The Developmental Origins of Health: Cognition, Personality, and Education

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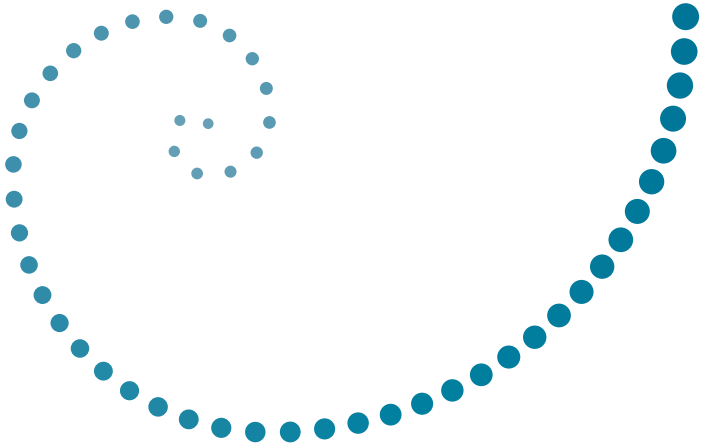

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Introduction

- Among early deaths, it has been estimated for the U.S. that:
  - (i) 40% are due to behavioral patterns
  - (ii) 30% due to genetic predispositions
  - (iii) 15% due to social circumstances
  - (iv) 10-15% due to shortfalls in medical care

- What causes the practice of unhealthy behaviors?
- Can we do anything about them?

- Tonight I present a developmental approach to these questions.
- Consider health policy as a part of a general human development strategy.

The Economics of Human Development

Recent studies in the Economics of Human Development establish that:

1. A core low-dimensional set of capabilities explains a variety of diverse socioeconomic outcomes.
2. Cognitive and noncognitive capabilities are both important causal determinants with equal strength for many outcomes.
3. Early health conditions also play a powerful role in explaining adult behaviors.
4. Critical and sensitive periods:
   (a) Earlier for cognitive capabilities
   (b) Later for noncognitive capabilities

5. Gaps in both types of capabilities open up early; persist strongly for cognitive capabilities; less strongly for noncognitive capabilities.
6. Many early childhood interventions operate primarily through noncognitive capabilities.
7. Adolescent remediation is ineffective especially for cognitive interventions.
8. Today I discuss a research agenda and the findings from our ongoing research to date which incorporates health into a general framework of policy analysis for interpreting data and devising interventions.

The Economics of Human Development

- Behaviors are shaped by abilities, incentives, and motivations.
- These traits emerge early, and are strongly influenced by the family.
- A neglected avenue of investigation is interventions that form these traits and that exploit the synergisms among the traits.

The Economics of Human Development

- A good health policy may be a good family policy.
- A good family policy may also be a good health policy.
- This argument goes beyond looking at education or nutrition but is consistent with both and integrates these more specialized approaches into a general framework.
- My analysis develops an approach to human development that unites and extends previous research in a common framework that is the basis for policy intervention in health, education, crime, and employment.

- Two currently unrelated bodies of research point to the importance of early factors on many outcomes including health.
- The "fetal programming" literature surveyed by Gluckman and Hanson (2005, 2006) demonstrates that *in utero* environments affect adult health.
- Fogel (1997, 2004) demonstrates important empirical relationships between early nutrition and adult health.

- Barker (1998) and subsequent research demonstrates the predictive power of environmental insults *in utero* and in infancy for the onset of adult coronary disease, stroke, diabetes and hypertension.
- Birthweight, fetal and maternal nutrition, growth by age 1, etc. are all predictive of later adult health.
- While the literature on the epidemiology of disease has taken a life cycle, developmental perspective, this approach has not yet made its way into the mainstream of health economics or into policy analysis.

- Parallel to the epidemiological literature, there is an emerging literature on child development in economics that demonstrates the importance of early environmental conditions on the evolution of adolescent and adult cognitive and noncognitive skills (Cunha and Heckman, 2007, Heckman and Mosso, 2014).
- These skills are important determinants of educational attainment, crime, earnings, and participation in risky behaviors (Almlund et al., 2011).
- A parallel, and in many ways richer literature on animal studies (Knudsen, Heckman et al. 2006; Szyf, McGowan, and Meaney, 2008; Coles, Heckman, and Suomi, 2009).
- Like the fetal programming literature, this literature documents critical and sensitive periods in the development of human capabilities.

- Unlike the fetal programming literature, it also considers environmental influences on development over the entire life cycle of the child and on into adulthood.
- Remediation of early disadvantage and resilience receive much more attention in this literature than in the literature on health economics.
- Each literature has much to learn from the other.
- Evidence on the importance of genes and environments on a spectrum of health, labor market, and behavioral outcomes suggests that common developmental processes are at work.

- Cognitive and noncognitive skills — self-regulation, motivation, time preference, far-sightedness, adventurousness and the like — affect the evolution of health capital through choices made by parents and children.
- Grossman (2000), Smith (2007) and Heckman et al. (2016) show that education is an important determinant of health disparities.
- The recent literature in economics and psychology shows the importance of personality and cognition in affecting educational choices.

- Those with greater self-control and conscientiousness follow medical instructions and take care of themselves in a variety of ways. (Hampson and Friedman, 2008; Roberts, 2007; Kaestner, 2009)
- A large literature on how personality traits and cognition affect health behaviors and outcomes.
- Certain personality types are at greater risk for mental health disorders (Borghans et al., 2008; Heckman and Kautz, 2014).

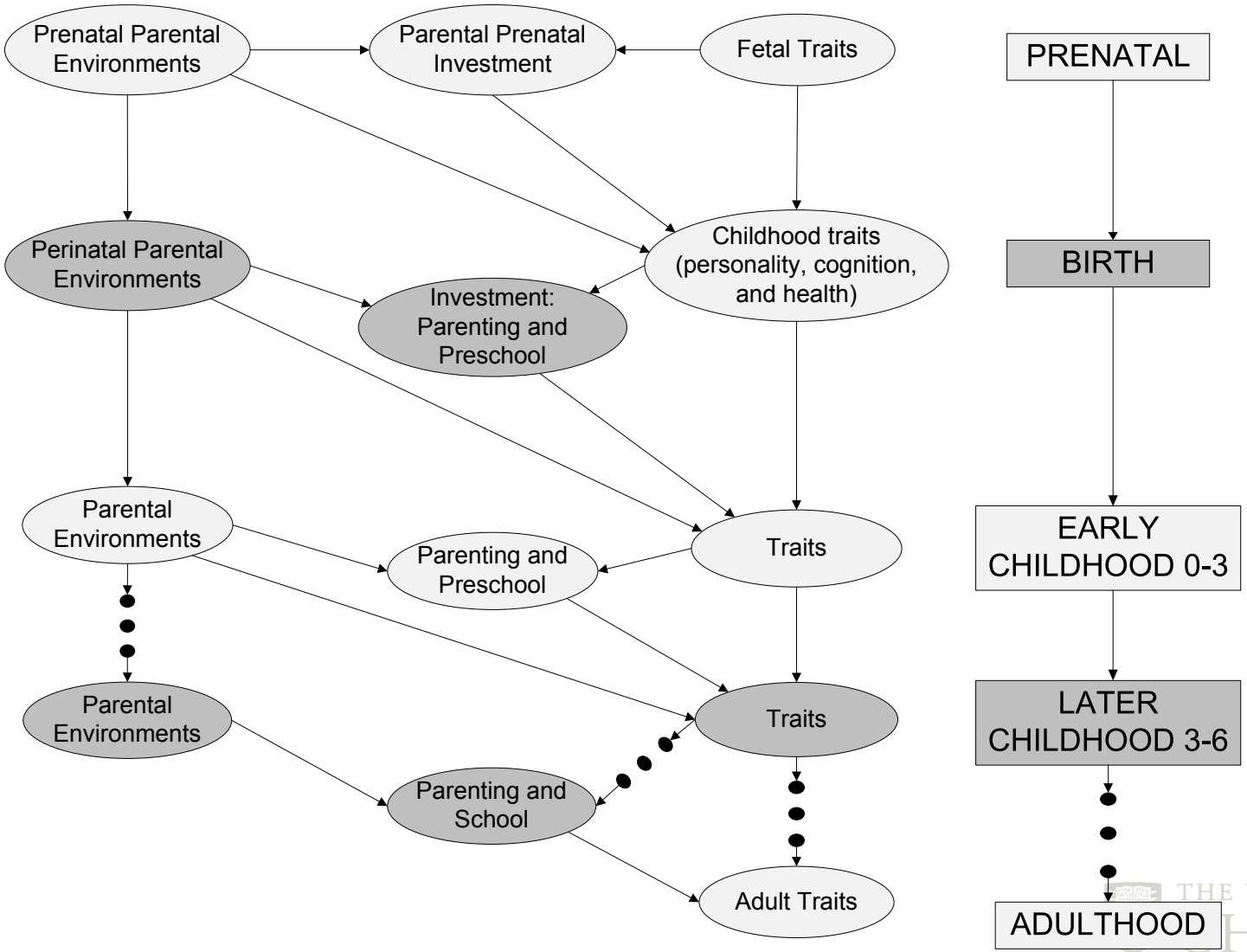
- Personality factors affect learning (Duncan, Dowsett, Claessens, Magnuson, Huston, Klebanov, Pagani, Feinstein, Engel, Brooks-Gunn, Sexton, Duckworth, and Japeli, 2007; Raver, Garner, and Smith-Donald, 2007).
- Adverse health conditions impair learning (Currie, 2006).
- Ram and Schultz (1979) show that raising health (extending life) promotes investment in human capital.

- People with longer horizons and lower rates of time preference invest more in themselves.
- Lower rates of time preference are associated with greater cognitive skills.
- Those with higher IQs are more farsighted (have lower time preference) because they envision future scenarios more clearly (Frederick, 2005).
- The recent literature on personality and preference formation establishes causal impacts of parental inputs and other environmental factors on cognitive and noncognitive skills (Cunha and Heckman, 2007; Cunha, Heckman, and Schennach, 2010; Borghans, Duckworth, Heckman, and ter Weel, 2008).

- The developmental focus adopted in this lecture suggests new channels of policy influence to remediate well documented health disparities.
- Early childhood interventions that affect personality traits and cognitive skills that promote health can be effective policy tools in preventing and curing disease.

- A simple investment framework unifies the literature on health and skill formation.
- It also reveals currently unexplored avenues for future research.
- The framework can be used to analyze synergies in producing health, cognitive skills, and noncognitive skills, which we group together as human capabilities.

Figure 1 : Resilience and Development: A Life Cycle Framework for the Technology of Skill Formation



Human Diversity and Human Development

Capabilities matter

Many empirical studies document that cognitive ability is a powerful determinant of wages, schooling, participation in crime and success in many aspects of social and economic life (Borghans et al., 2008; Heckman, 1995; Murnane, Willett, and Levy, 1995) including health (Auld and Sidhu, 2005).

Capabilities are multiple in nature

Cognitive abilities are important predictors of a variety of outcomes. So are noncognitive capabilities.

perseverance,	motivation,	time preference,
risk aversion,	self-esteem,	self-control,
preference for leisure,		

Both have direct effects on

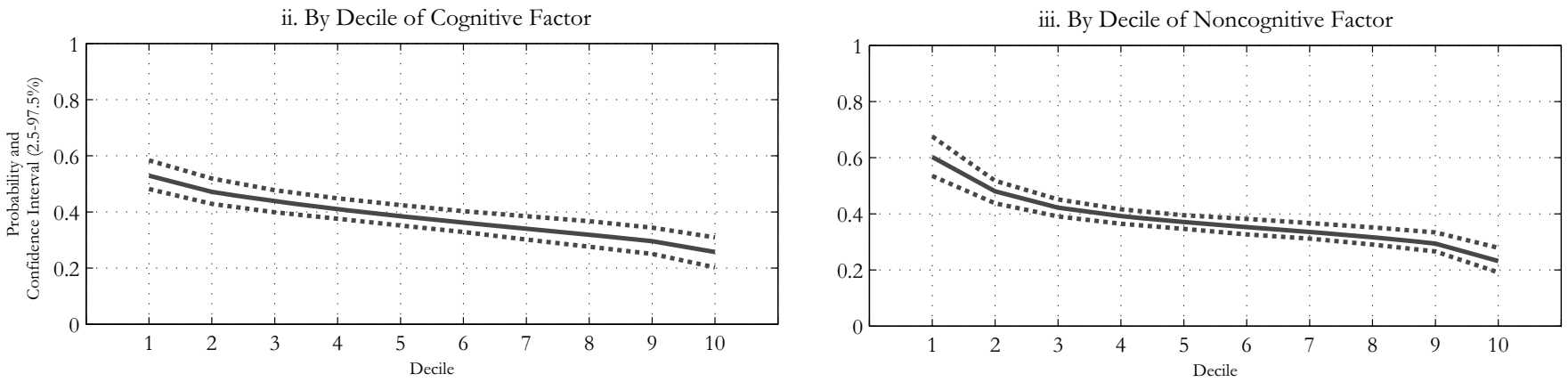
wages (controlling for schooling),	schooling,
performance on achievement tests,	crime,
teenage pregnancy,	smoking,

and many other aspects of social and economic life.

Borghans, Duckworth, Heckman, and ter Weel (2007); Bowles, Gintis, Osborne (2001).

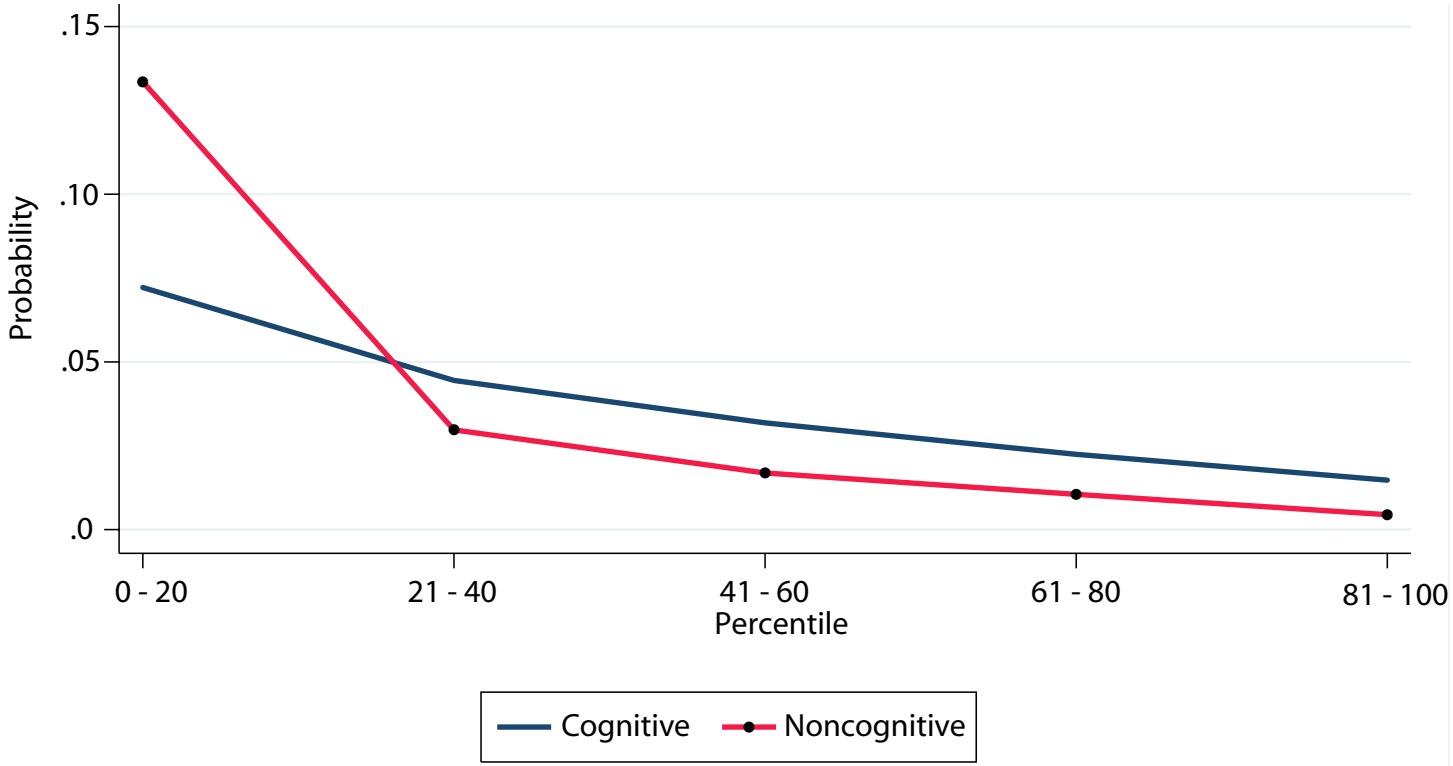
- They affect health choices (see the evidence on time preference and health in Grossman, 2000).
- Social and emotional factors affect adult health (Ryff and Singer, 2005).
- A common core of capabilities helps to explain many diverse behaviors.

Figure 2 : Probability of daily smoking by age 18 (males)



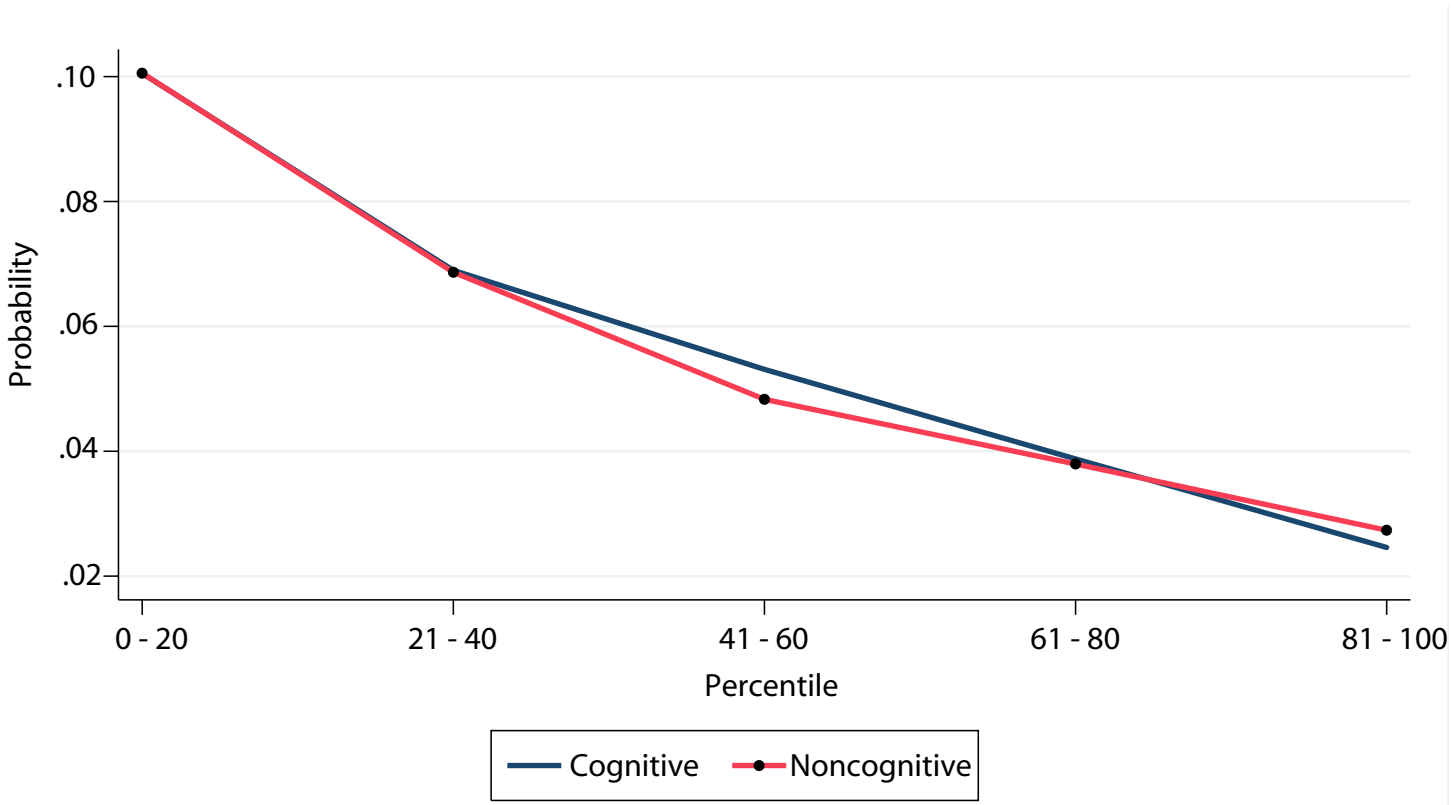
Notes: The data are simulated from the estimates of the model and our NLSY79 sample. We use the standard convention that higher deciles are associated with higher values of the variable. The confidence intervals are computed using bootstrapping (200 draws).

Figure 3 : 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 noncognitive ability after integrating the cognitive ability.
Source: Heckman, Stixrud, and Urzua (2006).

Figure 4 : Probability of teenage pregnancy



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

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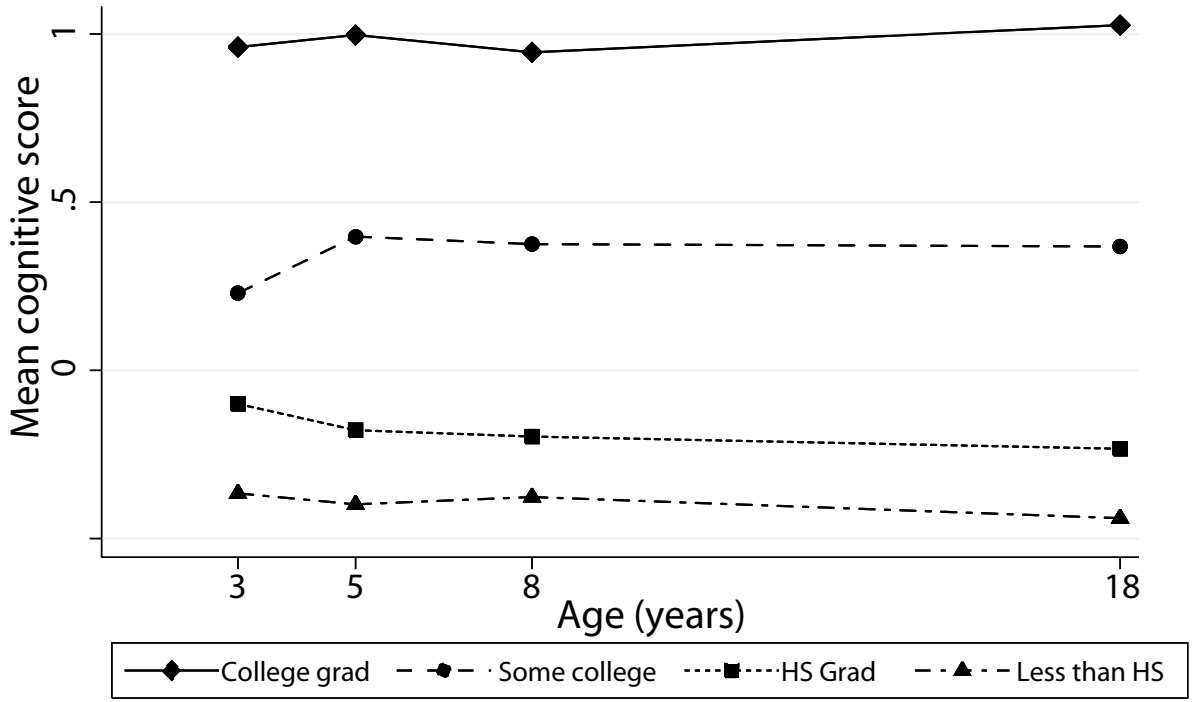
Noncognitive Epidemiology

- Noncognitive traits are major predictors of health and healthy behaviors.

For both cognitive and noncognitive traits, ability gaps among individuals and across socioeconomic groups open up at early ages and persist.

Figure 5 : 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).

- Research shows that schooling quality, pupil teacher ratios, teacher pay and the like play only small roles in accounting for these gaps or in widening or narrowing them.
- The gaps in abilities start early before school begins and they persist.
- Once one controls for early family environments in a statistical sense, the gaps substantially narrow.

- Similar gaps open up in health but the gaps appear to widen with age.
- This suggests a powerful role for environments into adult life.

- Such evidence leaves open the question of which aspects of families are responsible for producing these gaps.
- Is it due to genes?
- Family environments and investment decisions?
- The evidence from the intervention studies suggests an important role for investments and family environments in determining adult capabilities.
- First consider how dramatically family environments differ.

Gaps in cognitive and noncognitive skills of children 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.

Mothers' Speech and Child Vocabulary: 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

1. Early environments dramatically affect life outcomes

The Adverse Childhood Experiences (ACE) Study (Felitti and Anda)

- The largest study of its kind ever done to examine the effects of adverse childhood experiences on health and human development over the lifespan (17,337 participants).
- The study shows with data that the insights of Freud about the effects of adverse early childhood environments are correct.
- Exactly what feature of early trauma or adverse environment affects child outcomes is not yet known.
- A higher ACE score means worse early conditions (child abuse; molestation; poverty)

ACE Score: Components

- Childhood abuse
  (a) emotional
  (b) physical
  (c) sexual
- Witnessing domestic violence
- Growing up in a household where members:
  (a) mentally ill
  (b) substance abuser
  (c) sent to prison
- Physical neglect
- Emotional neglect

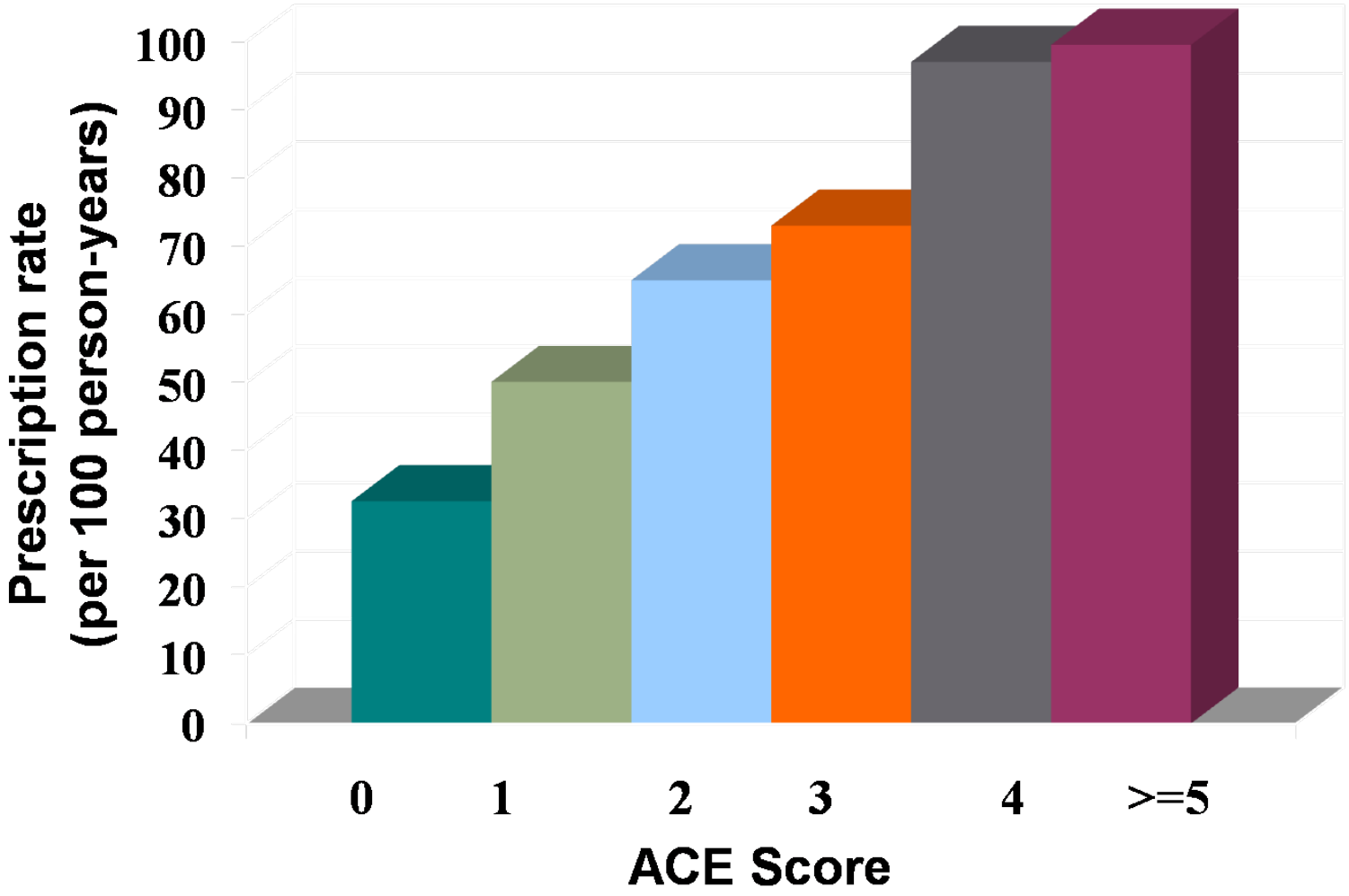
Disease

ACEs Increase Likelihood of Heart Disease*

• Emotional abuse	1.7x
• Physical abuse	1.5x
• Sexual abuse	1.4x
• Domestic violence	1.4x
• Mental illness	1.4x
• Substance abuse	1.3x
• Household criminal	1.7x
• Emotional neglect	1.3x
• Physical neglect	1.4x

**After* correction for age, race, education, and conventional risk factors like smoking and diabetes.
Circulation, Sept 2004.

Figure 6 : ACE Score and Rates of Antidepressant Prescriptions

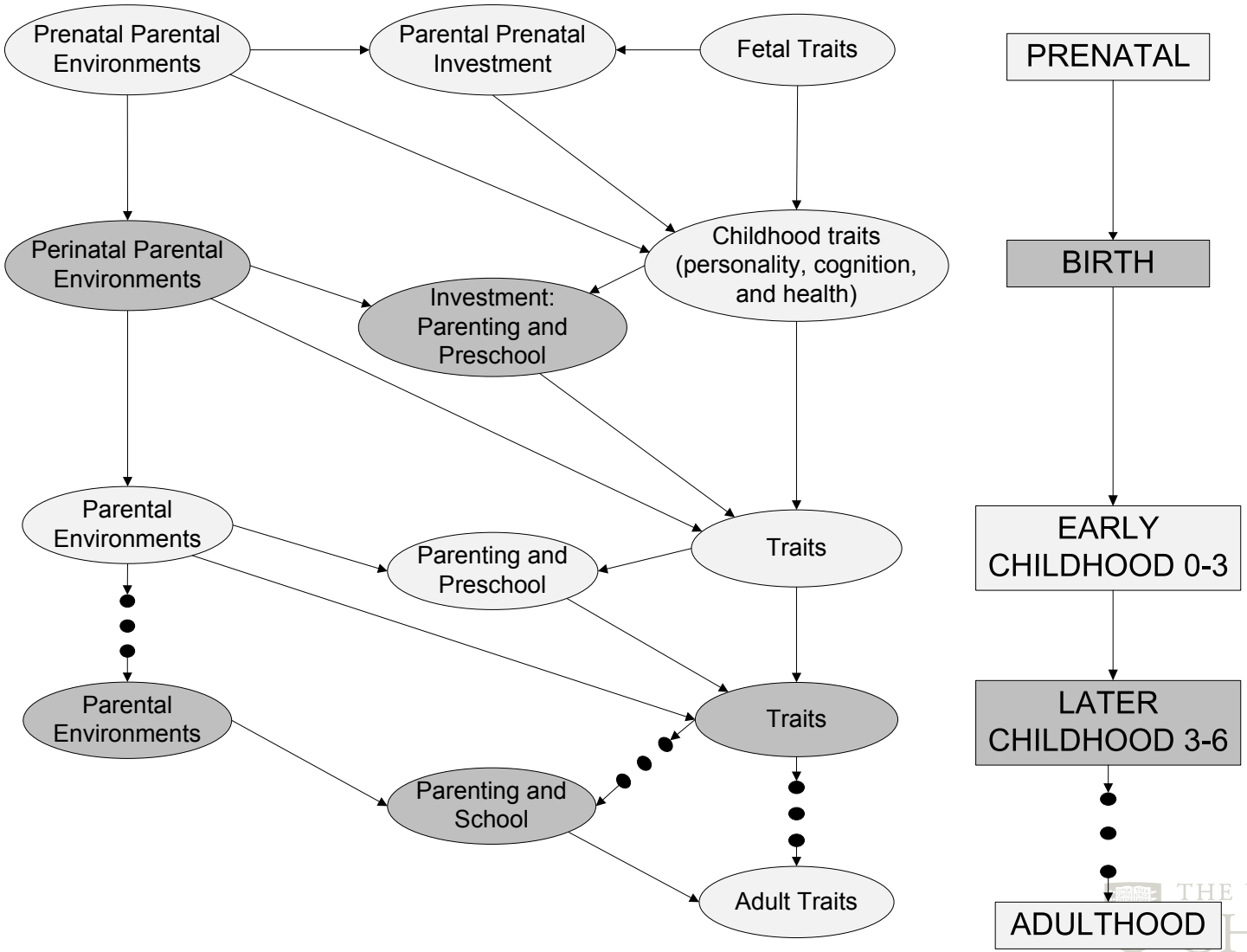


- Adverse early childhood conditions have dramatic effects on mortality and morbidity.
- (Brown, Anda, Henning, Felitti et al., 2009)

Effects of ACE on Mortality

- Average number of years lost per adult death ≈3 times greater if ACE score is ≥ 6.
- Adults with ACE ≥ 6,
  1.7 times more likely to die at age ≤ 75
  2.4 times more likely to die at age ≤ 65

Figure 7 : Resilience and Development: A Life Cycle Framework for the Technology of Skill Formation



Developmental Origins of Health and Diseases (DOHaD)

- Connects environmental cues during development with propensity to diseases later in life
- Next step from fetal origins hypothesis: DOHaD is concerned also with conception and infancy
- DohAD deals with factors that are based on the process of developmental plasticity
- Main triggering factors: malnutrition and hormonal stress
- So far literature mainly concerned with cardiovascular diseases later in life and diabetes.

