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# LESSONS FROM THE TECHNOLOGY OF SKILL FORMATION

James J. Heckman

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## ABSTRACT

This paper discusses recent advances in our understanding of differences in human abilities and skills, their sources, and their evolution over the lifecycle.

James J. Heckman
Department of Economics
The University of Chicago
1126 E. 59th Street
Chicago, IL 60637
and NBER
jheckman@uchicago.edu

# Lessons from the Technology of Skill Formation

James Heckman
University of Chicago

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**Abstract:**
This paper discusses recent advances in our understanding of differences in human abilities and skills, their sources, and their evolution over the lifecycle.

**Keywords:** skills, abilities, lifecycle, skill gaps, remediation policies

The study of human skill formation is no longer handicapped by the taboo that once made it impermissible to talk about differences among people. It is now well documented that people are very diverse on a large array of abilities, that these abilities account for a substantial amount of the variation found among people in terms of their socioeconomic success, and that gaps among children from various socioeconomic groups open up at early ages, and, if anything, widen as children become adults. The family plays a powerful role in shaping these abilities. From a variety of intervention studies, we know that these gaps can be partially remedied if the remediation is attempted at early enough ages. The remediation efforts that appear to be most effective are those that supplement family resources for young children from disadvantaged environments. Since the family is the fundamental source of human inequality, programs that target young children from disadvantaged families have the greatest economic and social returns. I make this case through a series of arguments, bolstered by graphs and tables extracted from Heckman and Masterov (2004), Cunha and Heckman (2003) and Carneiro and Heckman (2003).

First, *abilities matter*. A large number of empirical studies document that cognitive ability affects both the likelihood of acquiring advanced training and higher education, but also the economic returns to those activities. Abilities also matter in determining participation in crime, teenage pregnancy, drug use and participation in other deviant activities. Education has an

independent causal effect on participation in crime, the likelihood of producing an out of wedlock birth, drug use and the like apart from its role as a conduit of ability. The evidence that cognitive ability matters tells us nothing whatsoever about whether it is genetically determined. The frenzy generated by Herrnstein and Murray's book *The Bell Curve*, because of its claims about genetic determinism, obscured its real message which is that cognitive ability is an important predictor of socioeconomic success.

Second, *abilities are multiple in nature*. IQ has to be distinguished from what is measured by achievement tests, although it partly determines success on achievement tests. Achievement tests in turn have an independent effect on socioeconomic success apart from the effect of IQ, which is strongly correlated with success on achievement tests. Noncognitive skills (perseverance, motivation, self-control and the like) have direct effects on wages (controlling for schooling), schooling, teenage pregnancy, smoking, crime and achievement tests. Both cognitive and noncognitive skills affect socioeconomic success. Both are strongly influenced by family environments.

Third, *ability gaps between individuals and across socioeconomic groups open up at early ages, for both cognitive and noncognitive skills*. They are strongly correlated with family background factors like parental education and maternal ability, which, when controlled for in a statistical sense, largely eliminate these gaps (see Figures 1A-B and Figures 2A-B). Inputs of schooling quality and resources have relatively small effects on ability deficits but only marginally account for some of the divergence evident in Figure 1A (see De Los Santos, Heckman and Larenas, 2004). Parenting practices have strong effects on emotional development and motivation.

Fourth, *it is possible to partially compensate for adverse family environments*. Evidence from randomized trials conducted on intervention programs targeted at disadvantaged children who are followed into adulthood suggests that it is possible to eliminate some of the gaps evident in Figures 1a and 2a. Enriched early interventions at the youngest ages raise IQ. The Abecedarian program provided an enriched intervention for disadvantaged children starting at age 4 months. The children who received the intervention score consistently higher than the

children who do not, even long after the treatment is discontinued (see Figure 3). If we wait to intervene until age 4 or later, no lasting effects on IQ have been found (see Figure 4 for the Perry Preschool data). However, effects on motivation and, hence, achievement test scores are found. Children are less likely to commit crime and have out of wedlock births and are more likely to participate in regular schooling. Early interventions have a substantial effect on adult performance (see Figures 5-7) and have a high economic return (see Table 1).

Fifth, *different types of abilities appear to be manipulable at different ages*. Thus, while factors affecting IQ deficits need to be addressed at very early ages for interventions to be effective, there is evidence that later interventions in the adolescent years can affect noncognitive skills (see Tables 2 and 3 for evidence on this point). This evidence appears to be rooted in the neuroscience that establishes the malleability of the prefrontal cortex into the early 20s. This is the region of the brain that governs emotion and self-regulation.

Sixth, *the later the remediation, the less effective it is*. The study by O'Connor, et al. (2000) of adopted Romanian infants documents this for very early interventions (see Figure 8). The later the Romanian orphan is rescued from the social and emotional isolation of the orphanage and placed in an adoptive environment, the lower is his or her cognitive performance at age 6. Moreover, classroom remediation programs designed to combat early cognitive deficits have a poor track record. Public job training programs and adult literacy and educational programs, like the GED, that attempt to remediate years of educational and emotional neglect among disadvantaged individuals have a low economic return, and for young males, the return is negative.

Figure 9 summarizes the findings of an entire literature. The economic returns to the marginal investment at early ages are high. The economic return to investment at older ages is lower. The technology of skill formation derived from economic theory and estimated on longitudinal data suggests a strong self-productivity of investment. Investment at an early age produces a high return through this self-productivity. Complementarity (synergy) of investment reinforces self-productivity. Early investment in cognitive and noncognitive skills lowers the cost of later investment by making learning at later ages more efficient. Notice in Figures 5, 6a and 7c

that those who receive early interventions are less likely to repeat grades or require special education programs while in school. This complementarity highlights the value of early investment. It also demonstrates that there is no trade-off between equity (targeting programs at disadvantaged families) and efficiency (getting the highest economic returns), provided that the investments are made at early ages. There is such a trade-off at later ages.

The empirically established complementarity also suggests that early investments must be followed up by later investments to be effective. Nothing in the new economics of human skill formation suggests that we should starve later educational and skill enhancement efforts. The main finding from the recent literature is that we should prioritize, and shift our priorities, in a marginal fashion by redirecting a given total sum of expenditure on skill investment to earlier ages relative to how it is currently allocated.

The costs of delay implied by the evidence on self-productivity and complementarity are dramatically illustrated by Figure 10 from Cunha and Heckman (2003, 2004). Using data from the U.S., they establish that, for children from very poor backgrounds, a strategy of late remediation is economically inefficient. Late remediation, no matter how extensive, cannot restore children from disadvantaged environments to the level of performance they would have attained had they received economically efficient early interventions that compensate for disadvantage in the early years.

Nothing in the recent literature says that investments should not be made in older persons. The phenomenon of neurogenesis informs us that learning can continue into advanced ages. What is missing from that literature is a discussion of the relative costs and returns to investments in older persons compared to younger persons. What we do know is that investments in more able workers at any age generate higher returns than investments in younger workers, and ability is formed at early ages.

