Extract for "The Technology of Skill Formation"

by James J. Heckman and Flavio Cunha. Published in the *American Economic Review* (2007). Volume 97, Issue 2, pp.31–47.

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Cunha and Heckman, 2007, and later work

- This paper uses simple economic models of skill formation to organize a large body of evidence on the development of skills in children in economics, psychology, education and neuroscience.
- The existing theoretical literature on child development in economics treats childhood as a single period (see, e.g., Gary S. Becker and Nigel Tomes, 1986; Roland Benabou, 2000; S. Rao Aiyagari et al., 2002).
- The implicit assumption in this approach is that inputs into the production of skills at different stages of childhood are perfect substitutes.

- To account for a large body of evidence, it is important to build models of skill formation with multiple stages of childhood, where inputs at different stages are complements and where there is self-productivity of investment.
- In order to rationalize the evidence, it is also important to recognize three distinct credit constraints operating on the family and its children.
  1. The inability of a child to choose its parents. This is the fundamental constraint imposed by the accident of birth.
  2. The inability of parents to borrow against their children's future income to finance investments in them.
  3. The inability of parents to borrow against their own income to finance investments in their children.

- A model that is faithful to the evidence must recognize:
  a. Parental influences are key factors governing child development;
  b. Early childhood investments must be distinguished from late childhood investments;
  c. An equity-efficiency trade-off exists for late investments, but not for early investments;
  d. Abilities are created, not solely inherited, and are multiple in variety;
  e. The traditional ability-skills dichotomy is misleading. Both skills and abilities are created; and
  f. The "nature versus nurture" distinction is obsolete.
  g. Gene-environment or epigenetic interactions are important.

- These insights change the way we interpret evidence and design policy about investing in children.
- Point (a) is emphasized in many papers.
- Point (b) is ignored in models that consider only one period of childhood investment.
- Points (c), (d) and (e) have received scant attention in the formal literature on child investment.
- Point (f) is ignored in the literature that partitions the variance of child outcomes into components due to nature and components due to nurture.

Observations About Human Diversity and Human Development and Some Facts Our Model Explains

Three Observations

- The first observation is that *ability matters*.
- A large number of 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.

- Second observation: *Abilities are multiple in nature*.
- Noncognitive abilities (perseverance, motivation, time preference, risk aversion, self-esteem, self-control, preferences for leisure) have direct effects on wages (controlling for schooling), schooling, teenage pregnancy, smoking, crime, performance on achievement tests and many other aspects of social and economic life.
- See, e.g., Samuel Bowles and Herb Gintis (1976); Samuel Bowles et al. (2001); Lex Borghans et al. (2006); Heckman et al. (2006).

Some Evidence on the Importance of Cognitive and Noncognitive Skills

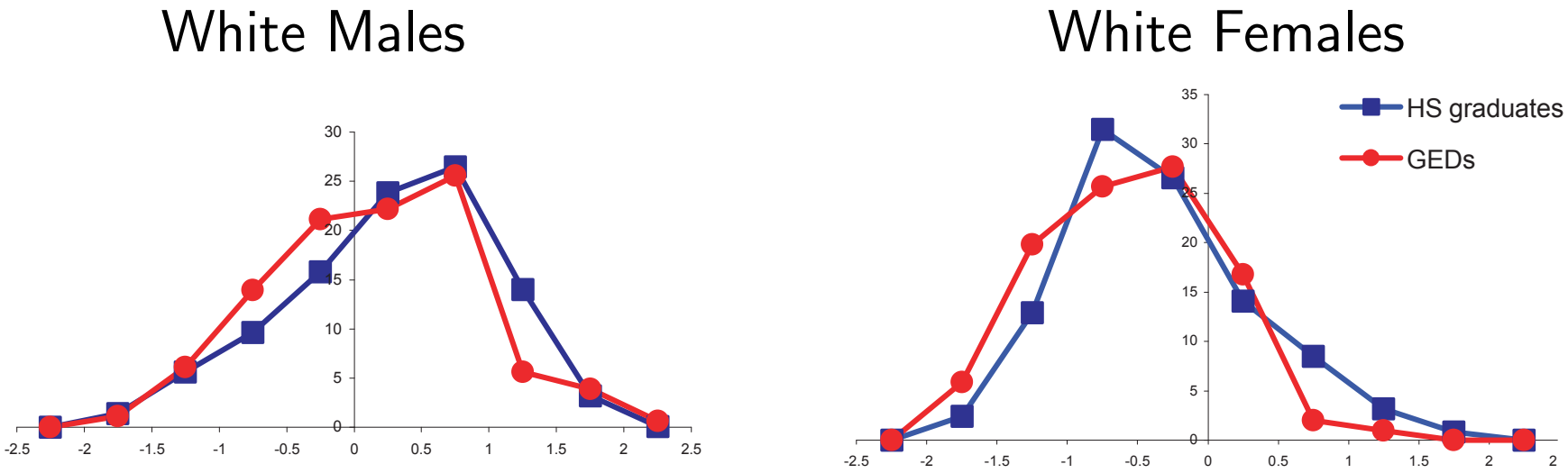
- Recent research has shown that earnings, employment, labor force experience, college attendance, teenage pregnancy, participation in risky activities, compliance with health protocols and participation in crime strongly depend on cognitive and noncognitive abilities.
- Noncognitive abilities mean socioemotional regulation, time preference, personality factors and ability to work with others.

- Much public policy discussion is devoted to cognitive scores or "smarts."
- Many governments and public policy officials focus on achievement on a test score at a certain age to measure success or failure in schools.
- Yet an emerging body of evidence shows that, as is intuitively obvious and commonsensical, much more than smarts are required.
    - Motivation,
    - Sociability; ability to work with others,
    - Attention,
    - Self Regulation,
    - Self Esteem,
    - Time Preference,
    - Health and Mental Health.

- The importance of noncognitive skills, for example, tends to be underrated in current policy discussions because they are not easily measured.
- A lot of recent evidence shows that the workplace is increasingly oriented towards a greater valuation of social interaction and sociability.
- Evidence from the GED program (Heckman and Rubinstein, 2001).

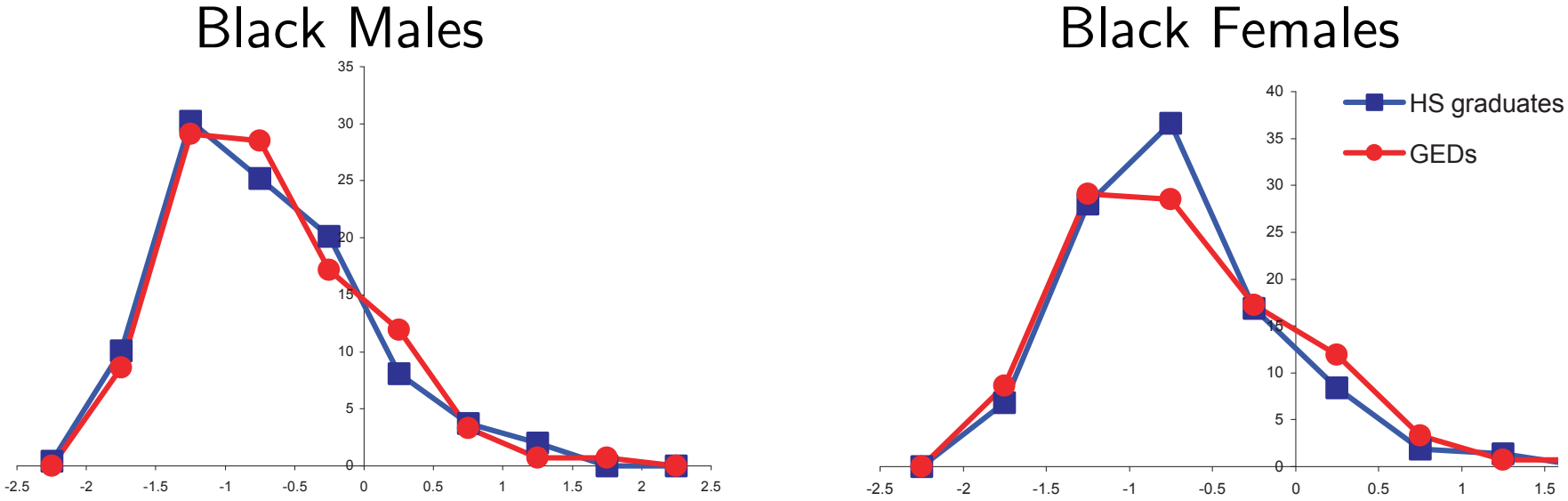
- The GED program is a second chance program given to secondary school dropouts in the U.S. and Canada.
- Participation in the GED program is growing. Currently 20% of U.S. high school "graduates" are dropouts who exam certify.
- GEDs are required to pass a test of cognitive abilities.
- Level relatively low–at the grade 8 to grade 10 level.
- Test is successful in its own terms.

Density of age adjusted AFQT scores, GED recipients and high school graduates with twelve years of schooling



Source: Heckman, Hsee and Rubinstein (2001)

Density of age adjusted AFQT scores, GED recipients and high school graduates with twelve years of schooling



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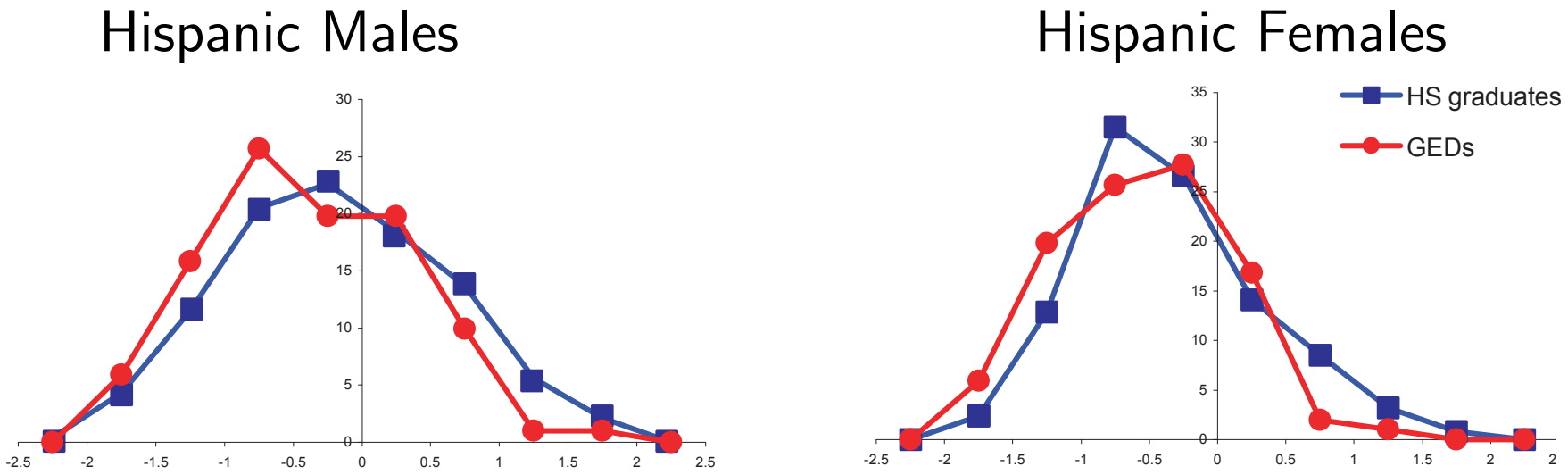
Density of age adjusted AFQT scores, GED recipients and high school graduates with twelve years of schooling



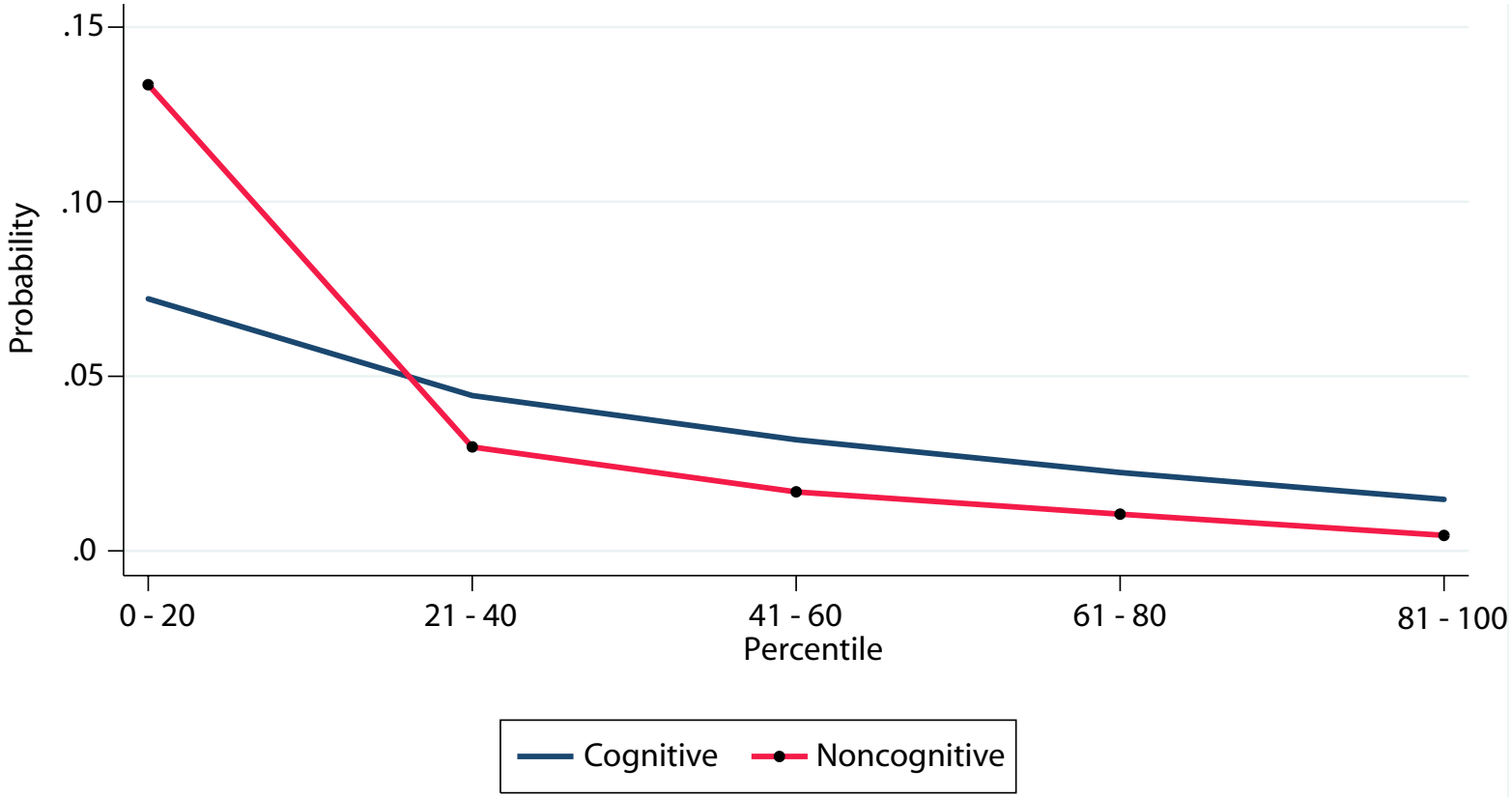
Source: Heckman, Hsee and Rubinstein (2001)

- Yet GEDs earn at the rate of high school dropouts.
- GEDs are as "smart" as ordinary high school graduates.
- They lack noncognitive skills.
- The GEDs are the wise guys who can't finish anything.
- Most branches of the U.S. military recognize this in their recruiting strategies.

- There is a lot of evidence that both cognitive and noncognitive skills are important.
- Both cognitive and noncognitive skills matter in a variety of aspects of life.

- Cognitive and noncognitive ability are important determinants of schooling and socioeconomic success.
- In the U.S. and many countries around the world, schooling gaps across ethnic and income groups have more to do with ability deficits than family finances in the school-going years.
- Those with higher abilities of both types are more likely to take post-school company job training, to participate in prevention programs; less likely be obese; have greater health and mental health.
- Look at effects of both cognitive and noncognitive skills on many measures of social performance.