- In adapting to undernourishment, the fetus programs its phenotypic expression to types with increased risk of cardiovascular disease (predictive adaptive response)
- Birth weight, but especially IUGR (Intrauterine Growth Restriction) are measures indicating insults in pregnancy, not the direct cause
- Crude measure, since not all insults necessarily translate into growth impairment.

- Malnutrition is a primary cause of IUGR in developing countries.
- Fetal alcohol (Nilsson, 2008); smoking and other risk factors mainly contribute in developed countries.
- Related animal evidence.
- However, there is also evidence of resilience and recovery at later ages.
- Early conditions are not fully determinative.
- Developmental Plasticity.
- Still an open question of how plastic is the human organism.

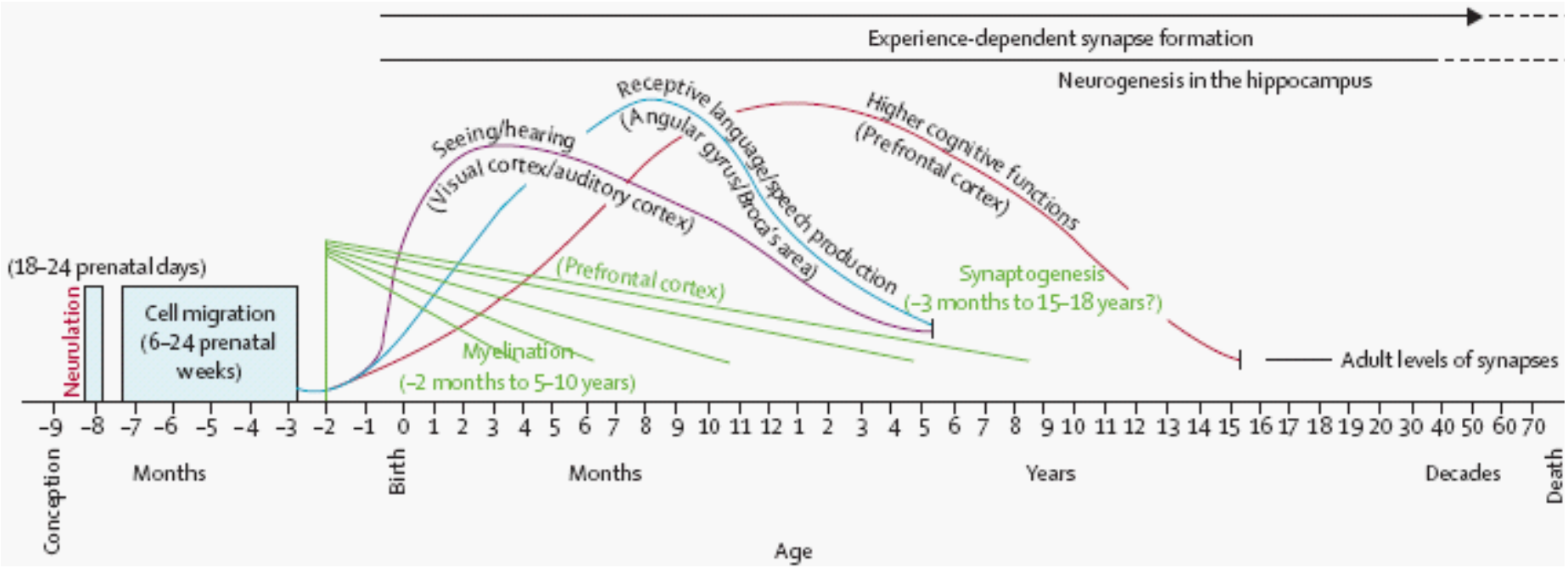
Famine

- Natural experiments, testing DOHaD, show lasting power of adversity in the early years

Critical and Sensitive Periods for Intervention have been Documented for the Development of a Variety of Capabilities

- Sensitive and critical periods have been documented extensively for:
  1. binocular vision in the cortex of mammals,
  2. filial imprinting in the forebrain of ducks and chickens,
  3. language acquisition in humans (Newport, 2002)
  4. early vitamin/nutrient deficiencies can have substantial lasting negative effects on human development.
     - E.g., Iron; Vitamin A; Iodine.
     - Blindness, Impaired IQ, etc.
     - Difficult to remediate at later ages.

Figure 8 : Human Brain Development



Source: Thompson and Nelson (2001)

- Different types of abilities appear to be manipulable at different ages. IQ scores become stable by age 10 or so, suggesting a sensitive period for their formation below age 10 (Schuerger and Witt, 1989).
- On average, the later remediation is given to a disadvantaged child, the less effective it is.

- A lot of evidence suggests that the returns to adolescent education for the most disadvantaged and less able are lower than the returns for the more advantaged (Carneiro and Heckman, 2003; Carneiro, Heckman, and Vytlacil, 2006; Meghir and Palme, 2001).
- The available evidence suggests that for many skills and human capabilities, later intervention for disadvantage may be possible, but that it is much more costly than early remediation to achieve a given level of adult performance (Cunha and Heckman, 2006).

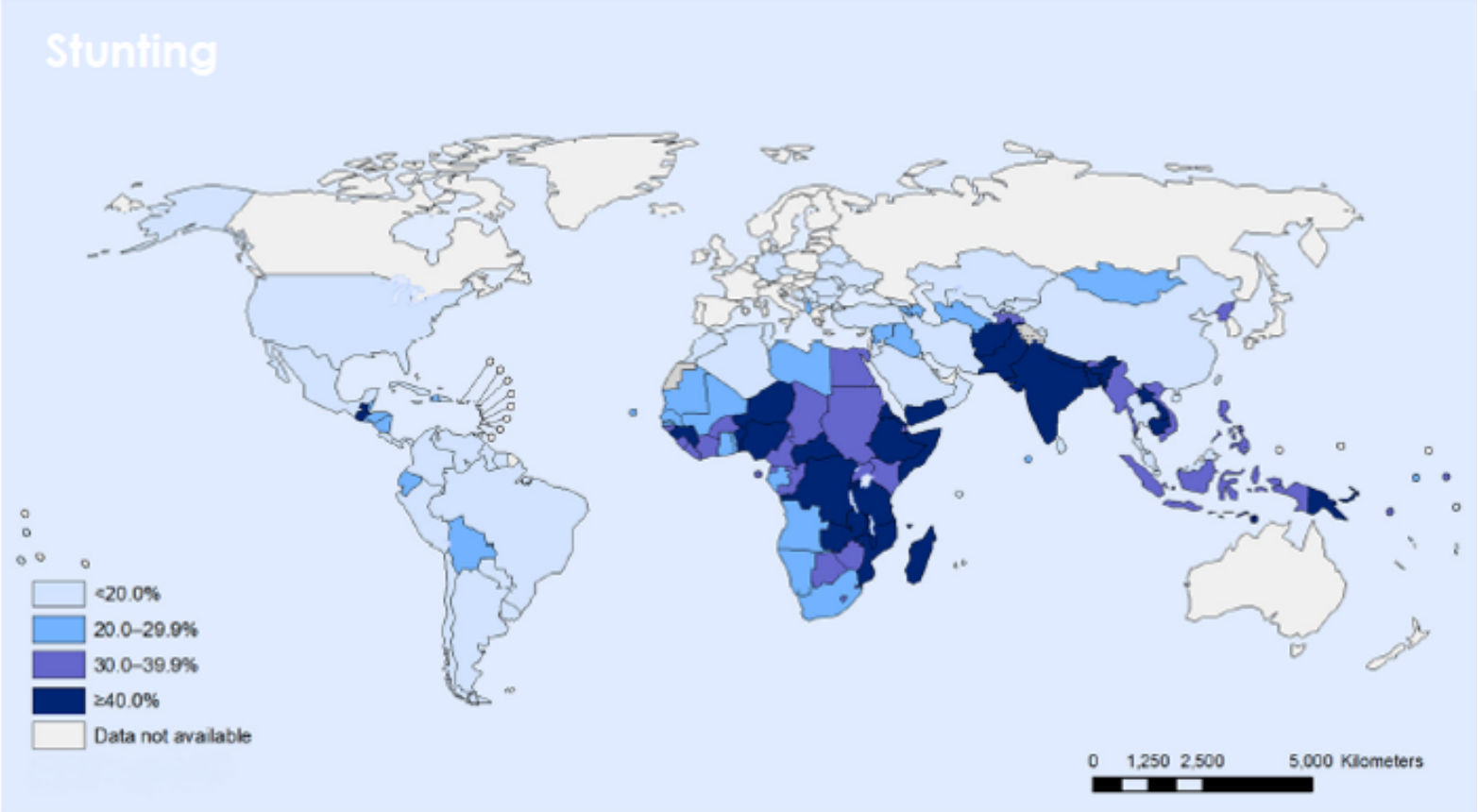
Enriched Early Environments Compensate in Part For the Risks Arising from Disadvantaged Environments

- A main mechanism of intervention through noncognitive or personality capabilities.
- Enriched nutrition affects basic biological and human development.

Nutrition as an investment?

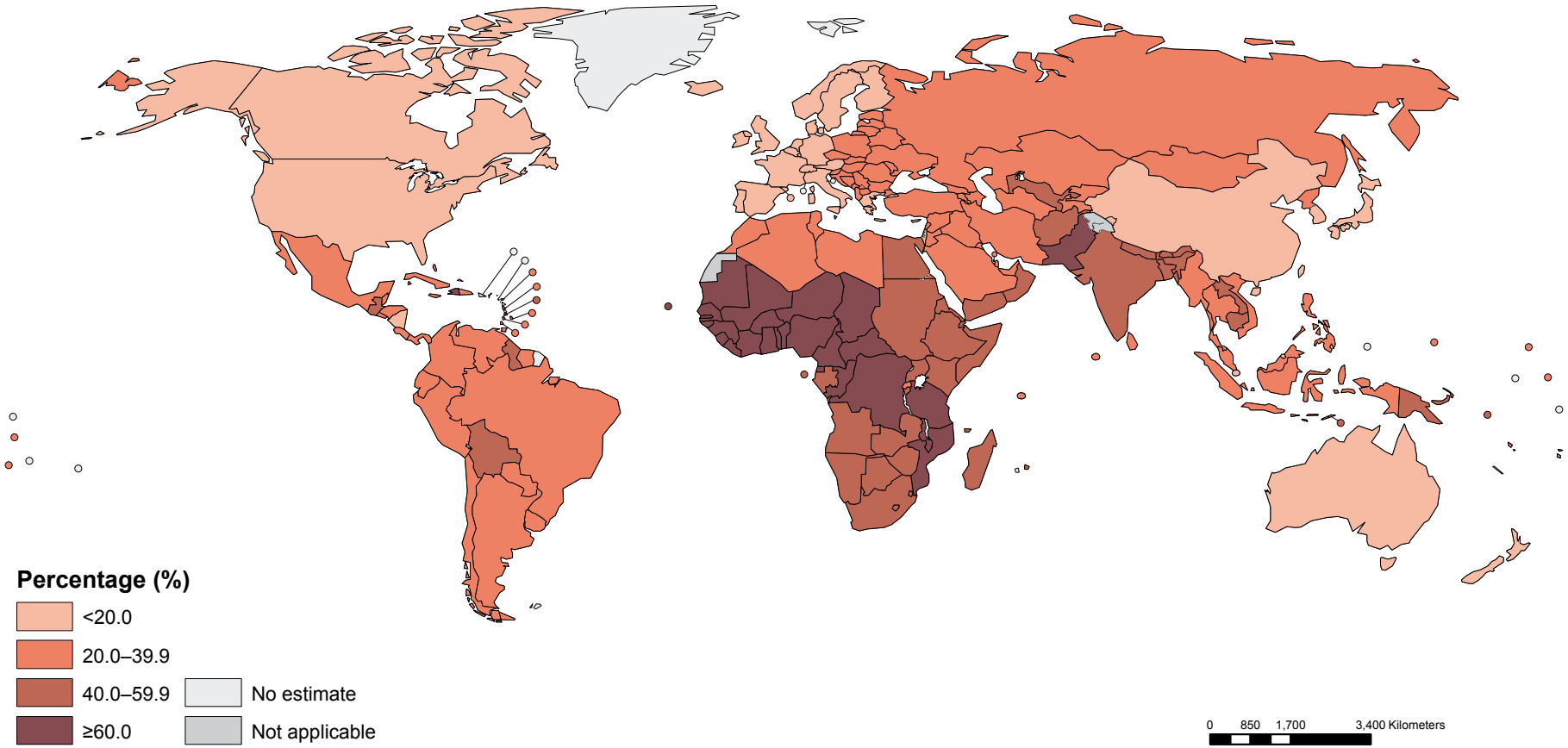
- Malnutrition in pregnancy affects initial conditions, especially in critical periods
- It **directly** affects cognitive and health capabilities
- Malnutrition in early childhood has effects on ability to learn and concentrate
- It **indirectly** affects the accumulation of cognitive skills
- While problem of malnutrition more widespread in developing countries, present in developed countries as well
- Obesity epidemic in developing countries is creating a "double burden of disease", kids mostly underweight but adults obese

Figure 9 : Latest country prevalence estimates for stunting among children under five years of age



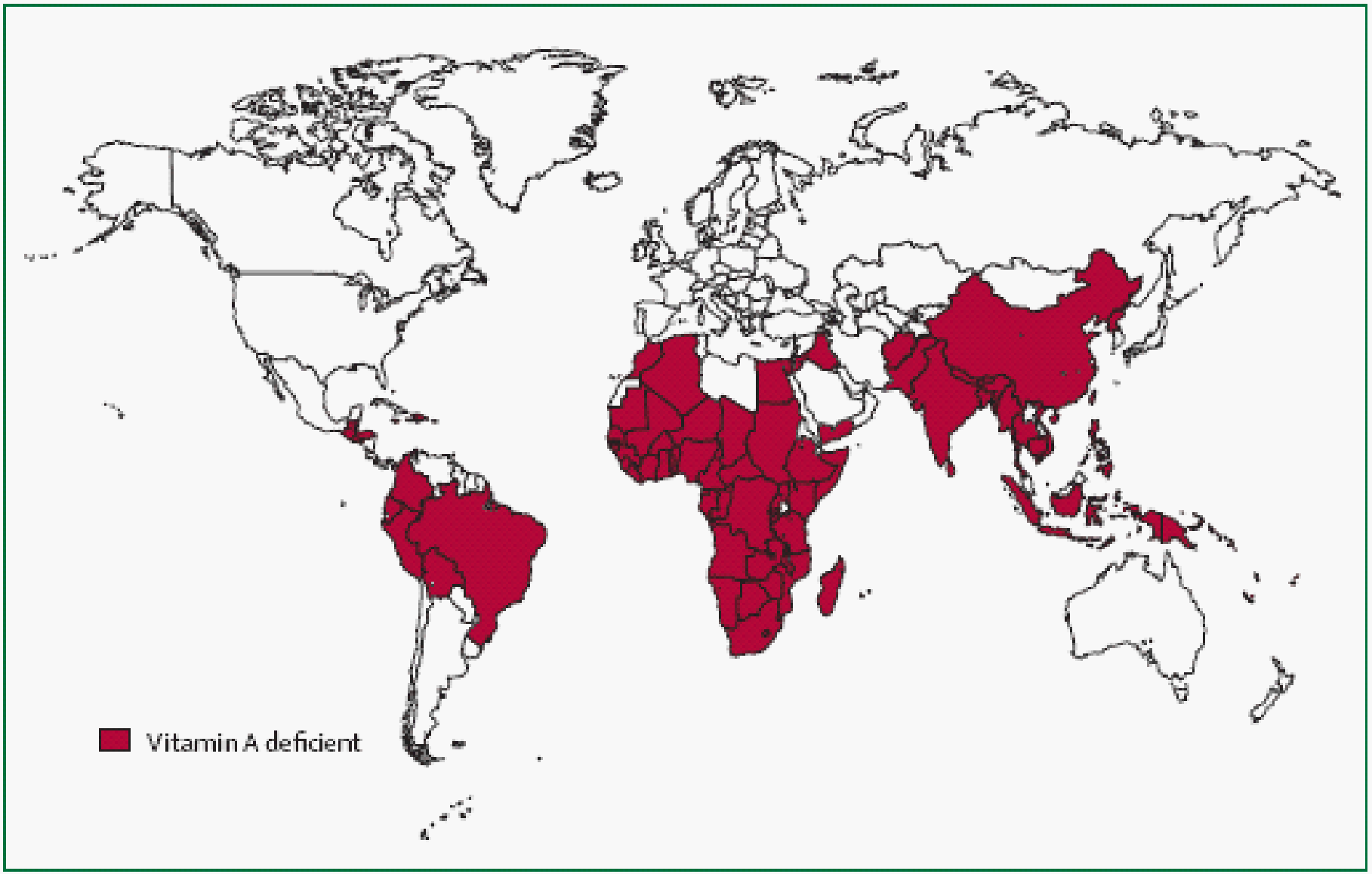
Note: UNICEF-WHO-The World Bank Joint Child Malnutrition Estimates 2012.

Figure 10 : Global estimates of the prevalence of anaemia in infants and children aged 6–59 months, 2011



Source: World Health Organization 2015.

Figure 11 : Severity of Vitamin A Deficiency



Effects of malnutrition on cognitive and health capabilities

Figure 12 : Effects of Nutrients on Brain Development

Important nutrients during late fetal and neonatal brain development[1]

Nutrient	Brain requirement for the nutrient	Predominant brain circuitry or process affected by deficiency
Protein-energy	Cell proliferation, cell differentiation	Global
	Synaptogenesis	Cortex
	Growth factor synthesis	Hippocampus
Iron	Myelin	White matter
	Monoamine synthesis	Striatal-frontal
	Neuronal and glial energy metabolism	Hippocampal-frontal
Zinc	DNA synthesis	Autonomic nervous system
	Neurotransmitter release	Hippocampus, cerebellum
Copper	Neurotransmitter synthesis, neuronal and glial energy metabolism, antioxidant activity	Cerebellum
LC-PUFAs	Synaptogenesis	Eye
	Myelin	Cortex
Choline	Neurotransmitter synthesis	Global
	DNA methylation	Hippocampus
	Myelin synthesis	White matter

[1] LC-PUFAs, long-chain polyunsaturated fatty acids.

Effects of micronutrients on health and cognitive development

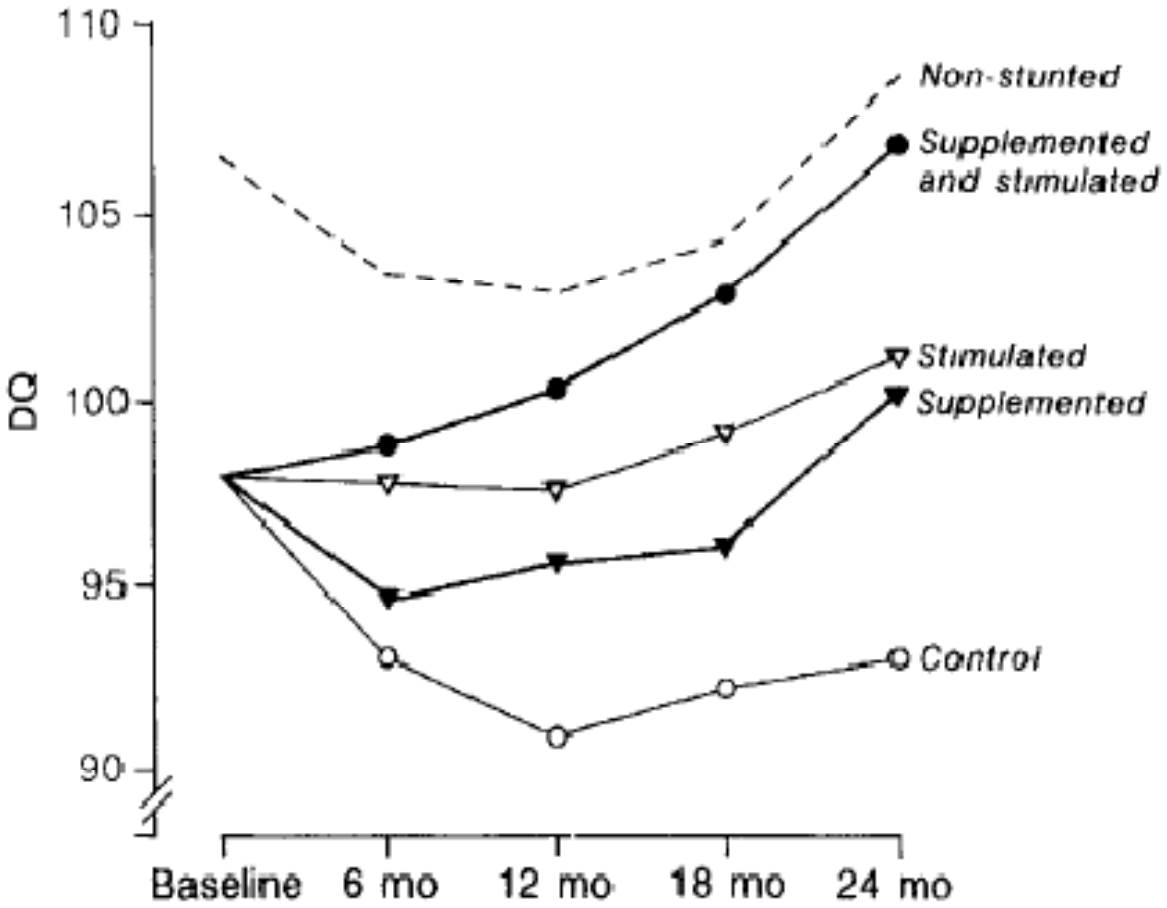
Nutrient	Mechanism	Critical Period	Effects on health	Effects on cognition
Iodine	Affects thyroid hormon, which play an important part in early growth and development of the brain	during all pregnancy and up to the third month after birth	hypothyroidism, goitre	mental retardation, cretinism, loss of IQ (Bleichrodt 1994, Delange 2001)
Iron	Important processes such as myelination are highly dependent on iron containing enzymes and hemoproteins; more detailed mechanisms explained through animal models (Lozoff and Georgieff 2006).	from last trimester of pregnancy to 16 months (Beard 2003). However, evidence polluted by confounders and not too convincing (Grantham McGregor 2003)	anemia, maternal mortality, probably preterm babies	lower attention, lower IQ scores (Stoltzfus 2004)
Zinc	Zinc is involved with RNA and Dna synthesis and is critical to cellular growth, differentiation and metabolism.	zinc deprivation during lactation showed signs of non remediability in rodents; some evidence also in humans (Bhatnagar 2001)	effects on diarrhea and pneumonia (Bhutta et al, 1999)	association, but lack of a clear consensus in humans (Black 2003); Evidence in animals (Bhatnagar 2001)
Vitamin A	Required for normal development of the embryonic hindbrain (brainstem), but exact mechanisms unclear (Clagett 2003)	none reported	mortality (WHO 1993, Lancet 2007), corneal scarring, mixed effects on diarrhea (Stansfield 1993, Barreto 1994). Debate over ideal dosage (Darboe 2007)	none convincingly reported'
Vitamin C and D	Animal Evidence for importance of brain development (Eyles 2003, McGrath 2004)	none reported	only evidence from animal studies	only evidence from animal studies

Enriched Early Environments Compensate in Part for the Risks Arising from Disadvantaged Environments

The Jamaican Intervention

- Randomized intervention, sample of 129 children
- Stunted children between 9 and 24 months
- Designed to individualize the different effects of nutritional and cognitive stimulation
- Follow up to age 22
- Four groups:
  1. No intervention
  2. Nutritional intervention only
  3. Cognitive stimulation intervention only
  4. Both cognitive and non-cognitive interventions
- Plus, a matched non-stunted group as a reference
- **The long-lasting effects were found for the cognitive/ socio-emotional components of interventions**

Figure 13 : Griffith developmental score in the period right after the intervention



Mean DQs of stunted groups adjusted for initial age and score, compared with non-stunted group adjusted for age only.

Findings:

- Fadeout effect of results on supplementation after 7 years of age
- Effects on stimulation persist all the way throughout 18 years old
- Stunted children remain in disadvantage for anthropometrics, cognitive capabilities as well as health ones

Figure 14 : The effect of cognitive stimulation persists throughout children adolescence, with a significant effect all the way to 18 years old

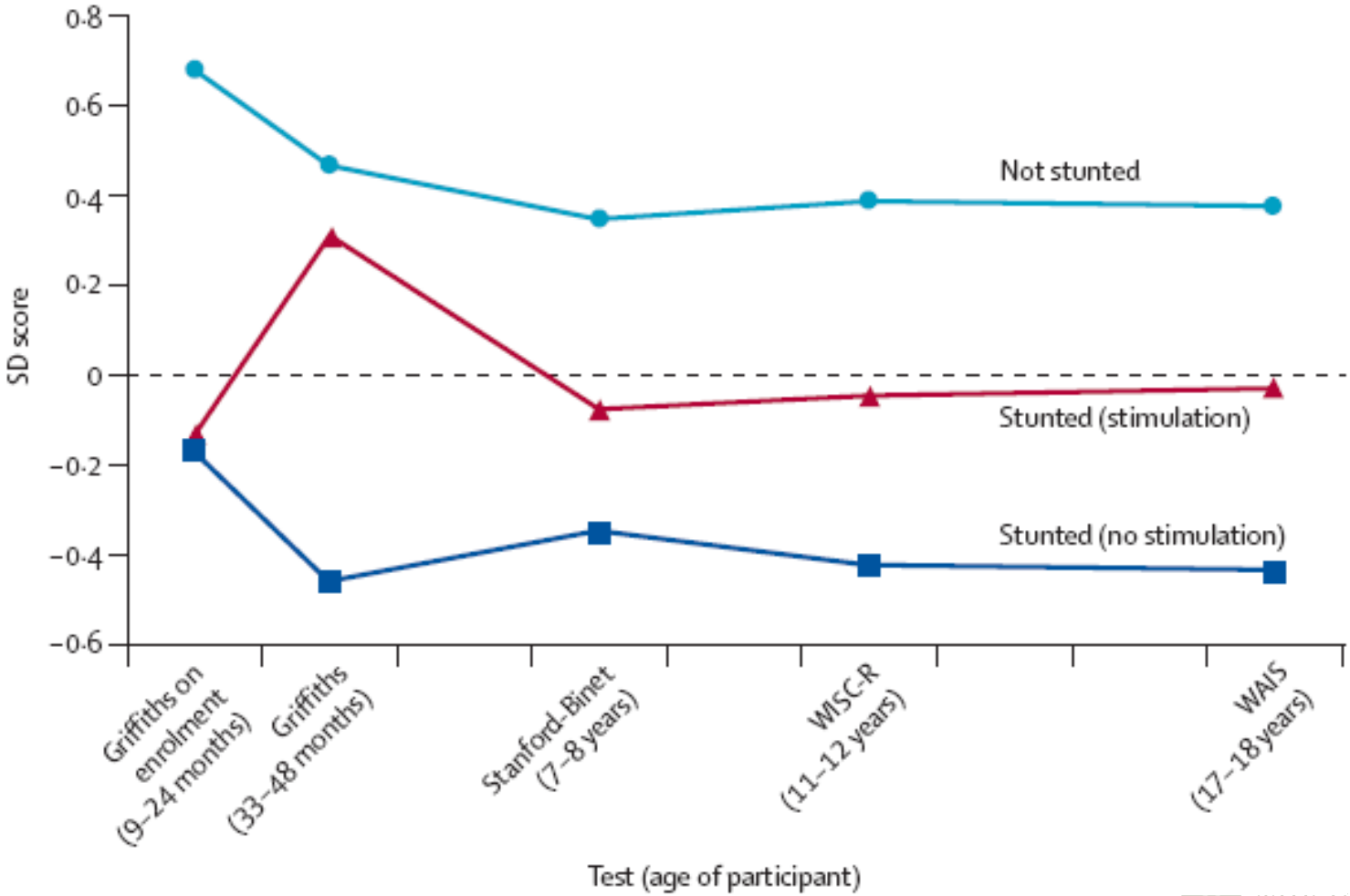


Table 1 : Impact of Stimulation Treatment on Log Earnings

	I. Observed Sample Treatment Effect	Stepdown p-value*
A. First Job		
All	0.27	0.11
Full Time	0.35	**0.06**
Non-Temporary	0.53	**0.03**
B. Last Job		
All	0.27	**0.06**
Full Time	0.40	**0.01**
Non-Temporary	0.50	**0.00**
C. Current Job		
All	0.27	**0.09**
Full Time	0.43	**0.02**
Non-Temporary	0.44	**0.02**
D. Average Earnings		
All	0.40	**0.01**
Full Time	0.34	**0.01**
Non-Temporary	0.47	**0.01**

* Adjusts for multiple hypothesis testing.

General Lessons Across a Variety of Interventions: The Main Findings of the Literature on Skill Interventions over the Life Cycle

Three Main Findings

- First, only very early interventions (before age 3) improve IQ in lasting ways consistent with the evidence that early childhood is a critical period for cognitive development.
- Second, programs targeting disadvantaged adolescents less effective than are early intervention programs.
- Many successful adolescent programs are consequences of the direct effect of incentives put in place by these programs (versions of incapacitation effects), but they fail to have lasting effects.

Parenting/Mentoring Is a Main Mechanism Through which the Programs Have an Effect

- Third, the most promising adolescent interventions feature mentoring and scaffolding.
- They often integrate work with traditional education and attenuate the rigid separation between school and work that characterizes the American high school.
- Mentoring involves teaching valuable character (noncognitive) skills (showing up for work, cooperating with others, and persevering on tasks).

- The effectiveness of mentoring programs is consistent with the evidence on the importance of attachment, parenting, and interaction.
- **Some form of mentoring/parenting is present in all successful intervention programs at all stages of childhood.**
- Mentoring is a form of age-adapted parenting.