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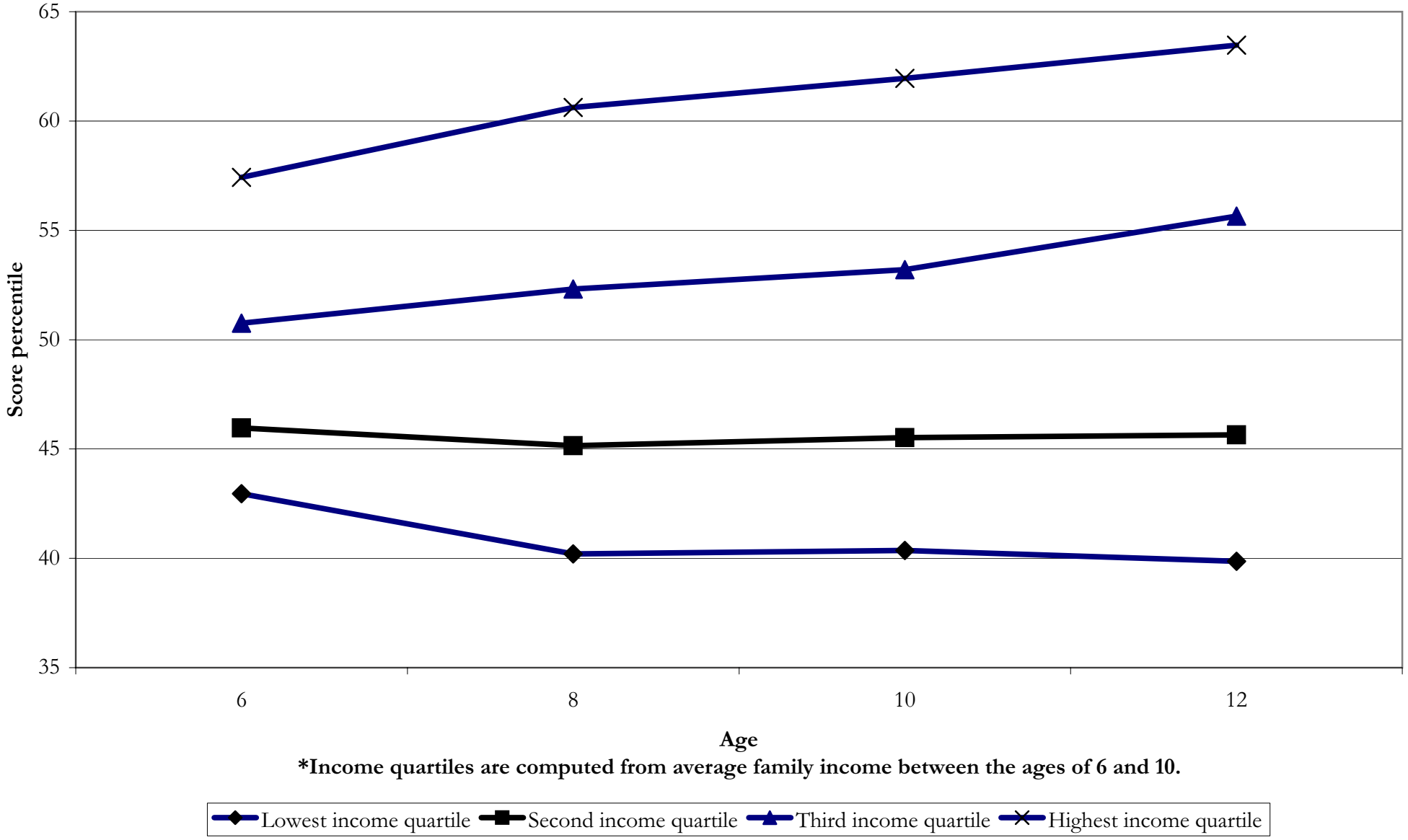
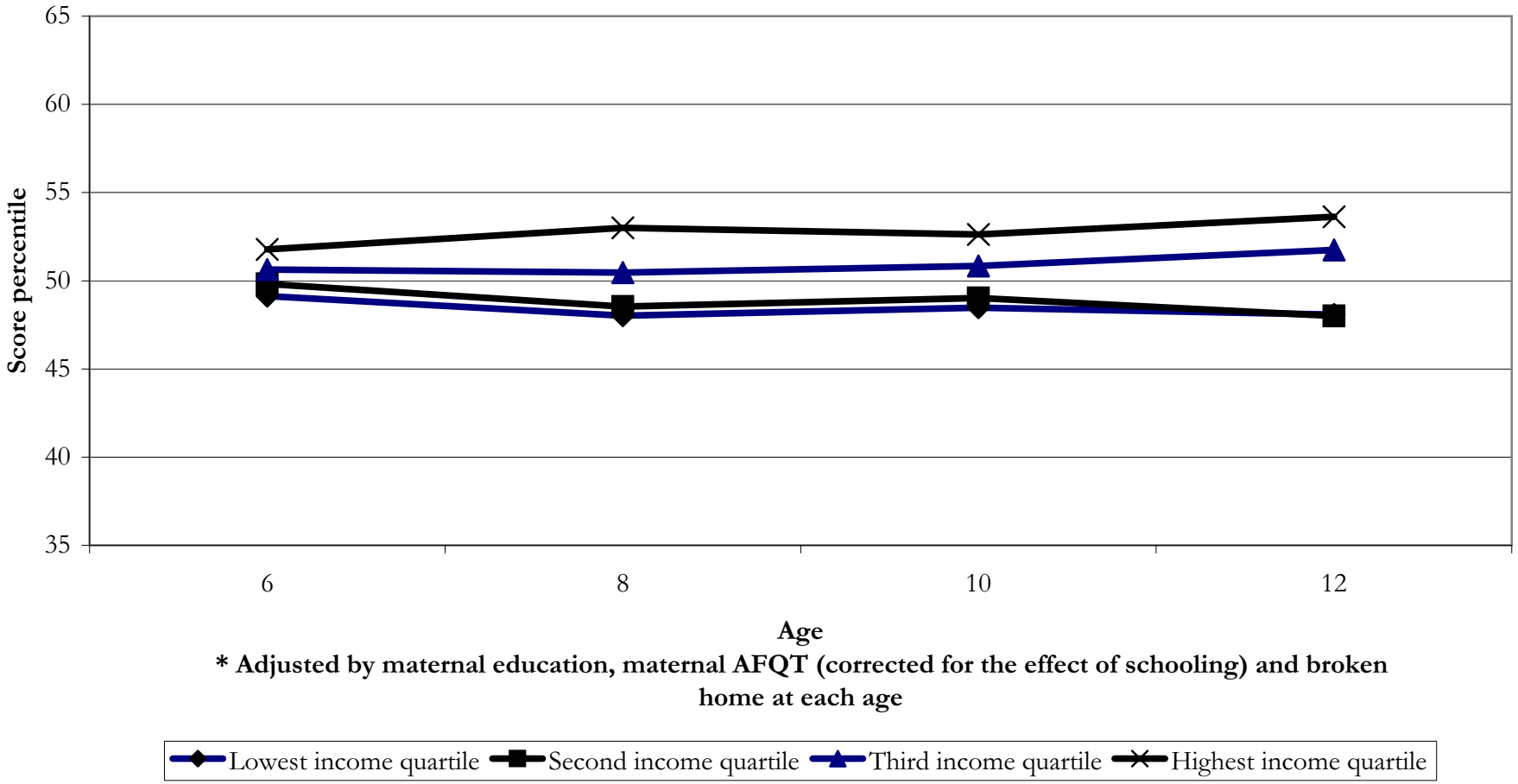
# Figure 1a
# Children of NLSY
**(a) Average percentile rank on PIAT-Math score, by income quartile***




***Income quartiles are computed from average family income between the ages of 6 and 10.**

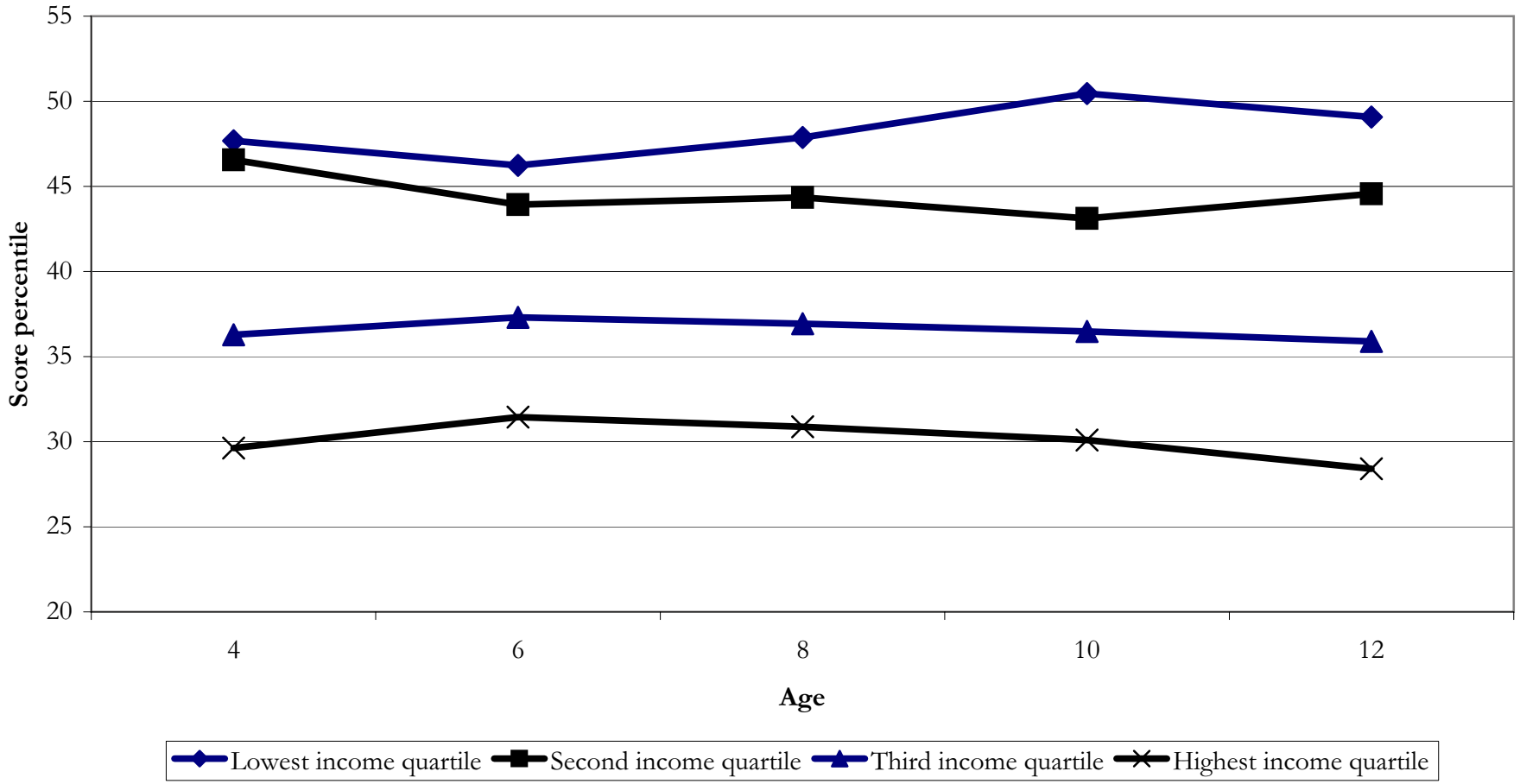
# Figure 1b
# Children of NLSY
**(a) Adjusted average PIAT-Math score percentiles by income quartile***