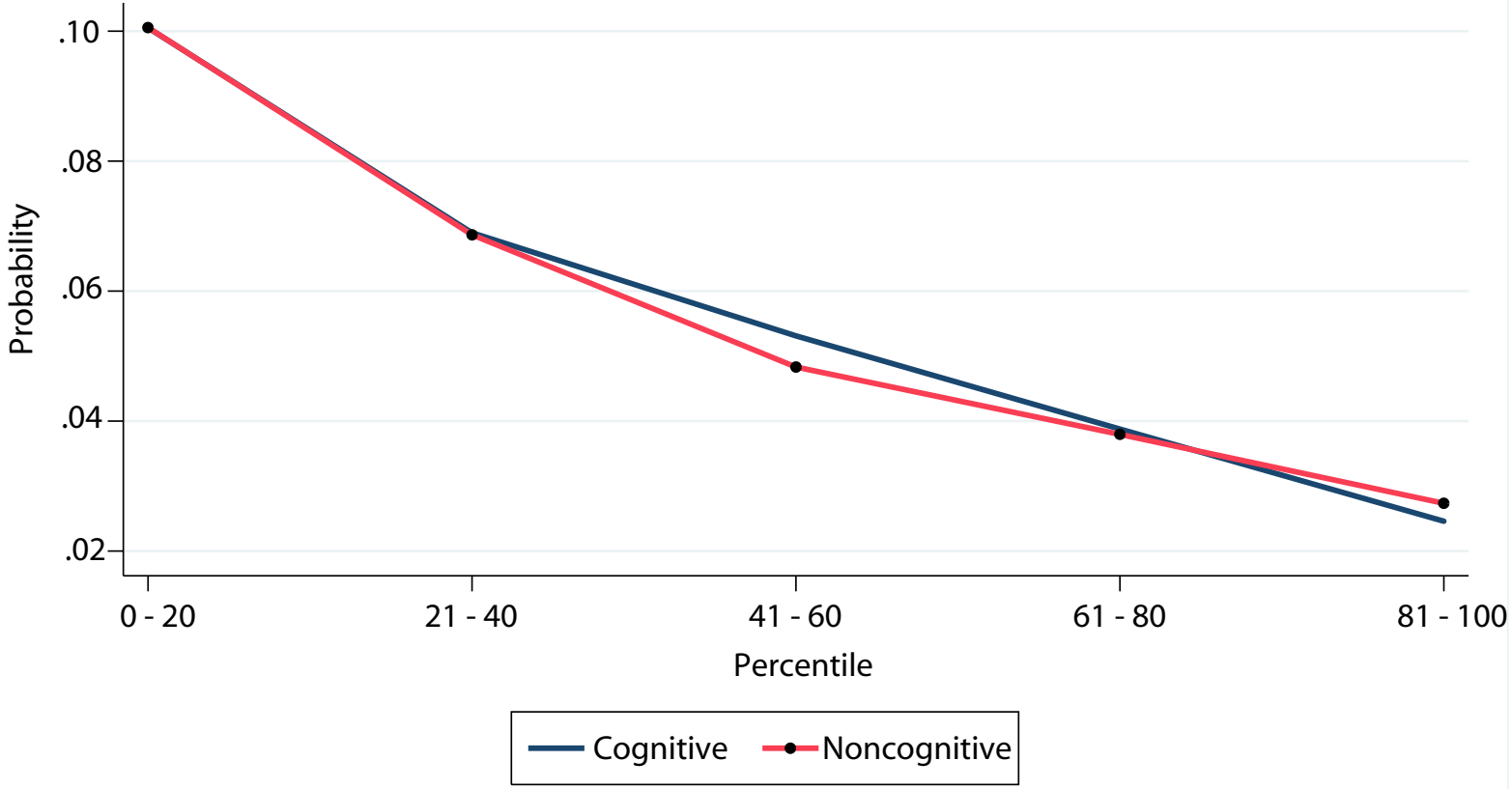
Ever been in jail by age 30, by ability (males)



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).

Probability of being single with children (females)



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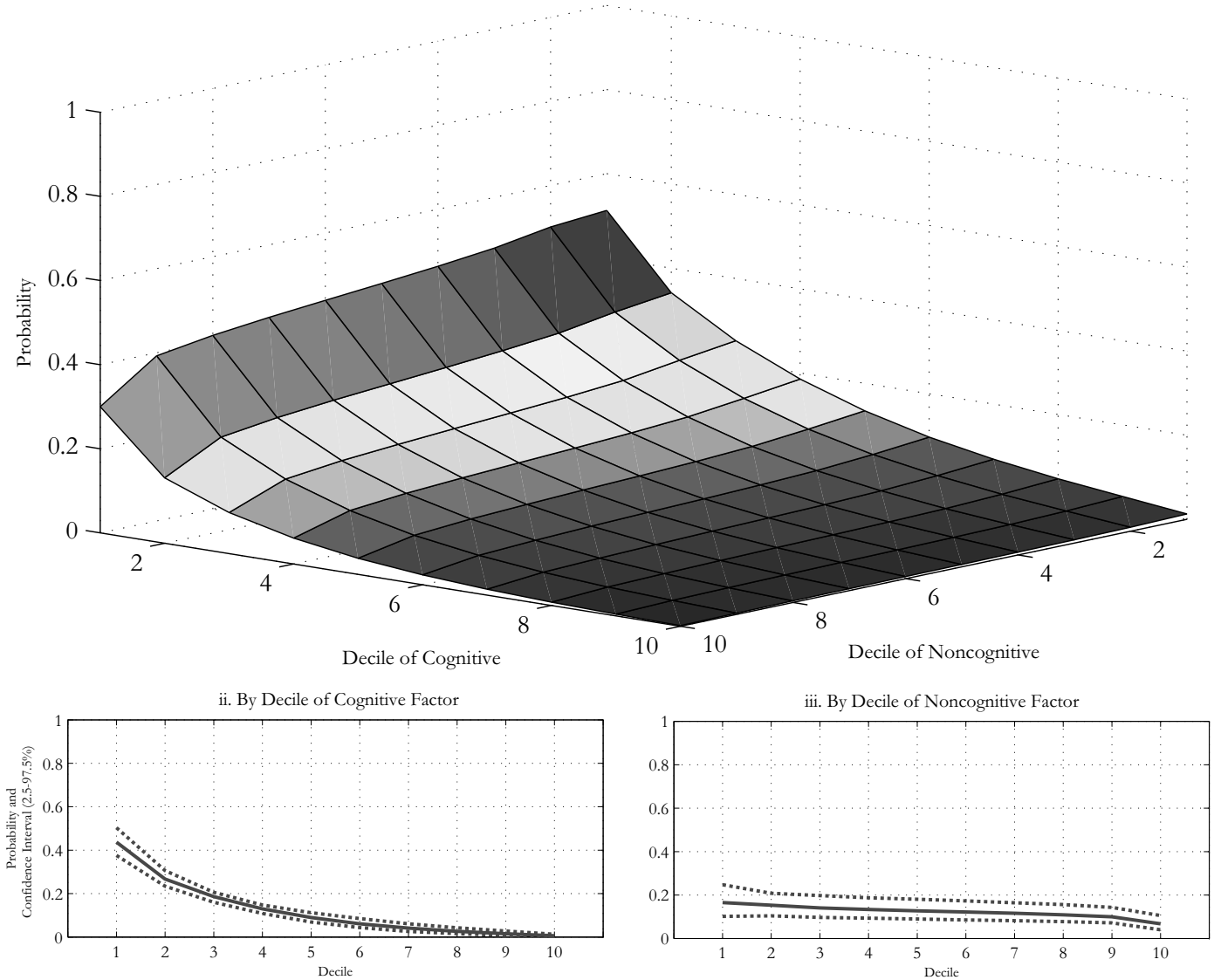
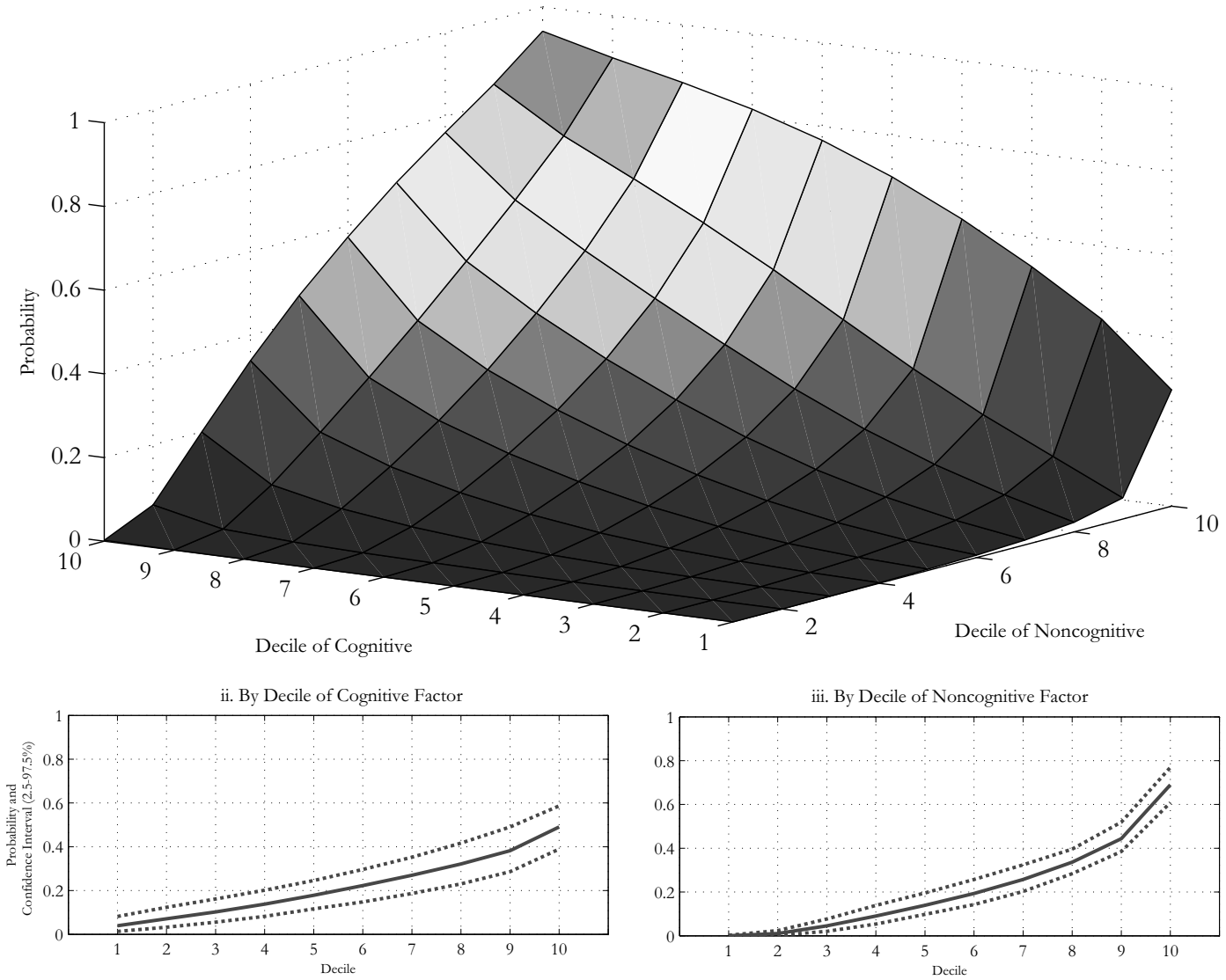
Source: Heckman, Stixrud, and Urzua (2006).

Probability of being a high school dropout by age 30 (males)



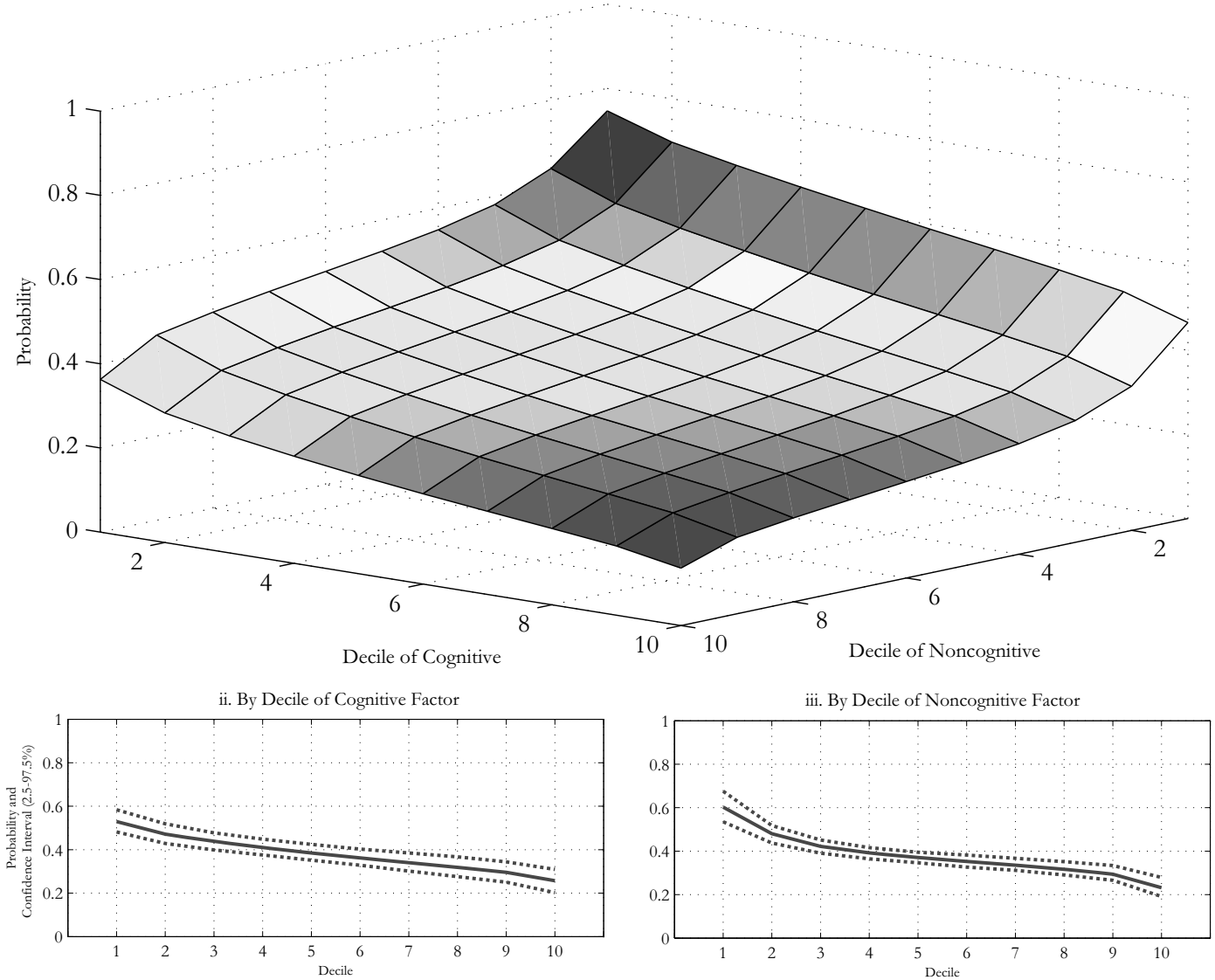
Notes: The data are simulated from the estimates of the model and our NLSY79 sample. We use the standard convention that higher deciles are associated with higher values of the variable. The confidence intervals are computed using bootstrapping (200 draws).

Probability of being a 4-year college graduate by age 30 (males)



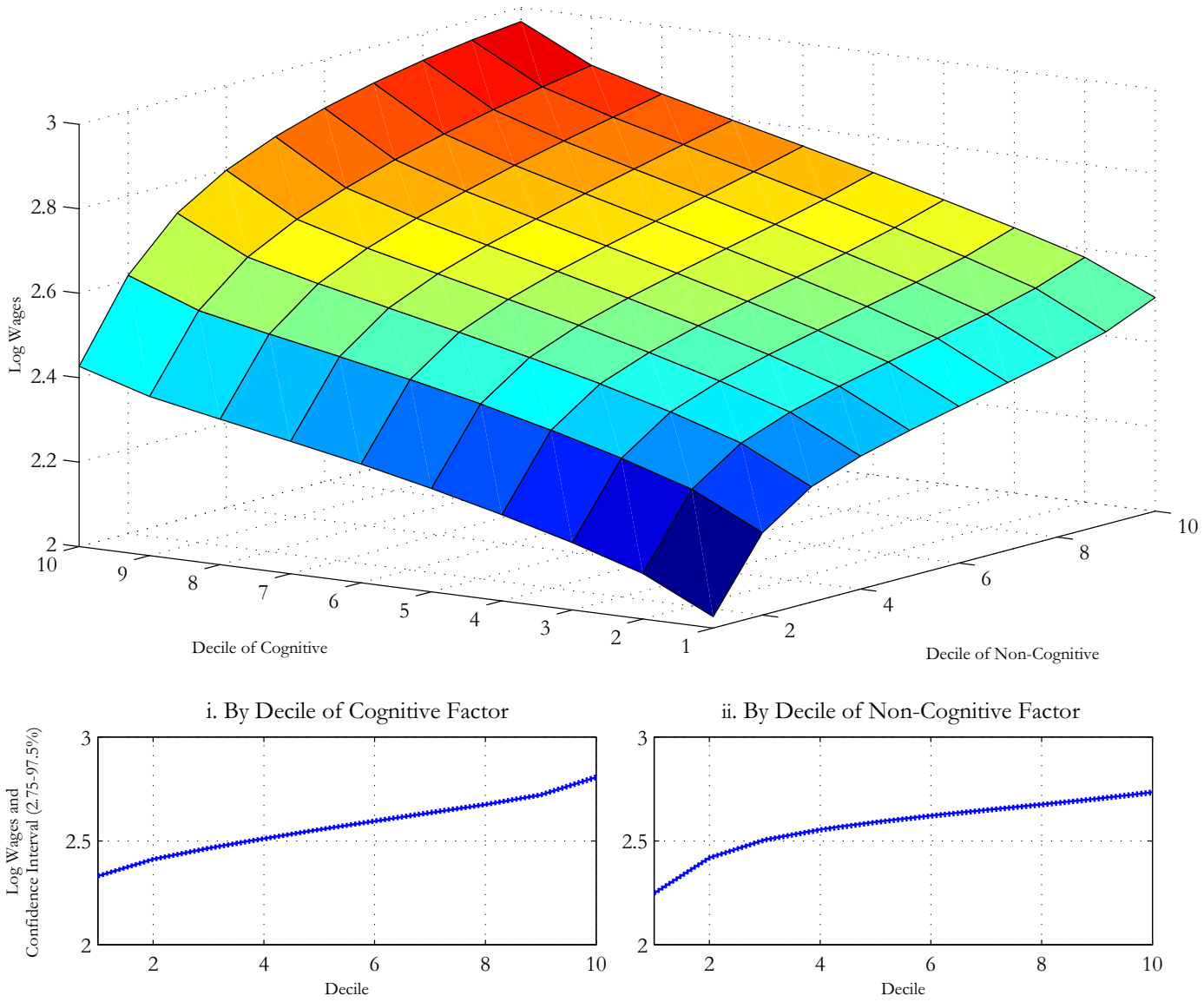
Notes: The data are simulated from the estimates of the model and our NLSY79 sample. We use the standard convention that higher deciles are associated with higher values of the variable. The confidence intervals are computed using bootstrapping (200 draws).

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).

Mean log wages by age 30 (males)



- Controlling for ability, minorities are *more likely* to attend college than others despite their lower family incomes (Cameron and Heckman, 2001).