Non-Cognitive Skills Are Important Channels of Childhood Benefits Throughout Early Childhood and Adolescence

- Only interventions that started before age 3 had a long-term effect on IQ
- Many interventions starting after age 3 have effectively improved outcomes by improving non-cognitive skills
- Adolescent interventions that teach personality skills in the workplace (or specific context) are promising

Perry Preschool Program

- The Perry Preschool program targeted 3- and 4-year old low income black children with initial IQ below 85 at age 3.
- Selection into the program was based on random assignment.
- Children attended 2.5 hours of center-based preschool five days a week for two years.
- Teachers were also involved in home visits during which they interacted, played and talked with the child.

- 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

- Implemented years: 1962–1967
- 5 cohorts of 3–4 year-olds; 123 participants
- Treatment lasted 1–2 years and included center-based care and home visits & parenting instruction

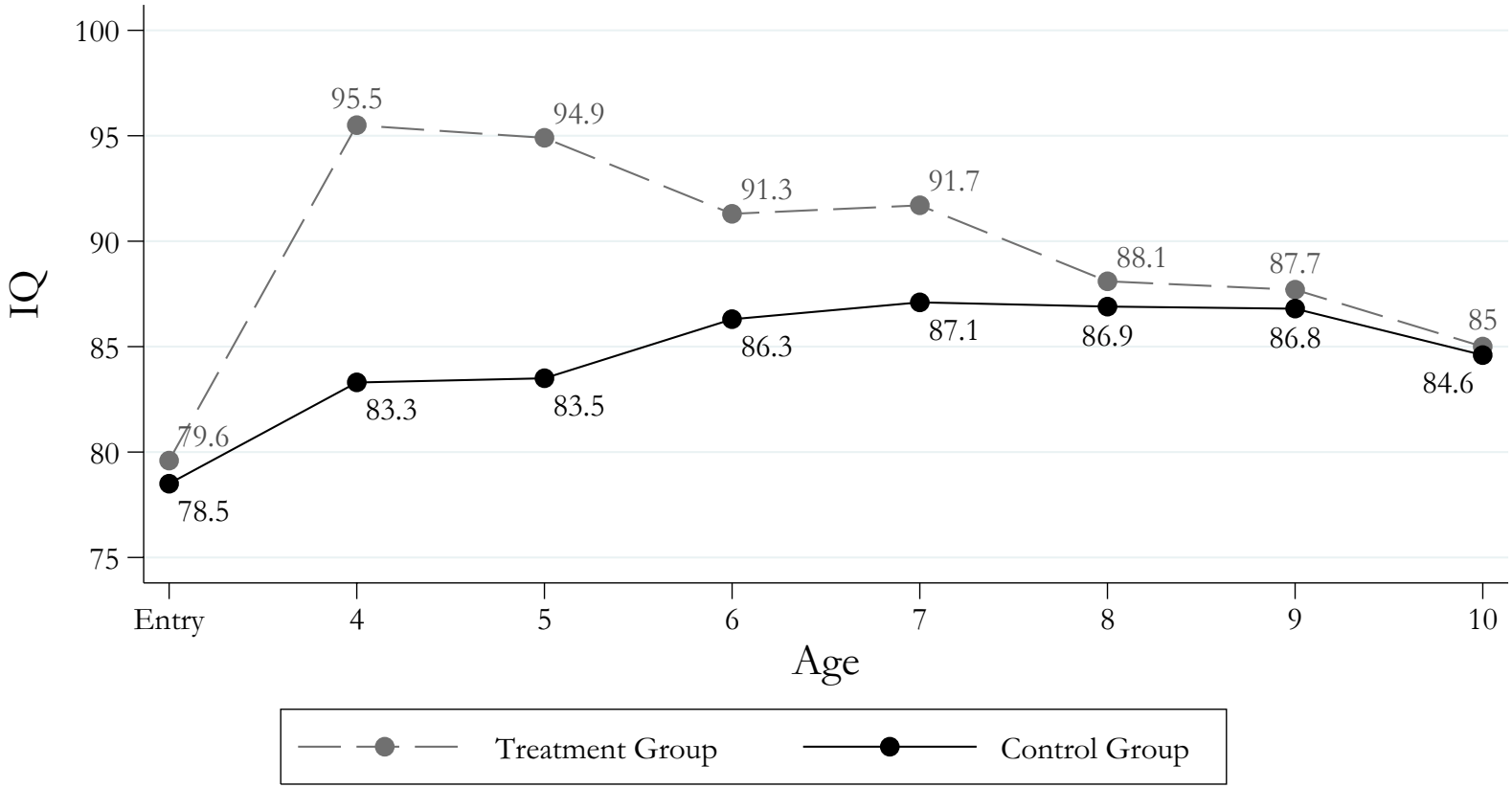
- Evaluated by the method of random assignment.
- Contrary to recent claims, strong effects are found for both boys and girls, although different effects at different ages for different outcomes.
- Did not lead to sustained gains in IQ for males.

- The program focused on building organizational and social skills and was designed to cultivate independence and a sense of responsibility in the children (Schweinhart et al., 1993).
- The daily routing was understood as a key component of teaching children temporal relations (Weikart et al., 1971).

- Children first planned an activity to execute and then would go to the art, large motor, doll or quiet center to complete their planned activity.
- The program ended after two years of enrollment and then children from both treatment and control group attended the same school.

No IQ Effects

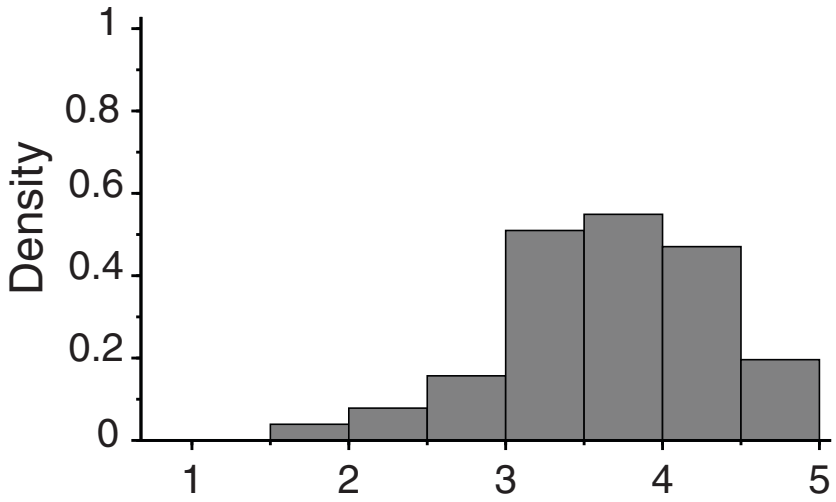
Figure 15 : Perry Preschool Program: IQ, by age and treatment group



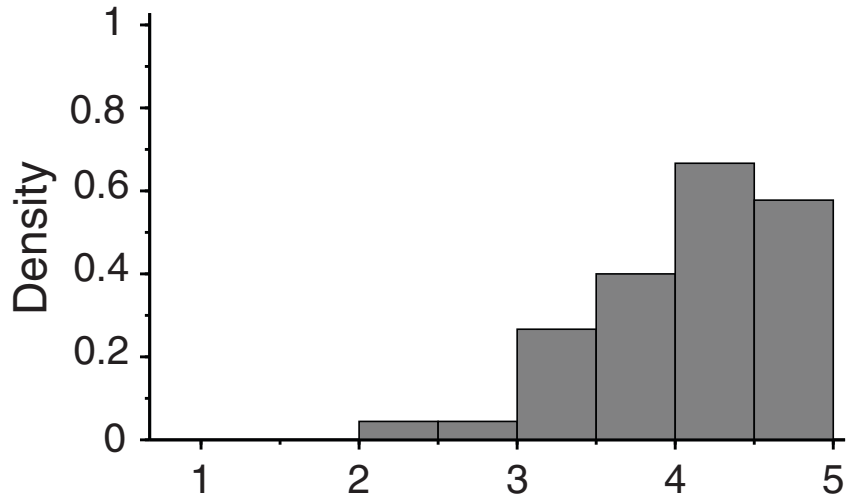
- Has a statistically significant rate of return of around 7–10% per annum – for both boys and girls – above the post-World War II stock market returns to equity in U.S. labor market, estimated to be 5.8%.
- The Perry Preschool Program worked primarily through **non-cognitive** channels.

Figure 16 : Perry Preschool Program: Histograms of Indices of Personality Skills and CAT Scores

Panel A. Externalizing behavior, control
(Higher is better)



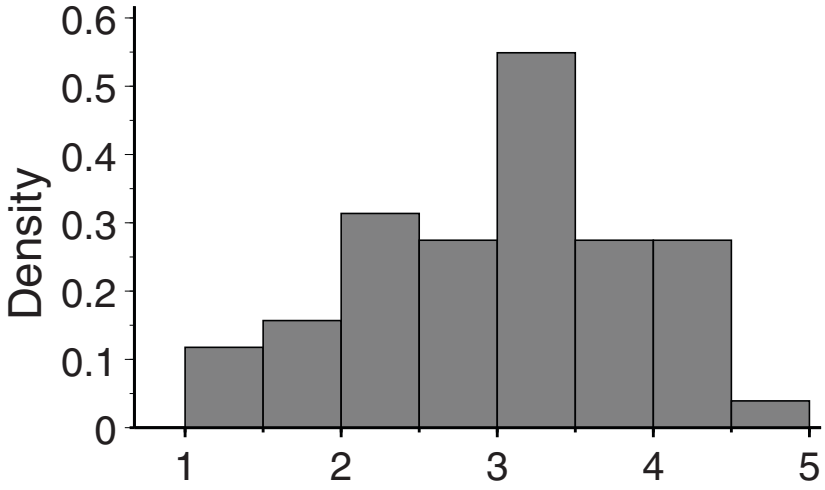
Panel B. Externalizing behavior, treatment
(Higher is better)



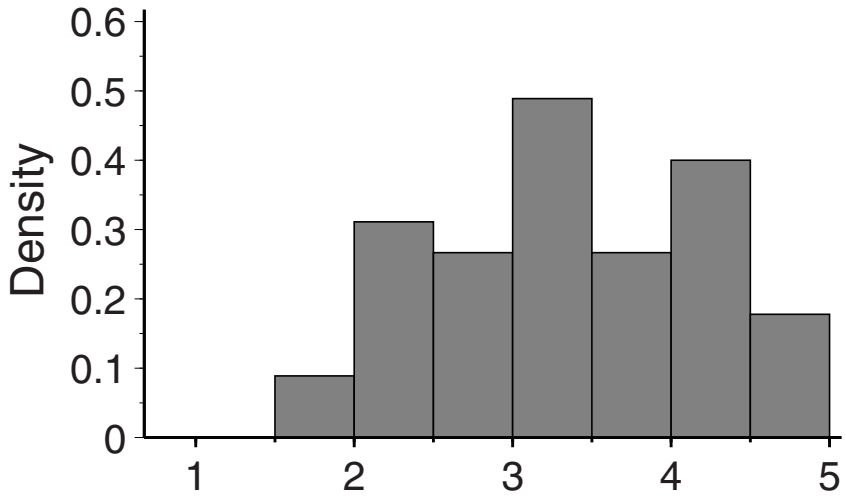
Source: Heckman et al. (2013).

Figure 16 : Perry Preschool Program: Histograms of Indices of Personality Skills and CAT Scores, Cont'd

Panel C. Academic motivation, control



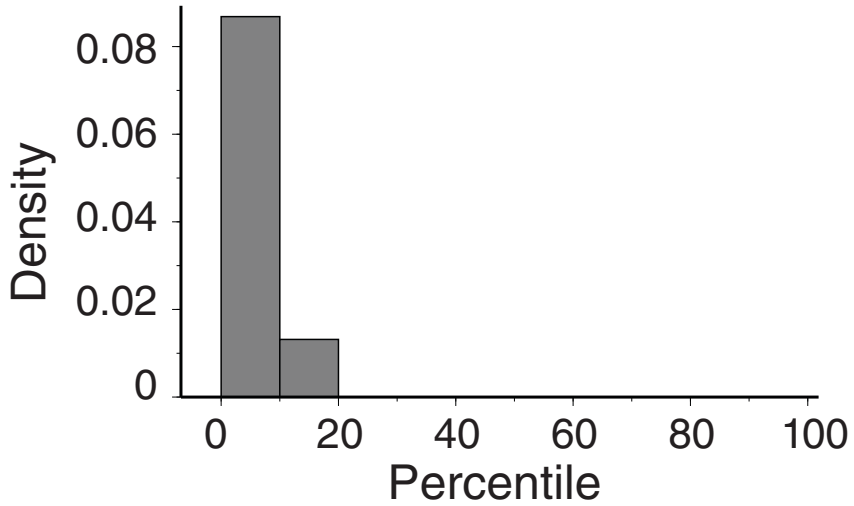
Panel D. Academic motivation, treatment



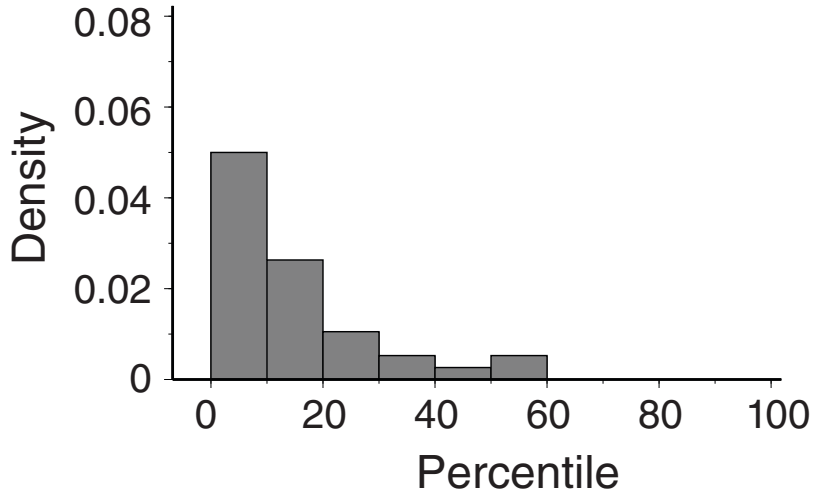
Source: Heckman et al. (2013).

Figure 16 : Perry Preschool Program: Histograms of Indices of Personality Skills and CAT Scores, Cont'd

Panel E. CAT total at age 14, control



Panel F. CAT total at age 14, treatment



Source: Heckman et al. (2013).

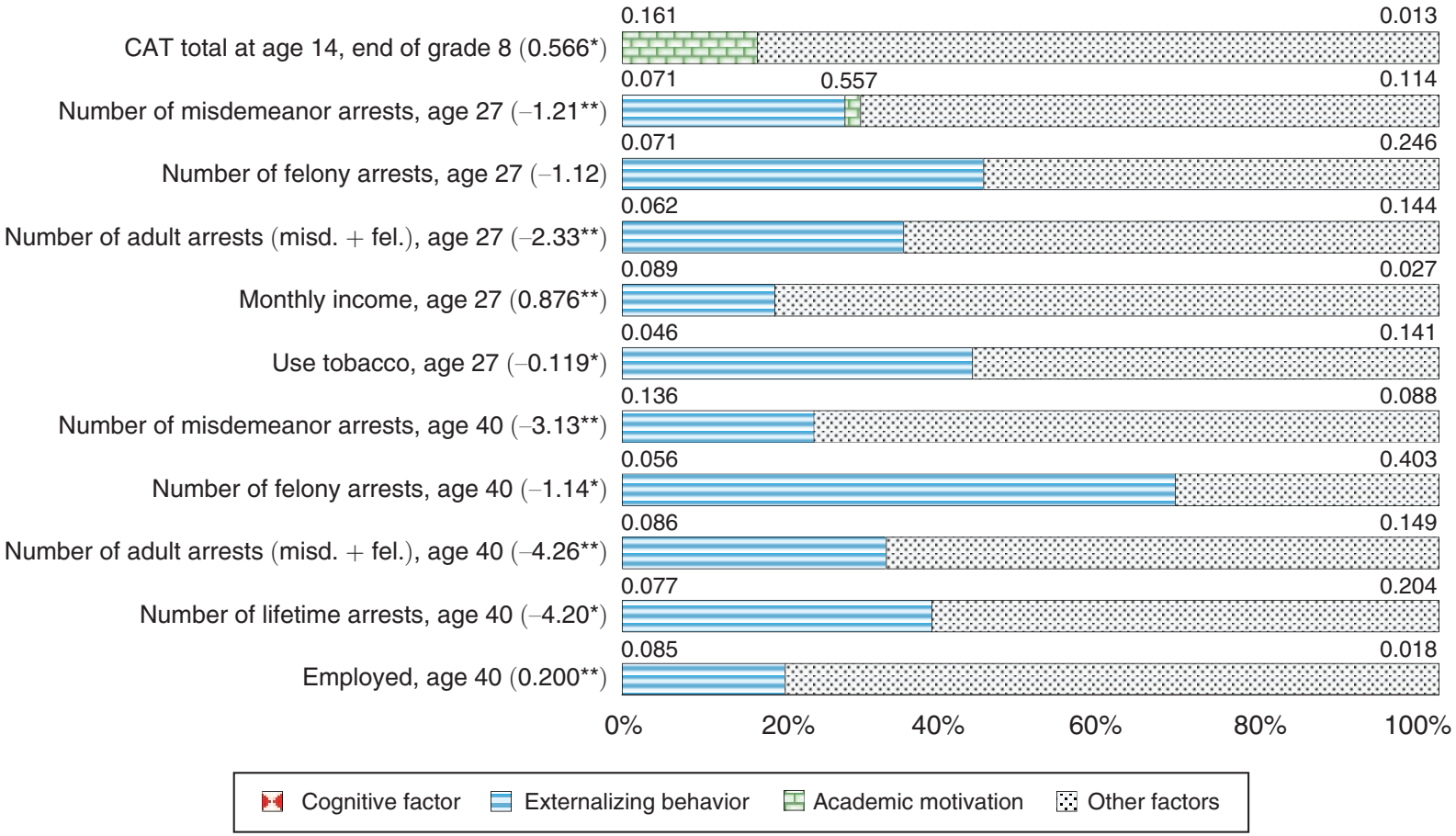
Table 2 : Impact on Healthy Behaviors: Perry Preschool Intervention

Variable	Ctr. M.	Treat. M.	Diff. Ms.	Blk. IPW P. *p*-val.	IPW P. S.D.
(1)	(2)	(3)	(4)	(5)	(6)
Lifestyles: Diet and Physical Activity at 40 y.o. - Males					
Physical activity	0.457	0.367	0.090	0.545	0.545
Healthy Diet	0.229	0.379	0.151	**0.020**	**0.072**
Lifestyles: Smoking at 27 y.o. - Males					
Not a daily smoker	0.462	0.581	0.119	**0.089**	**0.089**
Not a heavy smoker	0.615	0.903	0.288	**0.004**	**0.005**
No. of cigarettes	8.744	4.291	4.453	**0.006**	**0.011**
Lifestyles: Smoking at 40 y.o. - Males					
Never smoker	0.444	0.600	0.156	**0.040**	**0.040**
Not a daily smoker	0.472	0.667	0.194	**0.010**	**0.035**
Not a heavy smoker	0.743	0.929	0.186	**0.011**	**0.021**
No. of cigarettes	6.543	3.714	2.829	**0.035**	**0.049**

Table 2 : Impact on Healthy Behaviors: Perry Preschool Intervention

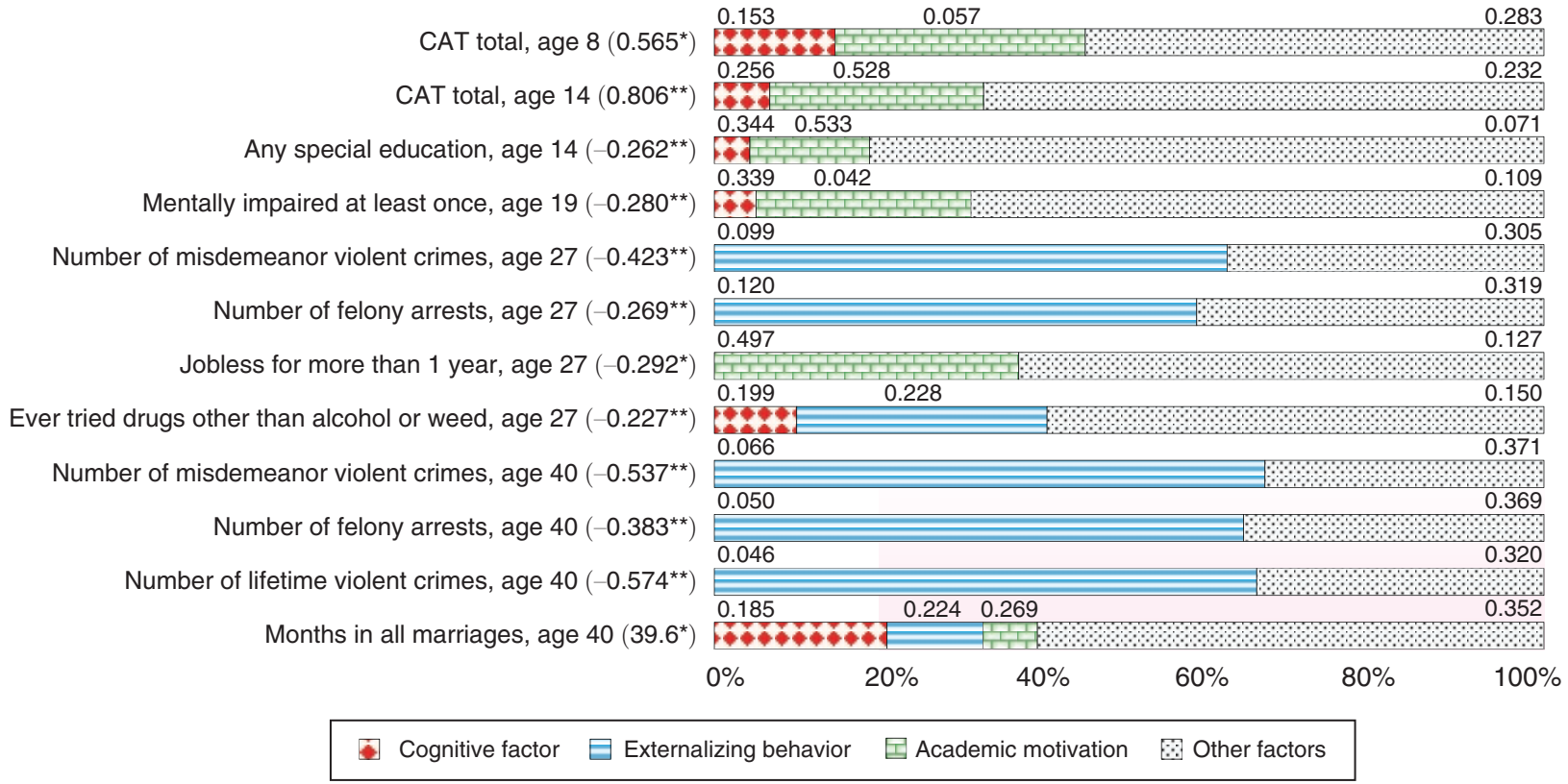
Variable	Ctr. M.	Treat. M.	Diff. Ms.	Blk. *p*-val.	IPW P. S.D.
(1)	(2)	(3)	(4)	(5)	(6)
Lifestyles: Diet and Physical Activity at 40 y.o. - Females					
Physical activity	0.045	0.375	0.330	**0.002**	**0.012**
Healthy Diet	0.227	0.375	0.148	0.283	0.283
Lifestyles: Drinking at 27 y.o. - Females					
Not a frequent drinker	0.773	0.880	0.107	**0.015**	**0.028**
Alcohol consumption	3.818	3.200	0.618	**0.094**	**0.094**

Figure 17 : Perry Preschool Program: Decompositions of Treatment Effects on Outcomes, Males



Source: Heckman et al. (2013).

Figure 18 : Perry Preschool Program: Decompositions of Treatment Effects on Outcomes, Females



Source: Heckman et al. (2013).

Abecedarian Program

The Carolina Abecedarian Project

- **Where & When:**
  - North Carolina, U.S, from the early 1970s to early 1980s.
  - Early intervention starting in the first months of life.
- **What:**
  - Full-day enriched center-based childcare (9 hours/day, 5 days/wk, 50 weeks/yr) for 5 years at age 0-5. Provided cognitive stimulation and education for developing self-control and social skills.
  - Bi-weekly home visits with individualized tutoring for 3 years at age 6-8 (but not during early childhood).
  - Health care (well-child checkups and ill-child medical care) was provided to the children attending the center-based program.

- Similarly to Perry, the Abecedarian program was also designed to promote self-reinforcement among the children and reduce dependence on adult feedback (Ramey et al., 1982).
- It was more intense than Perry combining a preschool component starting as early as at 6 weeks old and a school-age treatment through grade three.
- The curriculum focused on "educational games" to build cognitive abilities (language, math, reading, writing), behavioral skills (attending behavior, task orientation, listening, task completion), and creativity and motor skills (through action songs, rhymes, story telling, fingerplays).

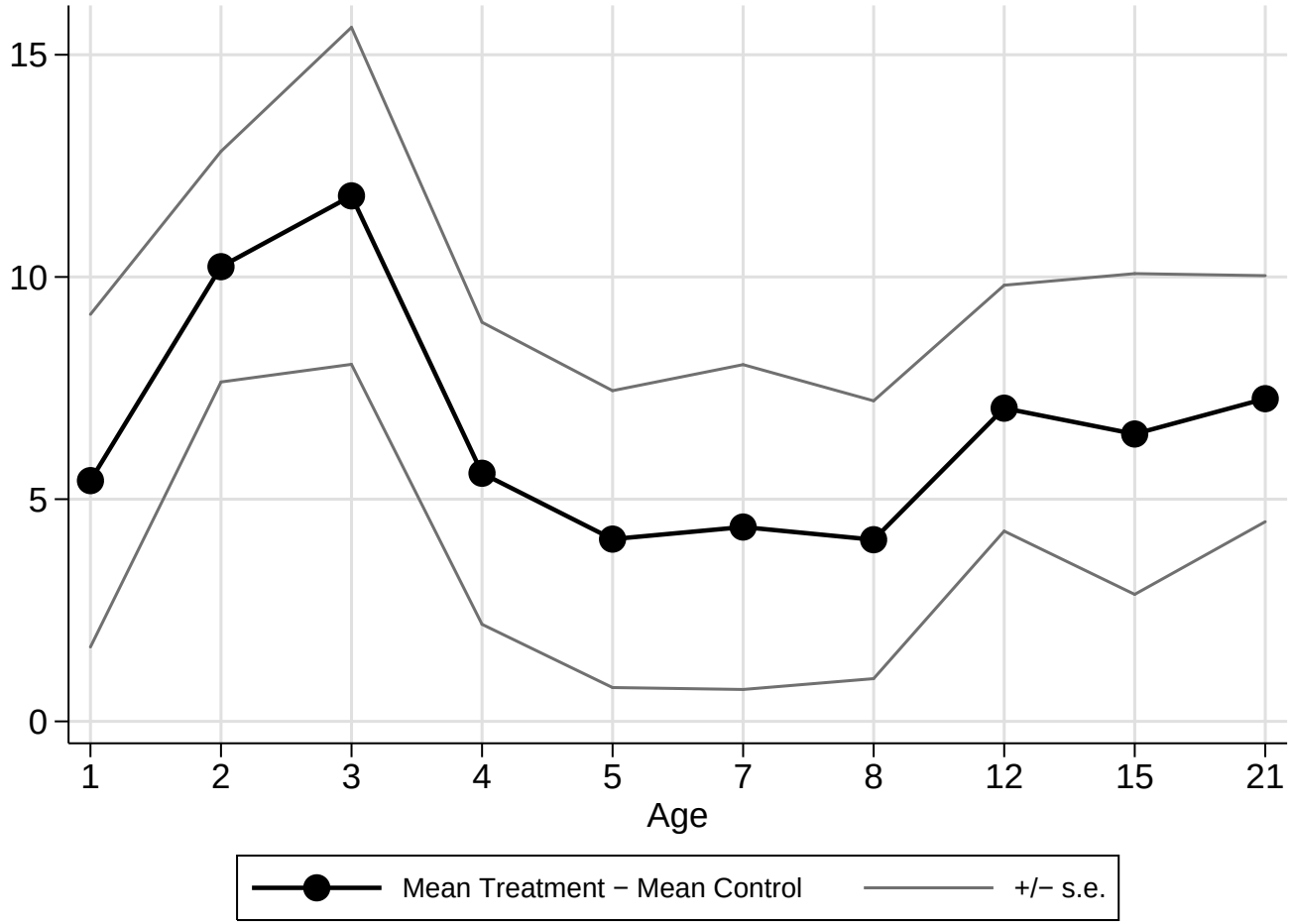
Carolina Abecedarian Project (ABC)

- Implemented years: 1972–1982
- 4 cohorts beginning at birth; 111 participants
- Target population fulfilled High Risk Index, including parents' IQ, father at home, etc.
- Treatment lasted 5 years and included center-based care, formula, diapers, health check-ups, and medical care

- It also had a medical and nutritional component.
- The program produced lasting improvements in IQ (mostly for girls) because the interventions started very early in life (Campbell et al., 2001).
- Evidence suggests that IQ is more malleable in the very early childhood (Shonkoff and Phillips, 2000).
- Girls also showed a greater educational attainment, reduced participation in crime, decrease in substance abuse, and improved internalizing and externalizing behavior.
- Boys showed better health conditions and improvements in non-cognitive skills.