*** Adjusted by maternal education, maternal AFQT (corrected for the effect of schooling) and broken home at each age**

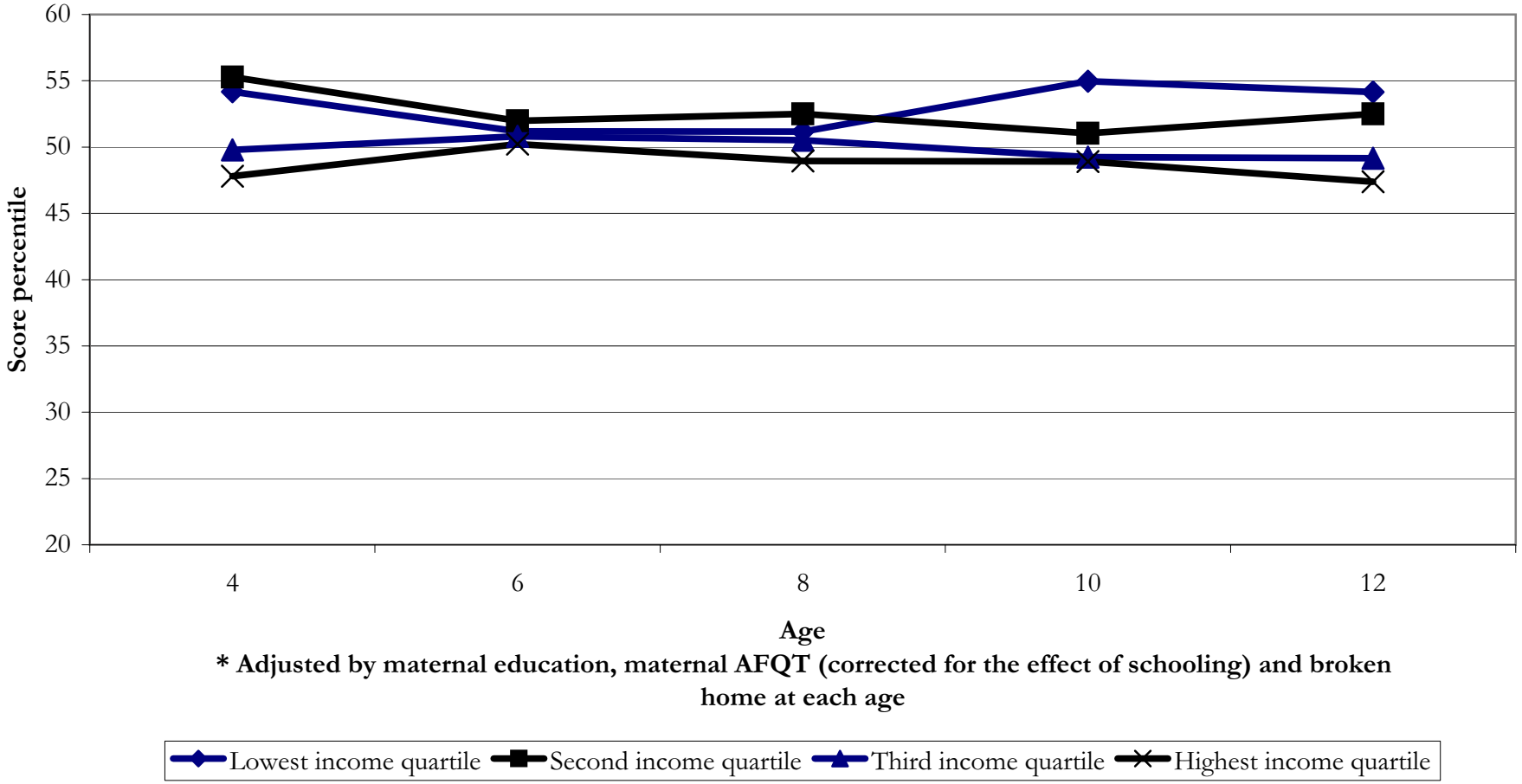
# Figure 2a
# Children of NLSY

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



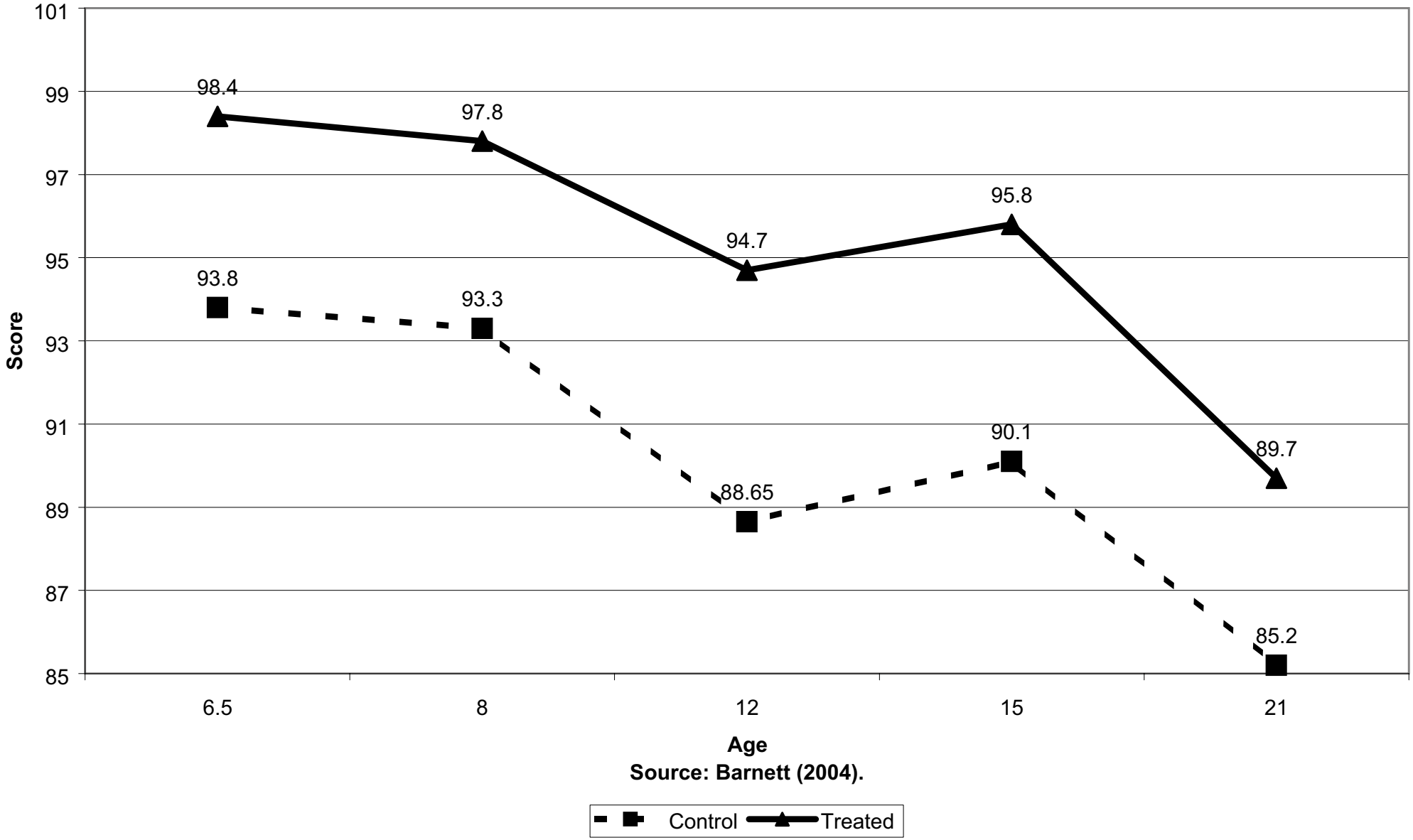
# Figure 2b
# Children of NLSY

**Adjusted average anti-social score percentile by income quartile***



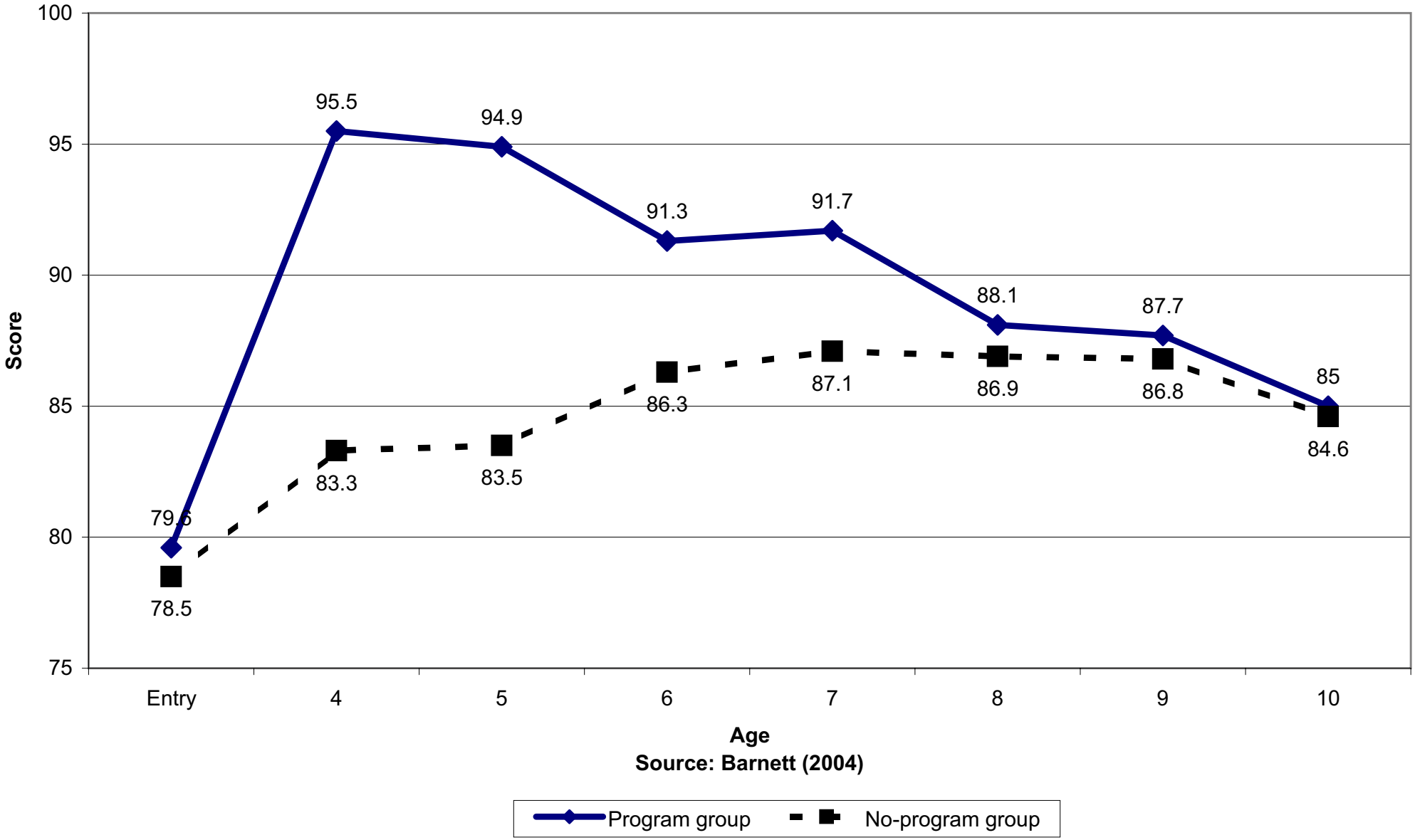

*** Adjusted by maternal education, maternal AFQT (corrected for the effect of schooling) and broken home at each age**

**Figure 3**
**Abecedarian IQ Scores Over Time**



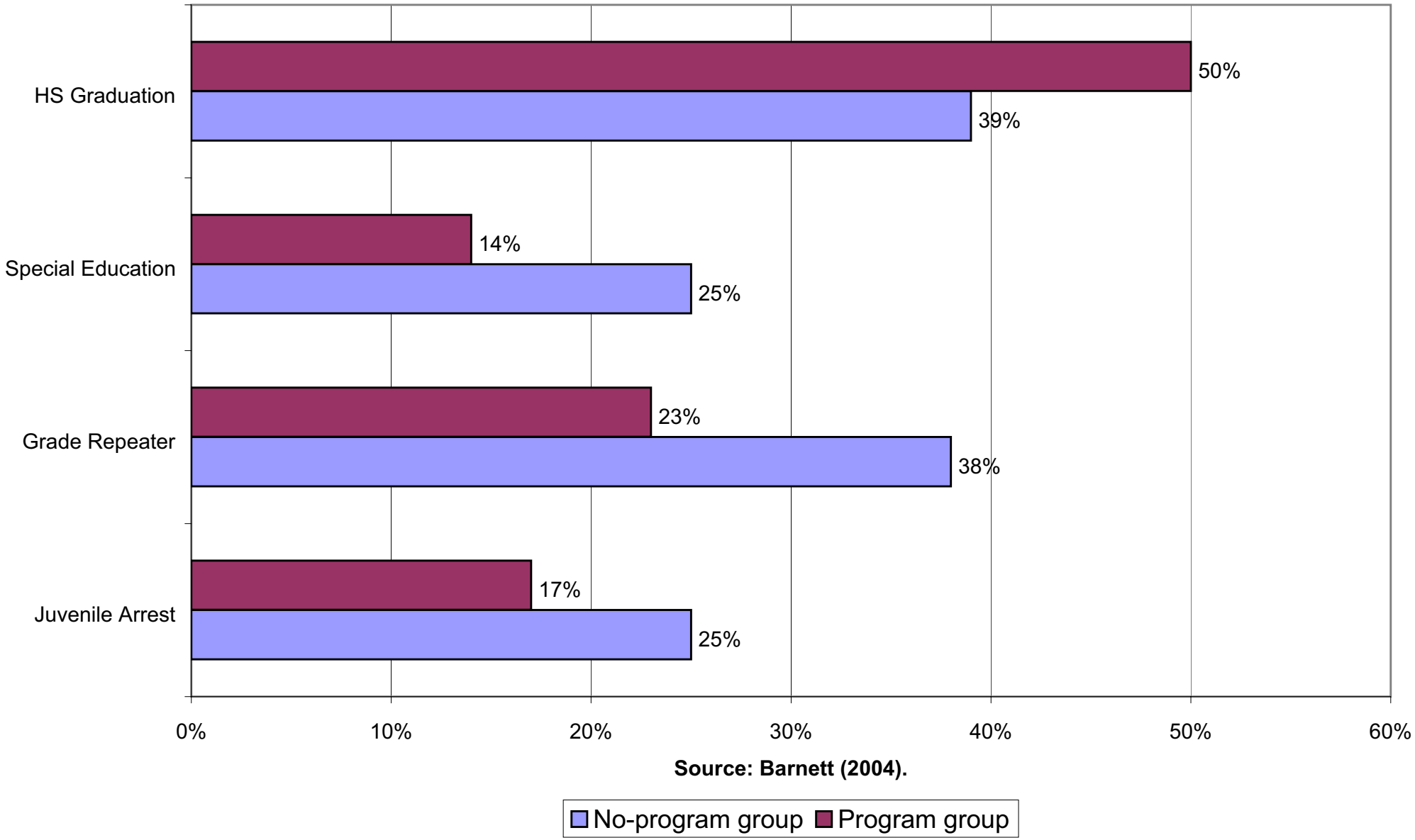

**Source: Barnett (2004).**

**Figure 4**
**Perry Preschool IQ Over Time**



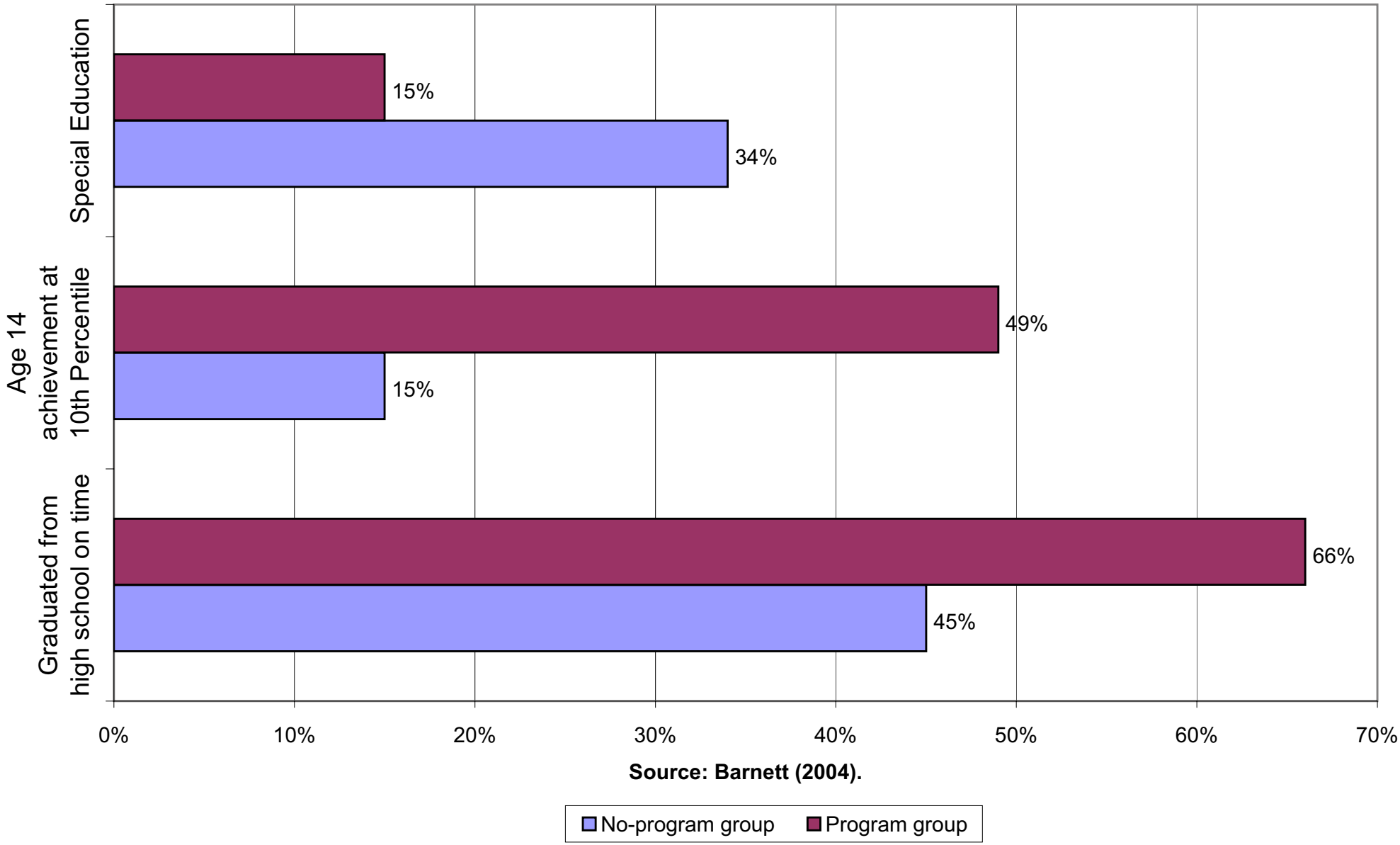

