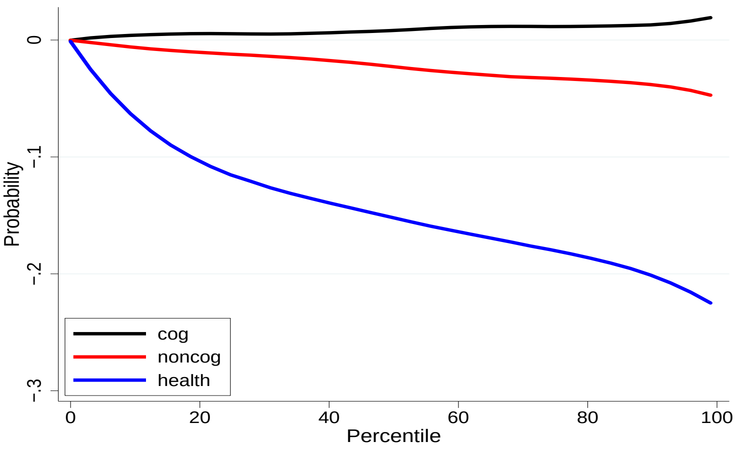
Daily Smoking at 30, Males: not conditioning on education



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

The Role of Early Physical Health

Obesity at 30, Males: not conditioning on education



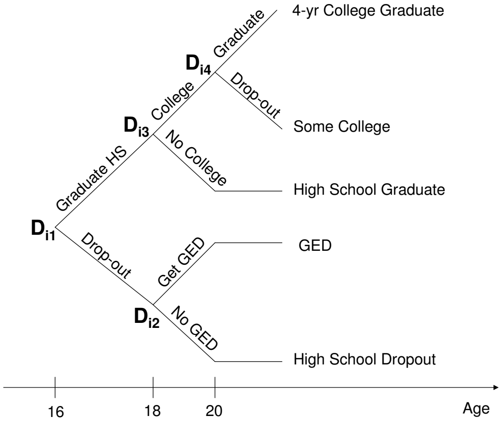
- Early physical health is the most important determinant of obesity for men.

Dynamic Sequential Models

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.

Sequential model for schooling decisions.



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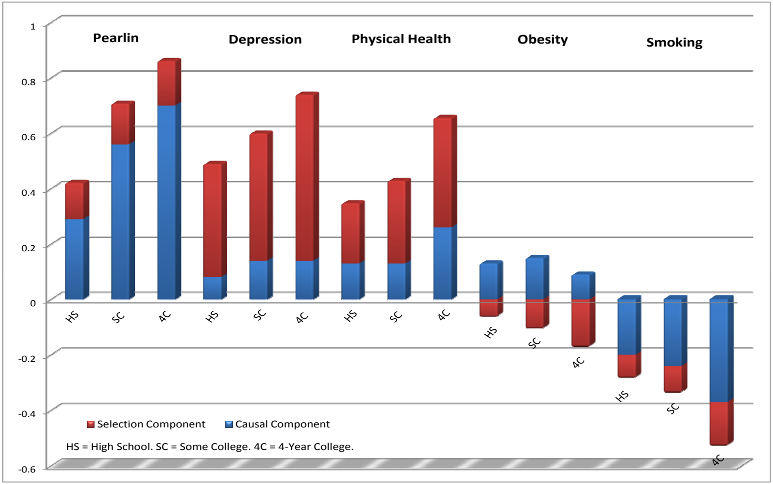
Decomposition of Mean Differences

Pairwise comparisons of a terminal education level to being a dropout



Some Additional Economic Intuition that Explains the Simulation Results

- This subsection provides an intuition for the simulation results just discussed.
- Why is it optimal to invest relatively more in the early years of the most disadvantaged?
- The answer hinges on the interaction between different measures of disadvantage.

- Consider the following example where individuals have a single capability, θ.
- Suppose that there are two children, A and B, born with initial skills θ_0^A and θ_0^B, respectively.
- Let θ_P^A and θ_P^B denote the skills of the parents A and B, respectively.
- Suppose that there are two periods for investment, which we denote by periods 1 (early) and 2 (late).
- For each period, there is a different technology that produces skills.

- Assume that the technology for period one is:

$$\theta_2 = \gamma_1 \theta_1 + \gamma_2 I_1 + (1 - \gamma_1 - \gamma_2)\, \theta_P.$$

- For period two it is:

$$\theta_3 = \min \{\theta_2, I_2, \theta_P\}\,.$$

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

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

$$\max \begin{bmatrix} \min\left\{\gamma_1\theta_1^A + \gamma_2 I_1^A + (1-\gamma_1-\gamma_2)\,\theta_P^A, I_2^A, \theta_P^A\right\} + \\ \min\left\{\gamma_1\theta_1^B + \gamma_2 I_1^B + (1-\gamma_1-\gamma_2)\,\theta_P^B, I_2^B, \theta_P^B\right\} \end{bmatrix}$$
$$\text{subject to: } I_1^A + I_2^A + I_1^B + I_2^B \leq M \tag{40}$$