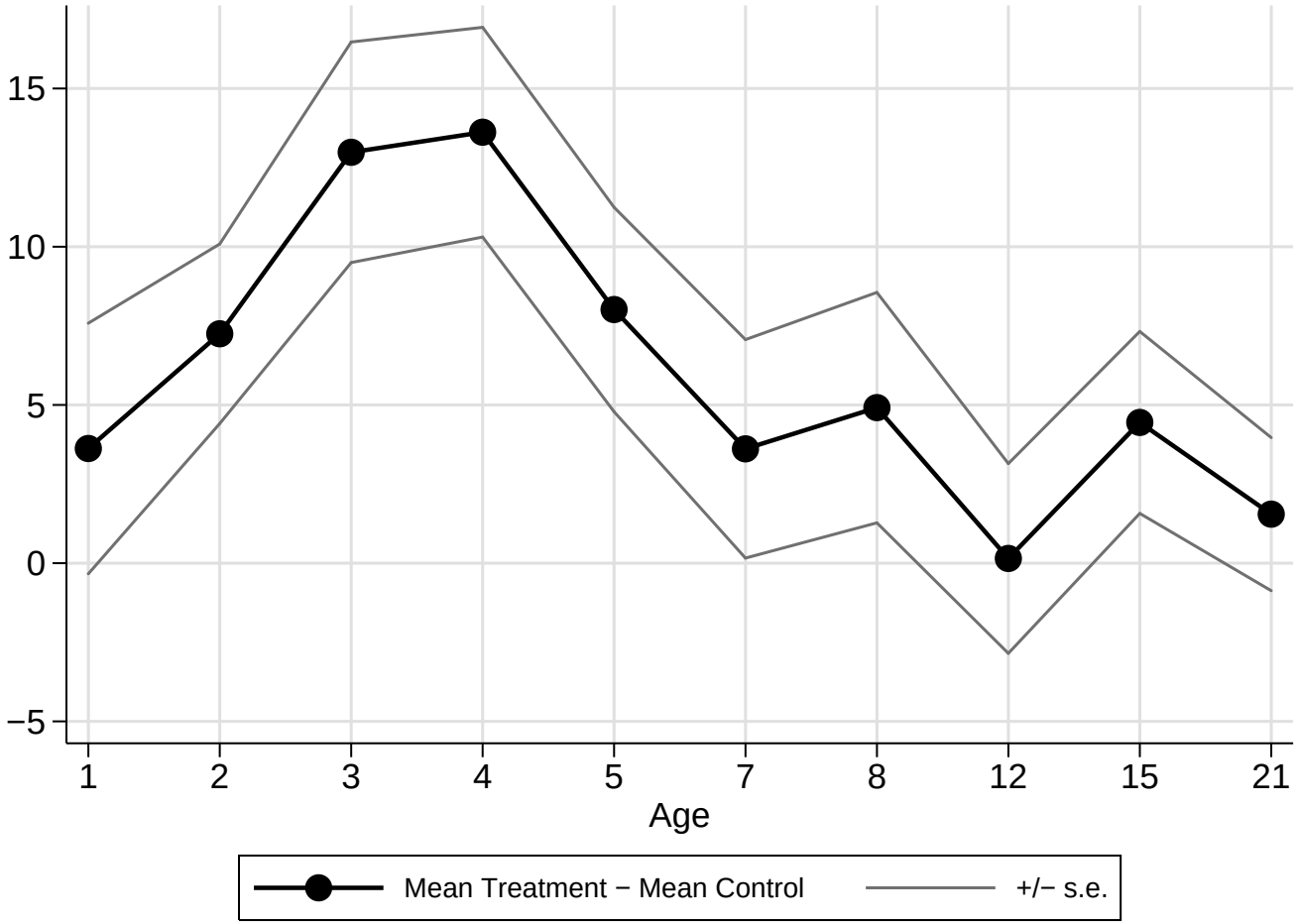
The Carolina Abecedarian Project: Early Start Boosts IQ

Figure 19 : Treatment Effects on IQ, Females



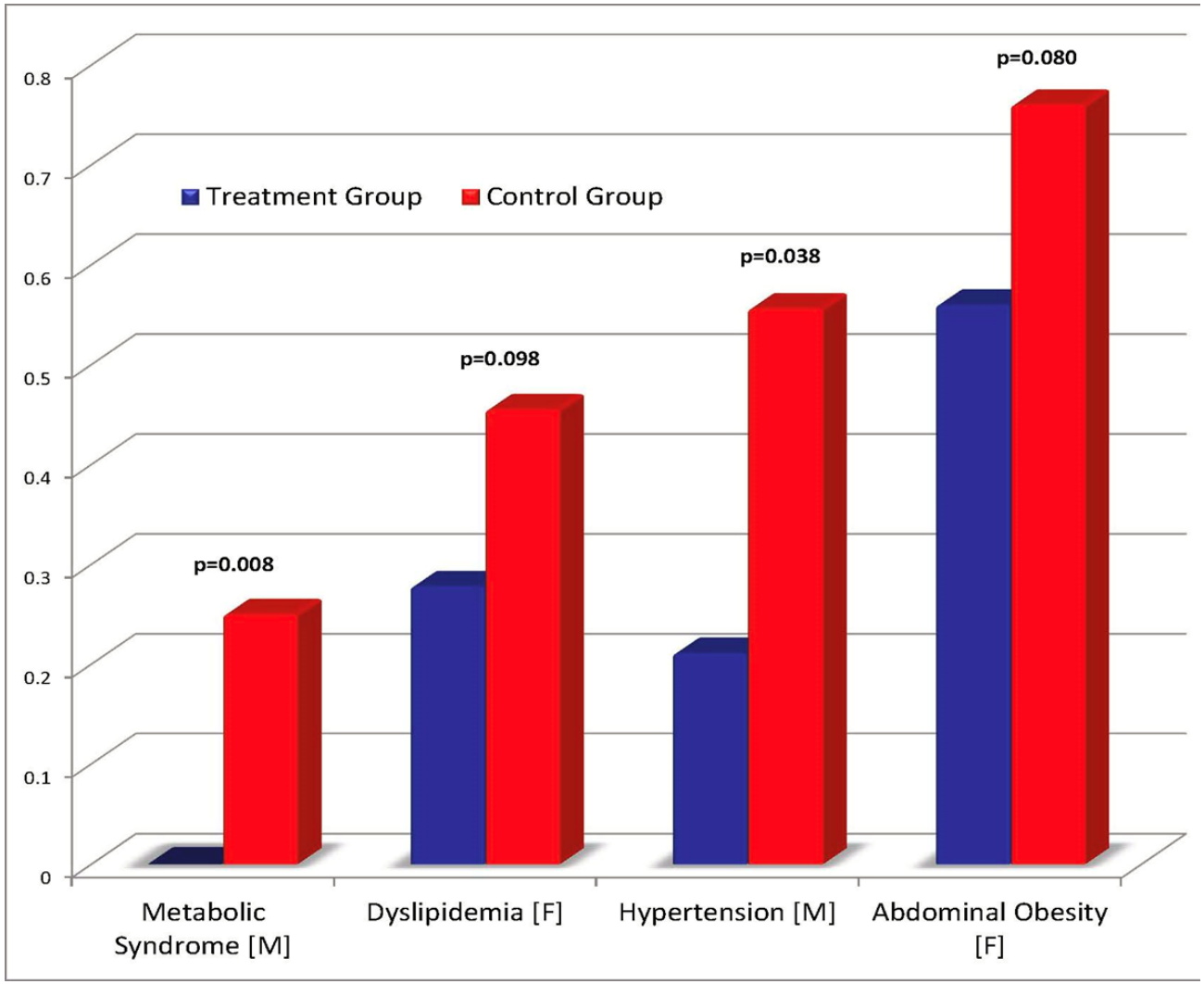
Note: This figure displays the mean difference in IQ at different ages between the treatment and control group. The line with circles represents the raw difference. The line with squares represents the difference when controlling for IQ at age 3 by linear regression. All measures are age-standardized to a nationally representative sample of the US with mean 100 and standard deviation 15.

Figure 20 : Treatment Effects on IQ, Males



Note: This figure displays the mean difference in IQ at different ages between the treatment and control group. The line with circles represents the raw difference. The line with squares represents the difference when controlling for IQ at age 3 by linear regression. All measures are age-standardized to a nationally representative sample of the US with mean 100 and standard deviation 15.

The Abecedarian Intervention



Source: Campbell et. al (2014).

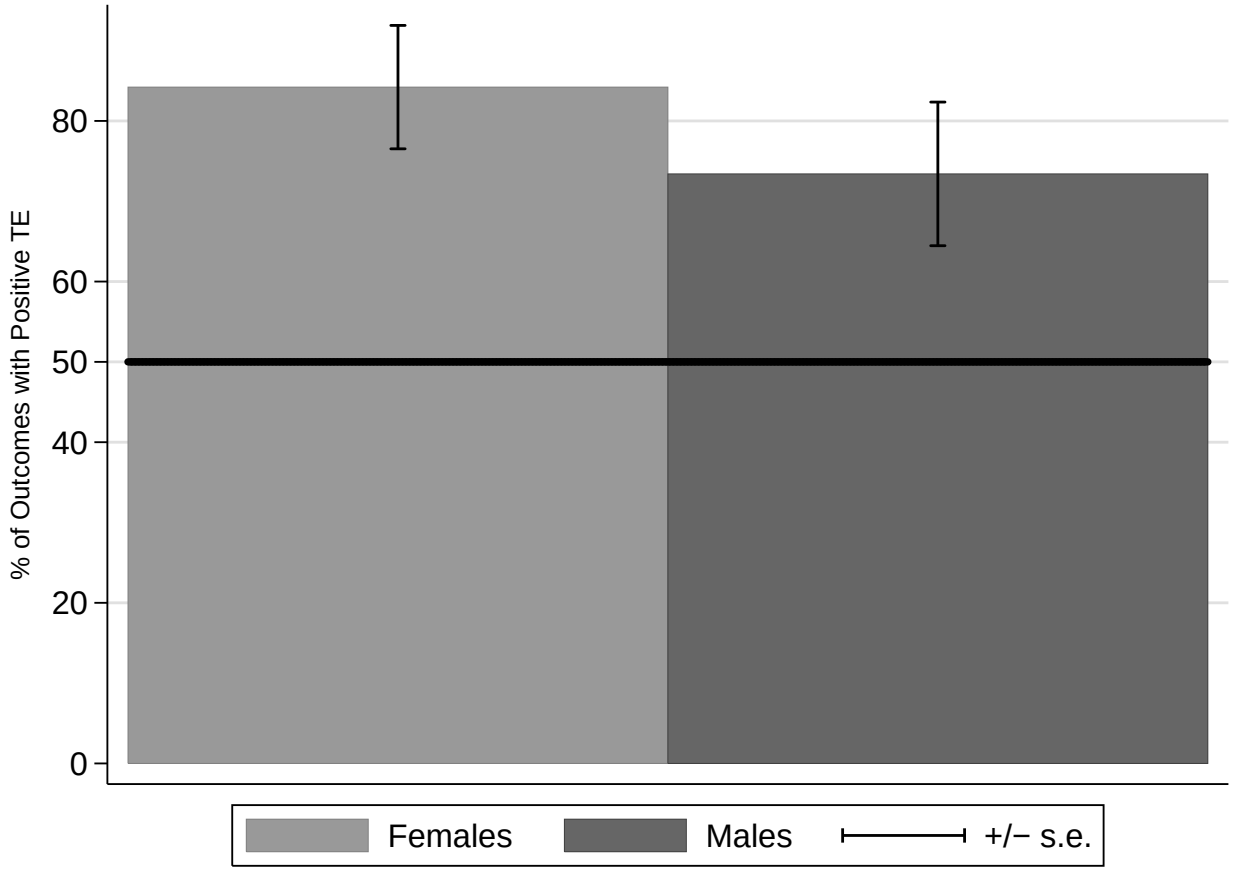
Figure 21 : Abecedarian Project, Health Effects at Age 34 (Males)

	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: Campbell, Conti, Heckman, Moon, Pinto, Pungello, and Pan (2014).

Preview of Results: Treatment Effects

Figure 22 : Percentage of Outcomes with a Positive Treatment Effect



Preview of Results: Treatment Effects

Figure 23 : Percentage of Outcomes with Positive and Significant Treatment Effects (at 10%)

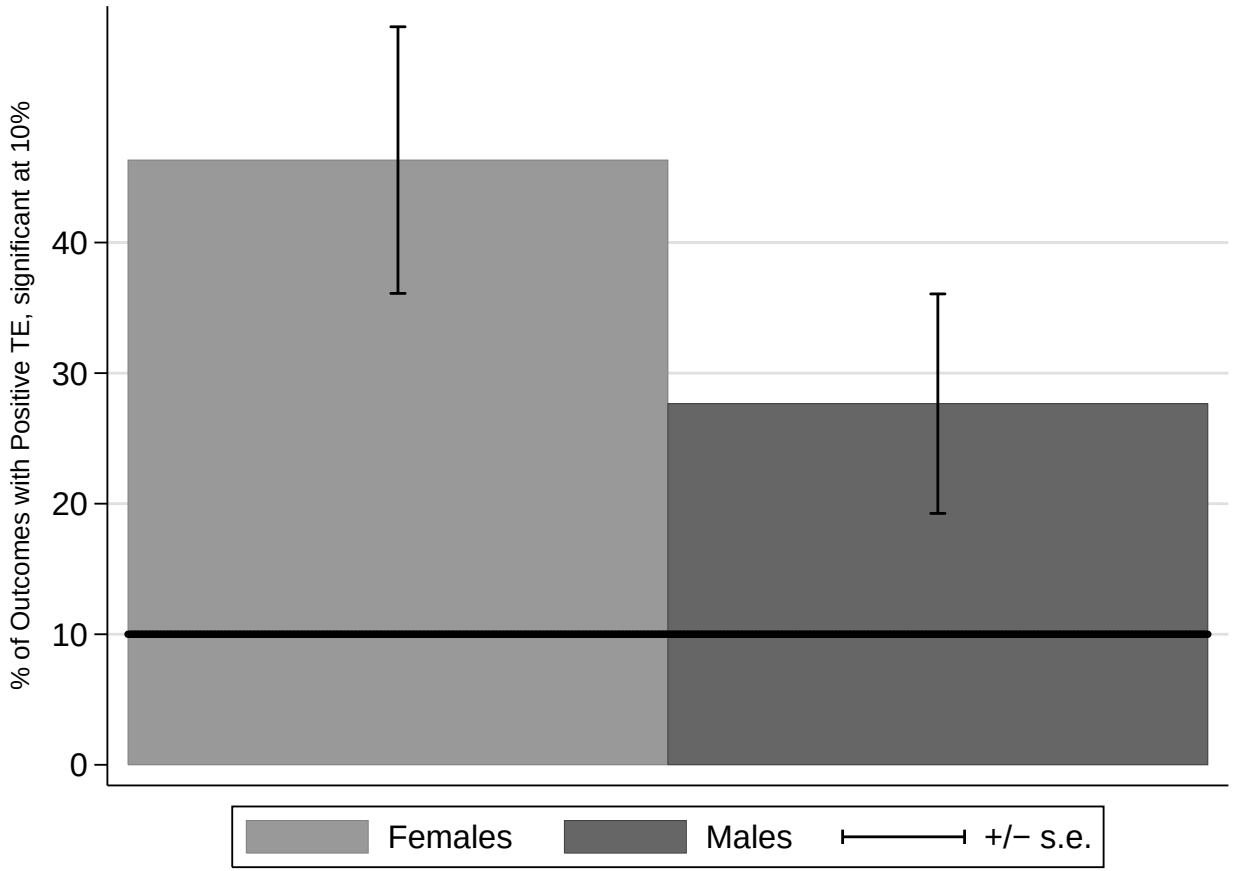


Figure 24 : Net Present Value of Main Components of the Cost/benefit Analysis Over the Life-cycle, ABC/CARE Males and Females

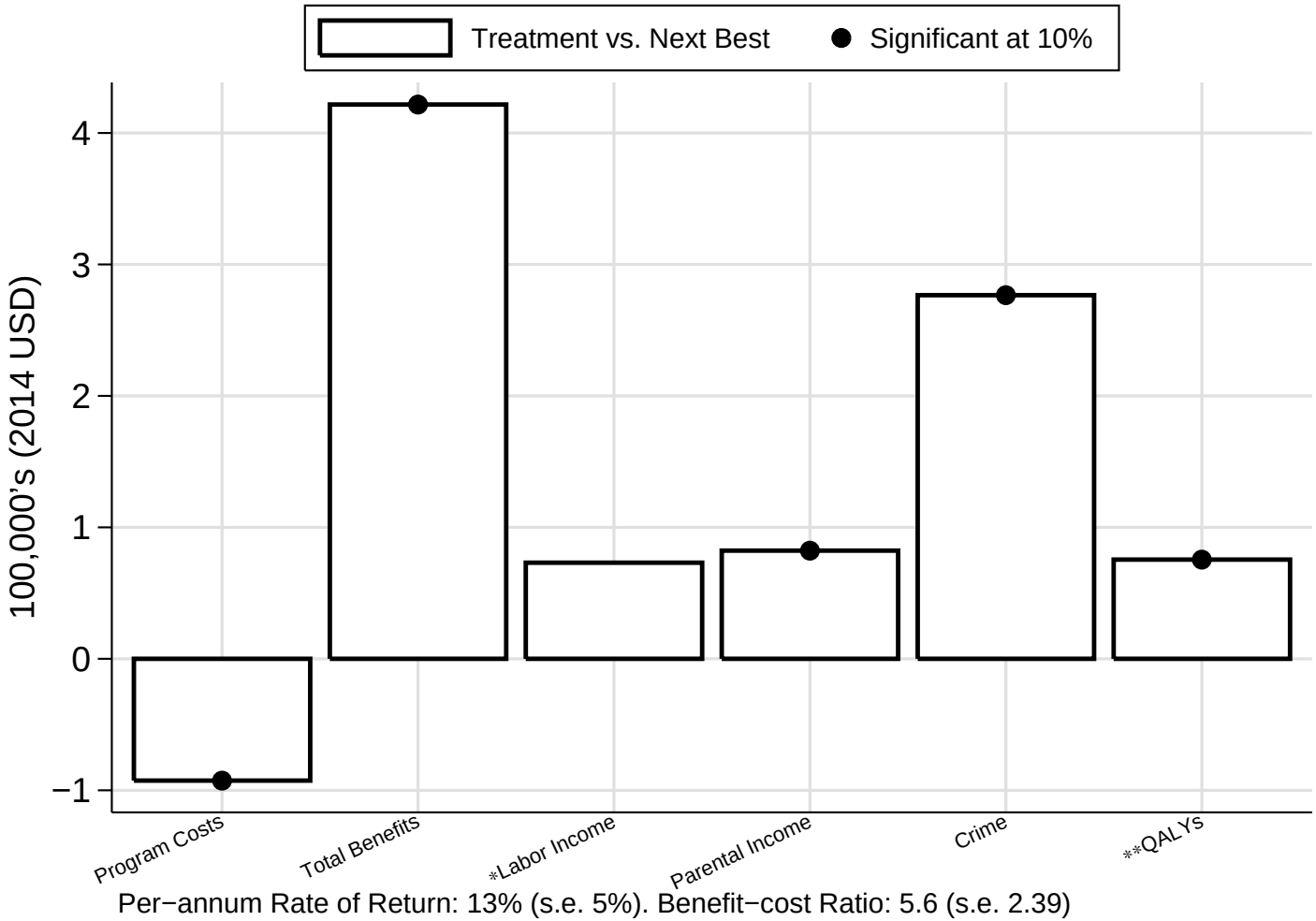


Table 3 : Cost/Benefit Analysis of ABC/CARE, Summary

	Pooled		
	NPV	IRR	B/C
Full Model	421,625	**0.13** (0.05)	**5.56** (2.39)
	Contribution of Component to NPV	**Estimate After Removing Component**	
Parental Income	82,287	**0.09** (0.03)	**4.66** (2.30)
Subject Labor Income	73,105	**0.12** (0.05)	**4.65** (2.08)
Subject Transfer Income	-2,798	**0.13** (0.04)	**5.59** (2.39)
Subject QALY	75,462	**0.11** (0.06)	**4.72** (2.34)
Medical Expenditures	-18,397	**0.13** (0.04)	**5.76** (2.37)
Control Substitution	15,376	**0.11** (0.04)	**5.39** (2.39)
Education Costs	-491	**0.12** (0.04)	**5.56** (2.39)
Crime Costs	276,621	**0.08** (0.04)	2.48 (1.21)
Deadweight Loss		**0.17** (0.06)	**8.25** (3.58)
0% Discount Rate			**13.39** (6.57)
7% Discount Rate			**2.34** (0.84)

Table 3 : Cost/Benefit Analysis of ABC/CARE, Summary, Cont.

	Females		
	NPV	IRR	B/C
Full Model	139,959	0.09 (0.05)	**2.53** (0.97)
	Contribution of Component to NPV	**Estimate After Removing Components**	
Parental Income	96,251	0.05 (0.02)	1.47 (0.89)
Subject Labor Income	50,580	0.08 (0.05)	**1.99** (0.70)
Subject Transfer Income	2,217	0.09 (0.05)	**2.50** (0.96)
Subject QALY	14,964	0.09 (0.05)	**2.37** (0.91)
Medical Expenditures	-14,881	0.09 (0.05)	**2.69** (0.98)
Control Substitution	17,246	0.07 (0.04)	**2.34** (0.97)
Education Costs	-2,195	0.09 (0.05)	**2.55** (0.97)
Crime Costs	65,209	0.08 (0.05)	1.81 (0.94)
Deadweight Loss		0.13 (0.09)	**3.60** (1.43)
0% Discount Rate			4.92 (3.36)
7% Discount Rate			1.37 (0.36)

Table 3 : Cost/Benefit Analysis of ABC/CARE, Summary, Cont.

	Males		
	NPV	IRR	B/C
Full Model	807,945	**0.14**	**9.75**
		(0.05)	(4.64)
	Contribution of Component to NPV	**Estimate After Removing Components**	
Parental Income	65,477	**0.11**	**9.00**
		(0.04)	(4.63)
Subject Labor Income	308,825	**0.12**	6.32
		(0.06)	(3.92)
Subject Transfer Income	-5,943	**0.14**	**9.81**
		(0.05)	(4.64)
Subject QALY	68,306	**0.14**	**9.05**
		(0.05)	(4.39)
Medical Expenditures	-18,601	**0.14**	**9.95**
		(0.04)	(4.64)
Control Substitution	13,889	**0.13**	**9.60**
		(0.04)	(4.64)
Education Costs	6,293	**0.13**	**9.68**
		(0.05)	(4.66)
Crime Costs	451,831	**0.10**	4.75
		(0.04)	(2.85)
Deadweight Loss		**0.18**	**14.54**
		(0.06)	(6.96)
0% Discount Rate			**25.40**
			(13.58)
7% Discount Rate			**3.54**
			(1.50)

The Nurse-Family Partnership Program

- The Nurse-Family Partnership (NFP) is a program targeted at low-income, unmarried, and/or adolescent mothers.
- It consists of nurse visits to young mothers from the first or second trimester of the mother's first pregnancy until the second birthday of her first child.
- The program encourages mothers to reduce smoking, teaches them how to take care of their children and helps them to pursue education and find jobs.

Table 4 : NFP Memphis, Parental Responses (Females)

Outcome	**Age** (years)	Sample Size # C	# T	Conditional Effect Size	Asymptotic *p*-values	Permutation Single *p*-val	Freedman-Lane Stepdown
Home Observation Measurement of the Environment (HOME)	1	220	104	0.354	**0.003**	**0.004**	**0.007**
Non-Abusive Parenting Attitudes (Bavolek)	1	227	105	0.288	**0.012**	**0.005**	**0.005**
Home Observation Measurement of the Environment (HOME)	2	222	101	0.301	**0.010**	**0.003**	**0.006**
Non-Abusive Parenting Attitudes (Bavolek)	2	222	102	0.370	**0.003**	**0.006**	**0.006**

Source: Moon (2013).

Table 5 : NFP Memphis, Parental Responses (Males)

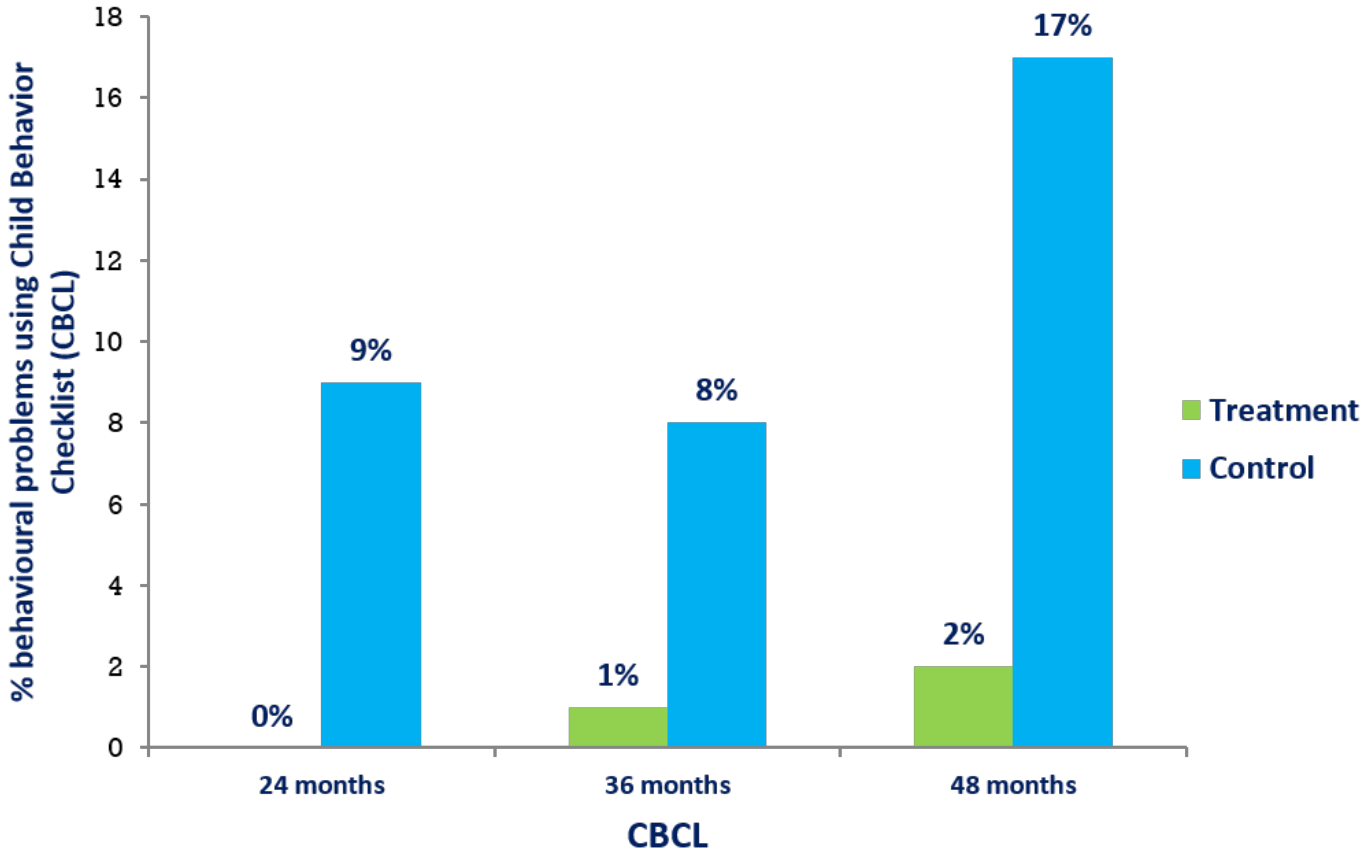
Outcome	**Age** (years)	Sample Size # C	# T	Conditional Effect Size	Asymptotic *p*-values	Permutation Single *p*-val	Freedman-Lane Stepdown
Home Observation Measurement of the Environment (HOME)	1	221	95	0.208	**0.051**	**0.041**	**0.041**
Non-Abusive Parenting Attitudes (Bavolek)	1	225	100	0.273	**0.015**	**0.003**	**0.006**
Home Observation Measurement of the Environment (HOME)	2	224	98	0.169	**0.092**	**0.075**	**0.075**
Non-Abusive Parenting Attitudes (Bavolek)	2	228	99	0.316	**0.006**	**0.003**	**0.006**

Source: Moon (2013).

Preparing For Life (PFL, 2016)
Home Visiting in Ireland – Orla Doyle

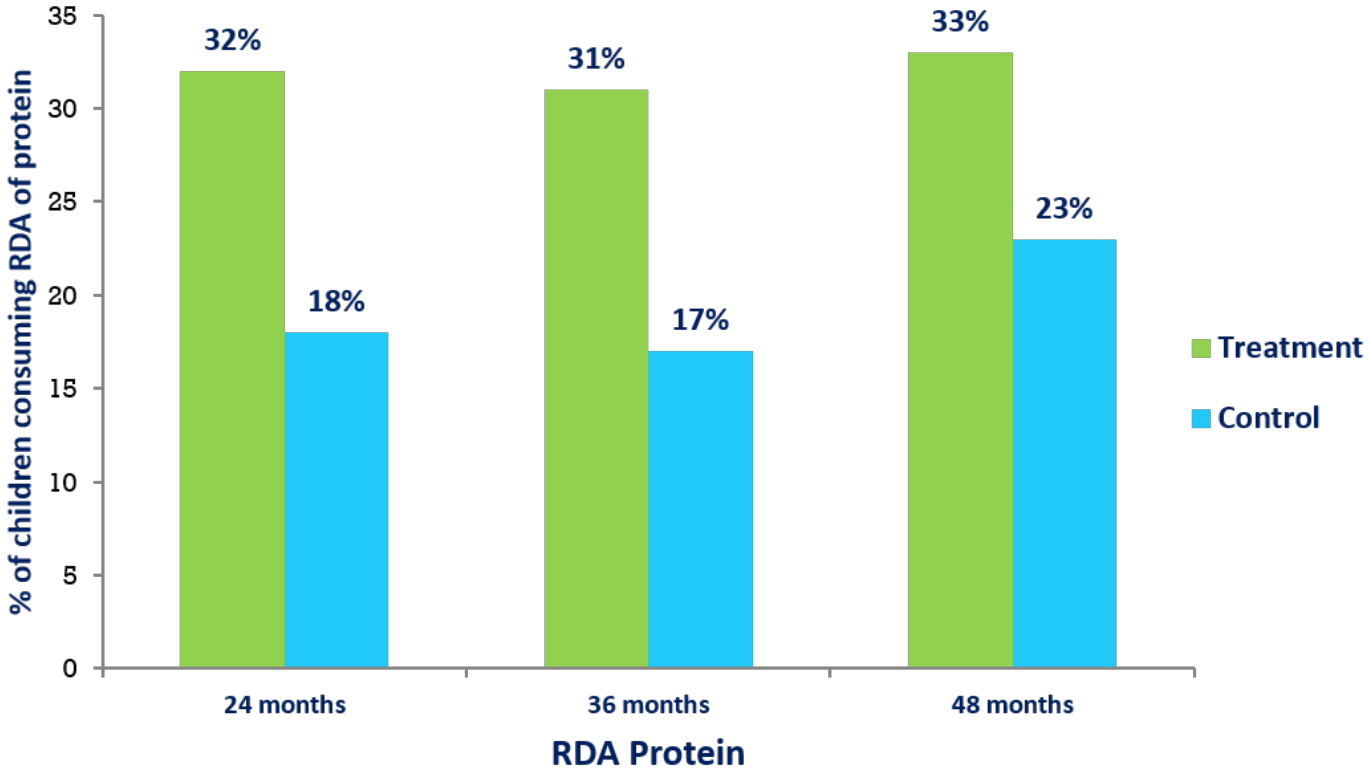
1. PFL provides support and education to parents from pregnancy/ birth onwards
2. Based on theories of attachment, social learning, & ecological development
3. PFL: **Fortnightly home-visits** from trained mentor - pregnancy to school entry
4. Mentors came from **different professional backgrounds**
5. **Mentor's role:** support parents about child development & parenting using role play, modelling, demonstration, discussion, encouragement, and feedback
6. Low intensity — one hour per month

Figure 25 : Behavioural Problems*



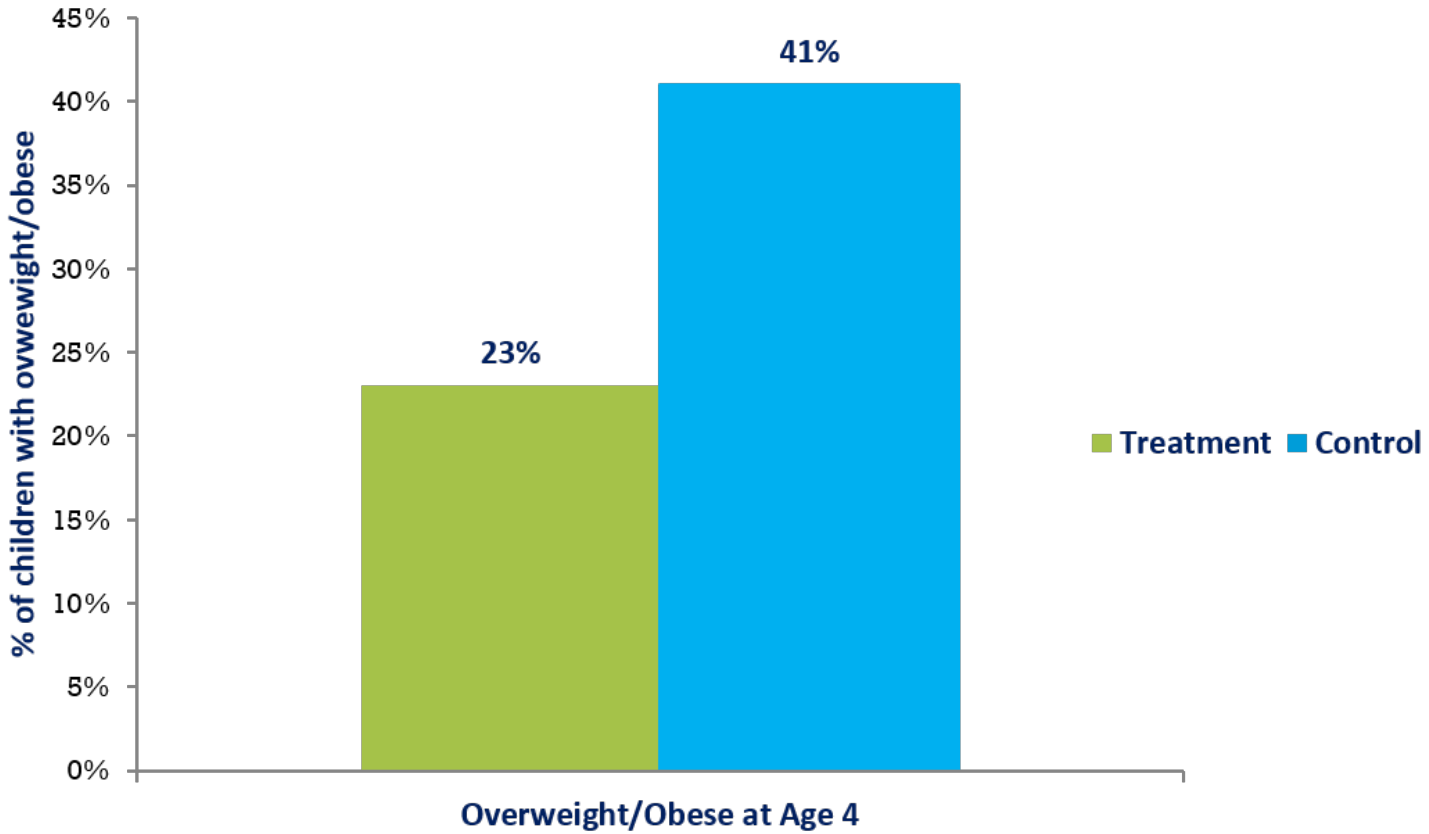
Preparing for Life (Doyle et al., 2016).
*IPW-adjusted permutation tests with 100,000 replications controlling for gender. One tailed (right-sided) test.