**Source: Barnett (2004)**

## Figure 5
## Academic and Social Benefits at School Exit For CPC Participants



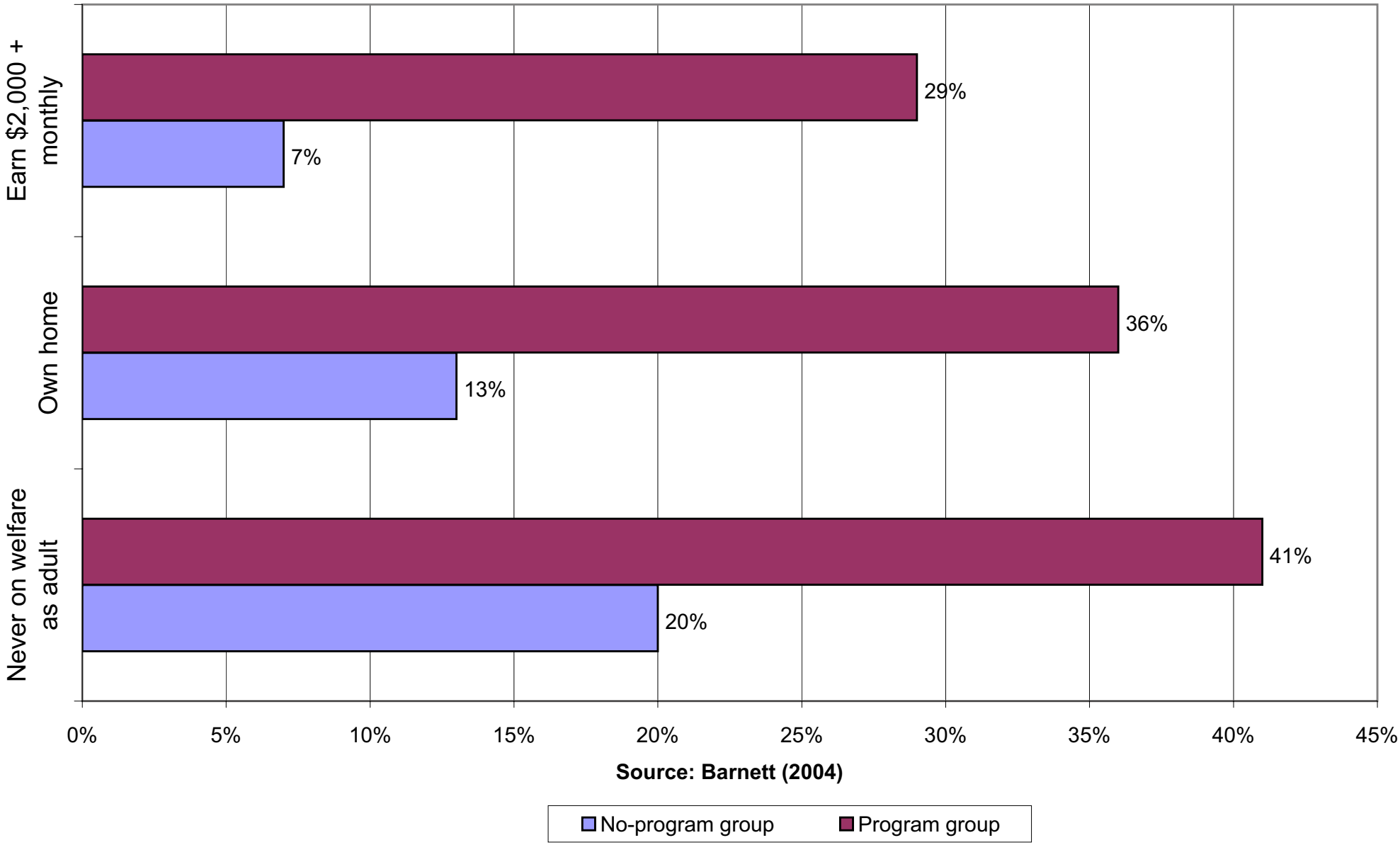

**Source: Barnett (2004).**

**Figure 6a**
**Perry Preschool: Educational Effects**



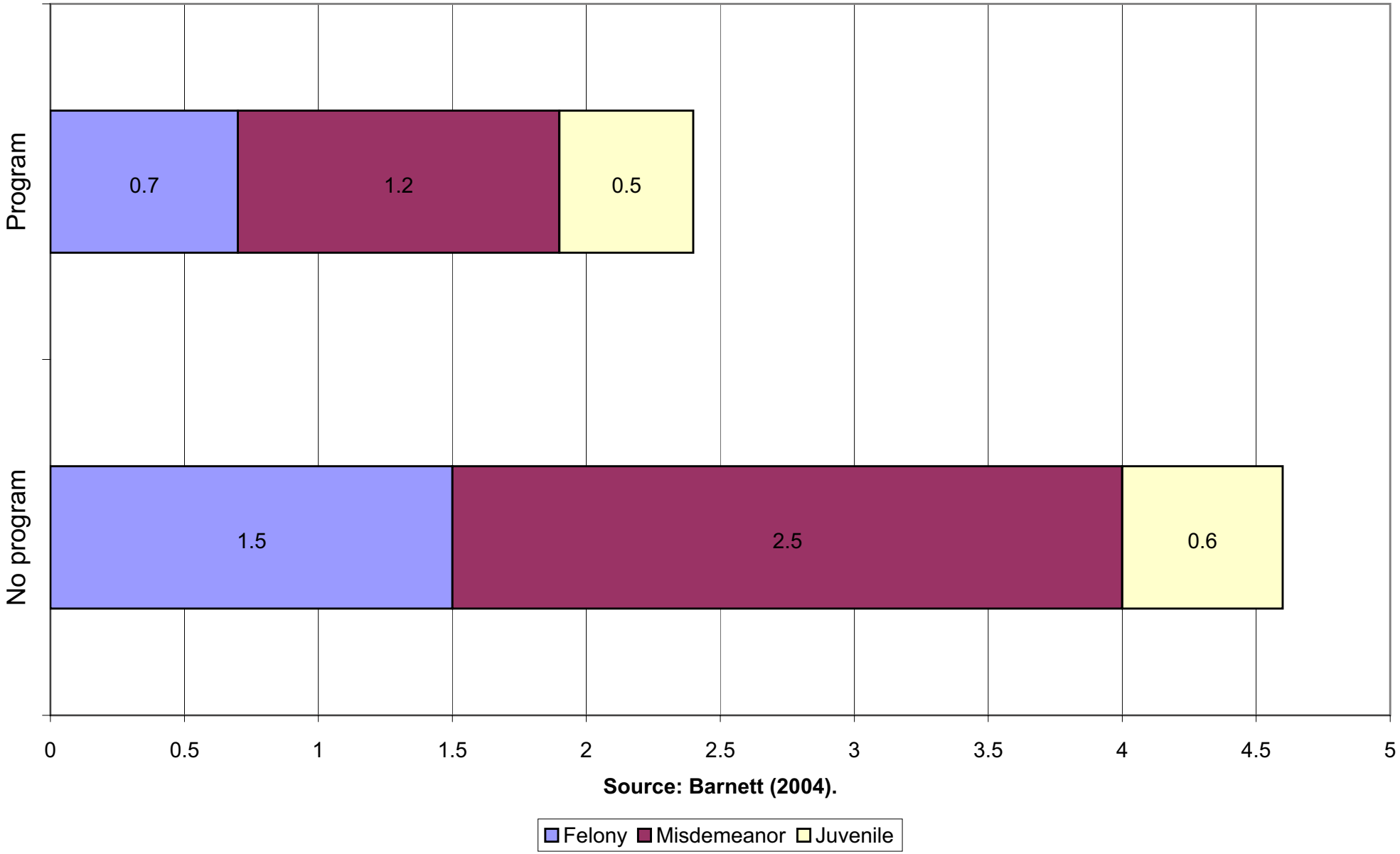

**Source: Barnett (2004).**

**Figure 6b**
**Perry Preschool: Economic Outcomes**



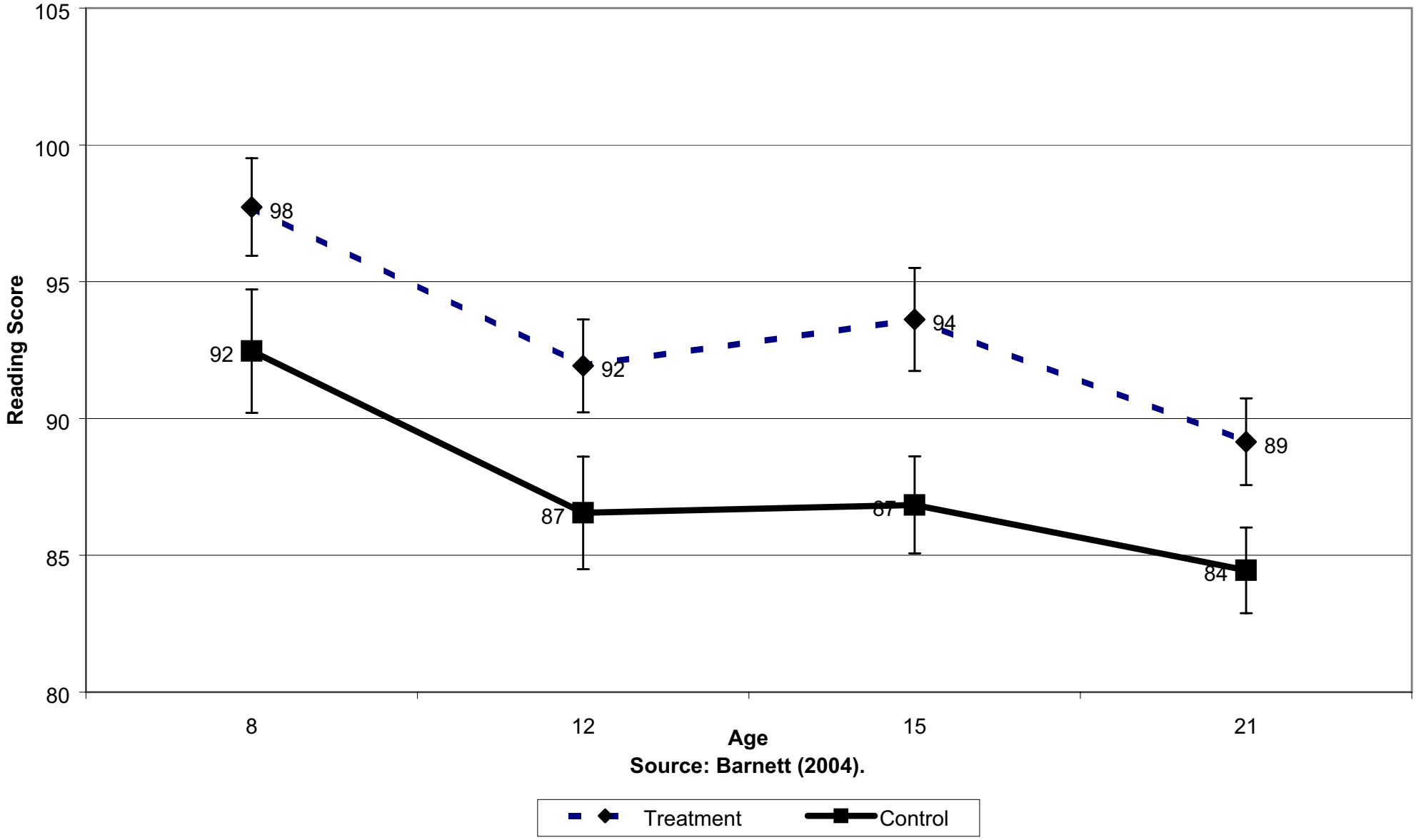

**Source: Barnett (2004)**

**Figure 6c**
**Perry Preschool: Arrests Per Person by Age 27**



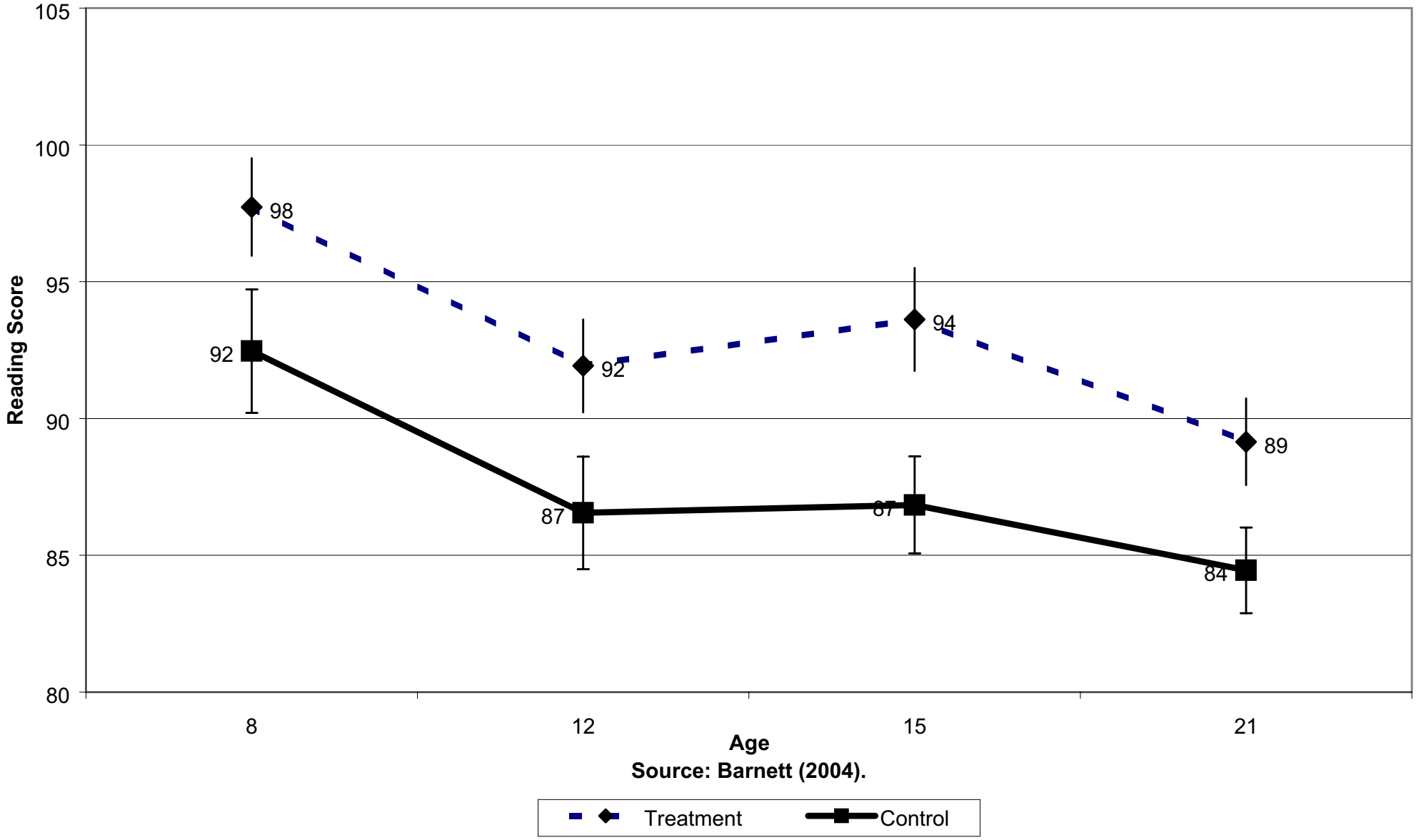

**Source: Barnett (2004).**

**Figure 7a**
**Abecedarian Reading Achievement Over Time**



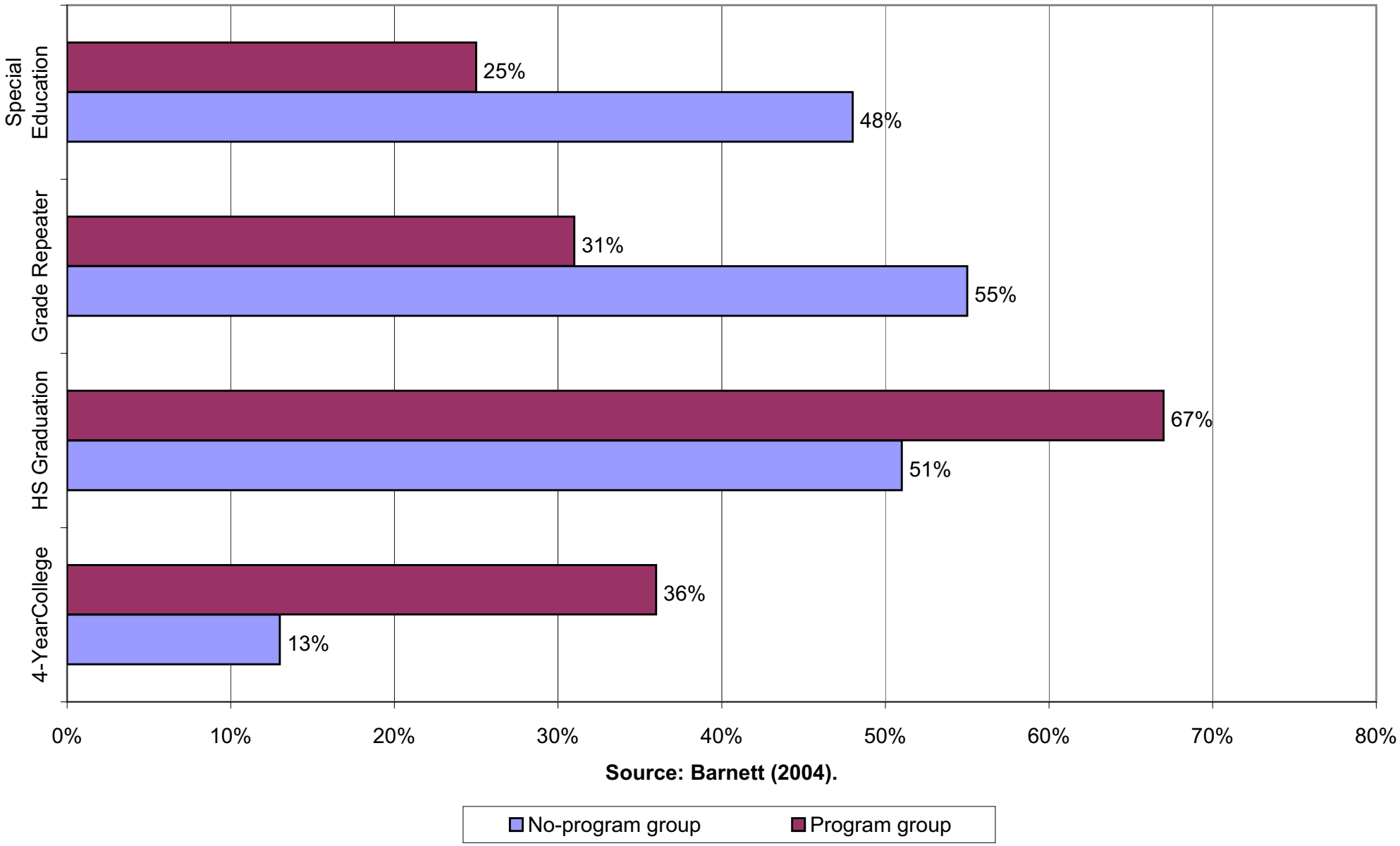