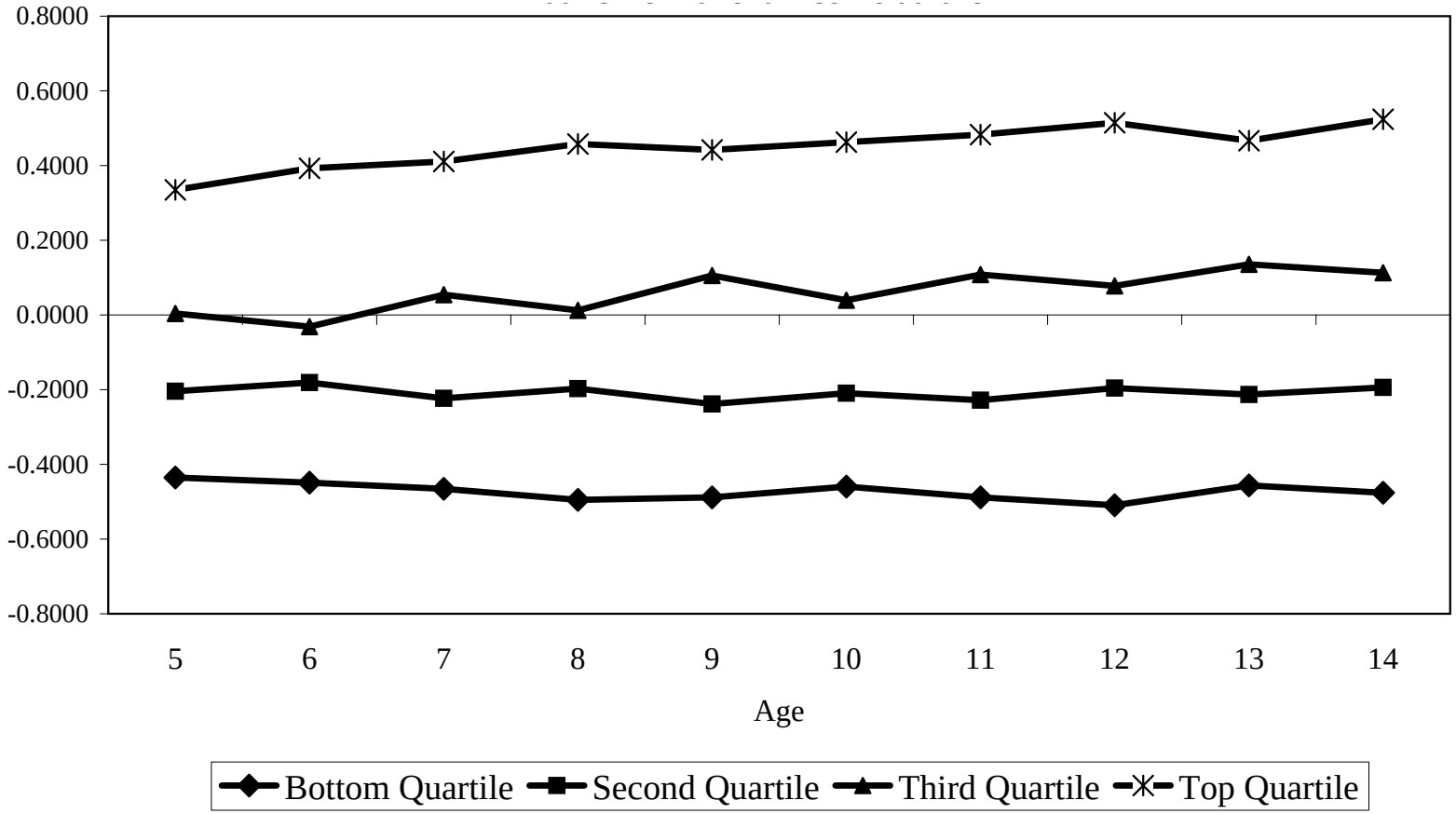
- A third observation is that the "nature versus nurture" distinction is obsolete.
- The modern literature on epigenetic expression teaches us that the sharp distinction between acquired skills and ability featured in the early human capital literature is not tenable.
- Additive "nature" and "nurture" models, while traditional and still used in many studies of heritability and family influence, mischaracterize how ability is manifested.

- Abilities are produced, and gene expression is governed by environmental conditions (Eric Turkheimer et al., 2003).
- Measured abilities are susceptible to environmental influences, including *in utero* experiences, and also have genetic components.
- These factors interact to produce abilities that have both a genetic and an acquired character and the modified genes are heritable. Genes and environment cannot be meaningfully parsed by traditional linear models that assign variance to each component, even though it is traditional to do so.

Six Facts We Explain

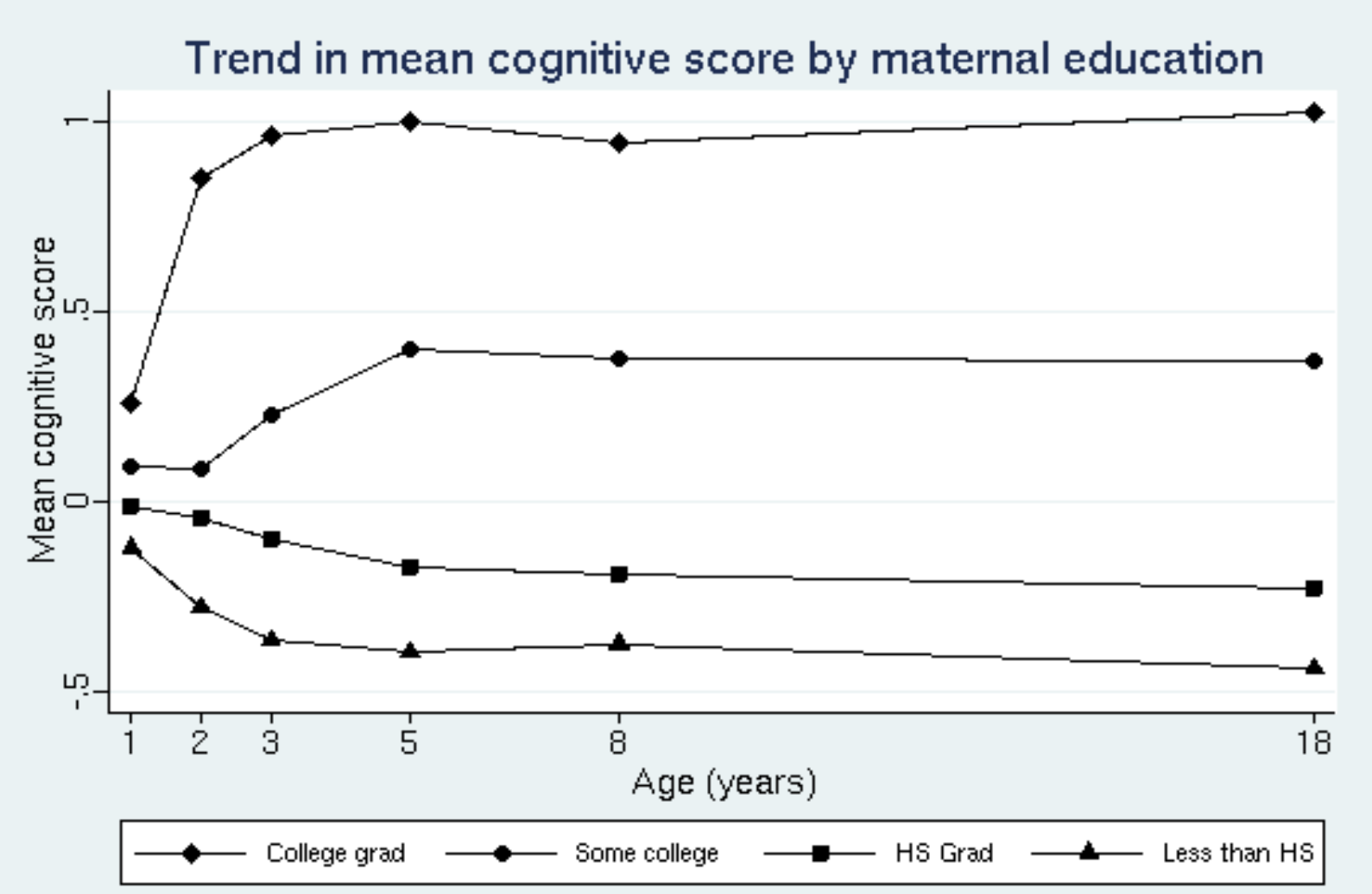
- First, *ability gaps between individuals and across socioeconomic groups open up at early ages, for both cognitive and noncognitive skills*.
- Adjusting for family background by regression analysis reduces these gaps.
- Experimental manipulations of early environments (Perry, Abecedarian et al.) show that these effects are causal.

Figure 1: Children of NLSY Average Standardized Score PIAT Math by Permanent Income Quartile



Source: Full Sample of CNLSY

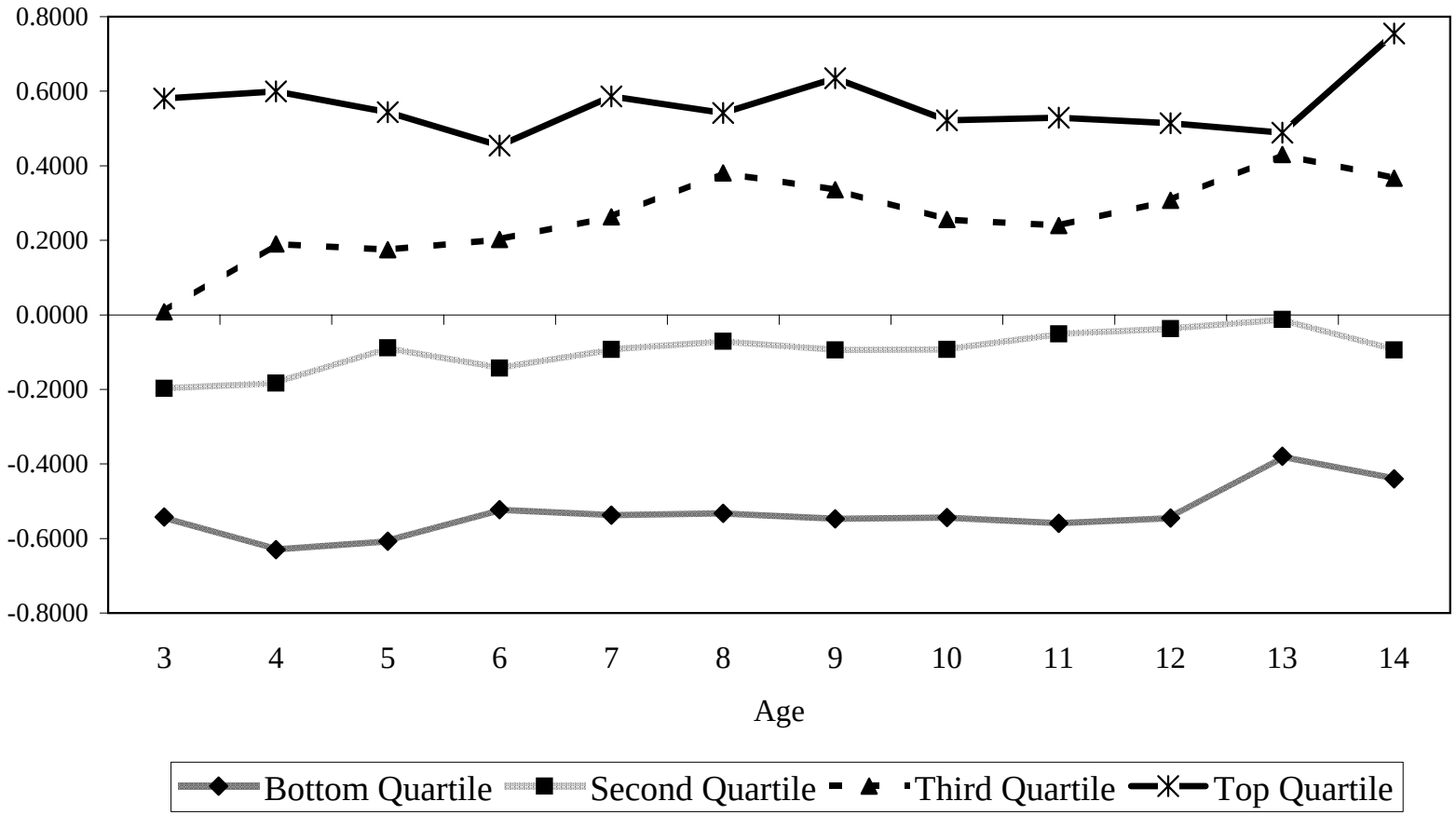
Figure D0: Trend in Mean Cognitive Score by Maternal Education



Source: Brooks-Gunn et al., (2006).

- The dramatic results on the importance of the early years in creating differences among children shown in the previous graph arise if "Bayley scores" are used as a measure of cognition at age 1.
- As Michael Lewis and Harry McGurk (1972) point out, this is illegitimate since the Bayley score tests other aspects of child development in addition to cognition.

Figure D00: Children of NLSY Average Standardized Score Peabody Picture Vocabulary Test by Permanent Income Quartile