Figure 26 : Protein Intake*



Preparing for Life (Doyle et al., 2016).
*IPW-adjusted permutation tests with 100,000 replications controlling for gender. One tailed (right-sided) test.

Figure 27 : Body Mass Index at Age 4*



Preparing for Life (Doyle et al., 2016).
*IPW-adjusted permutation tests with 100,000 replications controlling for gender. One tailed (right-sided) test.

Table 6 : Cognitive Development

	M_{HIGH} (*SD*)	M_{LOW} (SD)	*IPW-p**	*IPW-step p**	Effect size (Cohen's D)
BAS Standard Scores					
General Conceptual Ability	97.7 (14.4)	88.0 (12.6)	**0.000**	**0.000**	0.72
Spatial Ability	96.0 (17.0)	86.0 (15.3)	**0.000**	**0.001**	0.62
Pictorial Reasoning	99.2 (12.9)	93.2 (10.9)	**0.002**	**0.002**	0.51

Preparing for Life (Doyle et al., 2016).
*IPW-adjusted permutation tests with 100,000 replications controlling for gender. One tailed (right-sided) test.

Table 7 : Cognitive Development

	M_{HIGH} (*SD*)	M_{LOW} (SD)	*IPW-p**	*IPW-step p**	Effect size (Odds ratio)
BAS Below Average %					
General Conceptual Ability	19.9%	59.9%	**0.000**	**0.000**	6.03
Spatial Ability	31.2%	59.9%	**0.001**	**0.003**	3.29
Pictorial Reasoning	29.1%	45.6%	**0.047**	**0.047**	2.04
BAS Above Average %					
General Conceptual Ability	25.2%	7.9%	**0.019**	**0.023**	3.95
Spatial Ability	13.8%	9.2%	0.153	0.153	3.81
Pictorial Reasoning	17.1%	9.1%	**0.066**	0.116	2.05

Preparing for Life (Doyle et al., 2016).
*IPW-adjusted permutation tests with 100,000 replications controlling for gender. One tailed (right-sided) test.

Figure 28 : Distribution of BAS GCA Cognitive Scores

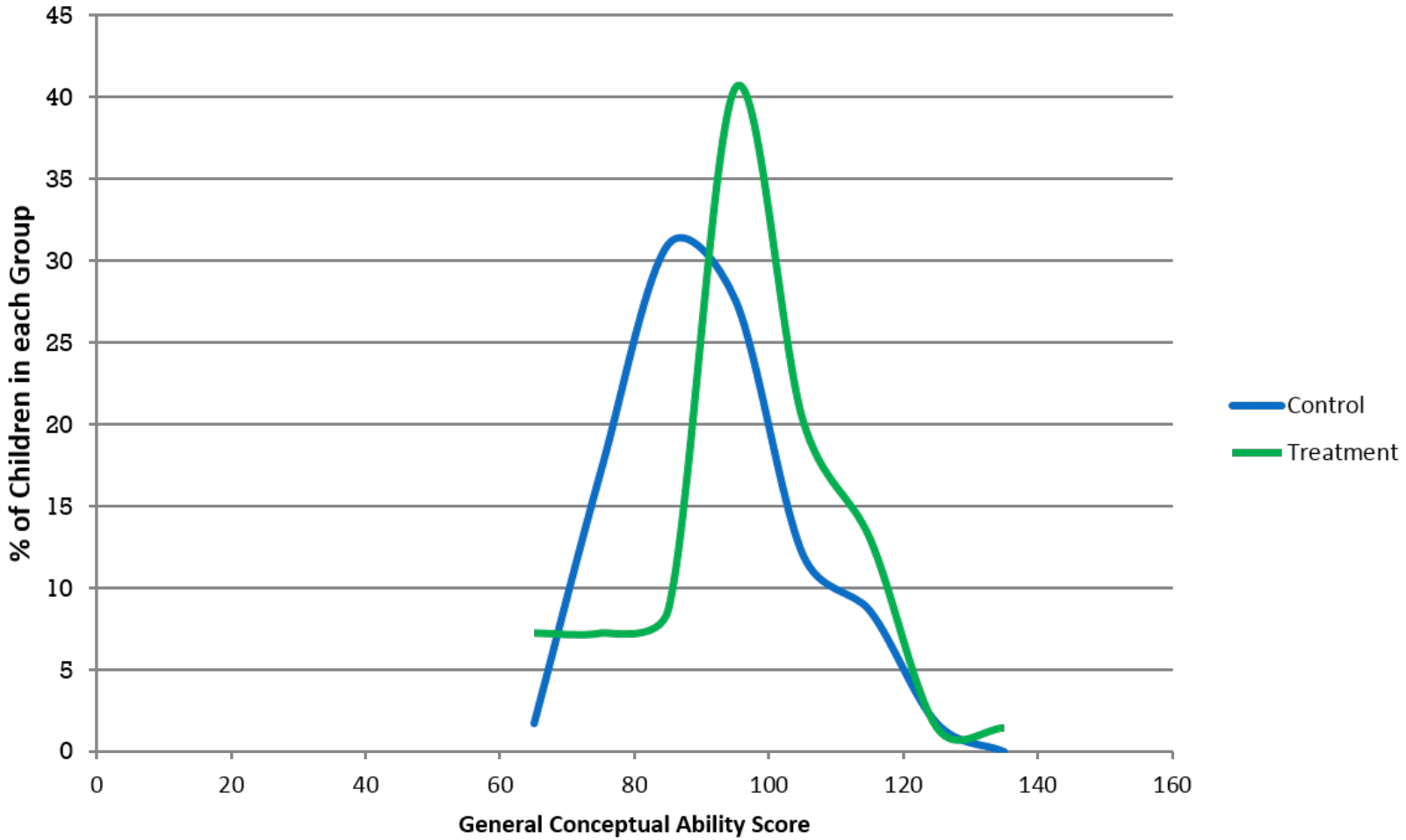


Table 8 : Cognitive Development

	M_{HIGH} (*SD*)	M_{LOW} (SD)	*IPW-p**	*IPW-step p**	**Effect Size** (Cohen's D/Odds Ratio[a])
BAS Subscales: T-Scores					
Pattern Construction	49.51 (12.82)	41.75 (10.98)	**0.001**	**0.002**	0.65
Copying	45.93 (9.86)	41.92 (10.03)	**0.002**	**0.012**	0.40
Early Number Concepts	48.27 (8.41)	43.24 (8.09)	**0.001**	**0.001**	0.61
Picture Similarities	51.51 (9.39)	49.59 (7.74)	**0.077**	**0.077**	0.22
Teacher Reported Numeracy Skills					
S-EDI Basic Numeracy Skills	2.64 (2.56)	1.85 (2.24)	**0.041**	**0.041**	0.33
S-EDI Basic Numeracy Skills 'Not on Track' %	38%	56%	**0.025**	**0.025**	2.06[a]

Preparing for Life (Doyle et al., 2016).
*IPW-adjusted permutation tests with 100,000 replications controlling for gender. One tailed (right-sided) test.

Table 9 : Language Development

	M_{HIGH} (SD)	M_{LOW} (SD)	*IPW-p**	*IPW-step p**	Effect Size (Cohen's D/Odds Ratio[a])
BAS Verbal Ability					
Verbal Ability Standard Score	98.60 (13.09)	90.28 (12.35)	**0.002**	**0.003**	0.65
Verbal Ability Below Average	25.7%	45.7%	**0.017**	**0.017**	2.44[a]
Verbal Ability Above Average	24.6%	7.9%	**0.017**	**0.025**	3.81[a]
BAS Verbal Ability Subscales: T-Scores					
Naming Vocabulary	53.29 (11.20)	45.95 (11.24)	**0.002**	**0.003**	0.65
Verbal Comprehension	44.66 (6.78)	42.13 (6.84)	**0.022**	**0.022**	0.37

Preparing for Life (Doyle et al., 2016).
*IPW-adjusted permutation tests with 100,000 replications controlling for gender. One tailed (right-sided) test.

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Table 10 : Approaches to Learning

	M_{HIGH} (SD)	M_{LOW} (SD)	*IPW-p**	*IPW-step p**	Effect Size (Cohen's D/Odds Ratio[a])
Tasks for Controlling Attention and Impulsive Behaviour					
Day/Night Task Total Score	21.95 (6.38)	19.17 (5.90)	**0.023**	**0.037**	0.45

Preparing for Life (Doyle et al., 2016).
*IPW-adjusted permutation tests with 100,000 replications controlling for gender. One tailed (right-sided) test.

Table 11 : Physical Wellbeing

	M_{HIGH} (SD)	M_{LOW} (SD)	*IPW-p**	*IPW-step p**	Effect Size (Cohen's D/Odds Ratio[a])
Hospital Service Use					
No. of Initial Visits to Hospital	4.2 (2.9)	5.2 (4.3)	0.150	0.150	0.28
No. of Follow-up Services Used	2.2 (2.8)	4.8 (7.3)	**0.039**	**0.066**	0.46
Total No. of Hospital Services Used	6.4 (5.2)	10.2 (10.8)	**0.048**	**0.064**	0.45
Hospital Departments Attended					
% any ED visits	97%	96%	0.700	0.700	0.74[a]
No. of ED visits	3.5 (3.2)	4.6 (4.5)	**0.094**	**0.094**	0.30
% any ED Clinic visits	16%	24%	0.196	0.376	1.61[a]
No. of ED Clinic visits	0.2 (0.4)	0.5 (1.1)	**0.045**	**0.093**	0.35

Preparing for Life (Doyle et al., 2016).
*IPW-adjusted permutation tests with 100,000 replications controlling for gender. One tailed (right-sided) test.

Table 12 : Physical Wellbeing

	M_{HIGH} (SD)	M_{LOW} (SD)	*IPW-p**	*IPW-step p**	Effect Size (Odds Ratio)
Emergency Department Use					
% Visits with triage level three or higher (more urgent)	39%	69%	**0.019**	**0.042**	3.44
% Visits caused by accidents	59%	72%	0.159	0.388	1.85
% Visits prompted by GP referral	42%	54%	0.166	0.166	1.59
% Visits resulting in prescription	45%	69%	**0.024**	0.113	2.64
% Ever left without being seen	6%	14%	0.228	0.364	2.32

Preparing for Life (Doyle et al., 2016).
*IPW-adjusted permutation tests with 100,000 replications controlling for gender. One tailed (right-sided) test.

Evidence from Head Start

Summary of Evidence: Head Start

1. Studies evaluating long-term outcomes from Head Start find that the program has persistent beneficial effects on important outcomes such as health and education. Thus, even if the effects on cognition fade out, Head Start has positive outcomes on broader measures describing the socioeconomic life of an individual. This evidence is based on nationally-representative data sets.
2. Cost-benefit analyses of Head Start suggest that the program is probably socially efficient. More comprehensive evaluations could imply high internal rates of returns, as current calculations include only gains in earnings.

Evidence from Large-Scale Early Childhood Programs

Overview

Three Major Insights

- Universal programs do not imply universal take-up.
- Disadvantaged children benefit the most from programs.
- High quality programs benefit children, while lower quality ones may have negative effects.
- Early life non-cognitive skills mediate skills later in life, affecting relevant socioeconomic outcomes such as education, employment, health, and criminal activity.

Elementary School and Adolescent Programs

Mentoring is a Key Feature of All Successful Programs

- An age-adapted form of mothering

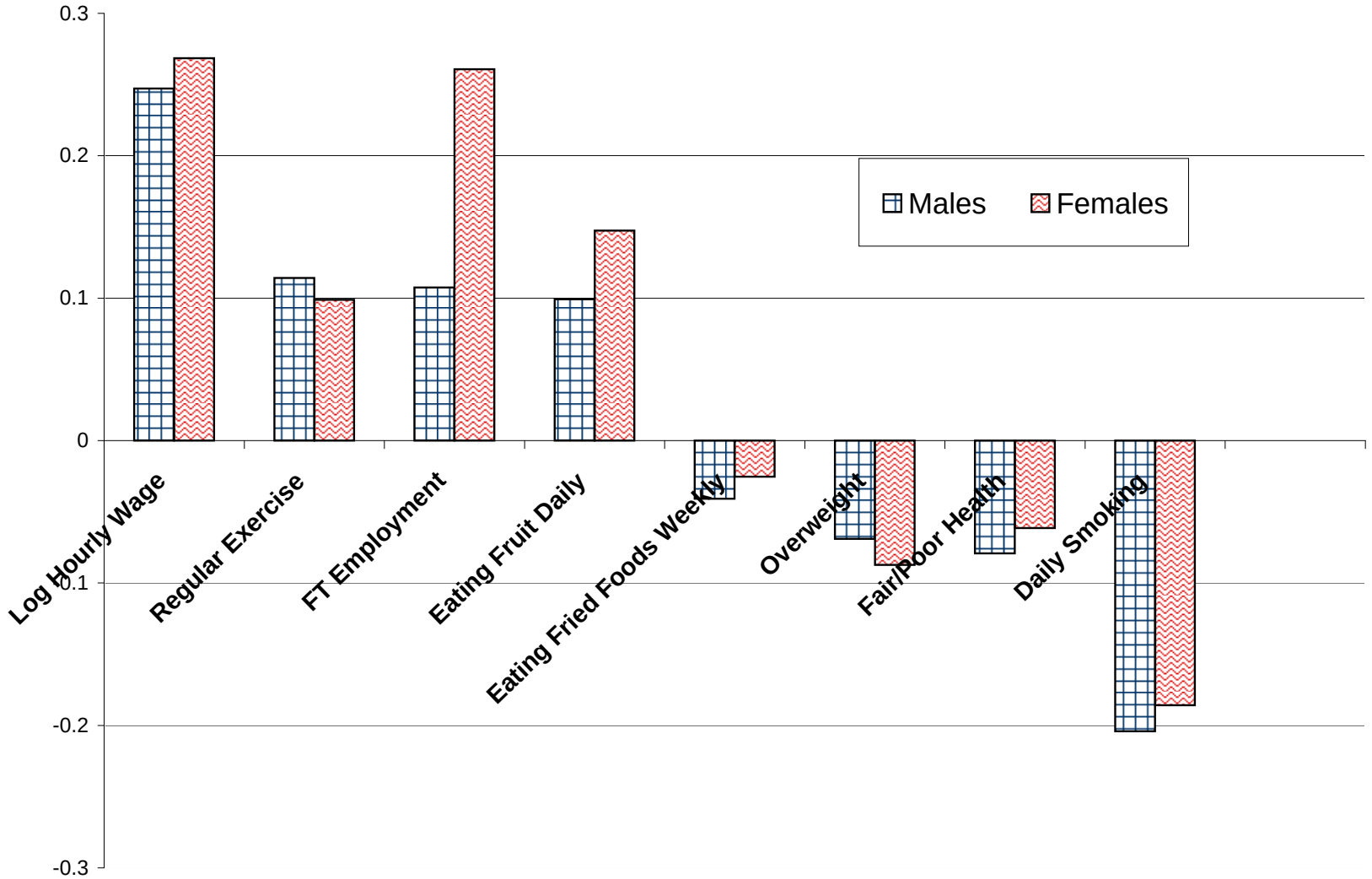
Education promotes healthy behaviors and health

Beneficial Causal Outcomes of Education at Different Stages of the Life Cycle

(Heckman, Humphries, and Veramendi, 2016)

1. Self-reported health
2. Voting
3. Trust
4. Employment
5. Wages
6. Participation in welfare
7. Depression
8. Self-esteem
9. Incarceration
10. Health related work limitations
11. Smoking
12. White-collar employment

Figure 29 : Benefits of Minimal "O-Level" Qualifications in Britain

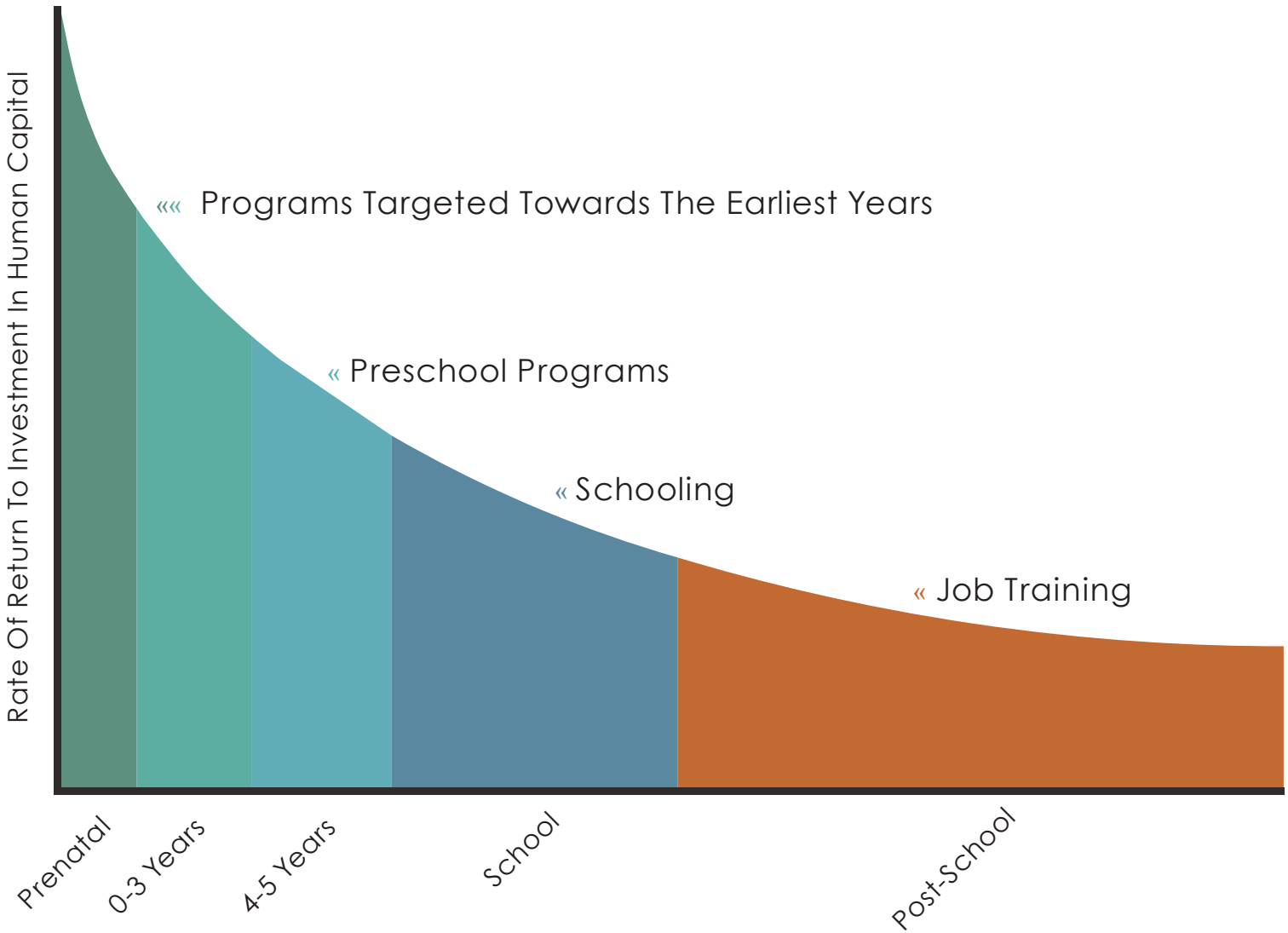


Note: Authors' calculations using BCS70.

The Economics of Human Development

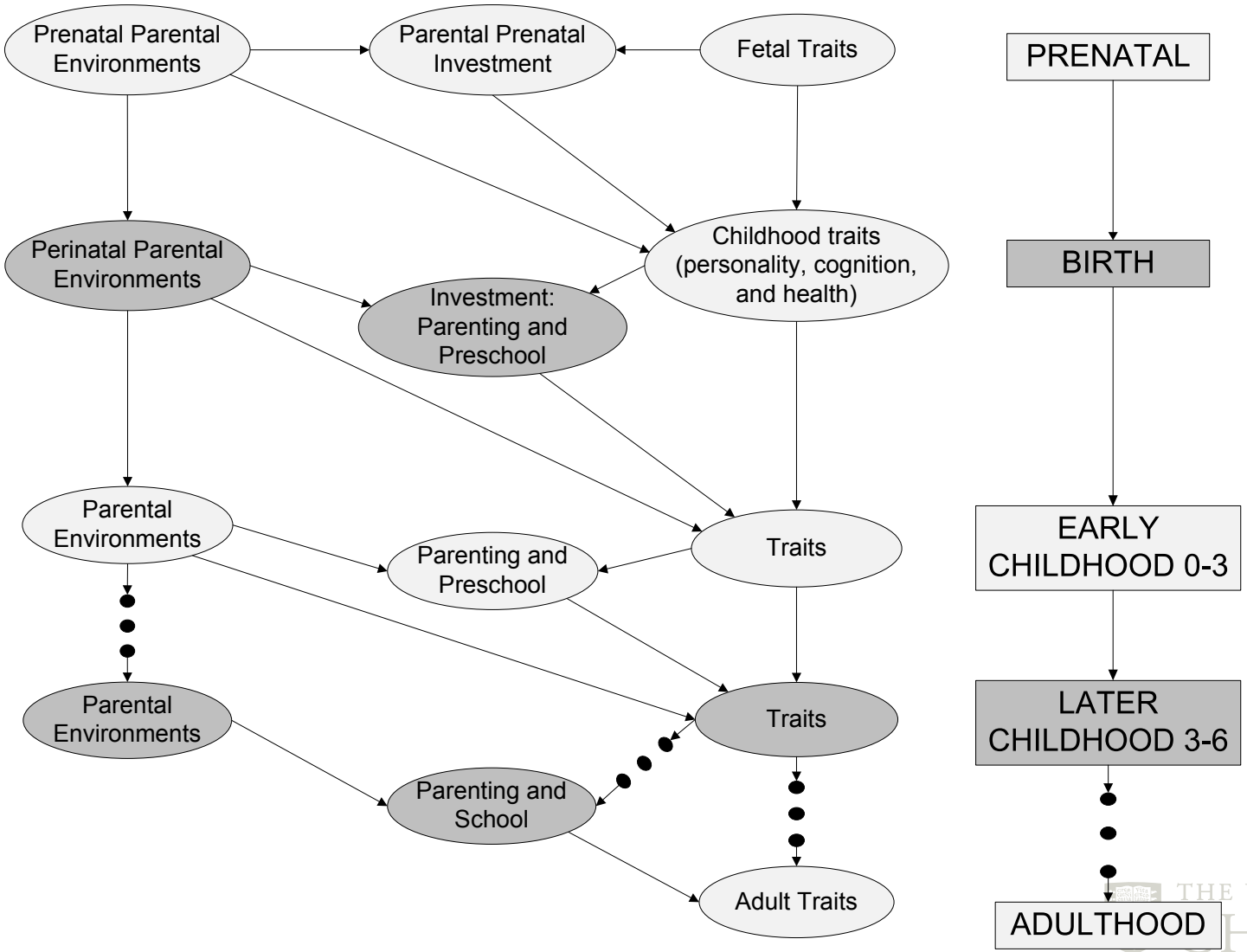
- A good health policy may be a good family policy.
- A good family policy may also be a good health policy.
- This argument goes beyond looking at education or nutrition but is consistent with both and integrates these more specialized approaches into a general framework.
- My analysis develops an approach to human development that unites and extends previous research in a common framework that is the basis for policy intervention in health, education, crime, and employment.

Returns to a Unit Hong Kong Dollar Invested



Source: Heckman (2008)

Figure 30 : Resilience and Development: A Life Cycle Framework for the Technology of Skill Formation



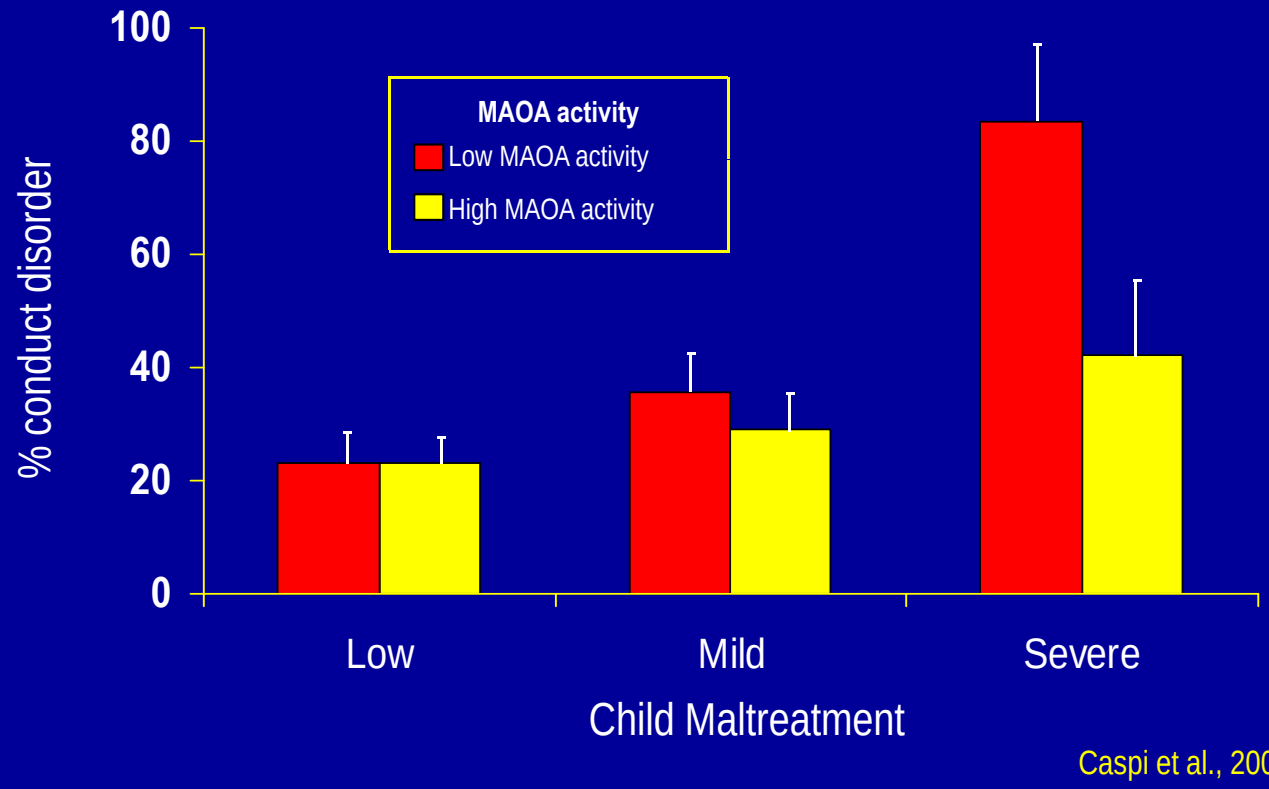
Appendices

Experience gets embodied in the biology of the organism. Evidence of gene-environment interactions: how experience gets under and stays under the skin

- The modern literature on epigenetic expression and gene-environment interactions teaches us that a sharp distinction between acquired skills and ability featured in the early human capital literature is not tenable
(Pray, 2004; Gluckman and Hanson, 2005; Rutter, 2006).

- Abilities are produced, and gene expression is governed by environmental conditions.
- Measured abilities are the outcomes of environmental influences, including *in utero* experiences, and also have genetic components.
- The literature on "fetal programming" emphasizes the importance of the environment in causing gene expression that gives rise to susceptibility to different diseases, abilities and personality characteristics.
- We can better target interventions using genetic and environmental data.

Male conduct disorder: Child maltreatment interacts with MAOA genotype

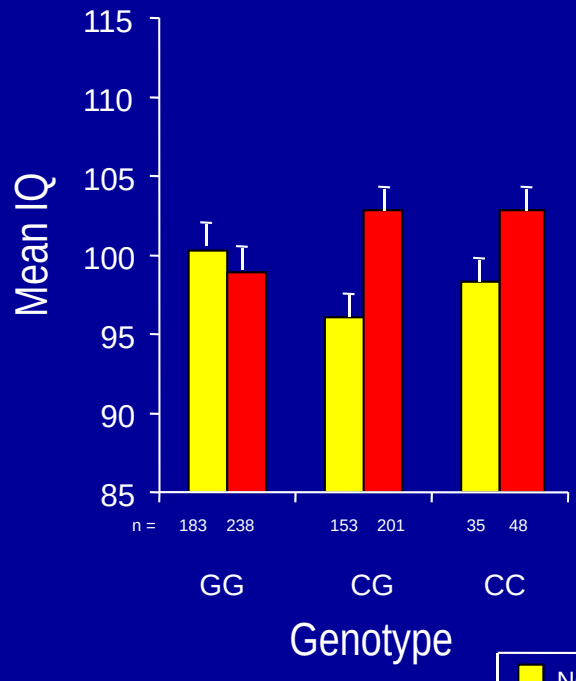


Caspi et al., 2002 (Science)

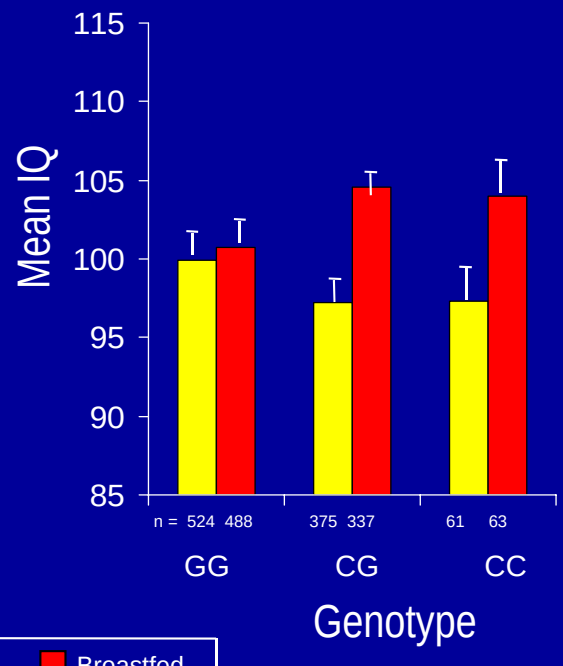
- Maltreatment coupled with absence of MAOA gene allele $\Rightarrow$ .8 probability of aggressive behavior.