**Source: Barnett (2004).**

**Figure 7b**
**Abecedarian Math Achievement Over Time**



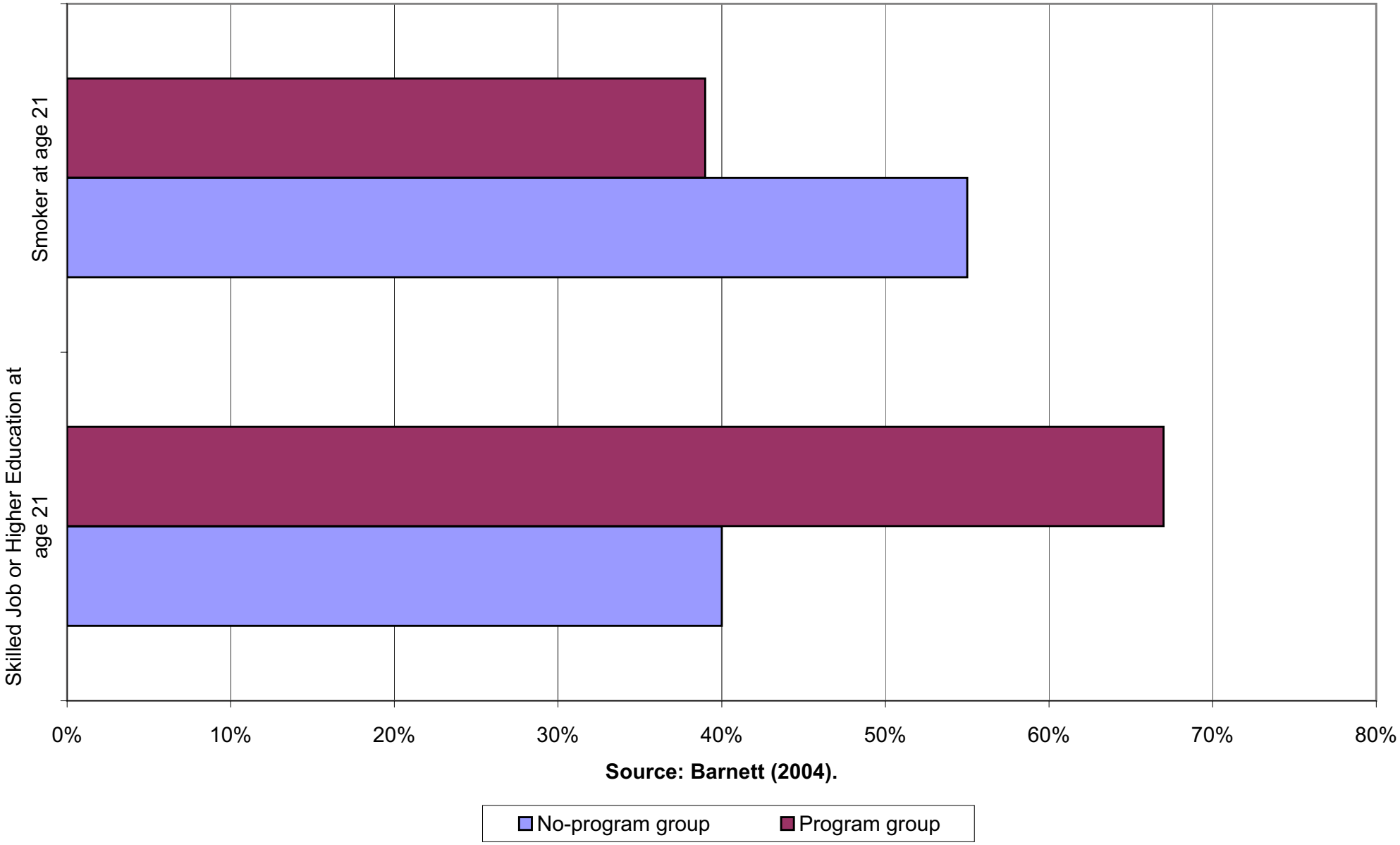

**Source: Barnett (2004).**

**Figure 7c**
**Abecedarian Academic Outcomes**




**Source: Barnett (2004).**

**Figure 7d**
**Other Benefits of Abecedarian**




**Source: Barnett (2004).**

Table 1. 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.

Table 2

Estimated Benefits of Young Adolescent Mentoring Programs (Treatment Group Reductions Compared to Control Group)

| Program | Outcome Measure | Change | Program Costs per Participant |
|---|---|---|---|
| Big Brother / Big Sister | | | $500 - $1500* |
| | Initiating drug use | -45.8% | |
| | Initiation alcohol use | -27.4% | |