Source: Full Sample of CNLSY

Figure D1a. Average percentile rank on PIAT-Math score, by income quartile

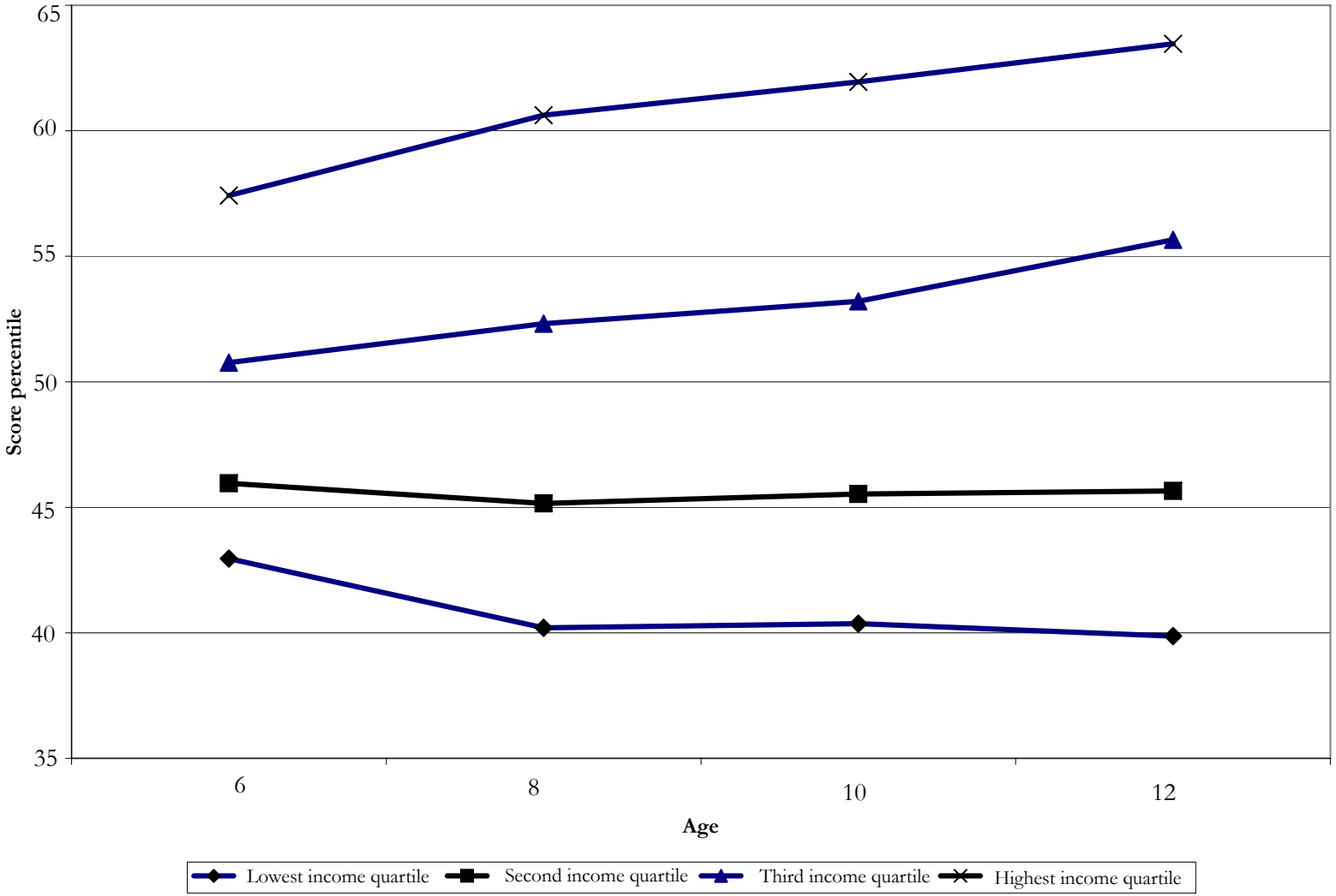


Figure D1b. Adjusted average PIAT-Math score percentiles, by income quartile

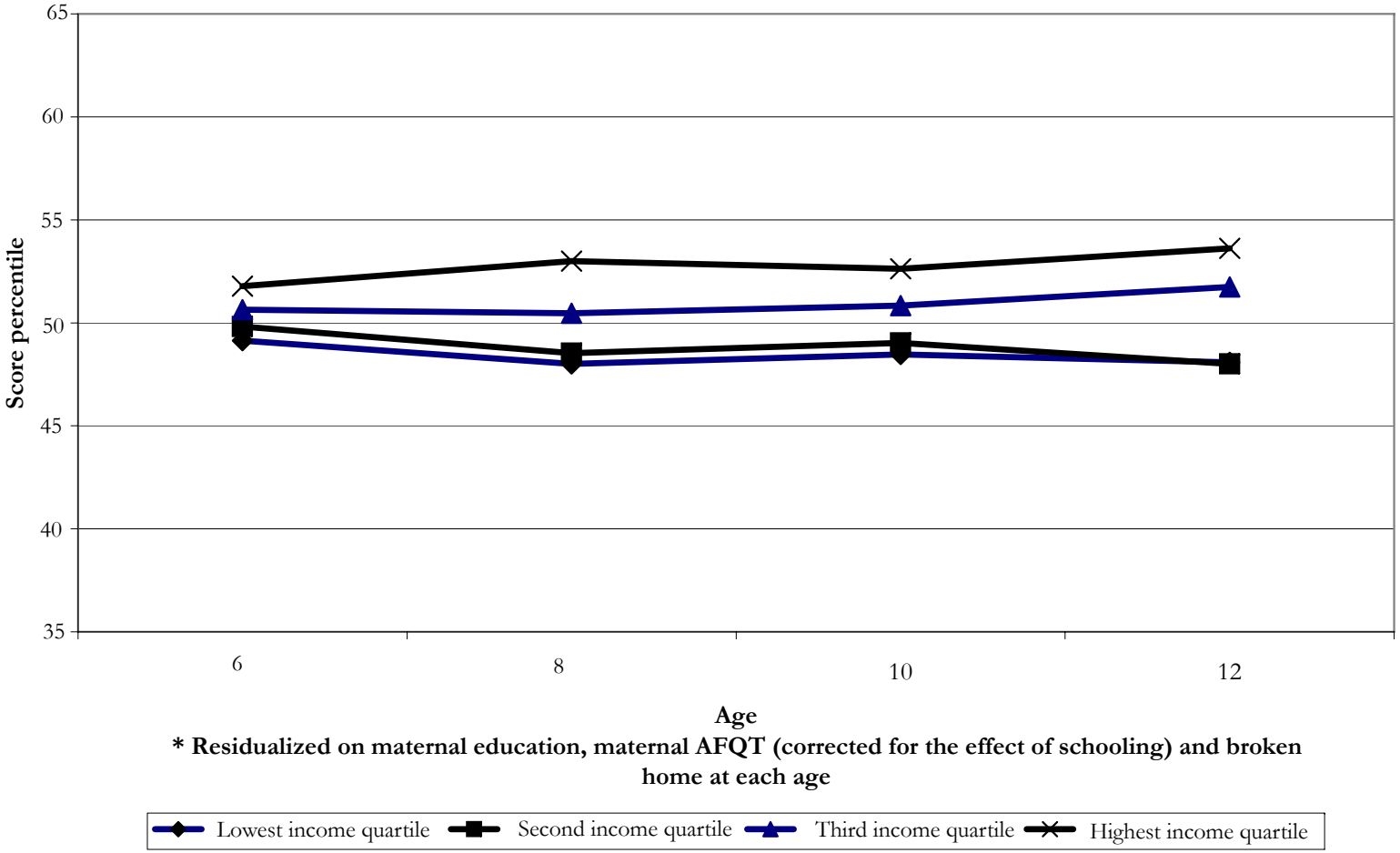


Figure D2a. Average percentile rank on PIAT-Math score, by race

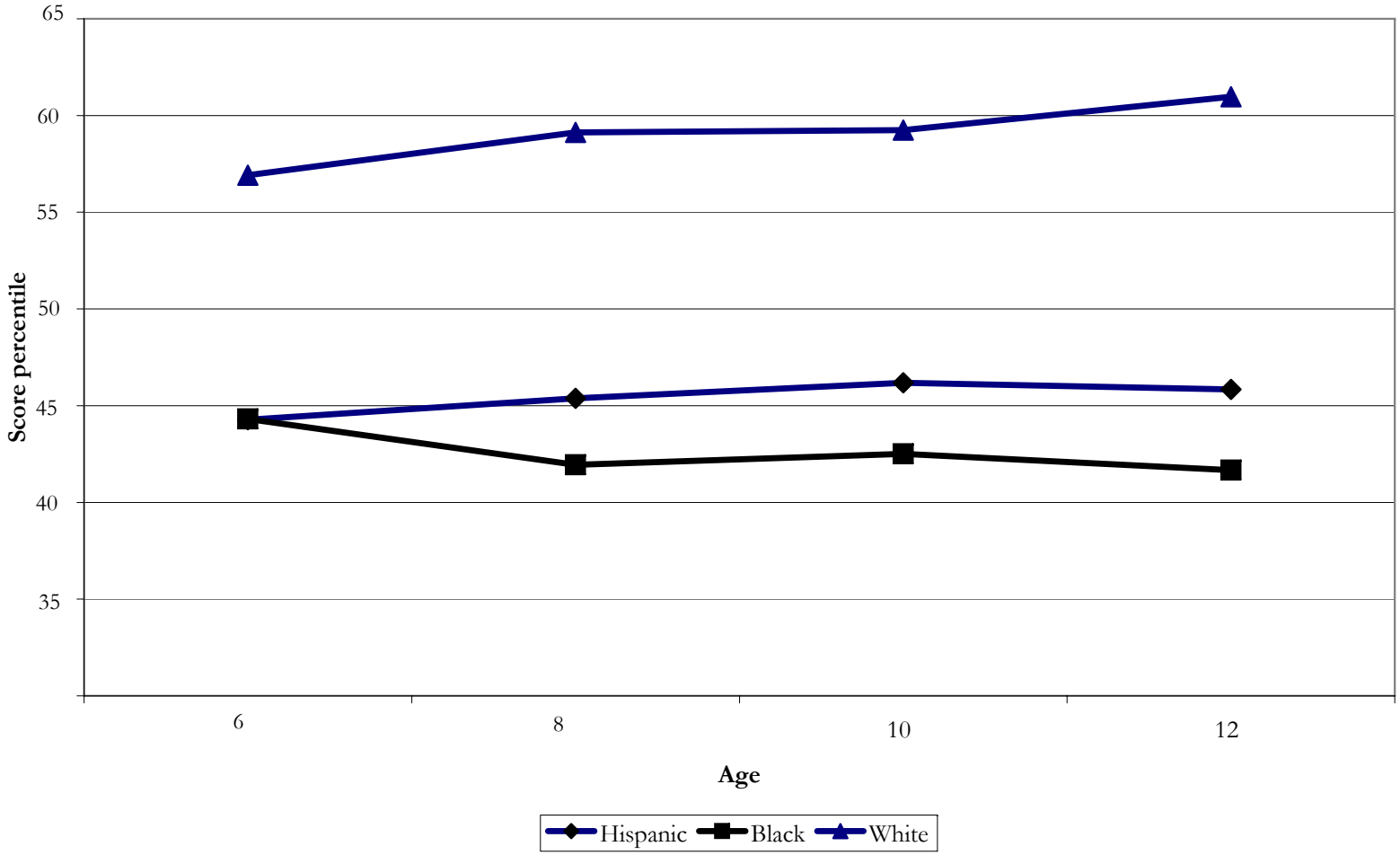


Figure D2b. Adjusted average PIAT-Math score percentiles, by race

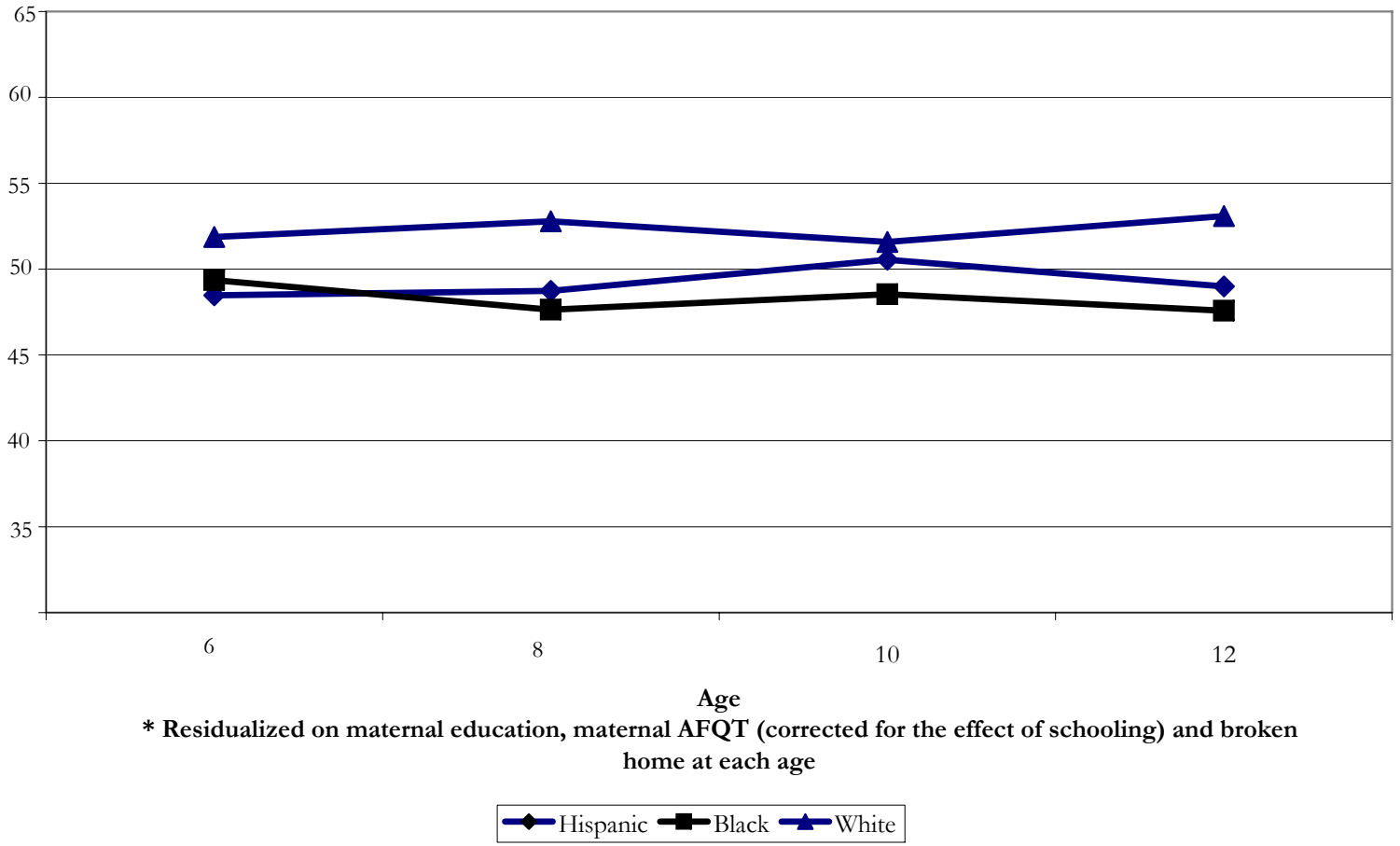


Figure D3a. Average percentile rank on anti-social behavior score, by income quartile

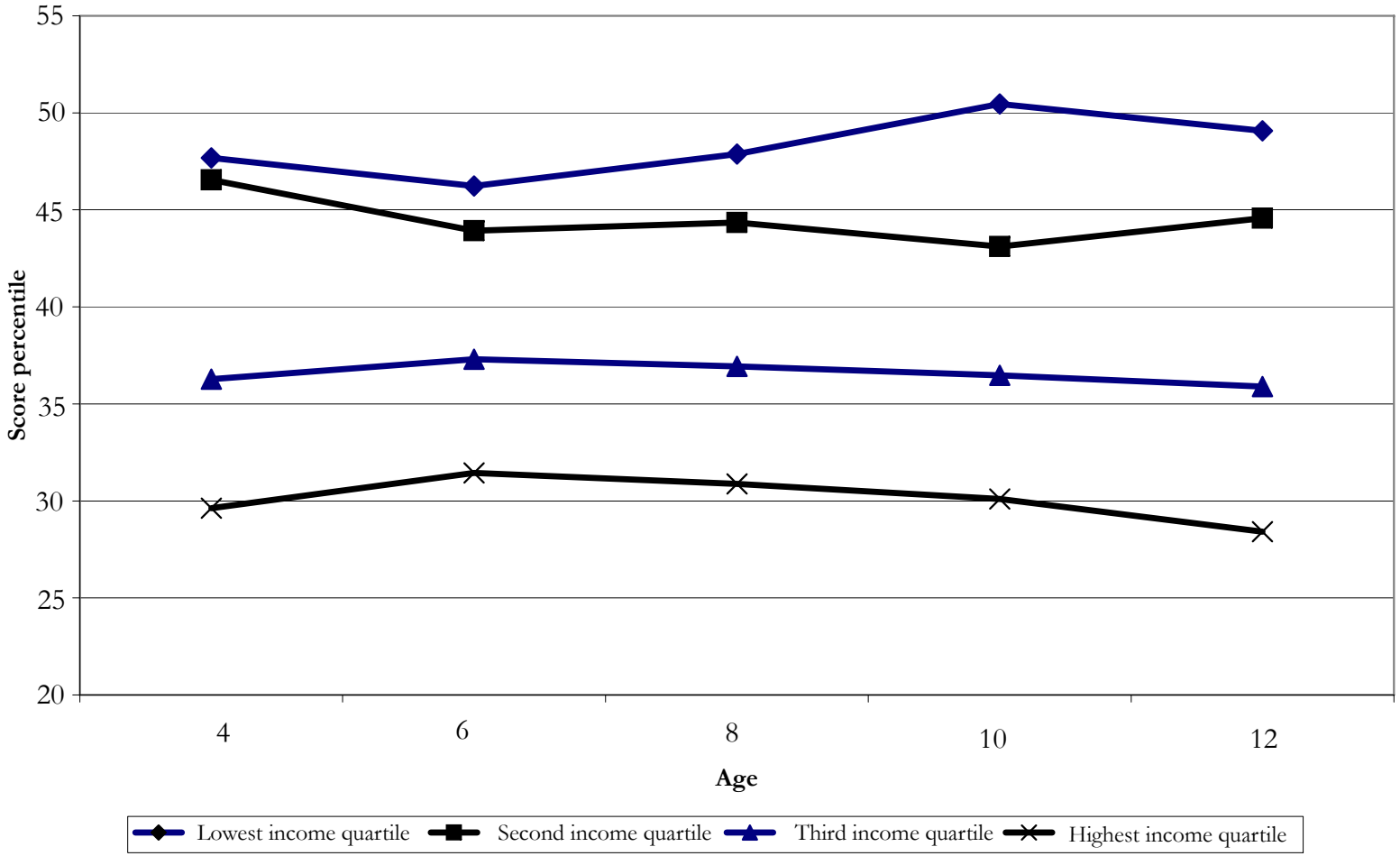


Figure D3b. Adjusted average anti-social behavior score percentile, by income quartile