The IQ:
Breastfeeding interacts with FADS2 genotype

(**A**) New Zealand Birth Cohort



(**B**) British E-risk Birth Cohort



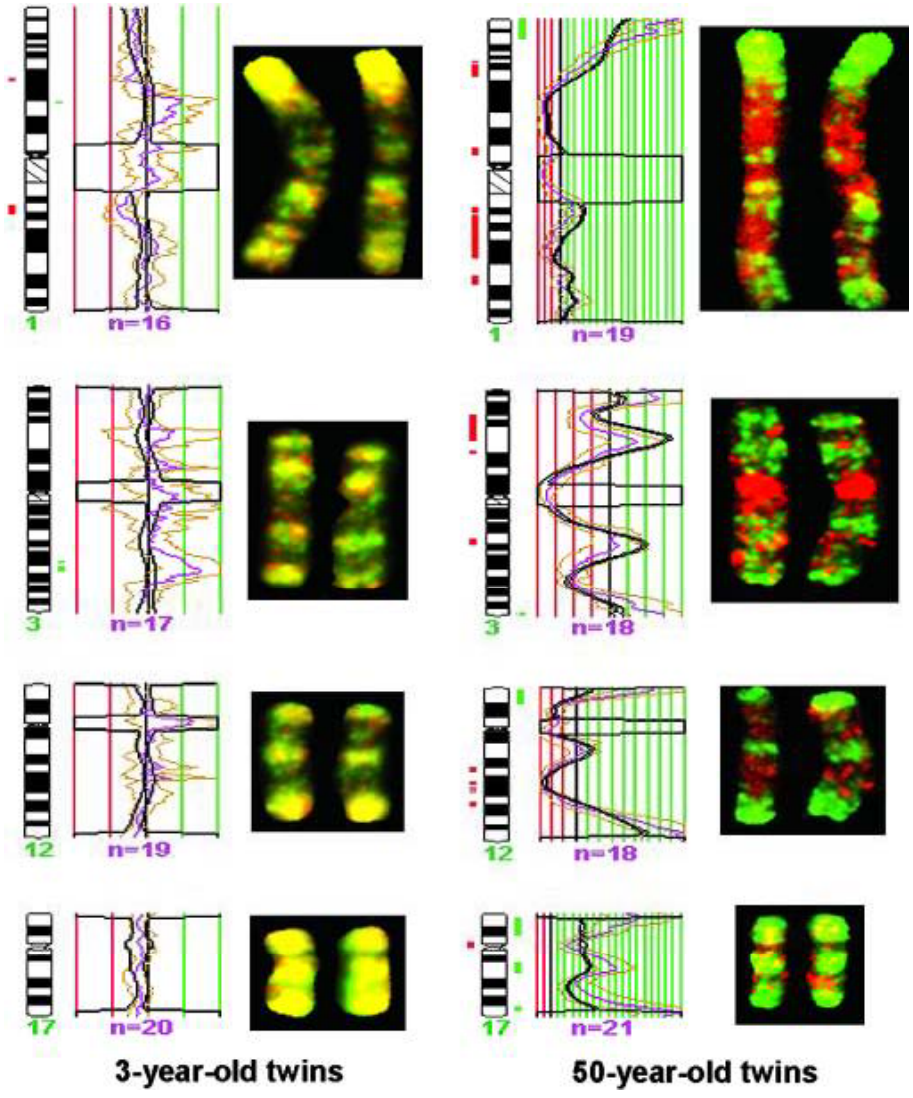
Not breastfed Breastfed

Caspi et al., 2007 (PNAS)

We are tracking predictors of future age-related disease and successful aging

- Physical health
  - Dental, respiratory, sexual, etc.
- Mental health
  - psychiatric disorders
  - substance abuse
- Personality
  - planfulness, self-control
  - agreeableness, social closeness
- Economic behaviors
  - Savings, debt
  - credit ratings
- Neuropsychological health
  - IQ subtests
  - Memory
  - Executive & attention
- Metabolic syndrome
  - biomarkers
- Telomere shortening
- Inflammation
  - biomarkers

Methylation patterns in young and old twins



Manel Esteller

CHILDHOOD MALTREATMENT

AGE 3-11 in Dunedin cohort

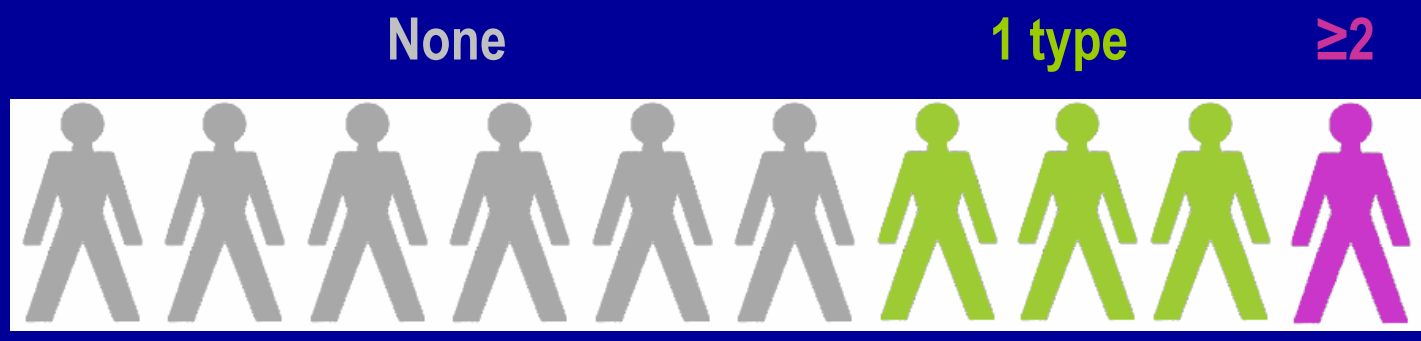
Maternal rejection (14%)

Harsh discipline (10%)

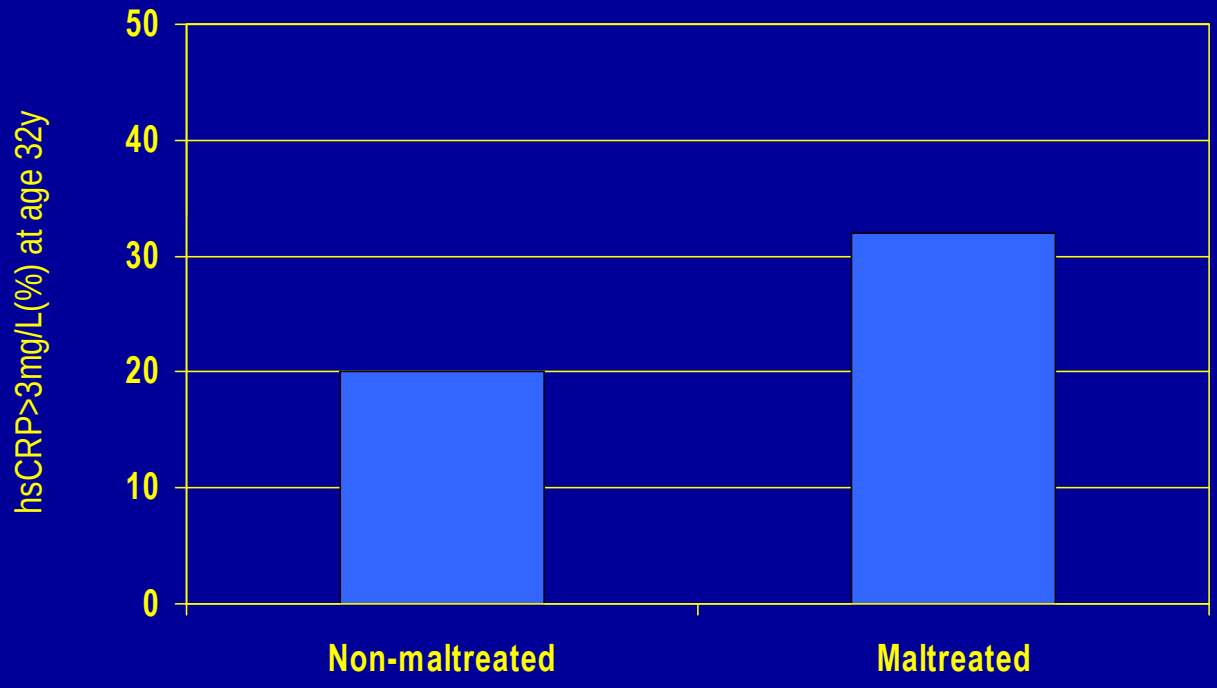
Caregiver changes (6%)

Physical abuse (4%)

Sexual abuse (12%)

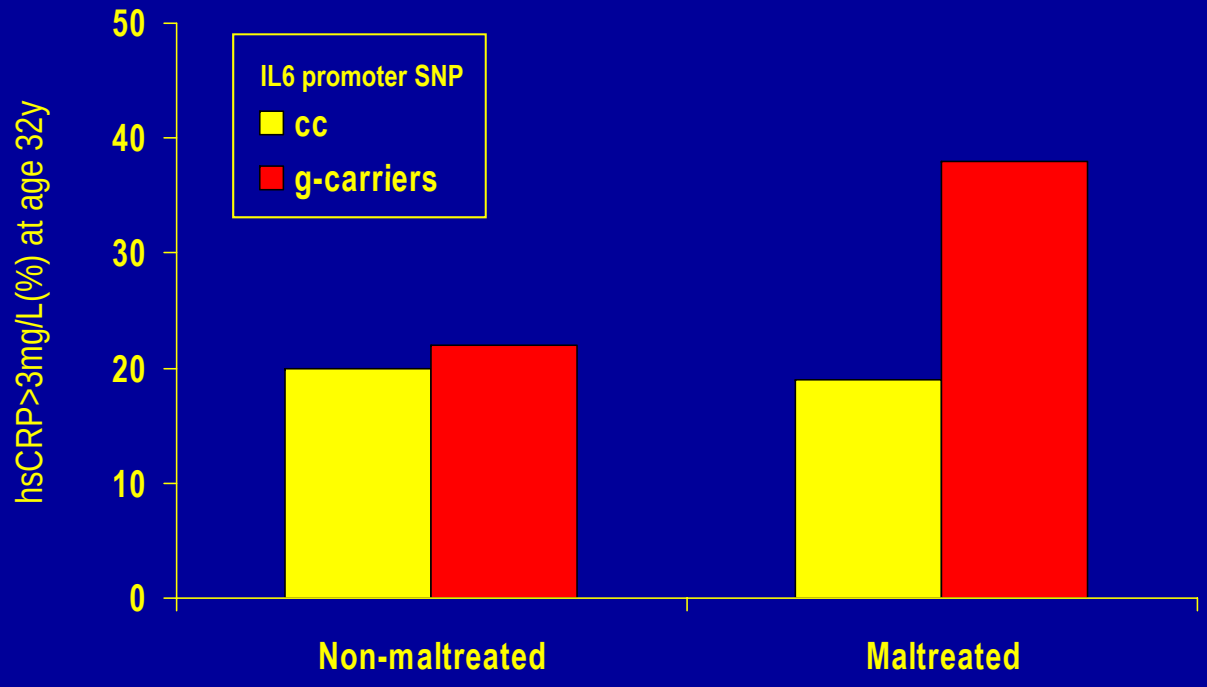


CHILDHOOD MALTREATMENT AND ADULT INFLAMMATION



Danese et al. 2007 (PNAS)

IL6 GENOTYPE x MALTREATMENT > ADULT INFLAMMATION: Gene x Environment interaction



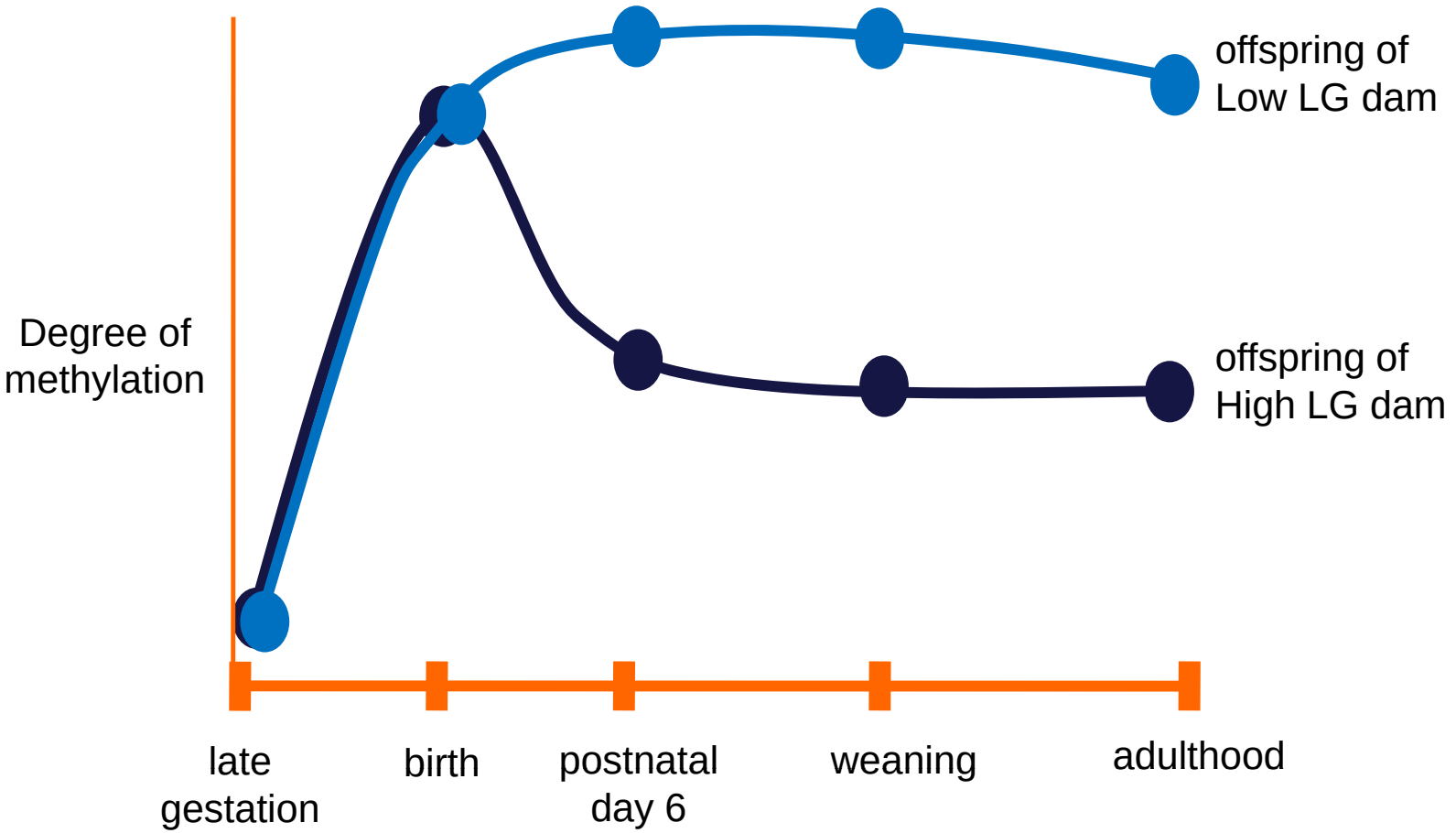
Danese et al. (in preparation)

1) Experiences occurring during an early period of development can have long-term effects on gene expression that are stably maintained into adulthood

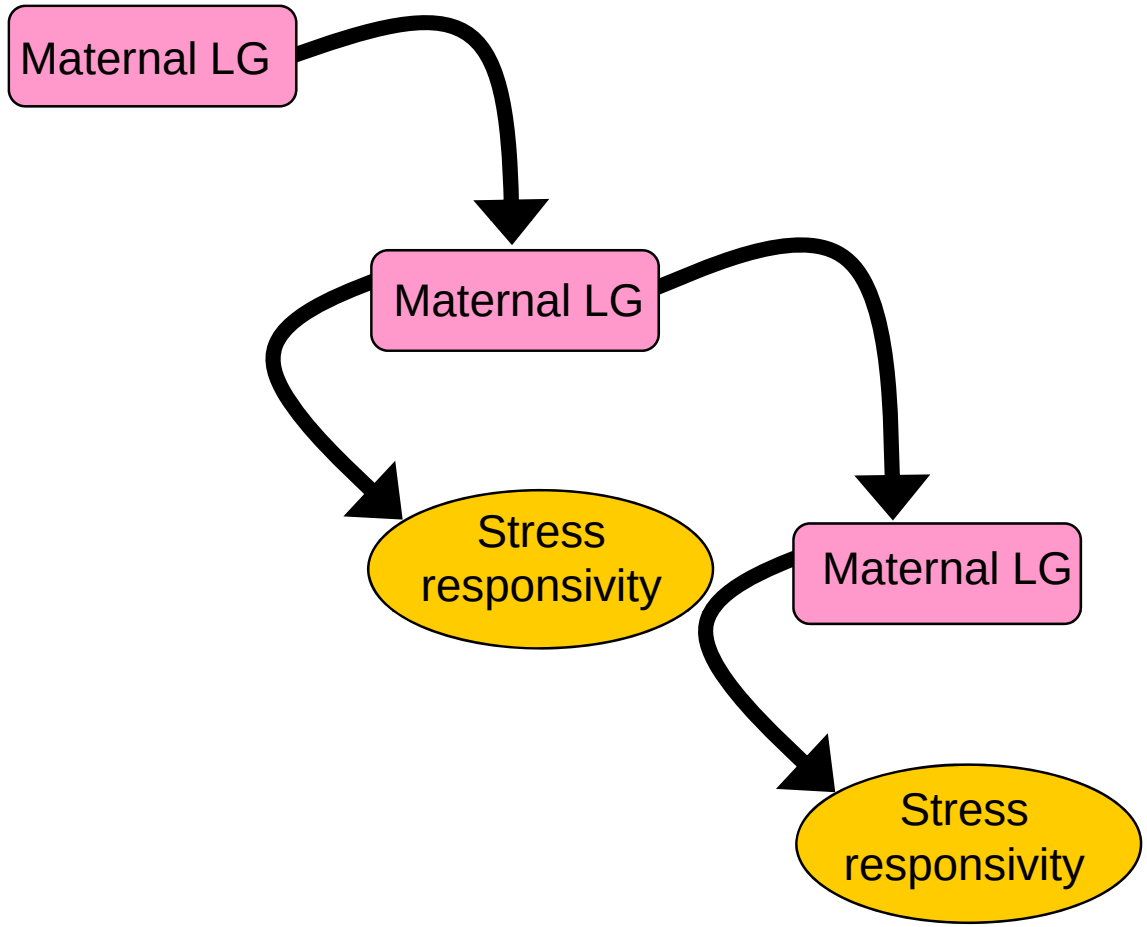
2) Social experiences can alter the epigenome and thus regulate gene expression

3) Neural systems regulating stress responsivity and thus risk of psychopathology can be regulated by these epigenetic mechanisms

Changes in Methylation Over Time



Transmission of maternal care and stress responsivity across generations



Champagne & Curley, *Current Opinion in Neurobiology*, 2005

Implications

1) Illustrates the developmental effects of early experiences on epigenetic mechanisms regulating long-term suppression of a gene involved in stress responsivity

2) Provides the potential for identifying therapeutic targets in adulthood (ie. pharmacological manipulation of the epigenome)

3) Provides evidence that experiences beyond so called “critical periods” can ameliorate the effects of early “adverse” experiences

4) Illustrates that via the transmission of maternal care from one generation to the next, individual differences in stress responsivity can be transmitted transgenerationally (ie. a non-genomic inheritance of variations in gene expression)

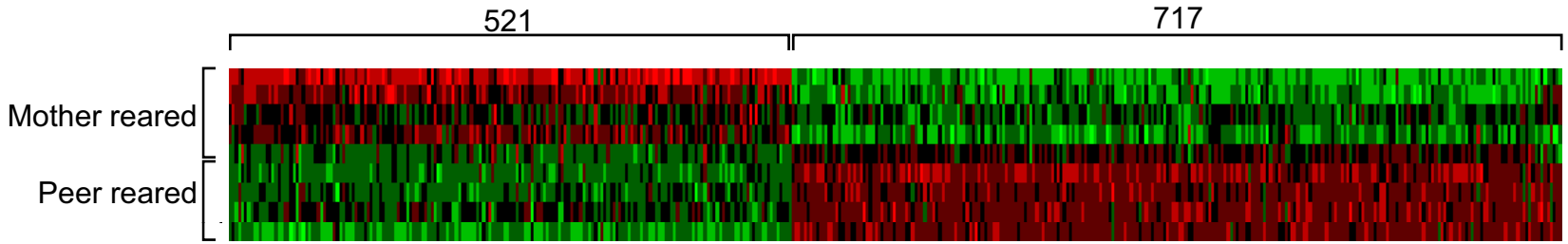
5) Environmental conditions can alter maternal care and thus alter offspring behavior

Gene Expression in Monkey Studies

- Remodeling of the basal leukocyte gene expression profile in 4 month-old rhesus monkeys (*Macaca mulatta*) reared under adverse social conditions
- Disadvantaged (peer-reared; surrogate-reared) monkeys exhibit leukocytes showing enhanced expression of genes involved in:
  (a) Inflammation
  (b) T lymphocyte activation
  (c) Cell proliferation
  (d) Suppression of genes involved in type I interferon antiviral response and immunoglobulin production of B lymphocytes

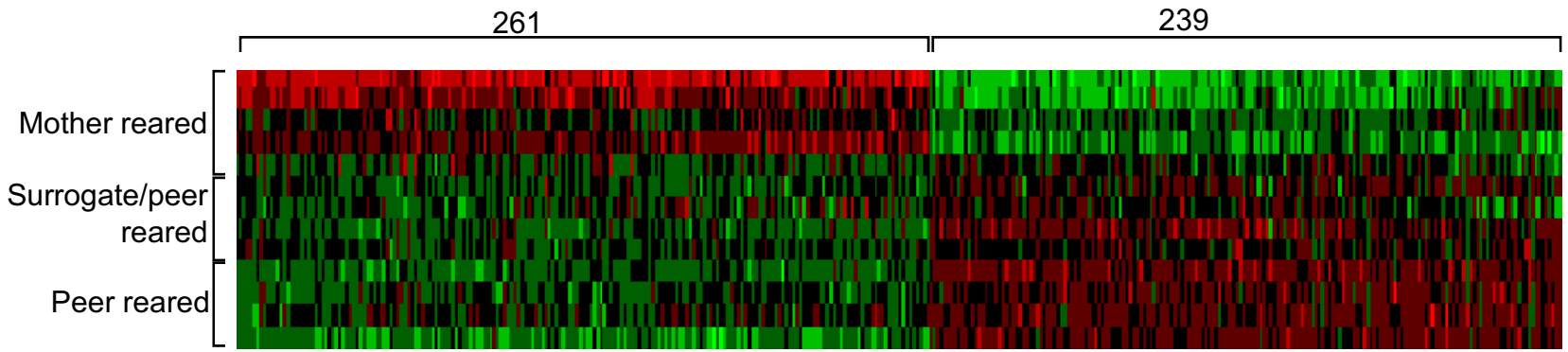
- Surrogate mothers partly reverse some of the adverse effects
- Social conditions become embedded in basal transcriptional stance of primate immune systems
- Sympathetic nervous system-linked signal transduction and transcriptional control pathways are candidate mediators of these effects

Figure 31 : Differential Gene Expression in Leukocytes from Mother-Reared vs. Peer-Reared Macaques



Source: Cole, Arevalo, Ruggiero, Heckman, and Suomi (2009).

Figure 32 : Distribution of Leukocyte Gene Expression in Surrogate/Peer-Reared Macaques on the 500-Gene Expression Vector Discriminating Mother-Reared from Peer-Reared Animals



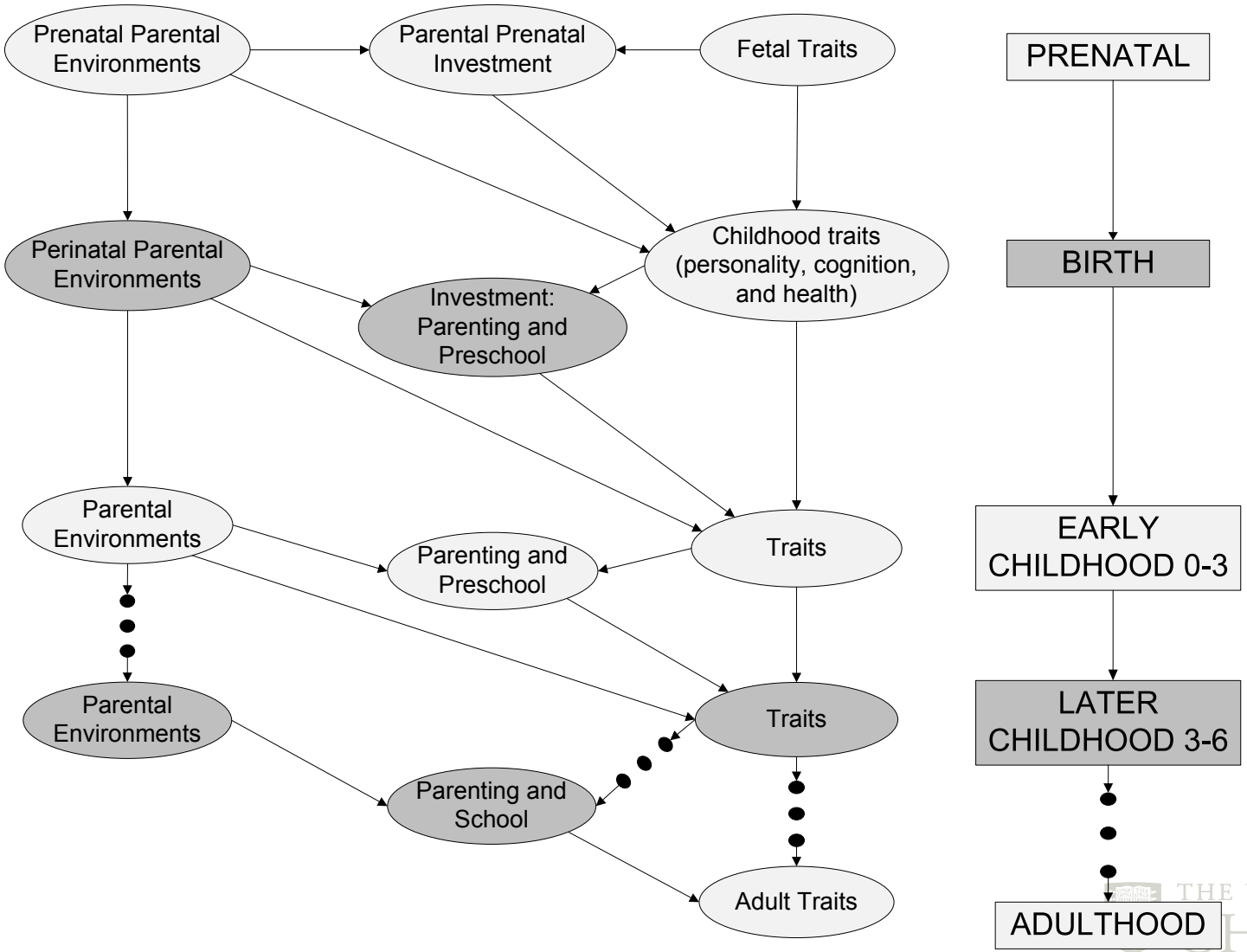
Source: Cole, Arevalo, Ruggiero, Heckman, and Suomi (2009).

- Meaney, Suomi and Szyf show that early peer rearing affects methylation in **22%** of rhesus monkey genes.

A Framework for Organizing the Evidence

- $\boldsymbol{\theta}_t = (\boldsymbol{\theta}_C, \boldsymbol{\theta}_N, \boldsymbol{\theta}_H)$ capabilities at t

Figure 33 : Resilience and Development: A Life Cycle Framework for the Technology of Skill Formation



Modeling Human Capability Formation

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

$$\theta_t = (\theta_t^C, \theta_t^N, \theta_t^H),$$

where

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

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

Formal models of child outcomes and investment in children

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

$$Y_t^k = \psi_k\left(\theta_t^C, \theta_t^N, \theta_t^H, e_t^k\right), \quad k \in \{1, \ldots, K\} \tag{1}$$

where e_t^k is effort devoted to activity k at time t where the effort supply function depends on rewards and endowments:

$$e_t^k = \delta_k\left(R_t^k, A_t\right) \tag{2}$$

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

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), and parental environments (θ_t^P):

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

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

- A crucial feature of the technology that helps to explain many findings in the literature on skill formation is *complementarity of capabilities with investment:*

$$\frac{\partial^2 f_t(\theta_t, I_t, \theta_{tP})}{\partial \theta_t \partial I_t'} \geq 0. \tag{4}$$

- Technology (3) is characterized by *static complementarity* between period t capabilities and period t investment.
- The higher θ_t, the higher the productivity of the investment.

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

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

- Using dynamic complementarity, 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.

- Adult choices and outcomes are shaped by *sequences* of investments over the life cycle of the child.
- The importance of the early years depends on how easy it is to reverse adverse early effects with later investment.
- Resilience and remediation are possible, but are more costly later on.
- The cumulation of investments over the life cycle of the child determines adult outcomes and the choices people will make when they become adults.

The framework allows us

1. To organize the evidence on outcomes and interventions from diverse literatures within a common framework
2. Identify synergies among capabilities: how health, cognition and personality traits produce outcomes and interact in the production of capabilities
3. Recognize gaps in the literature and the possibilities for a variety of interventions to promote health

Estimates and Applications of the Technology of Capability Formation

- These technologies have been estimated.
- The major findings from analyses based on them are:
  (a) Self-productivity becomes stronger as children become older, for both cognitive and noncognitive capability formation.
  (b) The elasticity of substitution for cognitive inputs is **smaller** in second stage production. It is more difficult to compensate for the effects of adverse environments on cognitive endowments at later ages than it is at earlier ages. This helps to explain the evidence on ineffective cognitive remediation strategies for disadvantaged adolescents.
  (c) It is easier at *later* stages of childhood to remediate early disadvantage using investments in noncognitive skills.
  (d) Optimal social policy is to invest in disadvantaged young children, especially in cognitive skill.
  (e) For policies to promote outcomes intensive in noncognitive skills, the optimal social policy is to invest later. (crime)

Example

- Suppose the goal is to maximize educational attainment in society.
- Plot the % increase in investment over that required for a child with mean parental and personal endowments to maximize schooling.