| | # of times hit someone | -31.7% | |
| | # of times stole something | -19.2% | |
| | Grade Point Average | 3.0% | |
| | Skipped Class | -36.7% | |
| | Skipped Day of School | -52.2% | |
| | Trust in Parent | 2.7% | |
| | Lying to Parent | -36.6% | |
| | Peer Emotional Support | 2.3% | |
| Sponsor - A - Scholar | | | $1485 |
| | 10th Grade GPA (100 point scale) | 2.9 | |
| | 11th Grade GPA (100 point scale) | 2.5 | |
| | % Attending College (1 year after HS) | 32.8% | |
| | % Attending College (2 years after HS) | 28.1% | |
| Quantum Opportunity Program | | | |
| | Graduated HS or GED | +26% | |
| | Enrolled in 4-year college | +15% | |
| | Enrolled in 2-year college | +24% | |
| | Currently employed full time | +13% | |
| | Self receiving welfare | -22% | |
| | % ever arrested | -4% | |

Source: Carneiro and Heckman (2003).

Notes: *Costs, in 1996 dollars, for school-based programs are as low as $500 and more expensive community based mentoring programs cost as high as $1500; HS = high school

## Table 3

**Effects of selected adolescent social programs on schooling, earnings, and crime**

| Program/Study | Costs[a] | Program Description | Schooling | Earnings[a] | Crime[a] |
|---|---|---|---|---|---|
| STEP (Walker and Viella-Velez, (1992)) | N/A | Two summers of employment, academic remediation and life skills for 14 to 15 year olds | Short-run gains in test scores; no effect on school completion rates | N/A | N/A |