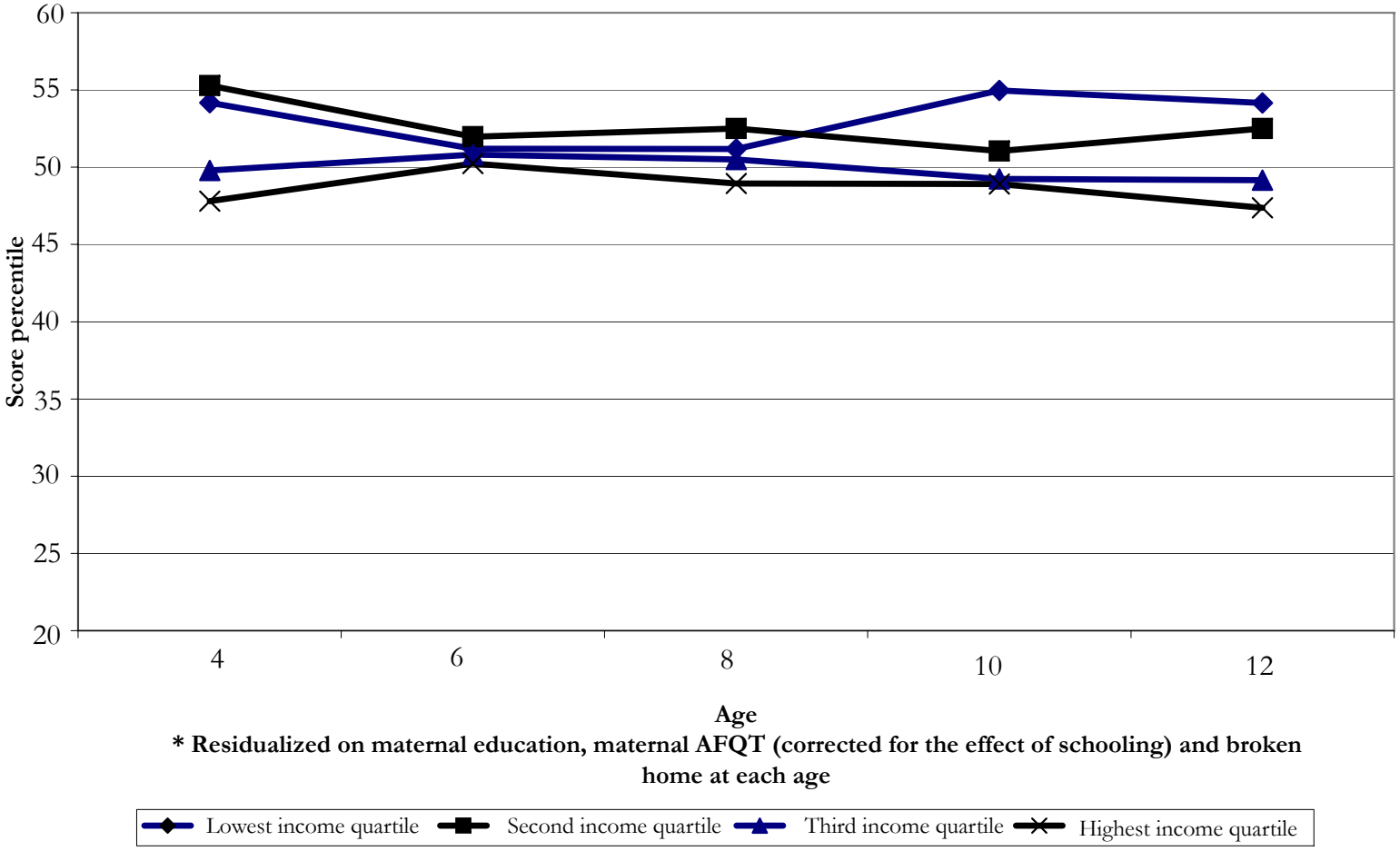


Figure D4a. Average percentile rank on anti-social behavior score, by race

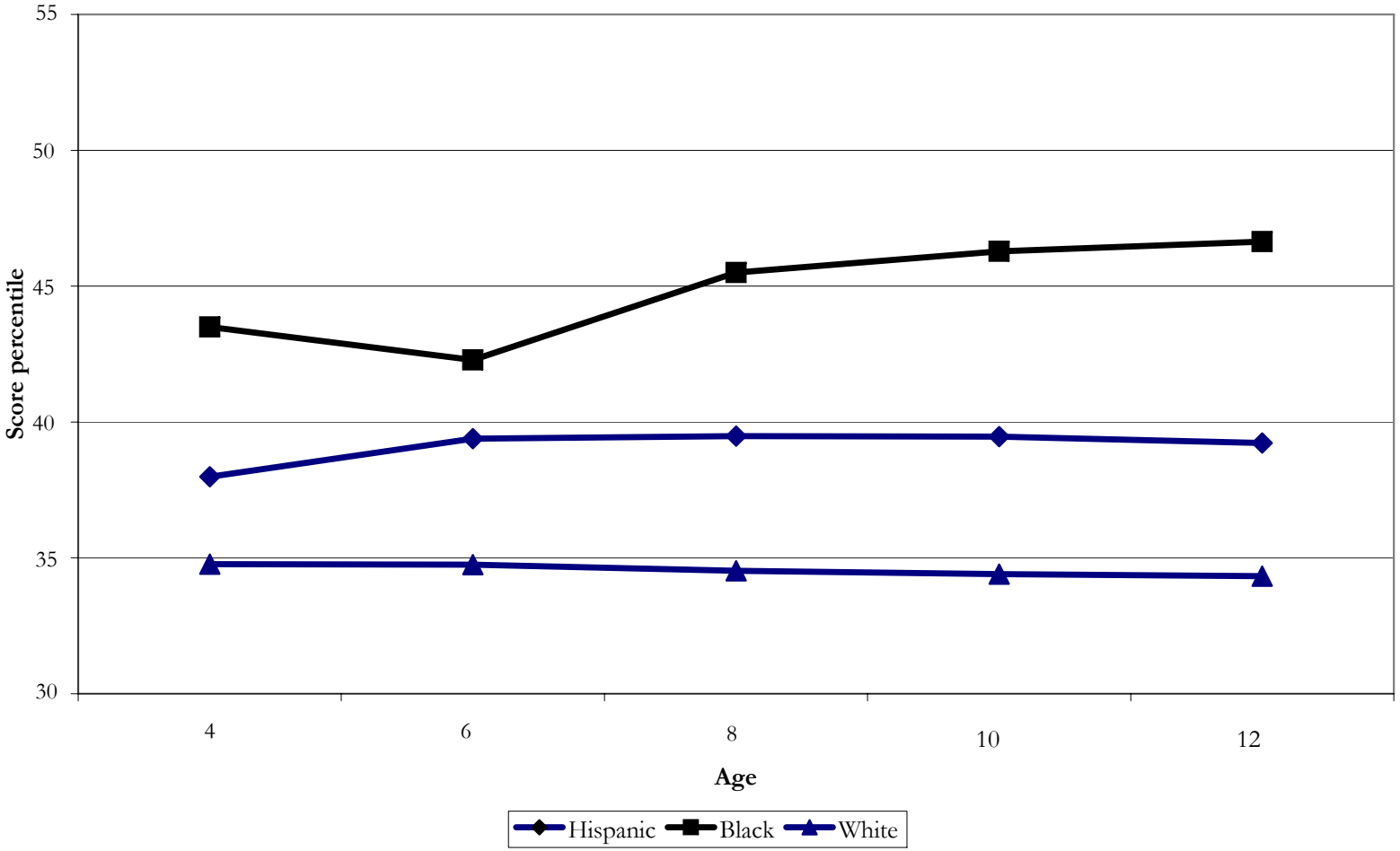


Figure D4b. Adjusted average anti-social behavior score percentile, by race

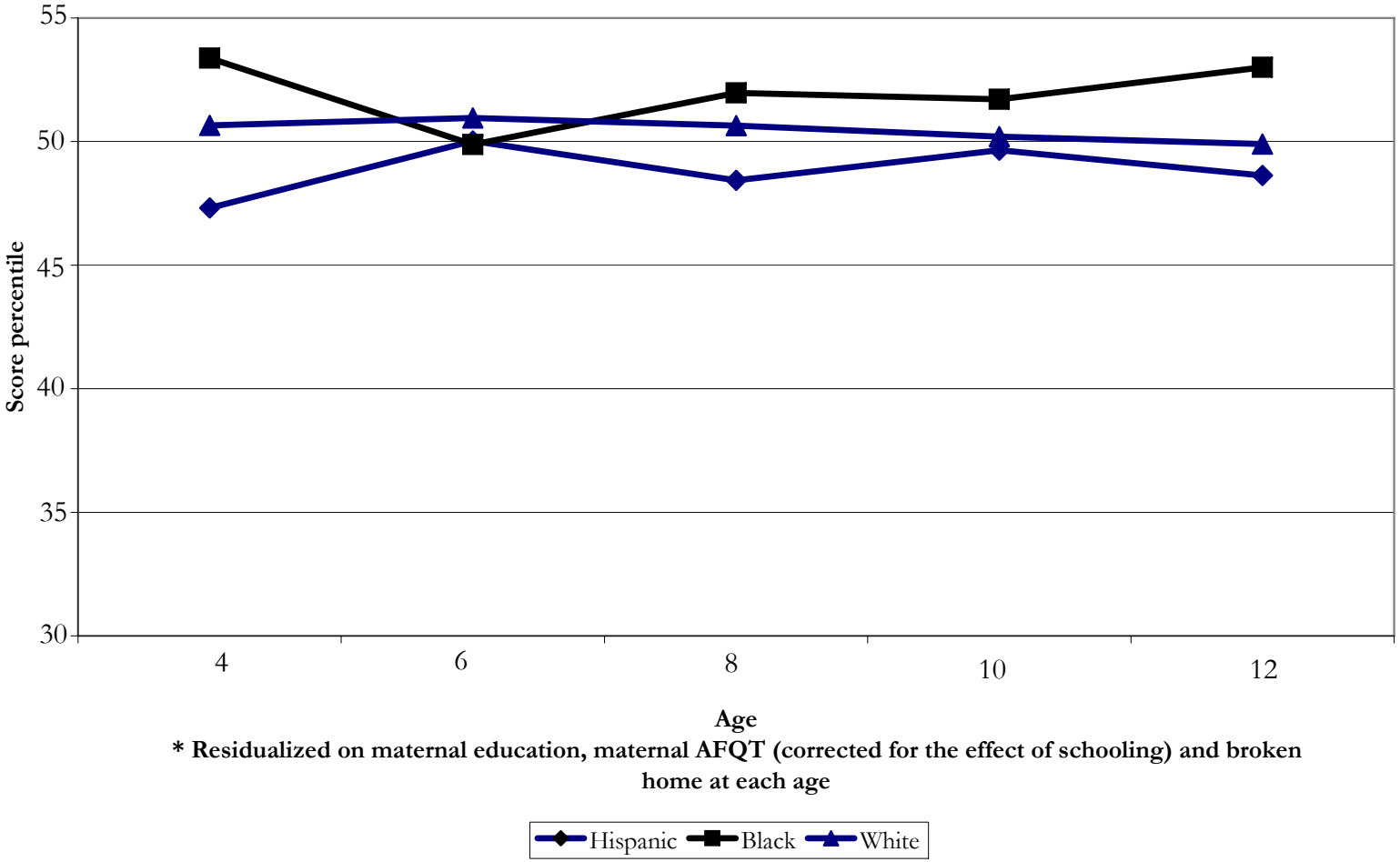
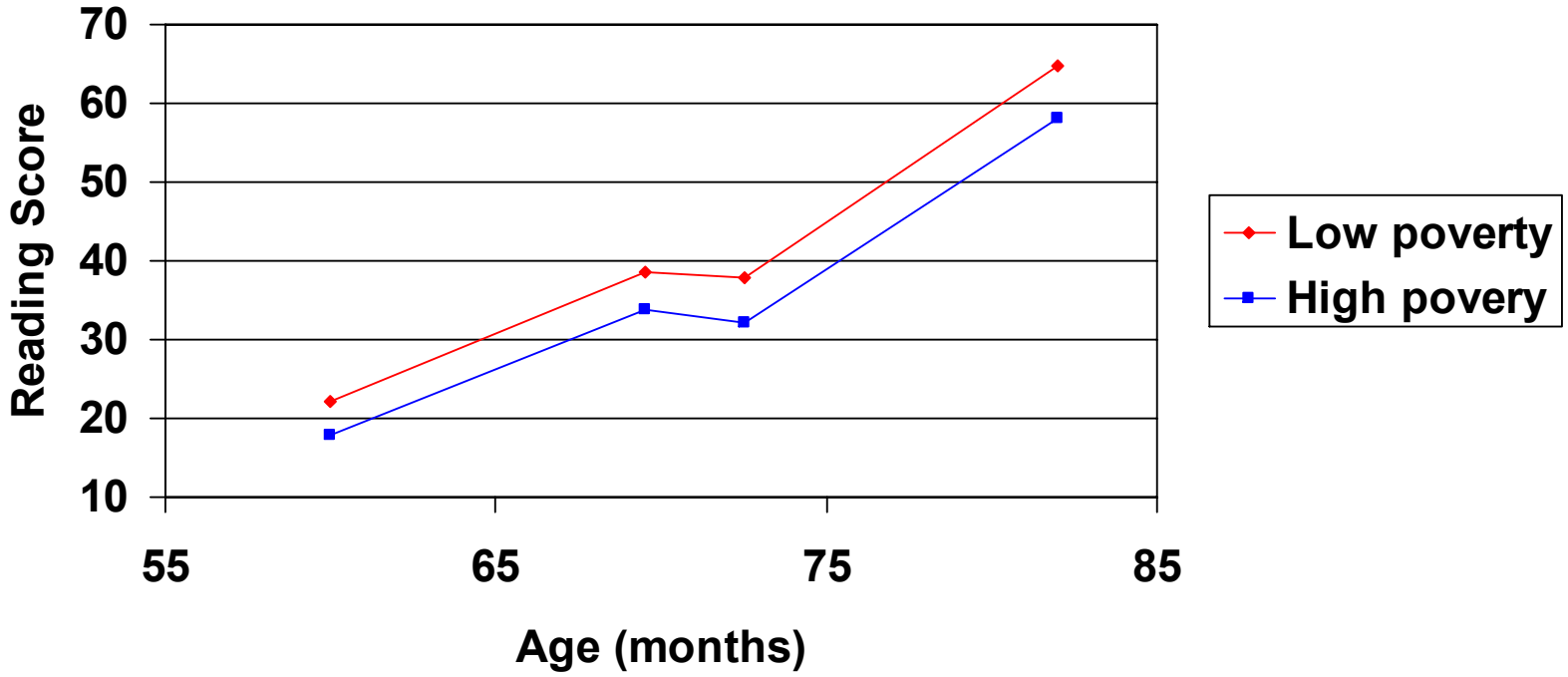
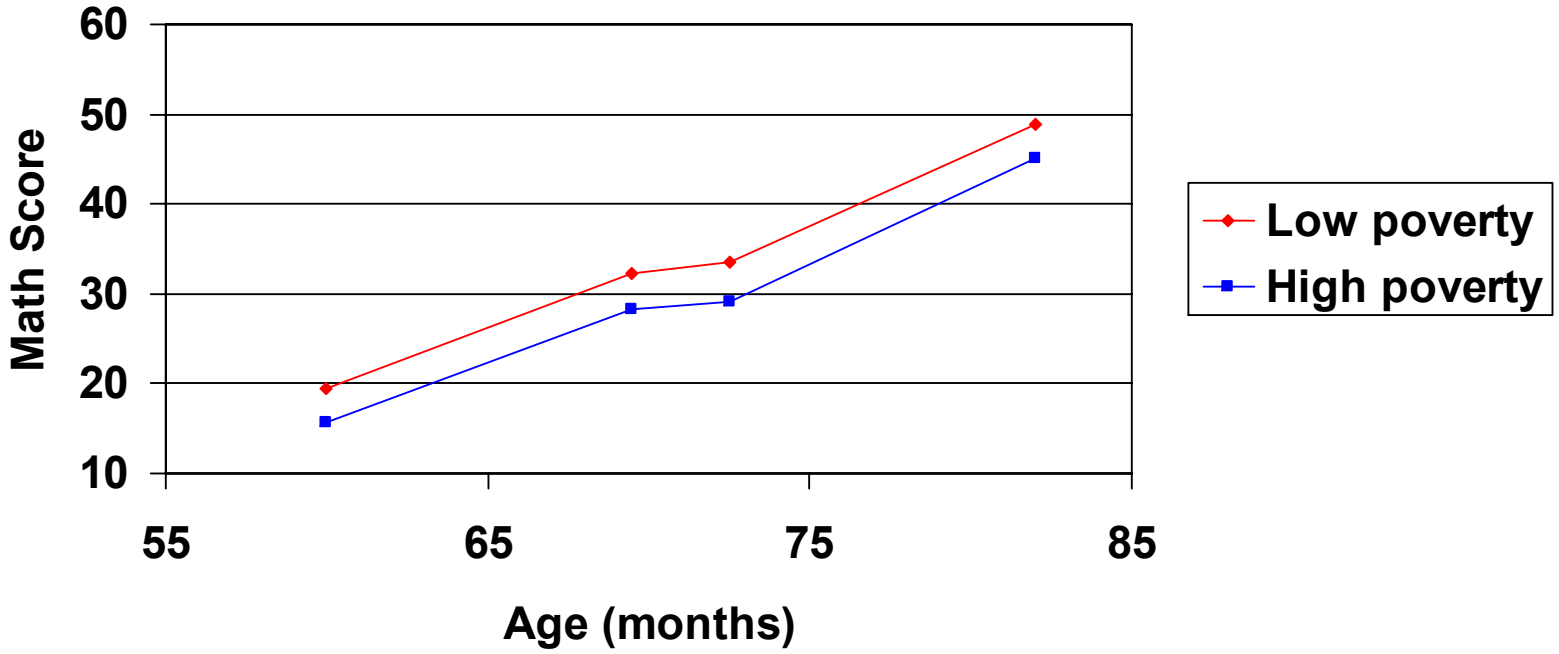


Figure D5a. Early Childhood Longitudinal Study (ECLS) Reading



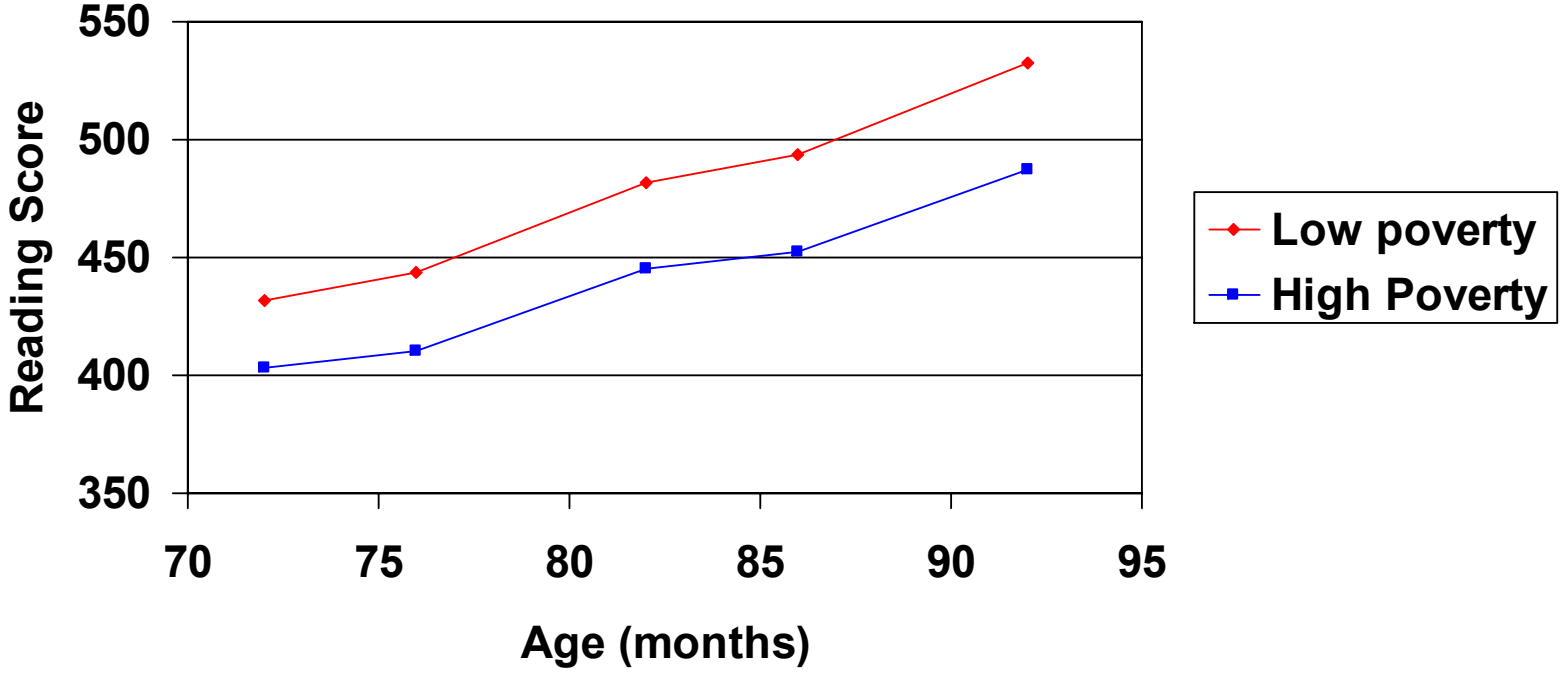
Source: Raudenbush (2006)