Figure 34 : Percentage Increase in Total Investments as a Function of Child Initial Conditions of Cognitive and Noncognitive Capabilities

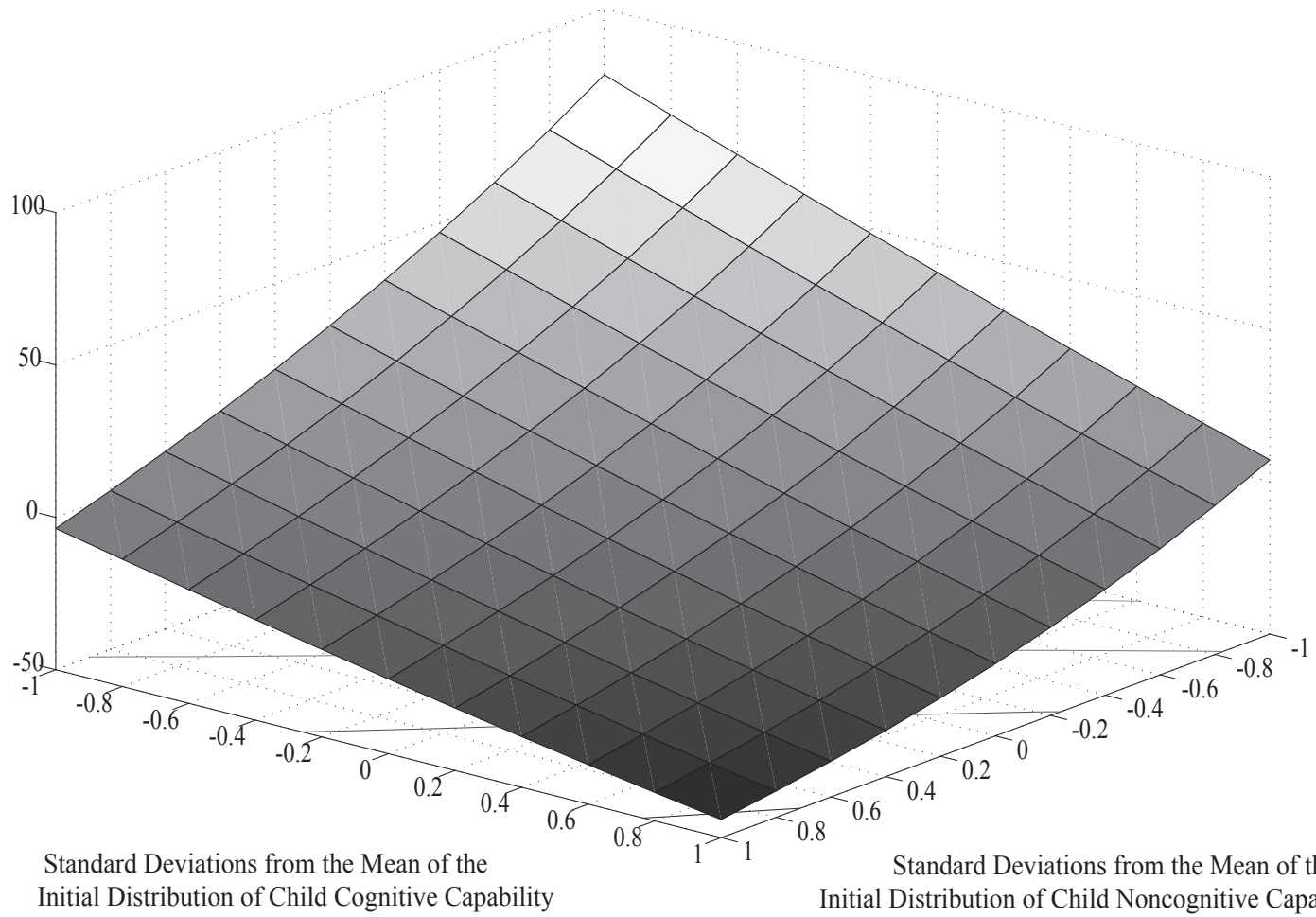
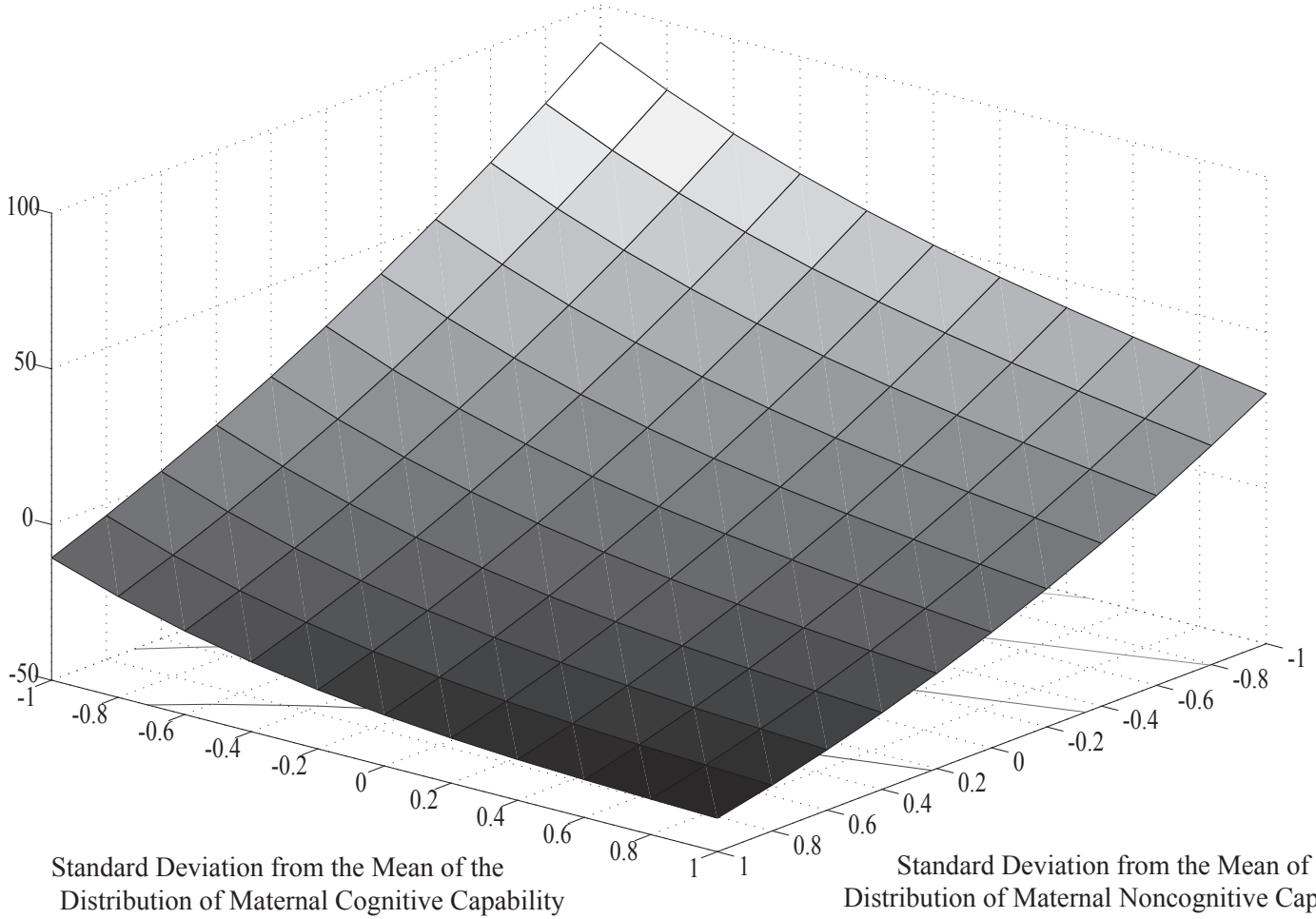


Figure 35 : Percentage Increase in Total Investments as a Function of Maternal Cognitive and Noncognitive Capabilities

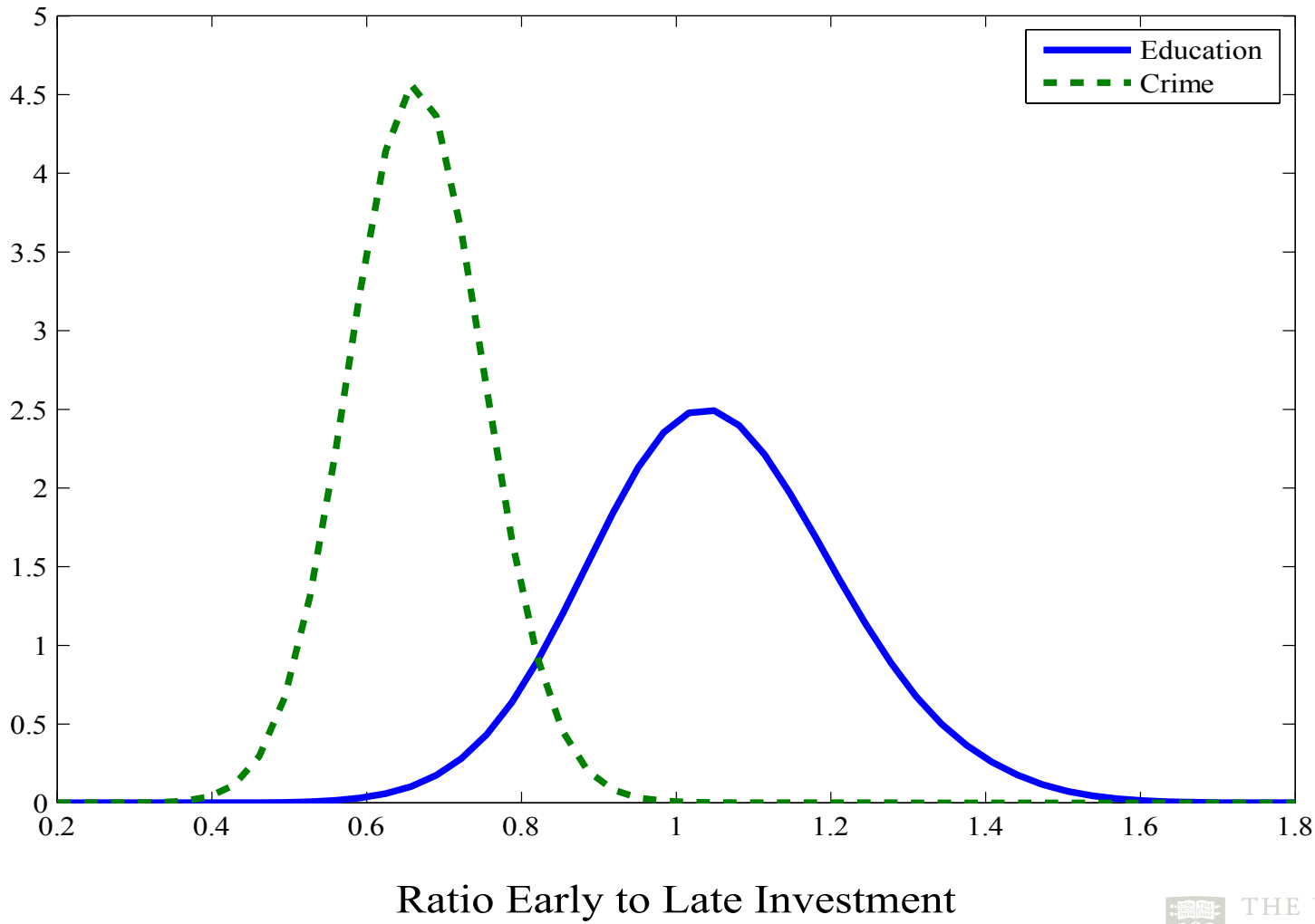


- In analyzing the investment required for a set of endowments, we set the other endowments at mean values.
- **Eighty percent** more investment is required for children with the most disadvantaged personal endowments.
- The corresponding figure for children with the most disadvantaged parental endowments is 95%.
- The negative percentages for children with high initial endowments is a measure of their advantage.

- The analysis of Moon (2008) shows that investments *received* as a function of a child's endowments are typically in reverse order from what are required to attain the goal of universal high school graduation.
- Children born with advantageous endowments typically receive more parental investment than children from less advantaged environments.

- Consider the density of the ratio of early-to-late investment for education and crime.
- Crime is more intensive in noncognitive skill than educational attainment, which depends much more strongly on cognitive skills.
- Because compensation for adversity in noncognitive skills is less costly in the second period than in the first period, while the opposite is true for cognitive skills, it is optimal to weight first and second period investments in the directions indicated in the figure.

Figure 36 : Densities of Ratio of Early to Late Investments Maximizing Aggregate Education versus Minimizing Aggregate Crime



Policy Analysis Based on Technology

- Structural models based on latent capabilities facilitate comparisons across diverse intervention programs and diverse outputs of these programs.
- They offer a scientifically valid alternative to crude metanalyses that force "treatment effects" from diverse programs and diverse populations into a common metric.
- Outcomes of various treatments can be placed on a common footing using versions of outcome equations (1).
- Recall our decomposition of treatment effects.

- Different programs indexed by q, $q \in \{1, \ldots, Q\}$, provide different packages of investment at stage t, $I_{q,t} = (I^C_{q,t}, I^N_{q,t}, I^H_{q,t})$ at cost $C_{q,t}$.
- Discounted costs of program q are C_q.
- The programs affect output θ_{t+1} through production at stage t by technology (3).
- **Using estimated structural models, analysts can compare different programs both in terms of their investment content and in terms of their output.**
- Thus they can determine how different programs affect cognition, personality and health, and can extrapolate out of the sample of programs previously tried to predict the consequences of new programs never previously implemented.

- Consider choice among a set of mutually exclusive programs that seek to boost outcomes at the first stage of adulthood, $T+1$.
- The goal is to achieve target objective $\bar{Y}^k_{T+1}$, $k \in \{1, \ldots, K\}$, at $T+1$ by a choice of program q.
- The problem can be formulated for objective k as

$$\min_{q \in \{1,\ldots,Q\}} C_q \tag{5a}$$

subject to technology constraints, initial endowments and the output constraint

$$Y^k_{T+1}(\theta_{T+1}, e^k_{T+1}) \geq \bar{Y}^k_{T+1}. \tag{5b}$$

- A version of this problem is used to generate the cost-minimizing simulations for high school attainment just discussed.
- Some programs may fail to achieve the constraint in (5b).
- They may have high returns but lack the ability to scale adequately to achieve desired targets.

- For programs in place, one may evaluate the costs and benefits of alternatives without determining technology (3) or outcomes (1), as in the traditional approach to program evaluation.
- However, if only some outcomes of a program are measured, but the investment content of other programs is known, we can construct the missing counterfactual outcomes using the estimated technology (3) and activity outcomes (1) determined on data from the other programs or from observational data like the CNLSY.
- We can also compare and evaluate a variety of programs never experienced.

- Characterizing outcomes by their capability content and diverse programs by their investment effect on capabilities, makes it possible to compare diverse outcomes and programs.
- This framework can be used to compare the effectiveness of historically experienced programs and proposed programs, never previously implemented.
- This approach can be extended to consider the choice of a portfolio of social programs.

Illustration of the Results of Our Empirical Analysis

- Consider the following target group.
- Children who are 6 years old, who come from a very disadvantaged background.
- They are at the bottom 10th percentile in the distribution of skills.
- They receive investments that are at the bottom 10th percentile in the distribution of investments.
- Mothers are also at 10th percentile in the distribution of skills.

Table 13 : Comparison of different investment strategies

Outcome	Baseline	Changing early conditions: changing investment from the 1^{st} to 4^{th} decile of distribution of early investment	Adolescent intervention: moving investments at last transition from 1^{st} to 9^{th} decile	Changing initial conditions and performing a balanced intervention using the resources of the adolescent 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	0.1773	0.1083
Probation	0.2152	0.1487	0.1562	0.0815
Welfare	0.1767	0.0905	0.0968	0.0259
			$35-50\%$ more costly	

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. Source: Cunha and Heckman (2006).

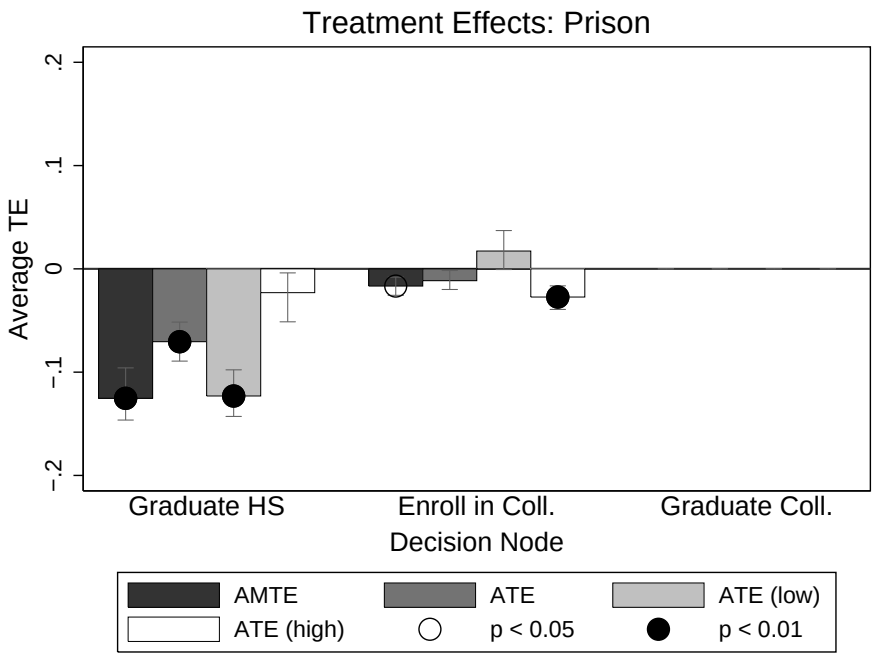
- The evidence strongly supports the economic efficiency of early initial investment that is sustained.
- Optimal distribution of investment:
  - Invest early? Yes.
  - But must be followed up to be effective.
- This is a consequence of dynamic complementarity.
- Later remediation is possible but to attain what is accomplished by early investment is much more costly (40%).
- If we start at too low a level, later skill investment is economically inefficient.

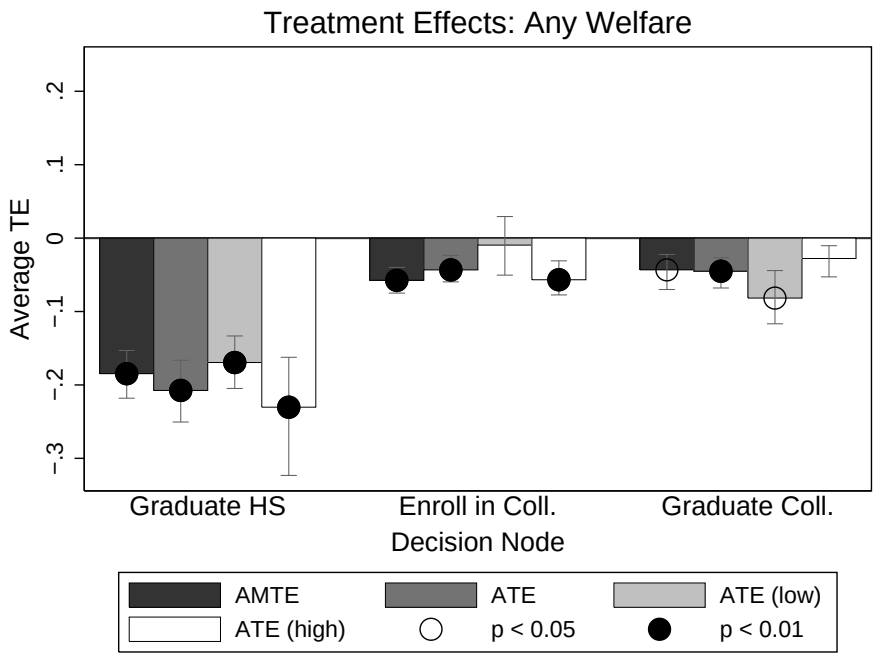
Summary

1. Life cycle approach to health policy
2. Recognize that a core set of capabilities produce a variety of outcomes (health and otherwise).
3. These capabilities have a genetic basis but they can also be altered by experience.
4. Capabilities interact and are self-productive.
5. Different interventions affect capabilities differently; can place all interventions on a common footing using the capabilities.
6. This leads to a broader conception of health policy. Family policy, education, nutrition, early childhood interventions, all promote health.

7. There are critical and sensitive periods in the production of capabilities and policy should recognize this.
8. Framework allows us to integrate a diverse literature on outcomes and interventions.
9. Enables us to evaluate the efficacy of a variety of policies that have never been tried.

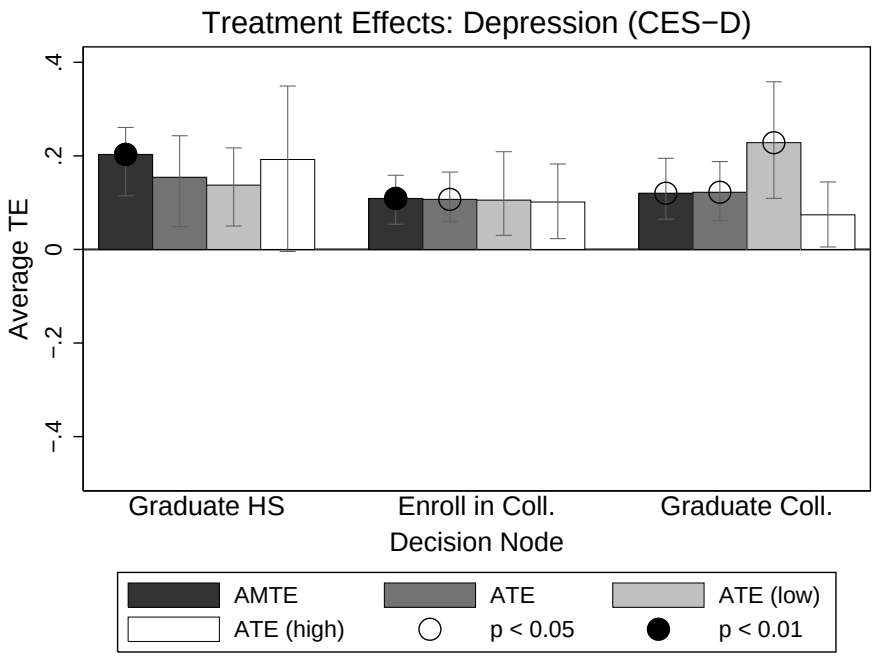
Figure 37 : Effects of Education at Various Stages on Outcomes

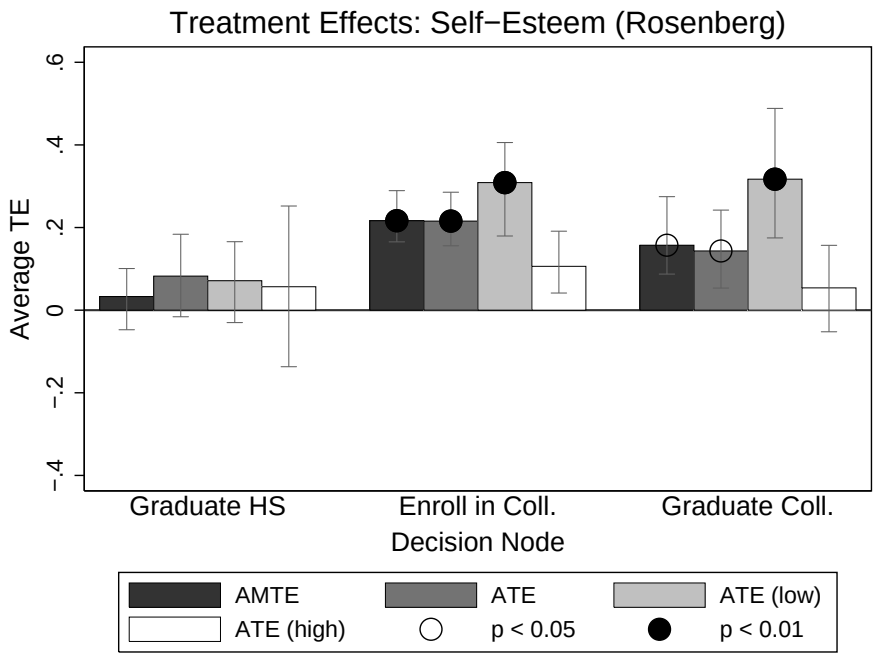




Source: Heckman, Humphries, and Veramendi (2016a).

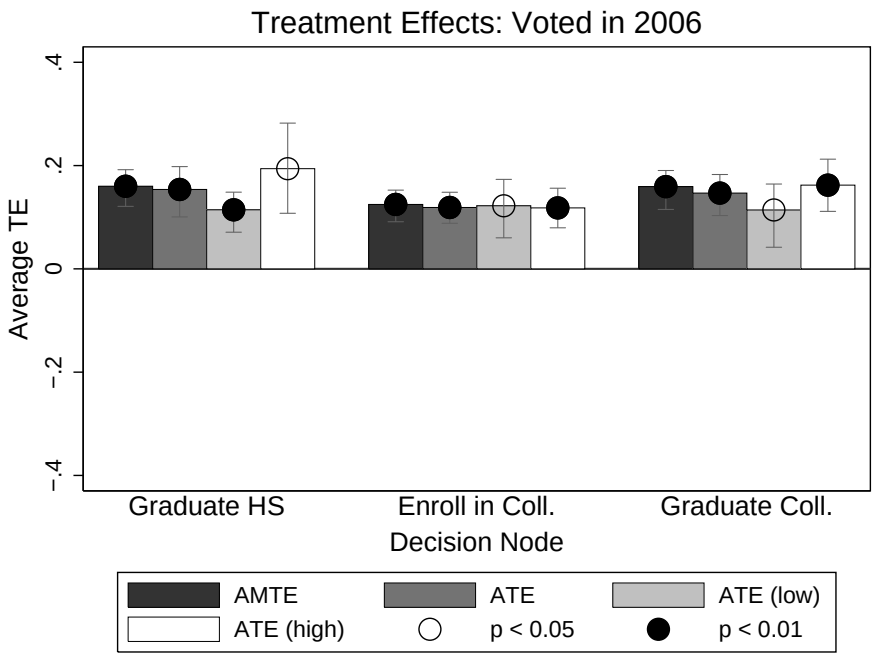
Figure 37 : Effects of Education at Various Stages on Outcomes (Cont.)

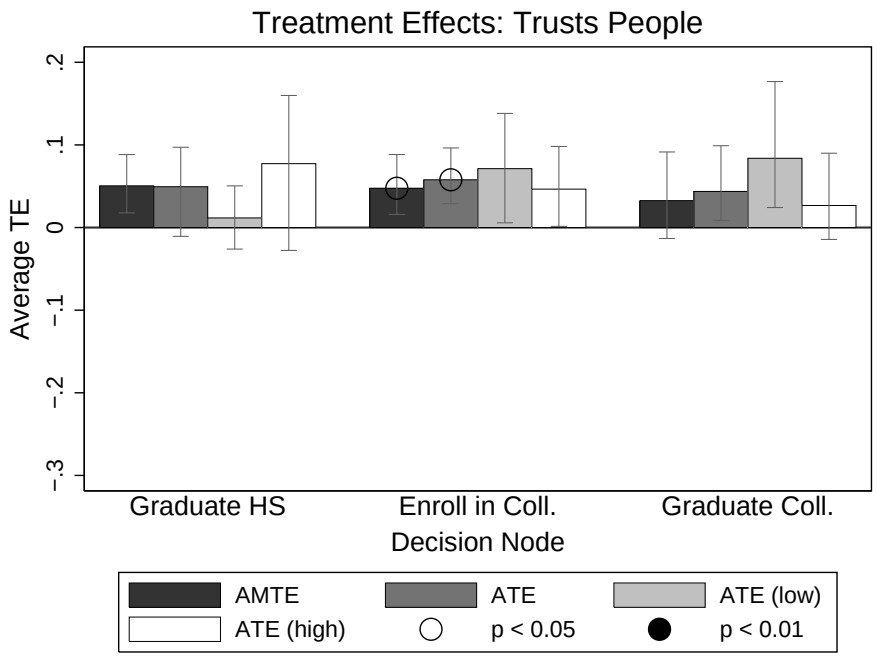




Source: Heckman, Humphries, and Veramendi (2016a).

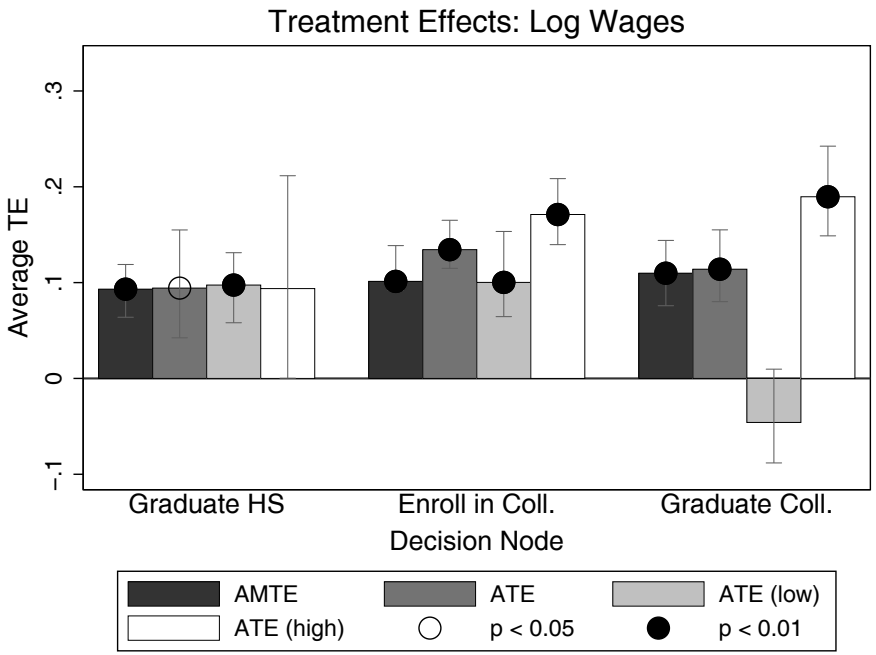
Figure 37 : Effects of Education at Various Stages on Outcomes (Cont.)

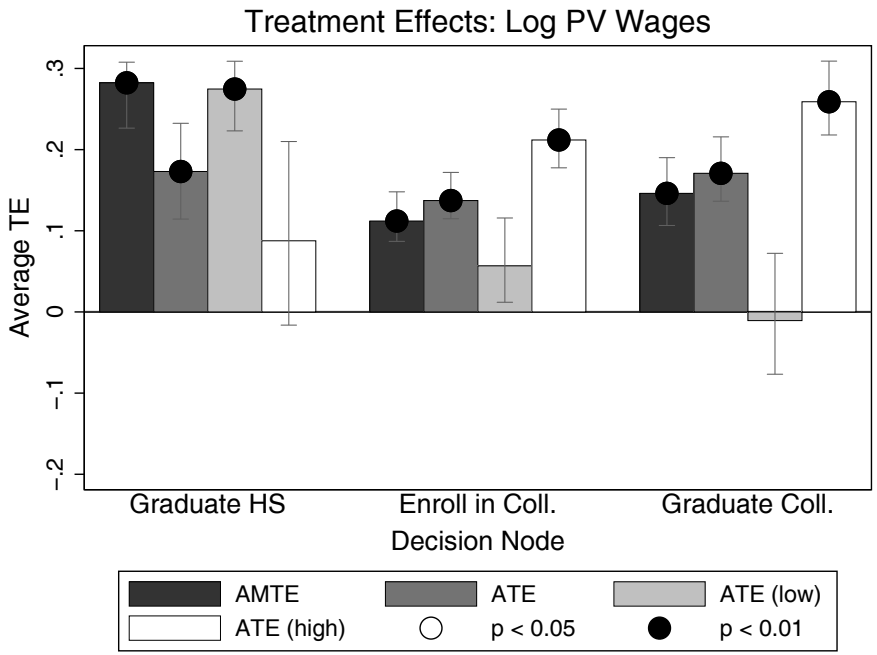




Source: Heckman, Humphries, and Veramendi (2016a).

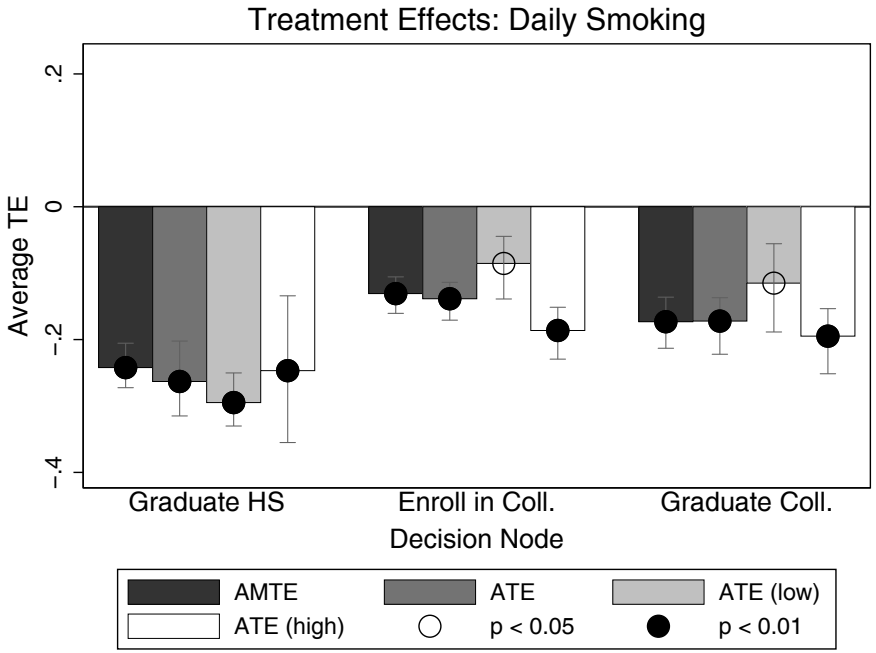
Figure 37 : Effects of Education at Various Stages on Outcomes (Cont.)