- When the resource constraint (40) does not bind, as it does not if M is above a certain threshold (determined by θ_P), optimal investments are

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

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

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

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

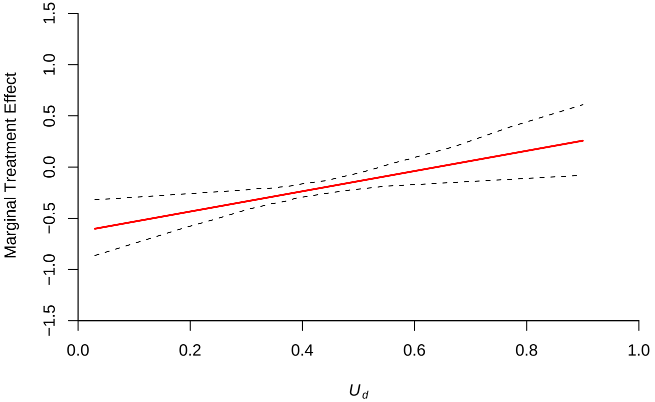
if

$$\theta_P^A - \theta_P^B > \frac{\gamma_1}{\gamma_1 + \gamma_2} \left(\theta_1^A - \theta_1^B\right).$$

- Thus, if parental endowments are less negative than the childhood endowments (scaled by $\frac{\gamma_1}{\gamma_1+\gamma_2}$), it is optimal to invest more in the early years for the disadvantaged and less in the later years.

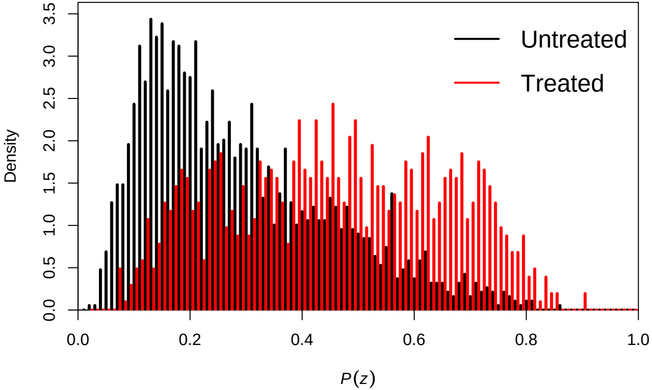
- Notice that since $(1 - \gamma_1 - \gamma_2) = \gamma_P$ is the productivity parameter on θ_P in the first period technology, we can rewrite this condition as $(\theta_P^A - \theta_P^B) > \frac{\gamma_1}{1-\gamma_P}(\theta_1^A - \theta_1^B)$.
- The higher the self-productivity (γ_1) and the higher the parental environment productivity, γ_P, the more likely will this inequality be satisfied for any fixed level of disparity.

IV Example: Marginal Treatment Effect: Diploma, Bad Health, Females



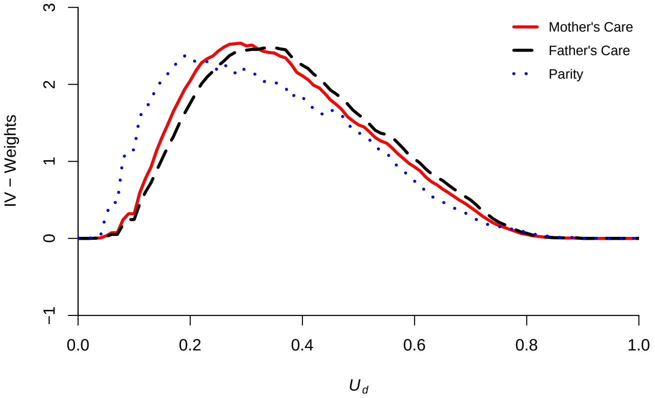
Conti, Eisenhauer, Heckman, and Piatek (2009)

IV Example: Common Support: Diploma, Bad Health, Females



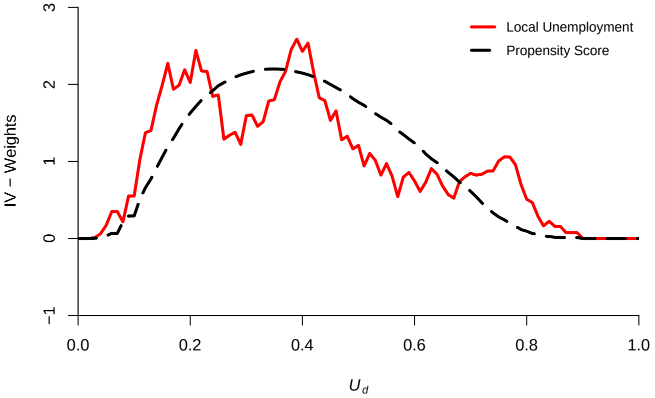
Conti, Eisenhauer, Heckman, and Piatek (2009)

IV Example: IV - Weights I: Diploma, Bad Health, Females



Conti, Eisenhauer, Heckman, and Piatek (2009)

IV Example: IV - Weights II: Diploma, Bad Health, Females



Conti, Eisenhauer, Heckman, and Piatek (2009)