Figure D5b. Mean trajectories, high and low priority schools (ECLS) Math



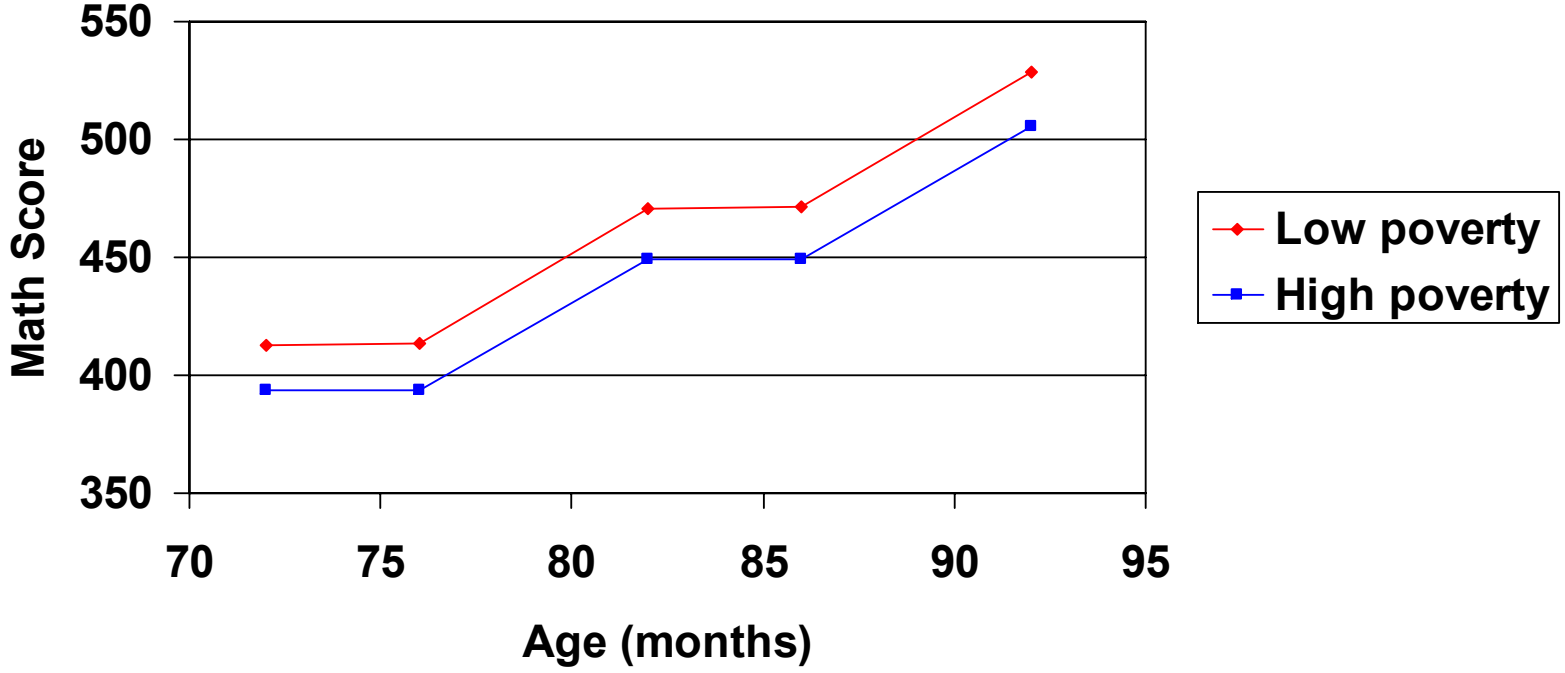
Source: Raudenbush (2006)

Figure D6a. Average Trajectories, Grades 1–3, high and low poverty schools (Sustaining Effects Study)
Reading



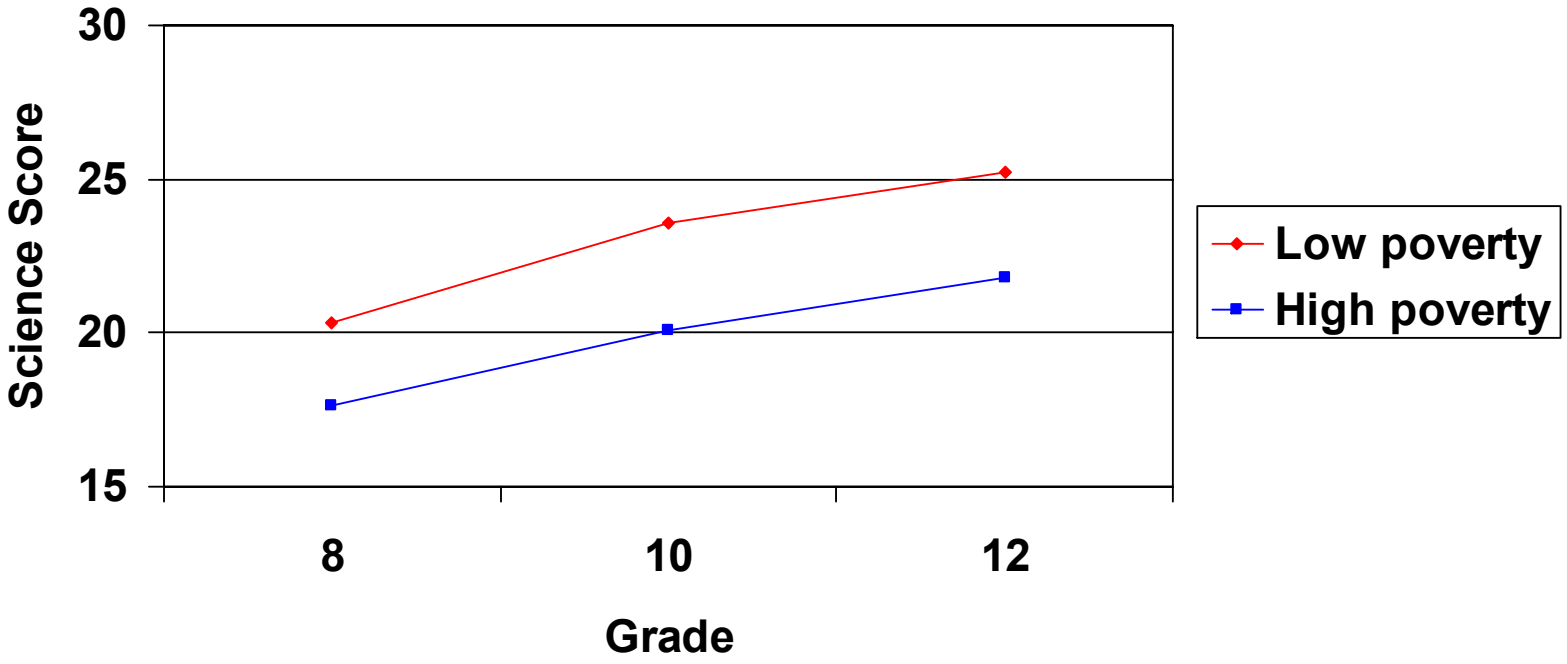
Source: Raudenbush (2006)

Figure D6b. Average Trajectories, Grades 1–3, high and low poverty schools (Sustaining Effects Study)
Math



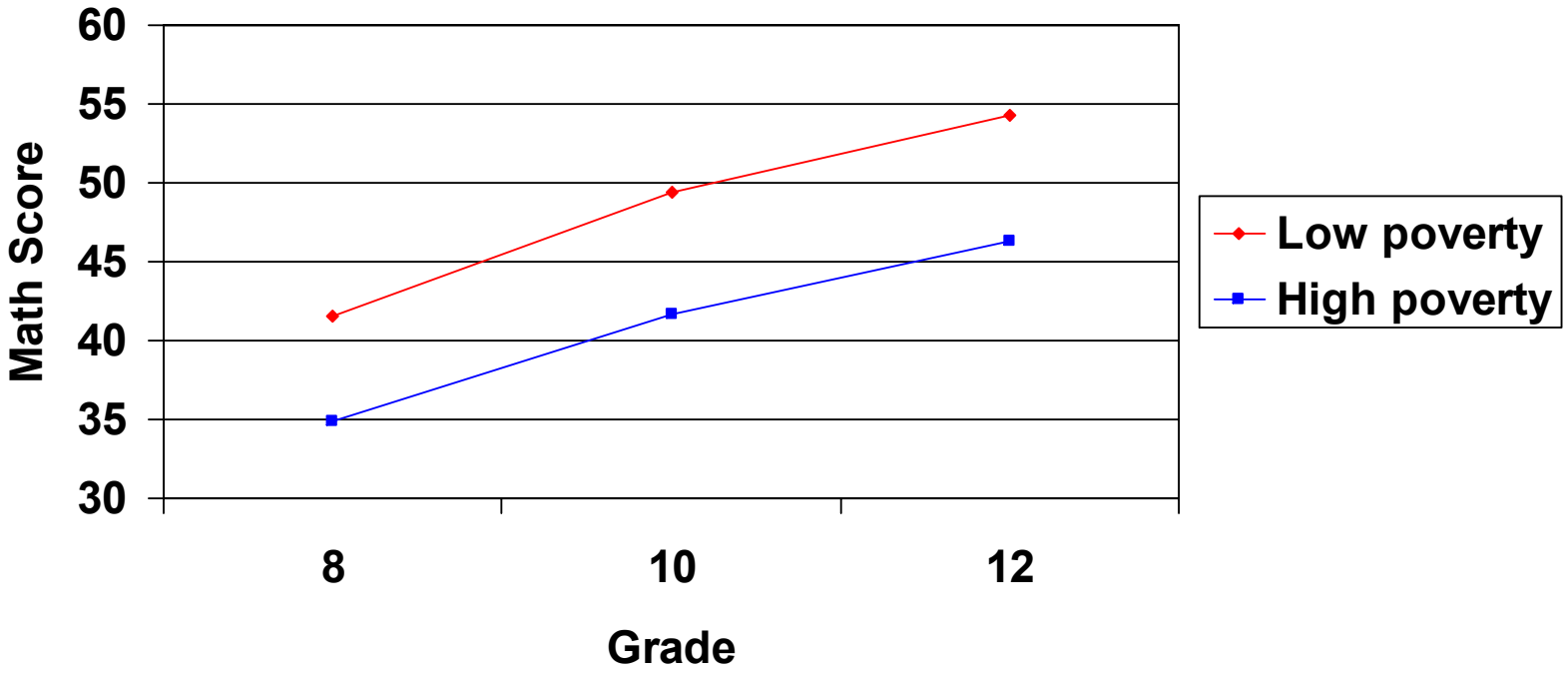
Source: Raudenbush (2006)

Figure D7a. Average achievement trajectories, grades 8–12, (NELS 88) Science



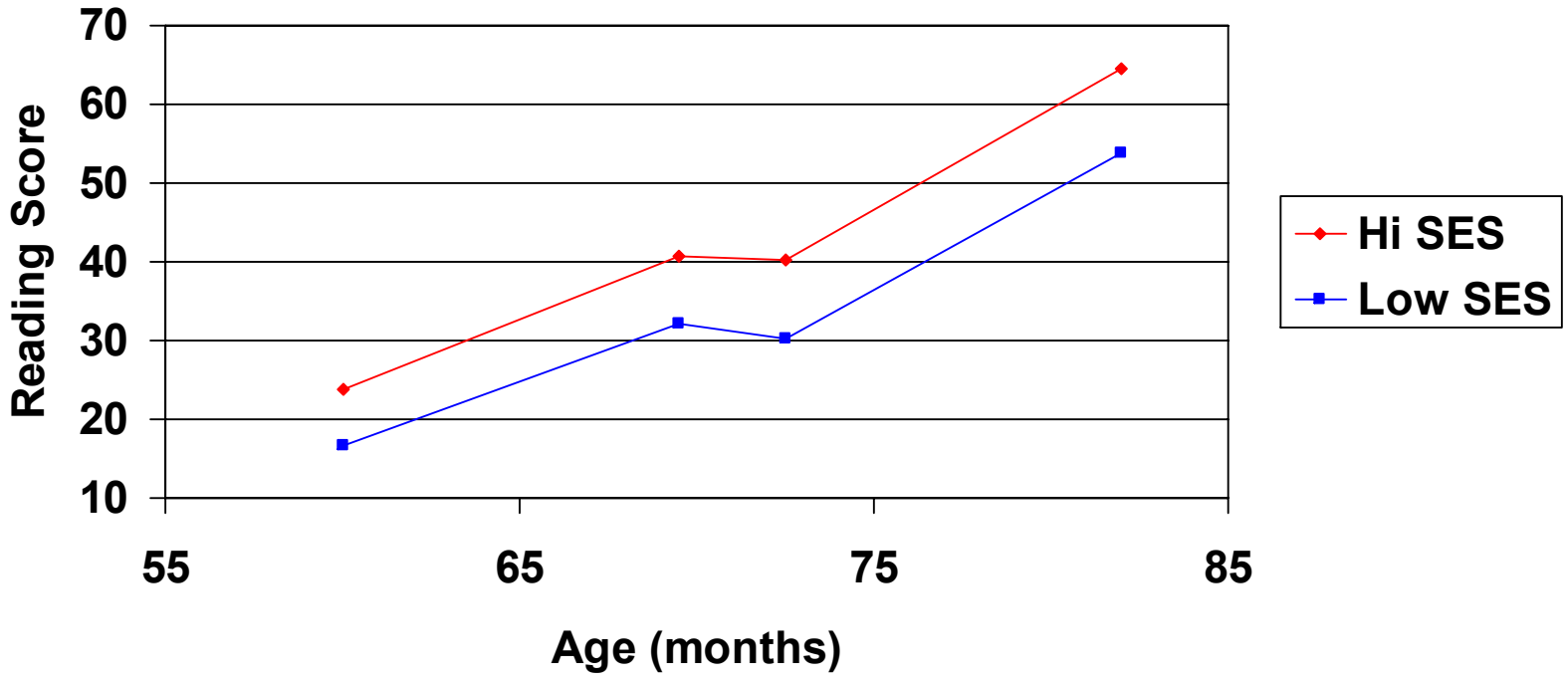
Source: Raudenbush (2006)

Figure D7b. Average achievement trajectories, grades 8–12, (NELS 88) Math



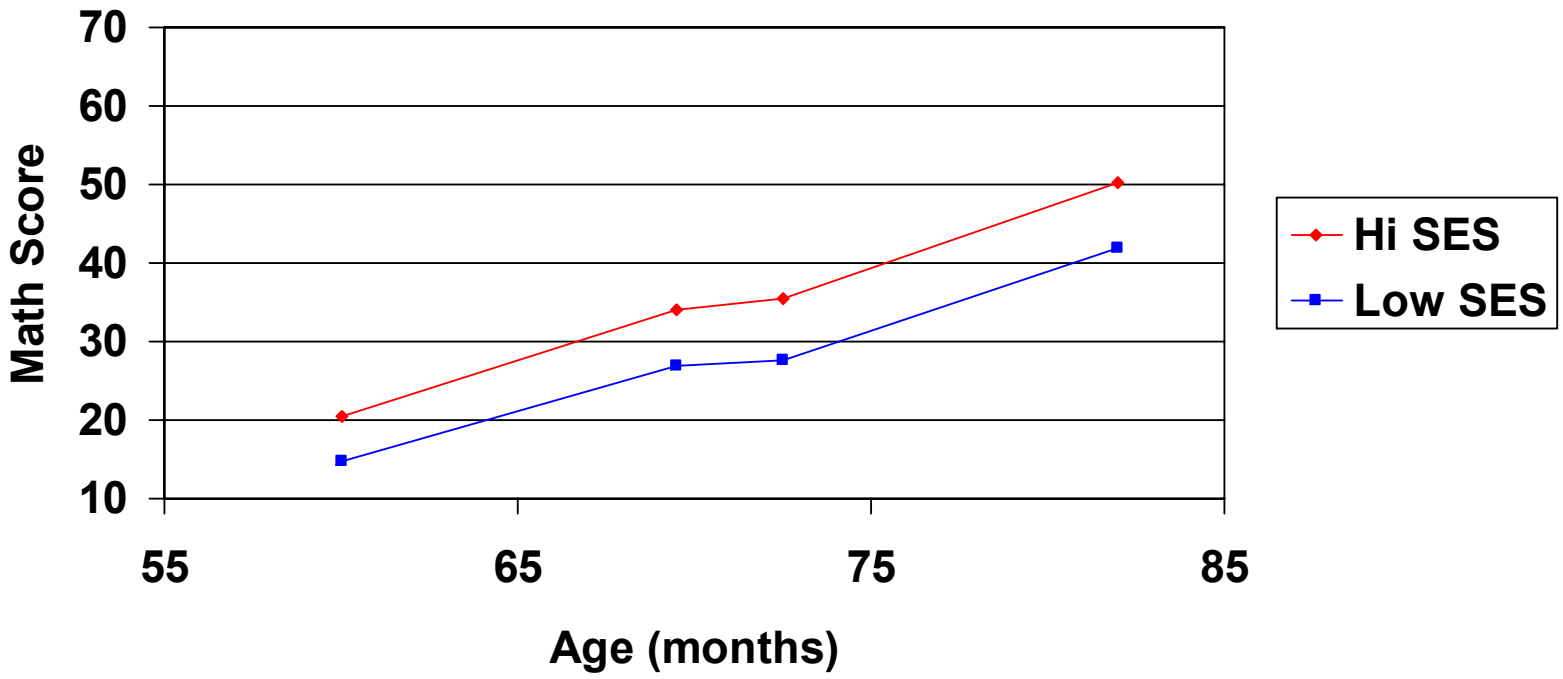
Source: Raudenbush (2006)