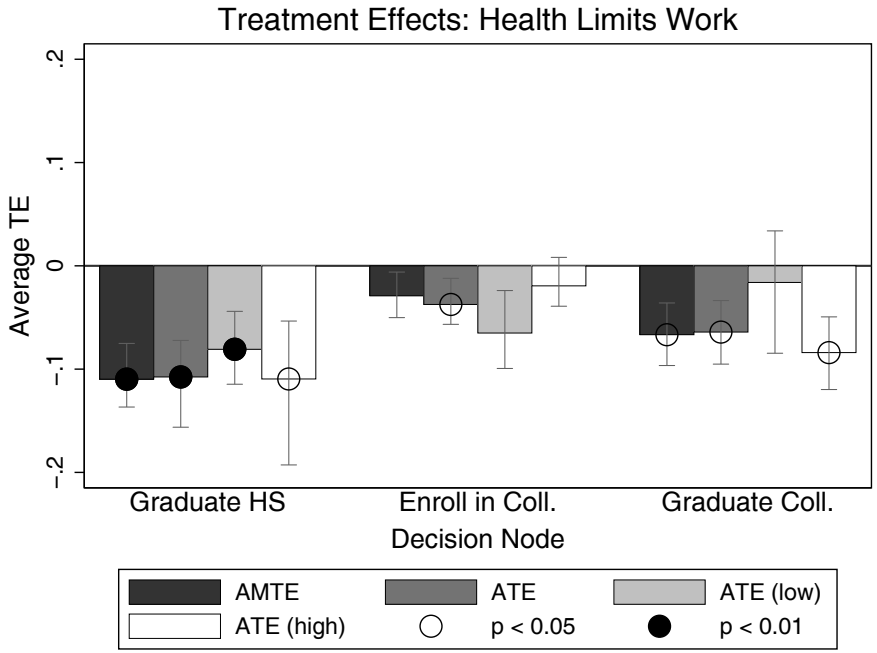




Source: Heckman, Humphries, and Veramendi (2016b).

Figure 37 : Effects of Education at Various Stages on Outcomes (Cont.)





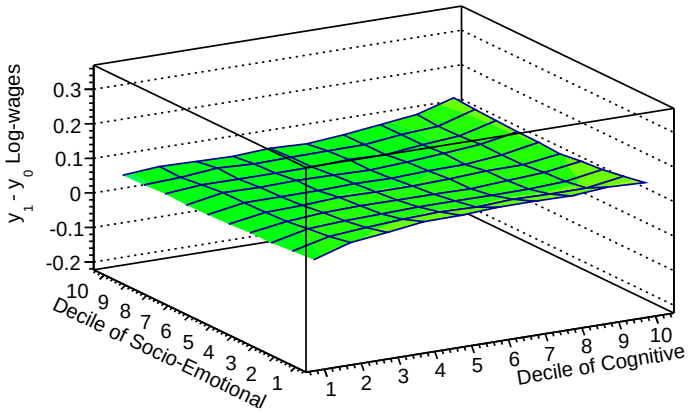
Sorting on Ability

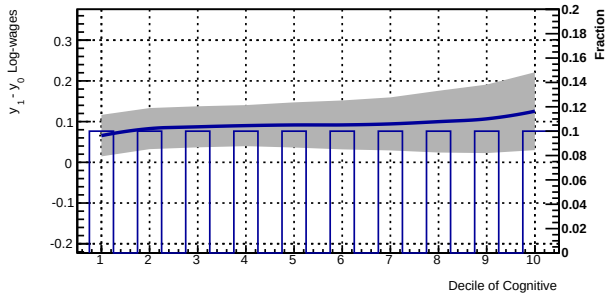
	Low Ability	High Ability
D_1: Dropping from HS vs. Graduating from HS	0.31	0.31
D_2: **HS Graduate** vs. College Enrollment	0.22	0.38
D_3: **Some College** vs. **4-year college degree**	0.13	0.51

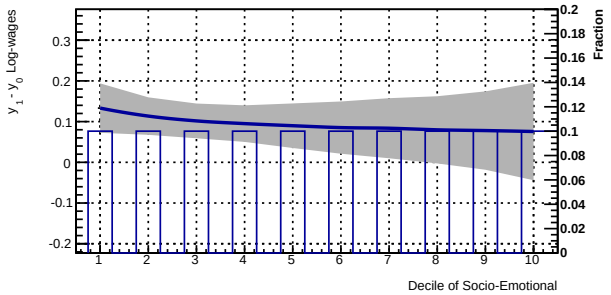
Source: Heckman, Humphries, and Veramendi (2016b).

Figure 38 : Average Treatment Effect of Education on Log Wages at Age 30, by Decision Node and Endowment Levels

A. Graduating from HS vs. Dropping from HS



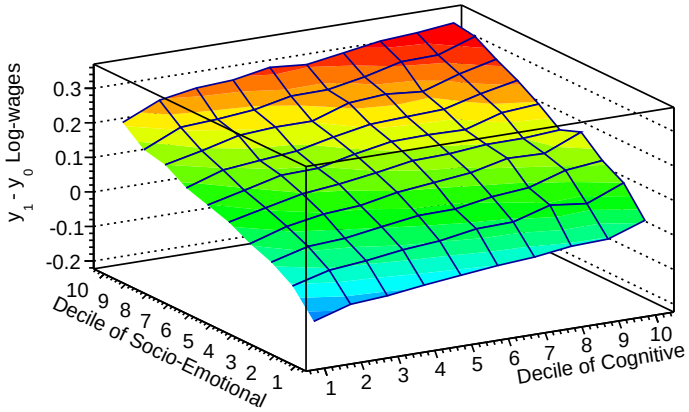


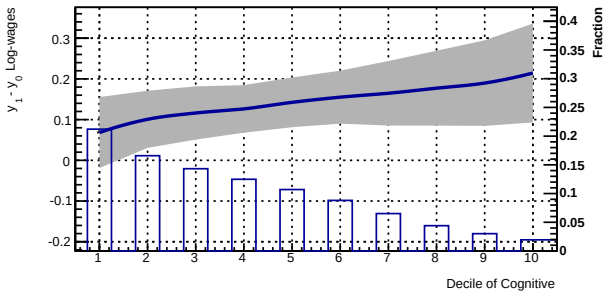


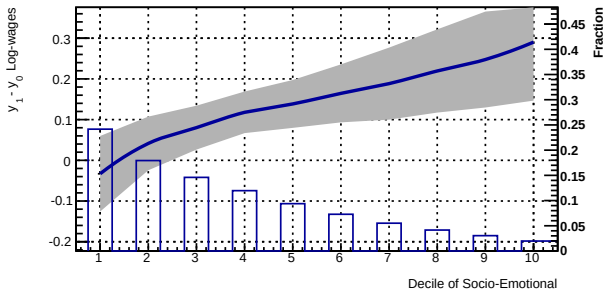
Source: Heckman et al. (2016b).

Figure 38 : Average Treatment Effect of Education on Log Wages at Age 30, by Decision Node and Endowment Levels, Cont'd

B. Getting a GED vs. **HS Dropout**



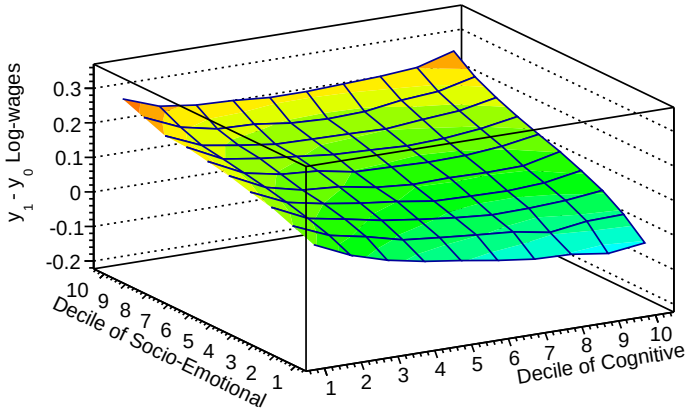


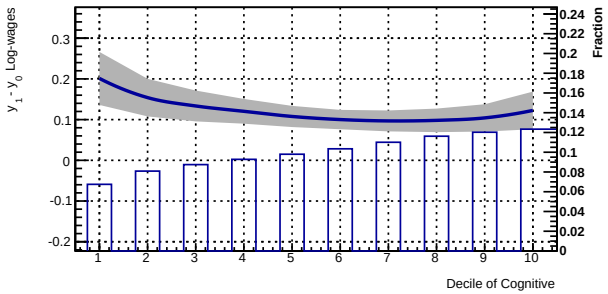


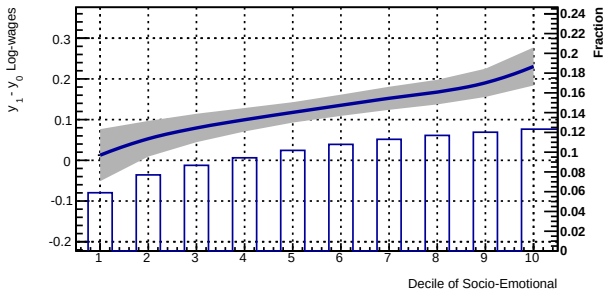
Source: Heckman et al. (2016b).

Figure 38 : Average Treatment Effect of Education on Log Wages at Age 30, by Decision Node and Endowment Levels, Cont'd

C. College Enrollment vs. **HS Graduate**



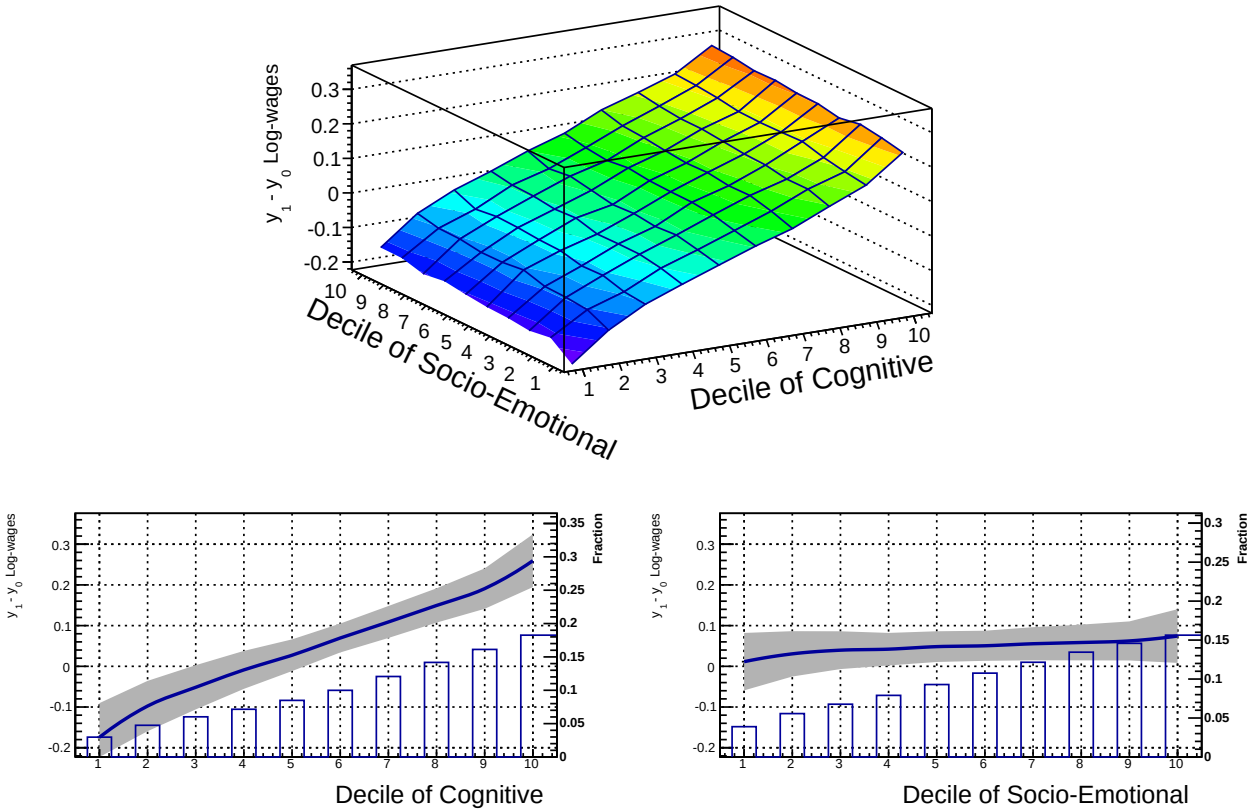




Source: Heckman et al. (2016b).

Figure 38 : Average Treatment Effect of Education on Log Wages at Age 30, by Decision Node and Endowment Levels, Cont'd

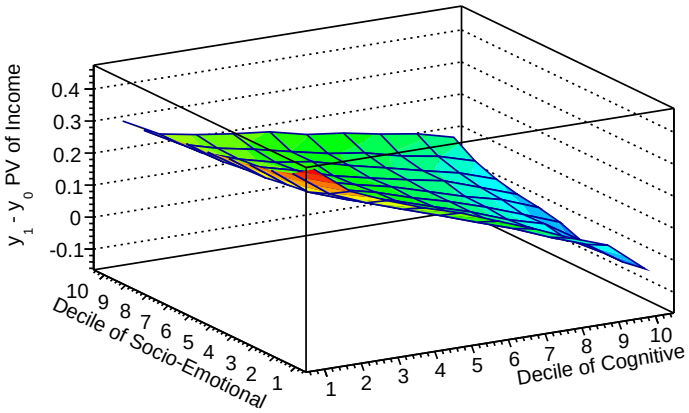
D. **Four-Year College Degree** vs. **Some College**

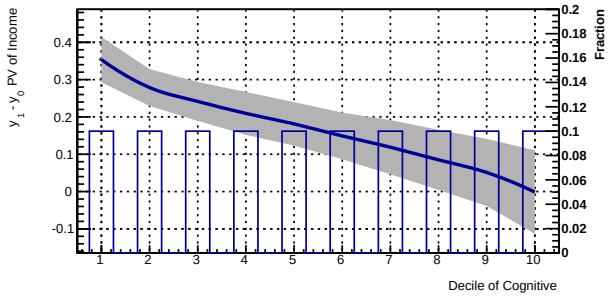


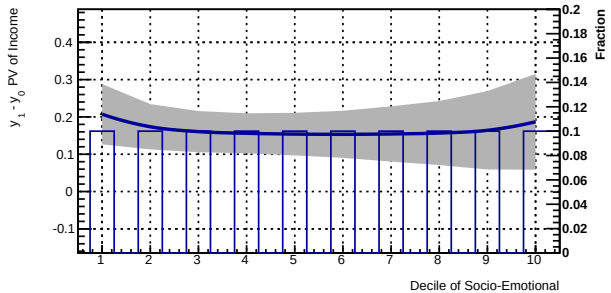
Source: Heckman et al. (2016b).

Figure 39 : Average Treatment Effect of Education on Present Value of Wages, by Decision Node and Endowment Levels

A. Graduating from HS vs. Dropping from HS



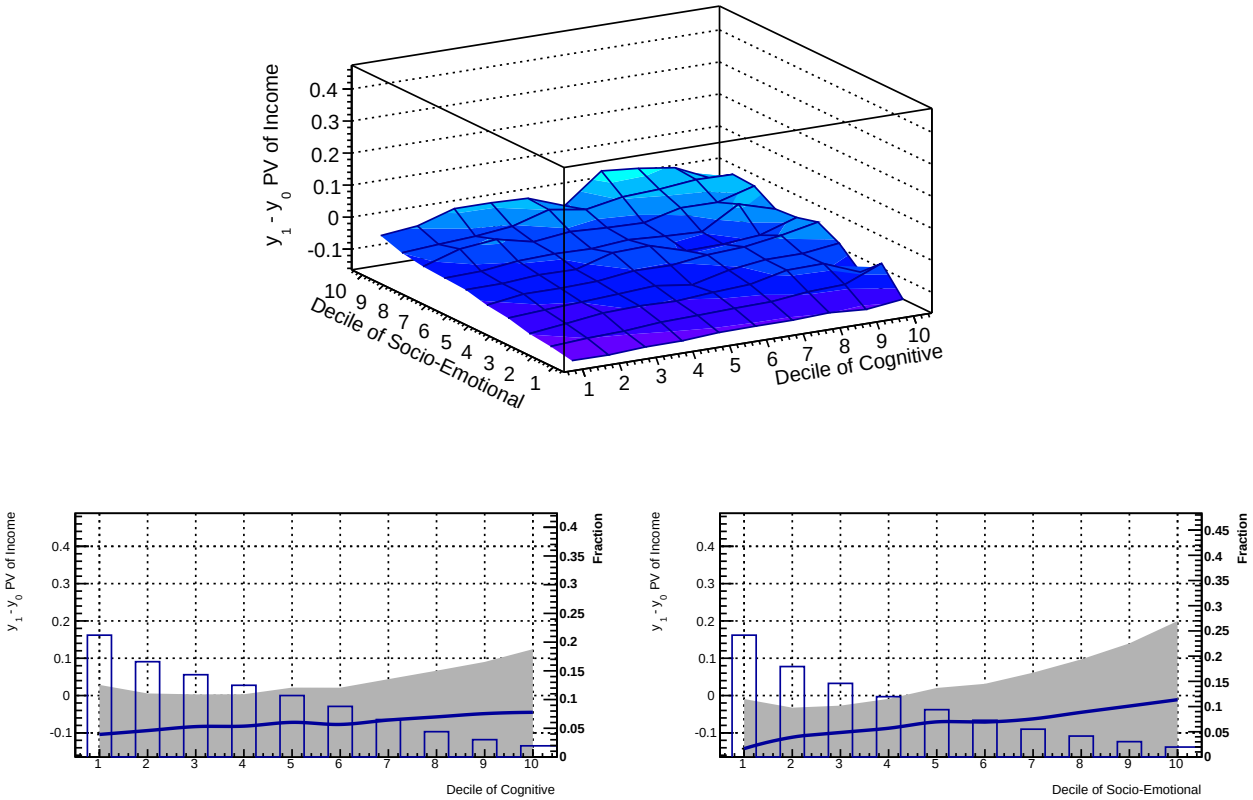




Source: Heckman et al. (2016b).

Figure 39 : Average Treatment Effect of Education on Present Value of Wages, by Decision Node and Endowment Levels, Cont'd

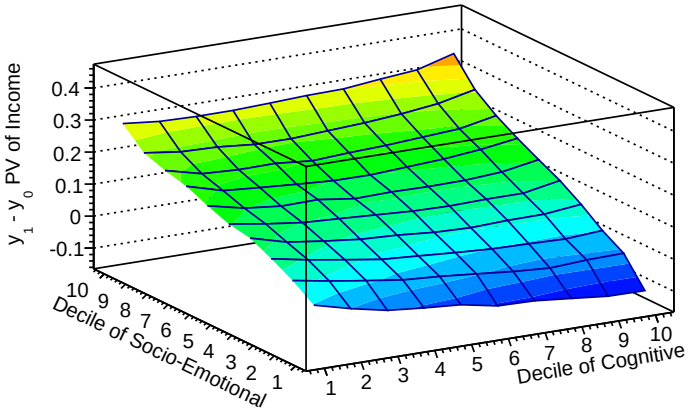
B. Getting a GED vs. **HS Dropout**

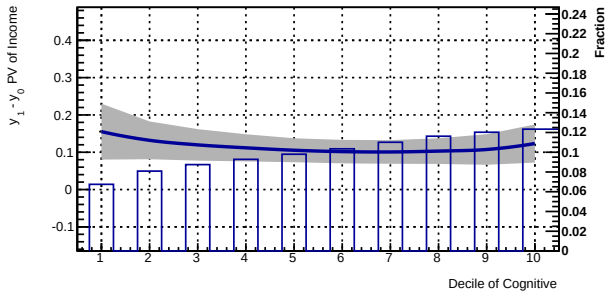


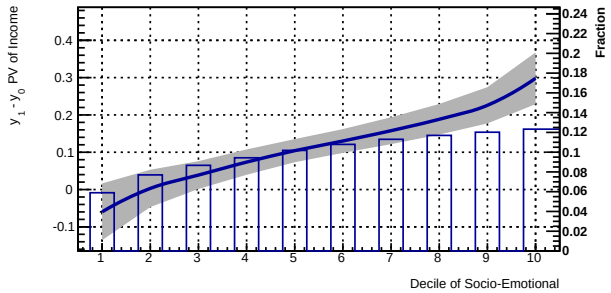
Source: Heckman et al. (2016b).

Figure 39 : Average Treatment Effect of Education on Present Value of Wages, by Decision Node and Endowment Levels, Cont'd

C. College Enrollment vs. **HS Graduate**



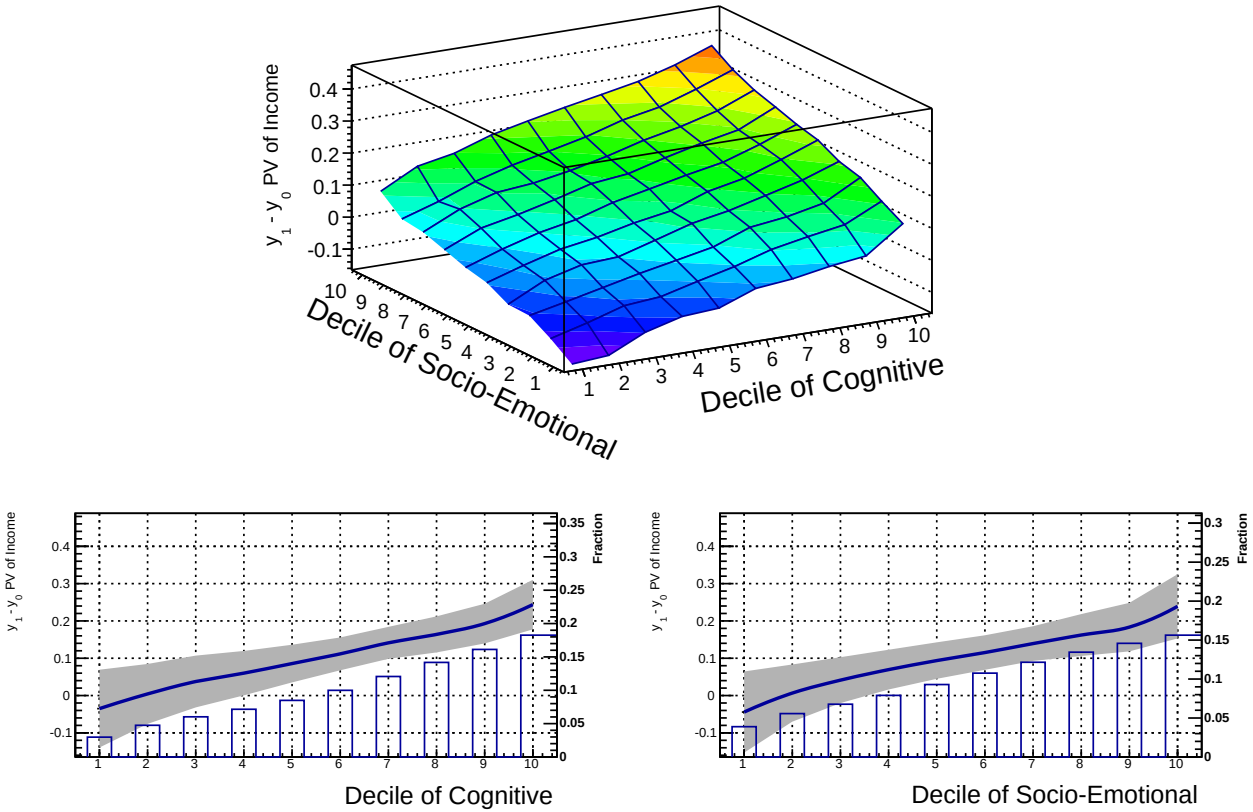




Source: Heckman et al. (2016b).

Figure 39 : Average Treatment Effect of Education on Present Value of Wages, by Decision Node and Endowment Levels, Cont'd

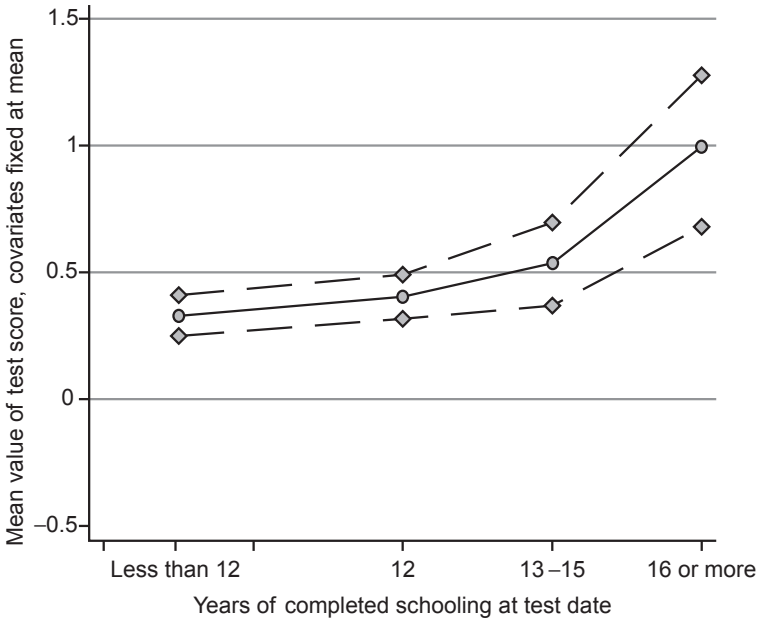
D. **Four-Year College Degree** vs. **Some College**



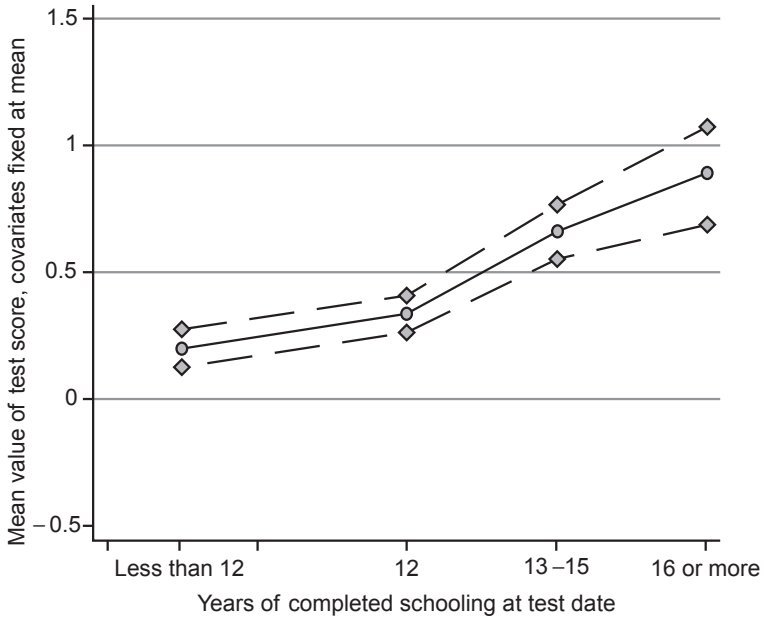
Source: Heckman et al. (2016b).

Figure 40 : Causal Effect of Schooling on ASVAB Measures of Cognition

(a) Arithmetic Reasoning



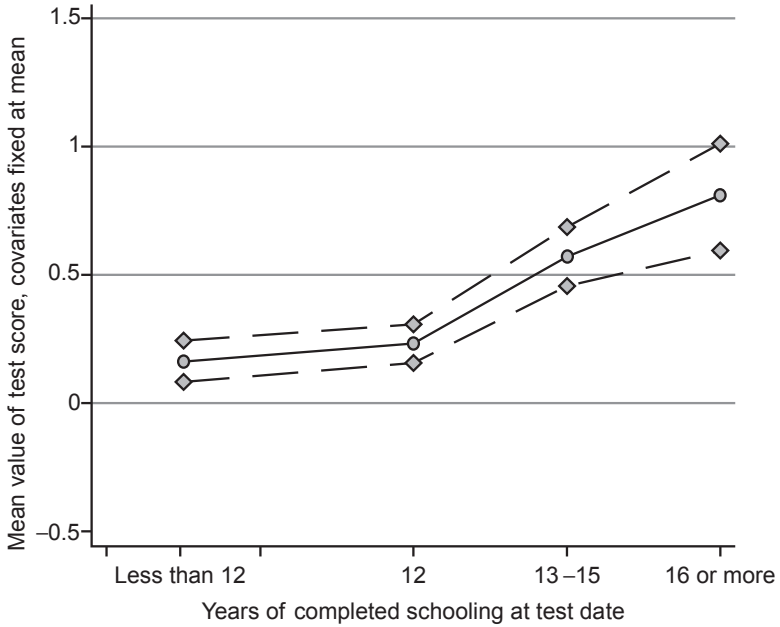
(b) Word Knowledge



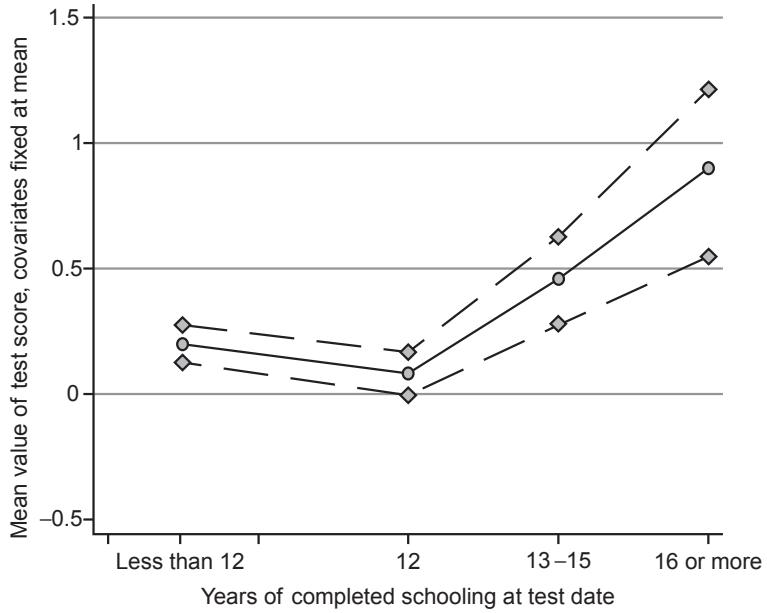
Source: Heckman et al. (2006, Figure 4).

Figure 40 : Causal Effect of Schooling on ASVAB Measures of Cognition

(c) Paragraph Comprehension



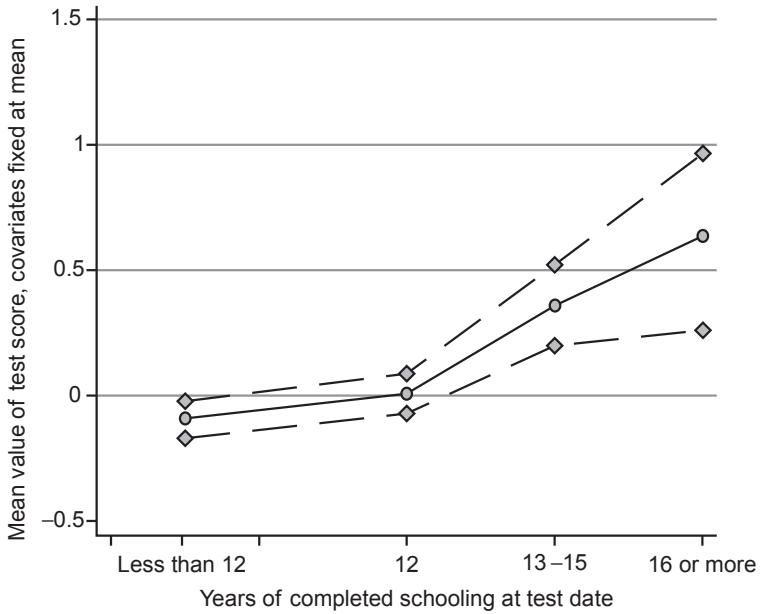
(d) Math Knowledge



Source: Heckman et al. (2006, Figure 4).

Figure 40 : Causal Effect of Schooling on ASVAB Measures of Cognition

(e) Coding Speed



Source: Heckman et al. (2006, Figure 4).