Figure D8a. Growth as a function of student social background: ECLS Reading



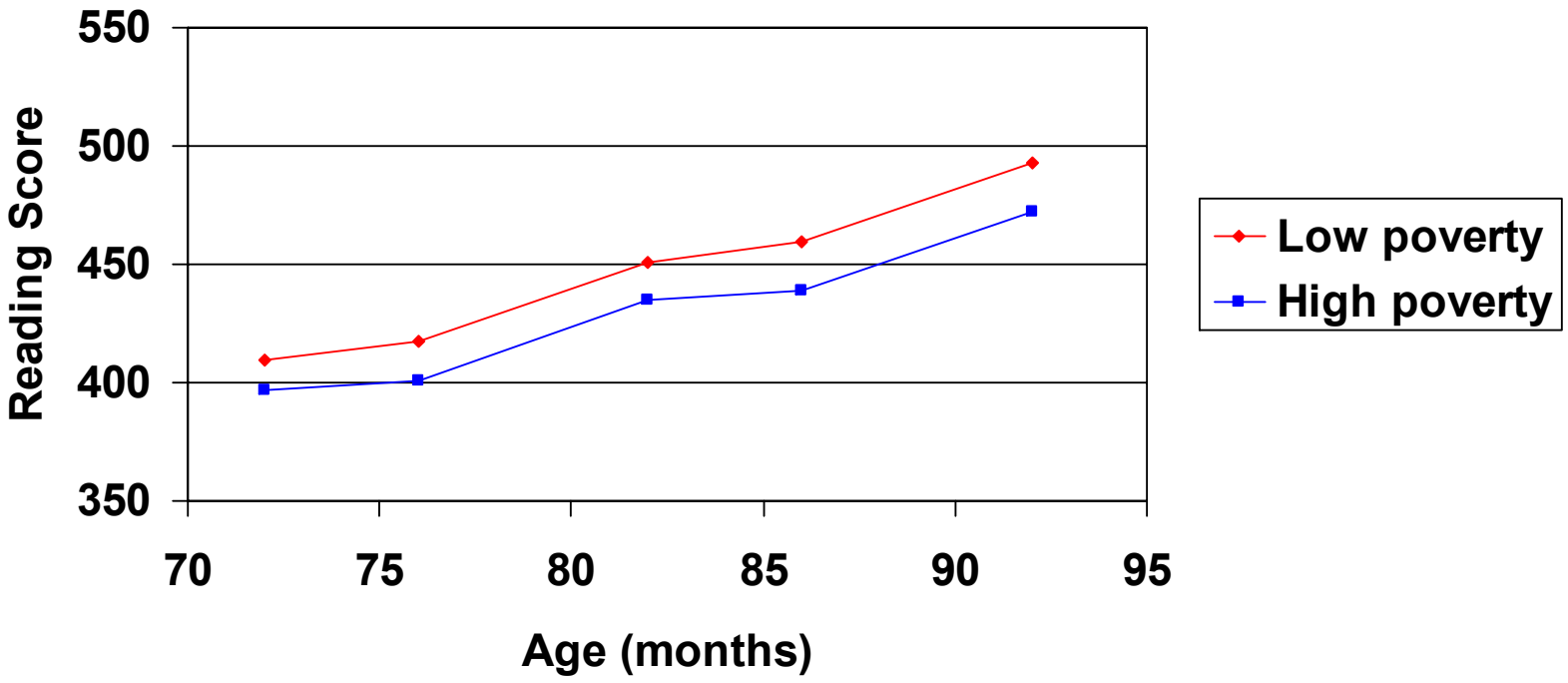
Source: Raudenbush (2006)

Figure D8b. Growth as a function of student social background: ECLS Math



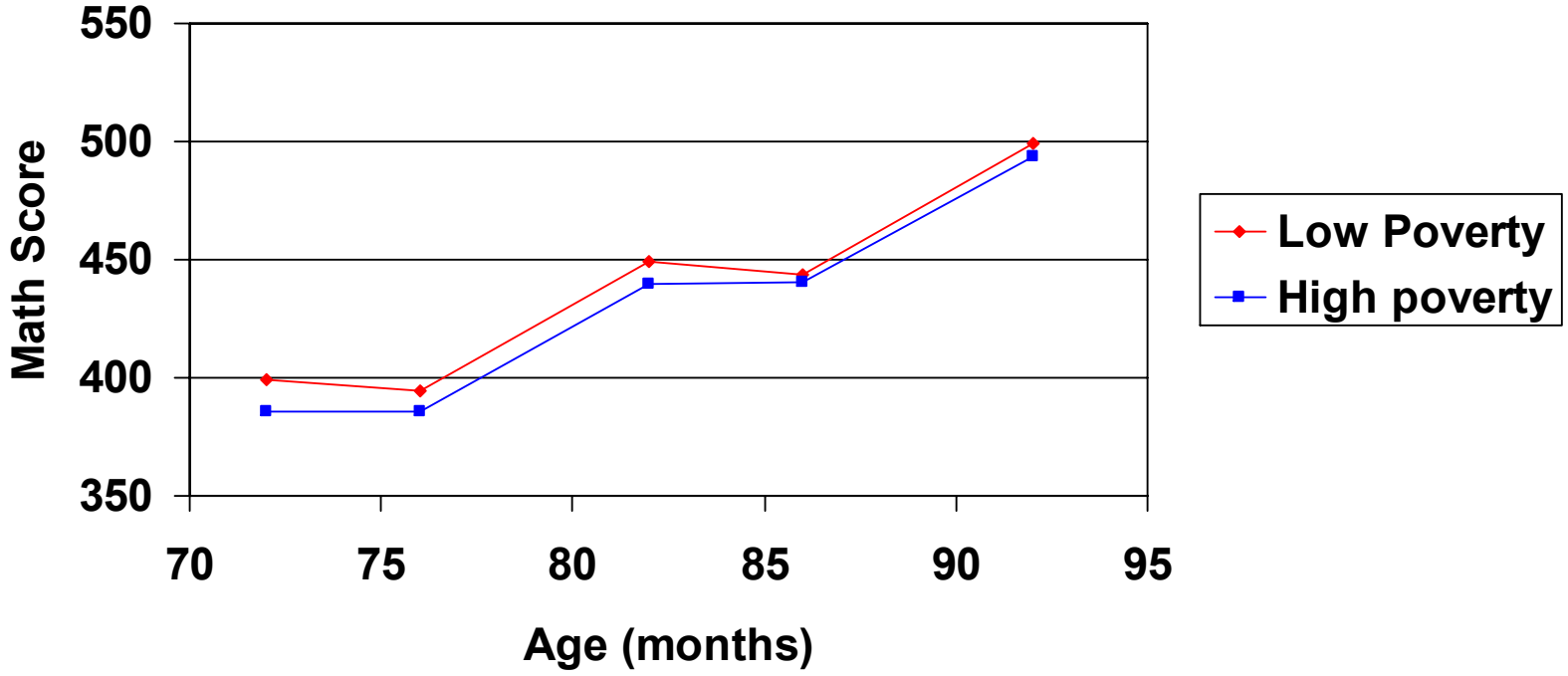
Source: Raudenbush (2006)

Figure D9a. Growth as a function of school poverty for poor children: sustaining effects data
Reading



Source: Raudenbush (2006)

Figure D9b. Growth as a function of school poverty for poor children: sustaining effects data
Math

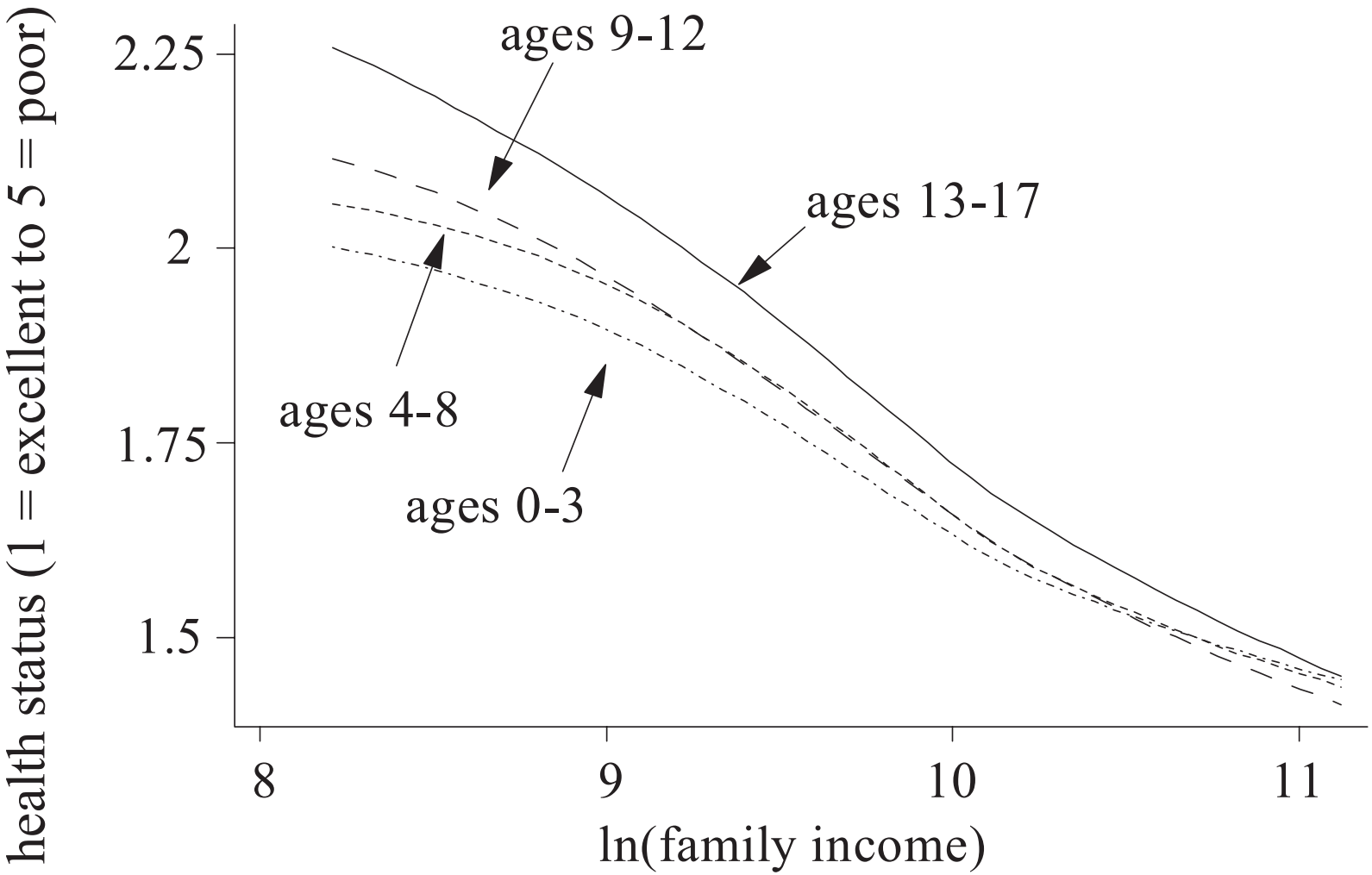


Source: Raudenbush (2006)

- Schooling quality and school resources have relatively small effects on ability deficits and only marginally account for any divergence by age across children from different socioeconomic groups in test scores.
- See Heckman, Larenas et al. (2004) and Raudenbush (2006).

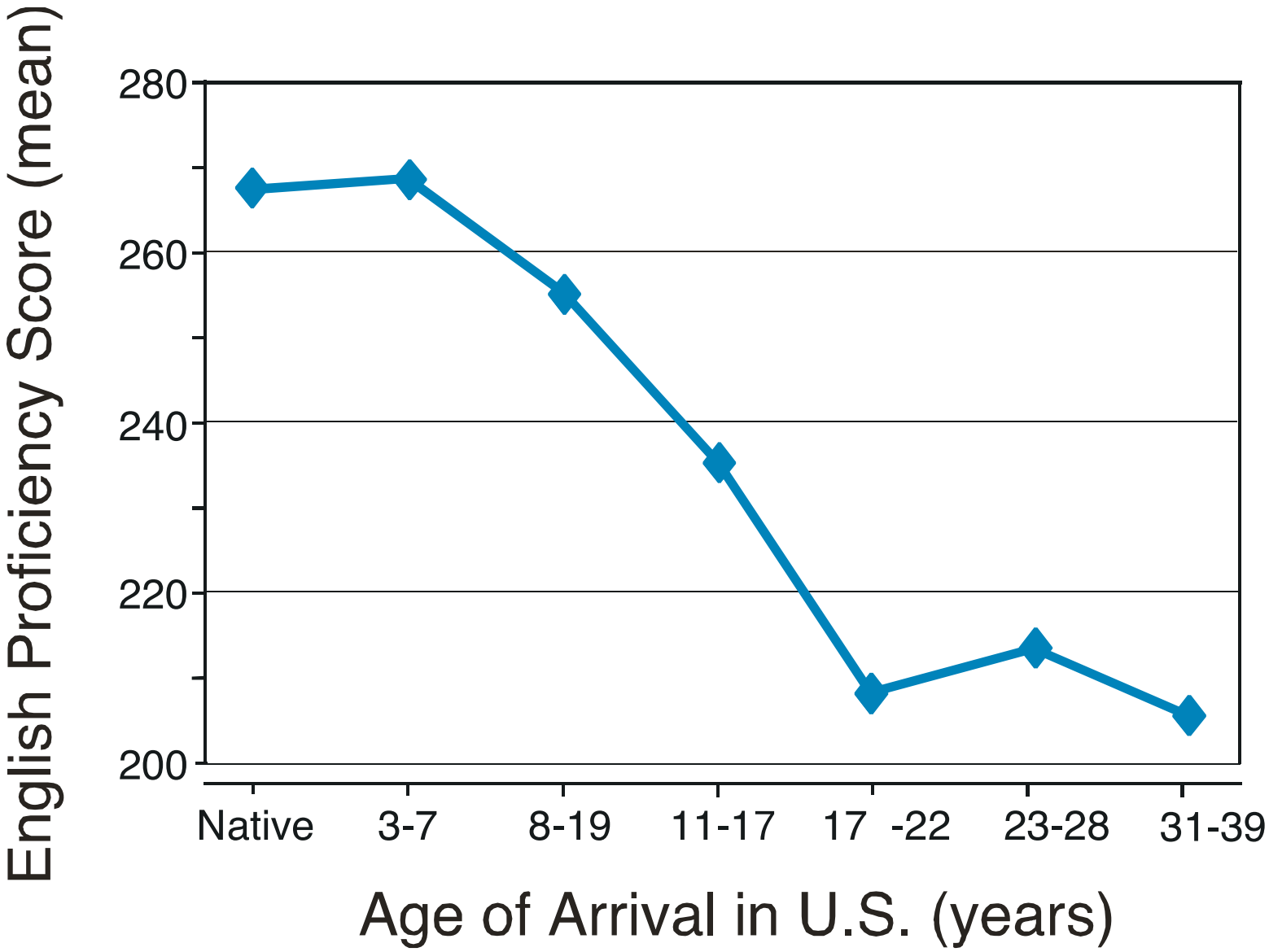
Gaps also emerge in health. These appear to be divergent with age, at least in the U.S.

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



- Second, *in both animal and human species, there is compelling evidence of critical and sensitive periods in the development of the child*.

Second language learning



- The later remediation is given to a disadvantaged child, the less effective it is.
- A substantial body of evidence suggests that returns to adolescent education for the most disadvantaged and less able are lower than the returns for the more advantaged.

- The economic returns to adolescent intervensions — job training, high school graduation, and college attendance — are lower for less able persons.

Table 1. Return to one year of college for individuals at different percentiles of the math test score distribution
White males from high school and beyond

	5%	25%	50%	75%	95%
Average return in the population	0.1121	0.1374	0.1606	0.1831	0.2101
	(0.0400)	(0.0328)	(0.0357)	(0.0458)	(0.0622)
Return for those who attend college	0.1640	0.1893	0.2125	0.2350	0.2621
	(0.0503)	(0.0582)	(0.0676)	(0.0801)	(0.0962)
Return for those who do not attend college	0.0702	0.0954	0.1187	0.1411	0.1682
	(0.0536)	(0.0385)	(0.0298)	(0.0305)	(0.0425)
Return for those at the margin	0.1203	0.1456	0.1689	0.1913	0.2184
	(0.0364)	(0.0300)	(0.0345)	(0.0453)	(0.0631)

Source: Carneiro and Heckman (2003)

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

- Fourth, *if early investment in disadvantaged children is not followed up by later investment, its effect tends to weaken at later ages.*
- Currie and Thomas (1995) document a decline in the performance of minority Head Start participants after they leave the program.

- Fifth, *the effects of credit constraints on the child's adult outcomes depend on the age at which they bind for the child's family*.
- Controlling for cognitive ability, under meritocratic policies currently in place in American society, family income during the child's college-going years plays only a minor role in determining child college participation.
- Holding ability fixed, minorities are *more likely* to attend college than others despite their lower family incomes.

- Carneiro and Heckman present evidence for the United States that only a small fraction (at most 8%) of the families of adolescents are credit constrained in making their college decisions.
- This evidence is supported in research by Cameron and Taber (2004) and Stinebrickner and Stinebrickner (2006).

- There is some evidence that credit constraints operating in the *early* years have effects on adult ability and schooling outcomes, but there is not full agreement in the literature on the magnitude of the effect (Duncan and Brooks-Gunn, 1997; Dahl and Lochner, 2004; Duncan and Ariel Kalil, 2006; Carneiro and Heckman, 2003).

- The empirically important market failures in the life cycle of skill formation in contemporary American society are the inability of children to buy their parents or the lifetime resources that parents provide.
- It is not credit constraints facing families seeking to secure loans for a child's education when the child is an adolescent.

- Sixth, *socioemotional (noncognitive) skills foster cognitive skills and are an important product of successful families and successful interventions in disadvantaged families.*
- The Perry Preschool Program, which was evaluated by random assignment, did not boost participant adult IQ but enhanced performance of participants in a number of dimensions, including elevated scores on achievement tests, employment and reduced participation in a variety of social pathologies.

Figure D10a. Perry Preschool Program: IQ, by age and treatment group

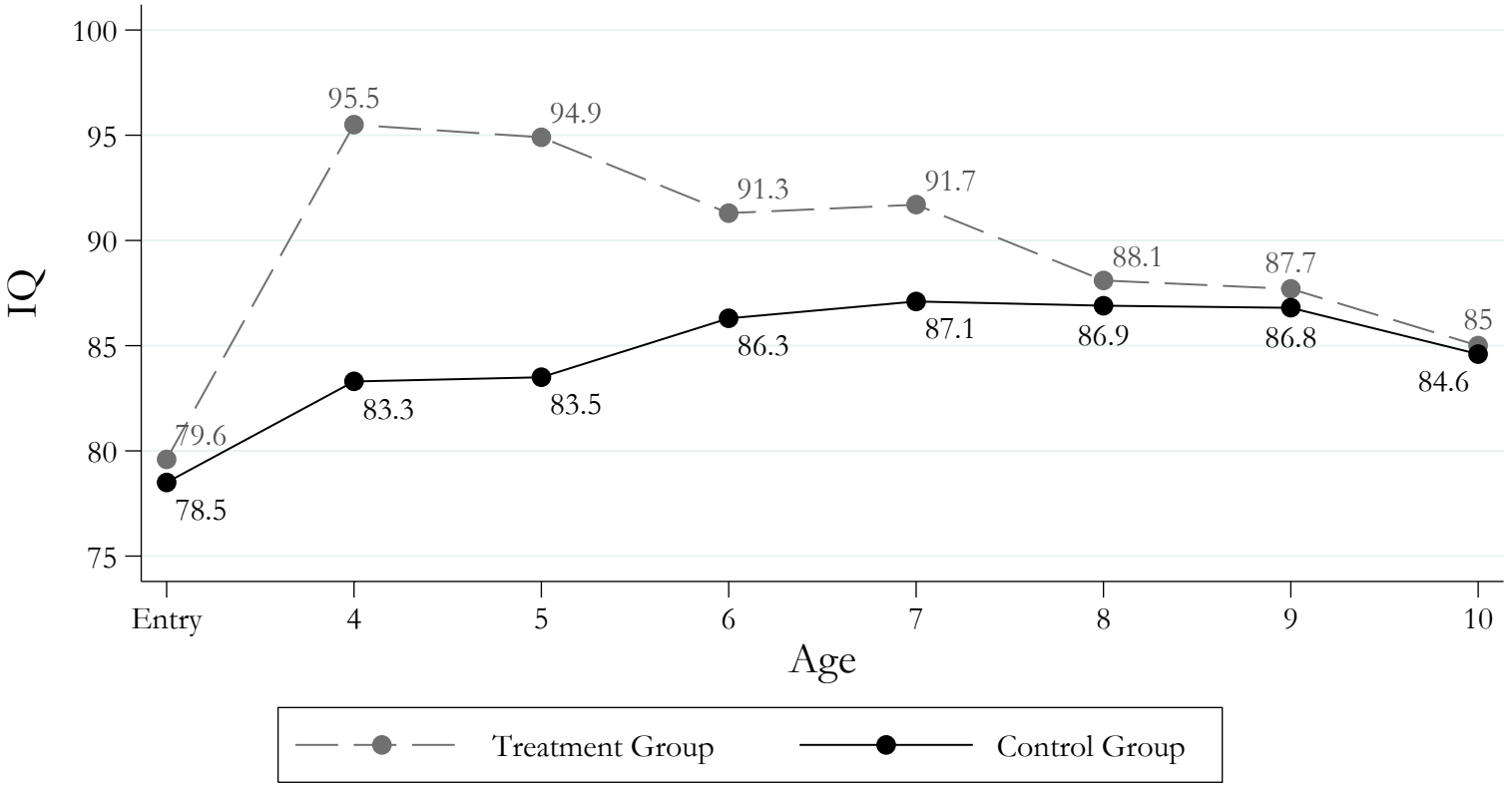
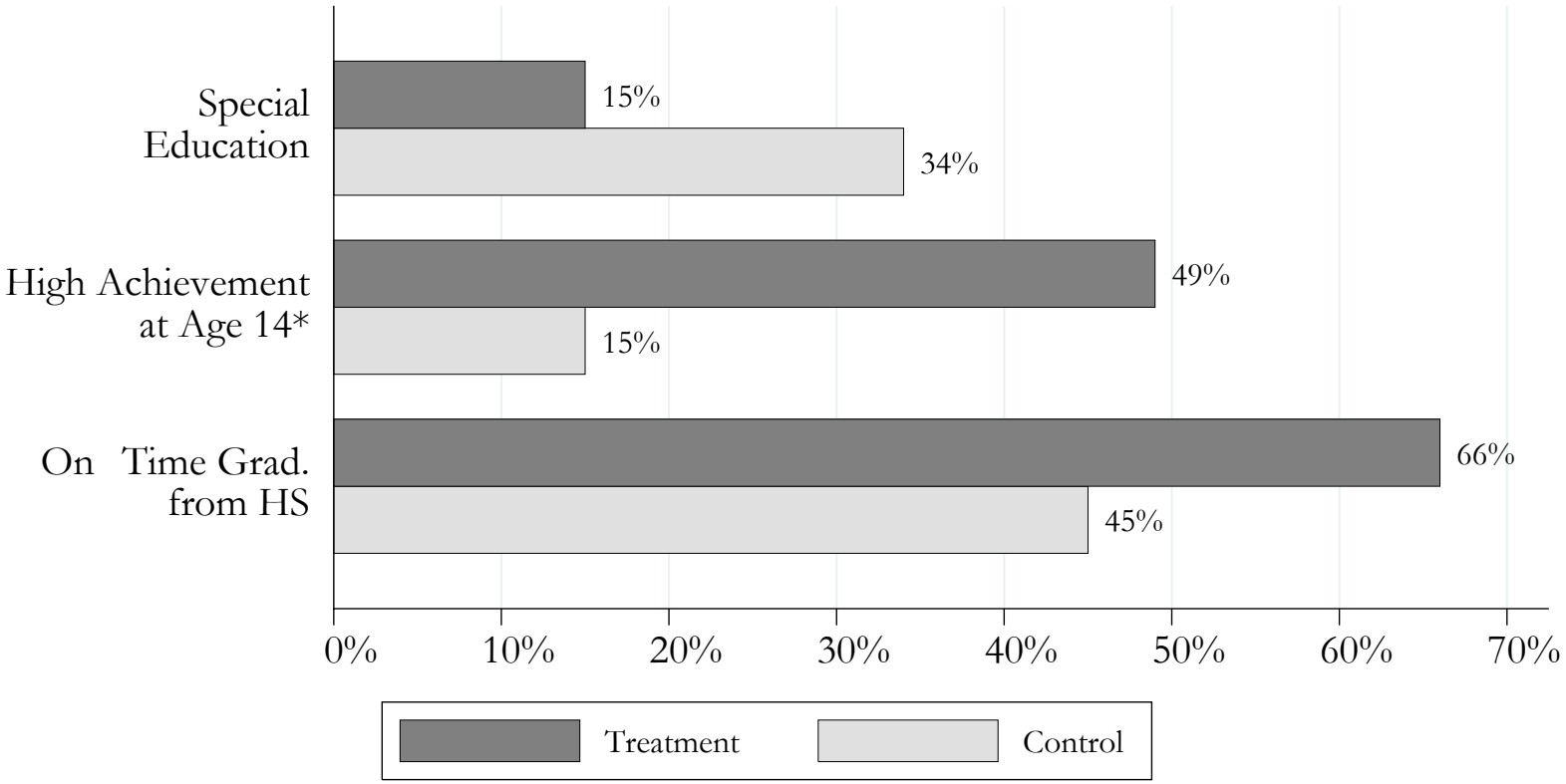
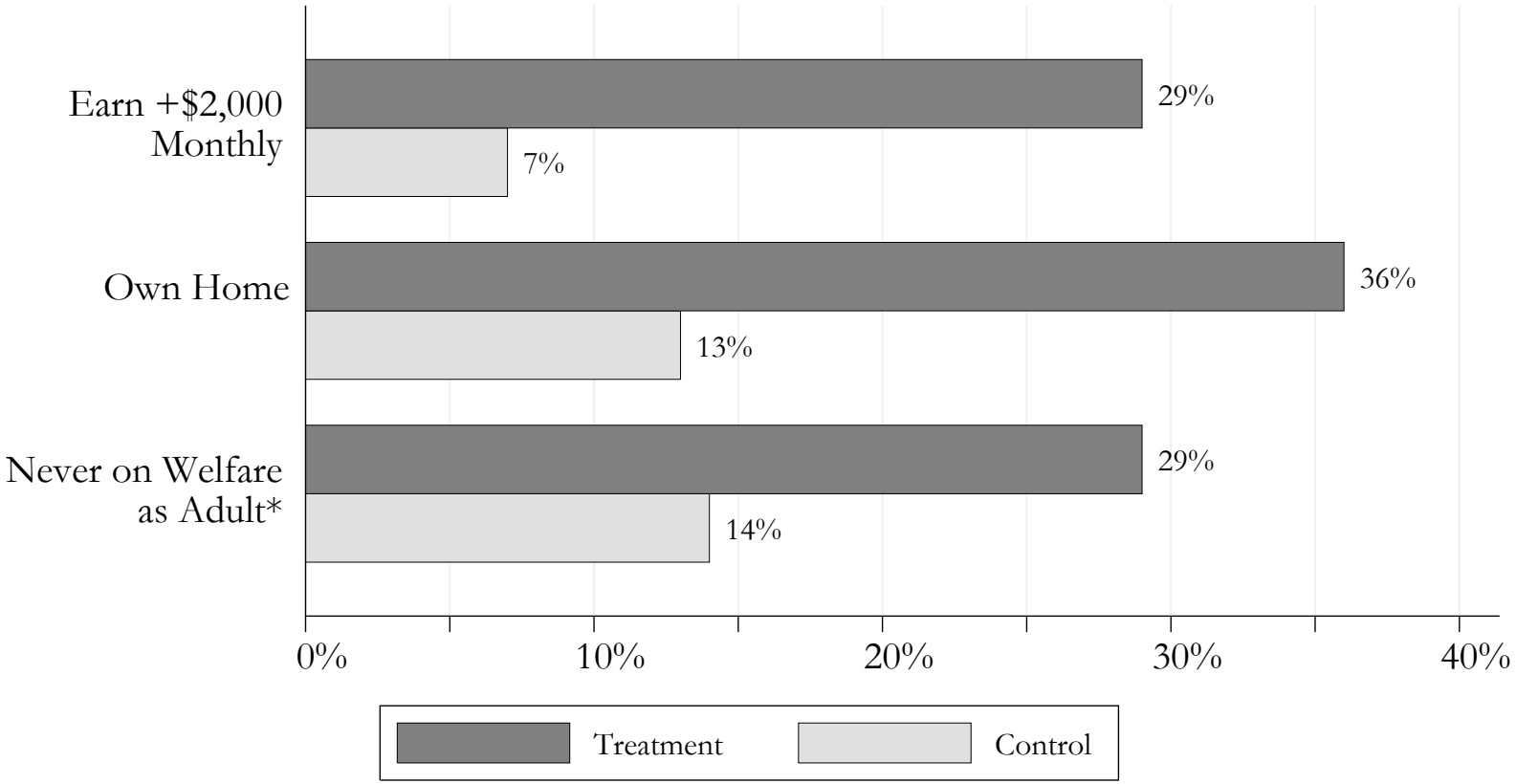


Figure D10b. Perry Preschool Program: educational effects, by treatment group



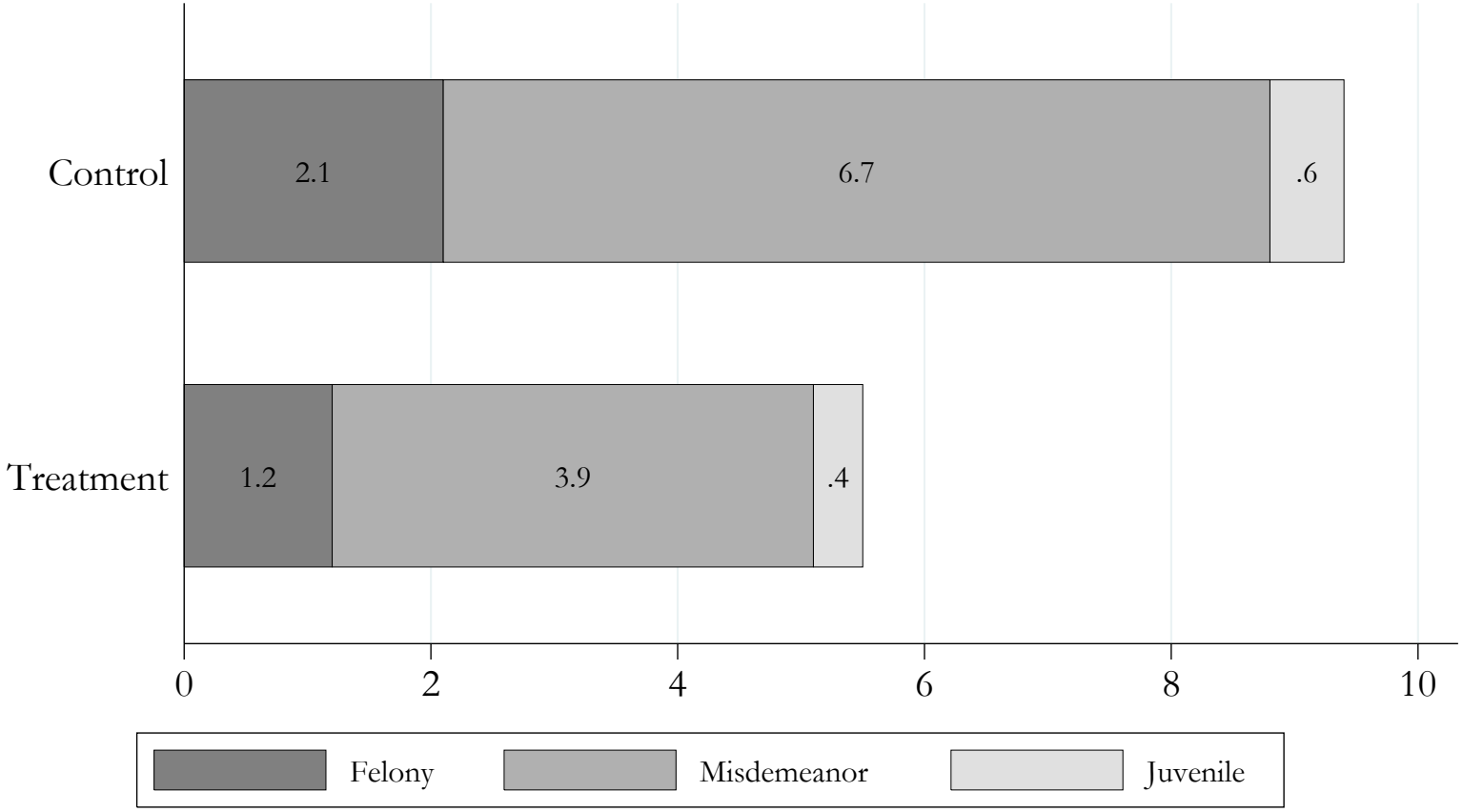
Source: Barnett (2004).
Notes: *High achievement defined as performance at or above the lowest 10th percentile on the California Achievement Test (1970).

Figure D10c. Perry Preschool Program: economic effects at age 27, by treatment group



Source: Barnett (2004). *Updated through Age 40 using recent Perry Preschool Program data, derived from self report and all available state records.

Figure D10d. Perry Preschool Program: arrests per person before age 40, by treatment group



Source: Perry Preschool Program. Juvenile arrests are defined as arrests prior to age 19.

Table D1. Economic benefits and costs

	Perry	Chicago CPC
Child Care	986	1,916
Earnings	40,537	32,099
K-12	9,184	5,634
College/Adult	-782	-644
Crime	94,065	15,329
Welfare	355	546
FG Earnings	6,181	4,894
Abuse/Neglect	0	344
Total Benefits	150,525	60,117
Total Costs	16,514	7,738
Net Present Value	134,011	52,380
Benefits-To-Costs Ratio	9.11	7.77

Notes: All values discounted at 3% and are in $2004. Numbers differ slightly from earlier estimates because FG Earnings for Perry and Chicago were estimated using the ratio of FG Earnings Effect to Earnings Effect (about 15%) that was found in Abecedarian

Source: Barnett (2004)

A Model of Skill Formation

- Agents possess a vector of abilities at each age.
- These abilities (or skills) are multiple in nature and range from pure cognitive abilities (e.g. IQ) to noncognitive abilities (patience, self control, temperament, risk aversion, time preference).
- These abilities are used with different weights in different tasks in the labor market and in social life more generally.

- The human skill formation process is governed by a multistage technology.
- Each stage corresponds to a period in the life cycle of a child.
- Like earlier work by Ben-Porath (1967), we use a production function to determine the relationship between inputs and the output of skill.
- Unlike Ben-Porath, in our models qualitatively different inputs can be used at different stages and the technologies can be different at different stages of child development.

- Ben-Porath focuses on adult investments where time and its opportunity cost play important roles.
- For child investments, parents make decisions and child opportunity costs are less relevant.

- The outputs at each stage in our technology are the levels of each skill achieved at that stage.
- Some stages of the lifecycle may be more productive in producing some skills than other stages, and some inputs may be more productive at some stages than at other stages.
- Those stages that are more effective in producing certain skills are called "sensitive periods" for the acquisition of those skills.
- If one stage alone is effective in producing a skill (or ability), it is called a "critical period" for that skill.

- The skills produced at one stage augment the skills attained at later stages. This effect is termed *self-productivity*.
- Skills are self-reinforcing and cross-fertilizing.
- A second key feature of skill formation is *dynamic complementarity*.
- Skills produced at one stage raise the productivity of investment at subsequent stages. Complementarity implies that levels of skill investments at different ages bolster each other. They are synergistic.

- Together, dynamic complementarity and self-productivity produce *multiplier effects* which are the mechanisms through which skills beget skills and abilities beget abilities.
- Dynamic complementarity, self-productivity of human capital, and multiplier effects imply an equity-efficiency trade-off for late child investments but not for early investments.
- These concepts, embedded in alternative market settings, explain the six facts previously listed.