| Quantum Opportunities Program[b] (Taggart, (1995)) | $10,600 | Counseling; educational, community, and development services; financial incentives for four years beginning in ninth grade) | 34% higher high graduation and GED reception rates (two years after program) | N/A | 4% versus 16% convicted; .28 versus .56 average. number of arrests (2 years after program) |

Notes: All comparisons are for program participants vs. non-participants. N/A indicated not available.

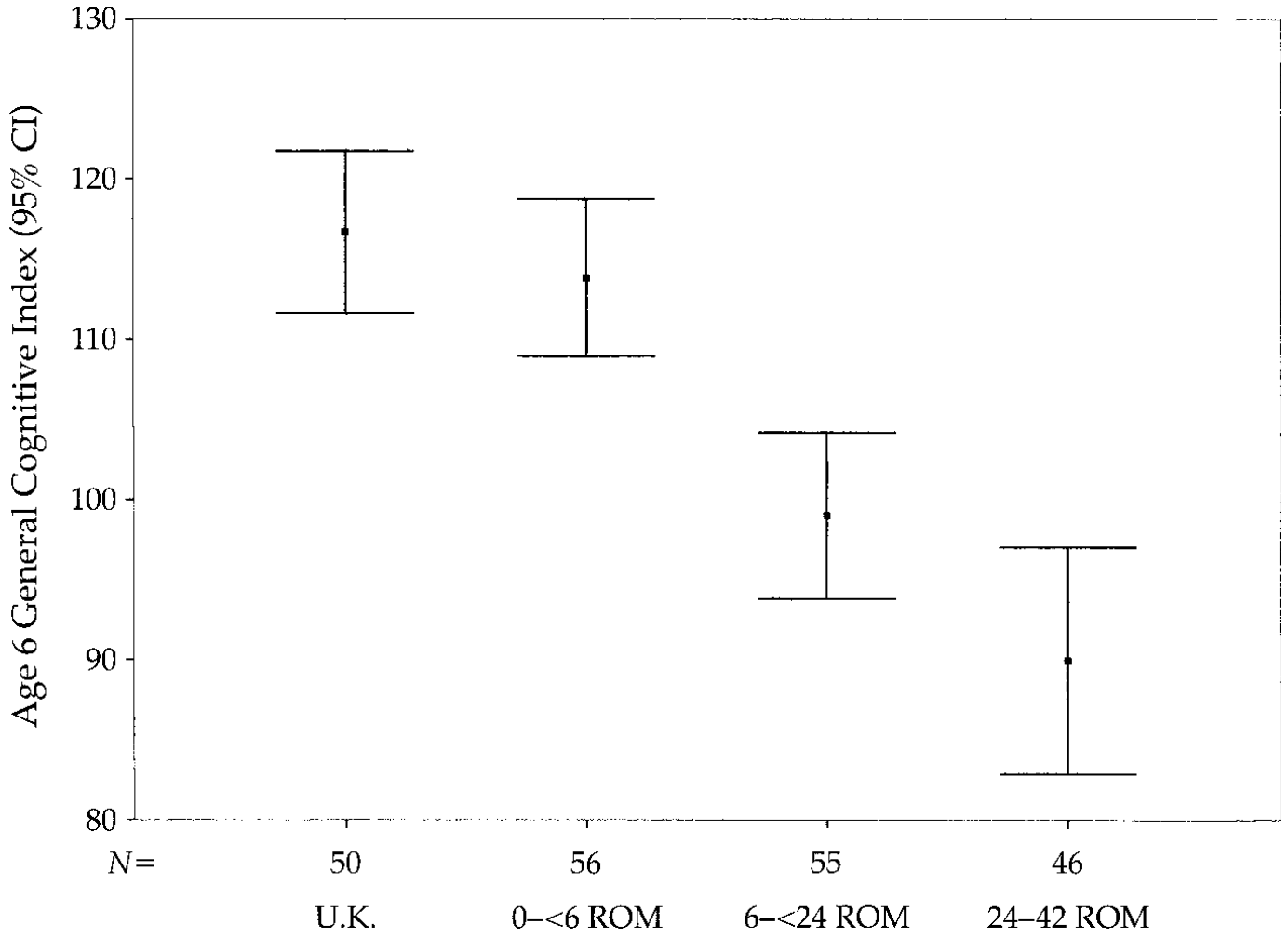
[a] All dollar figures are in 1990 values

[b] Studies used a random assignment experimental design to determine program impacts.

Source: Heckman, Lochner, Smith and Taber (1997)

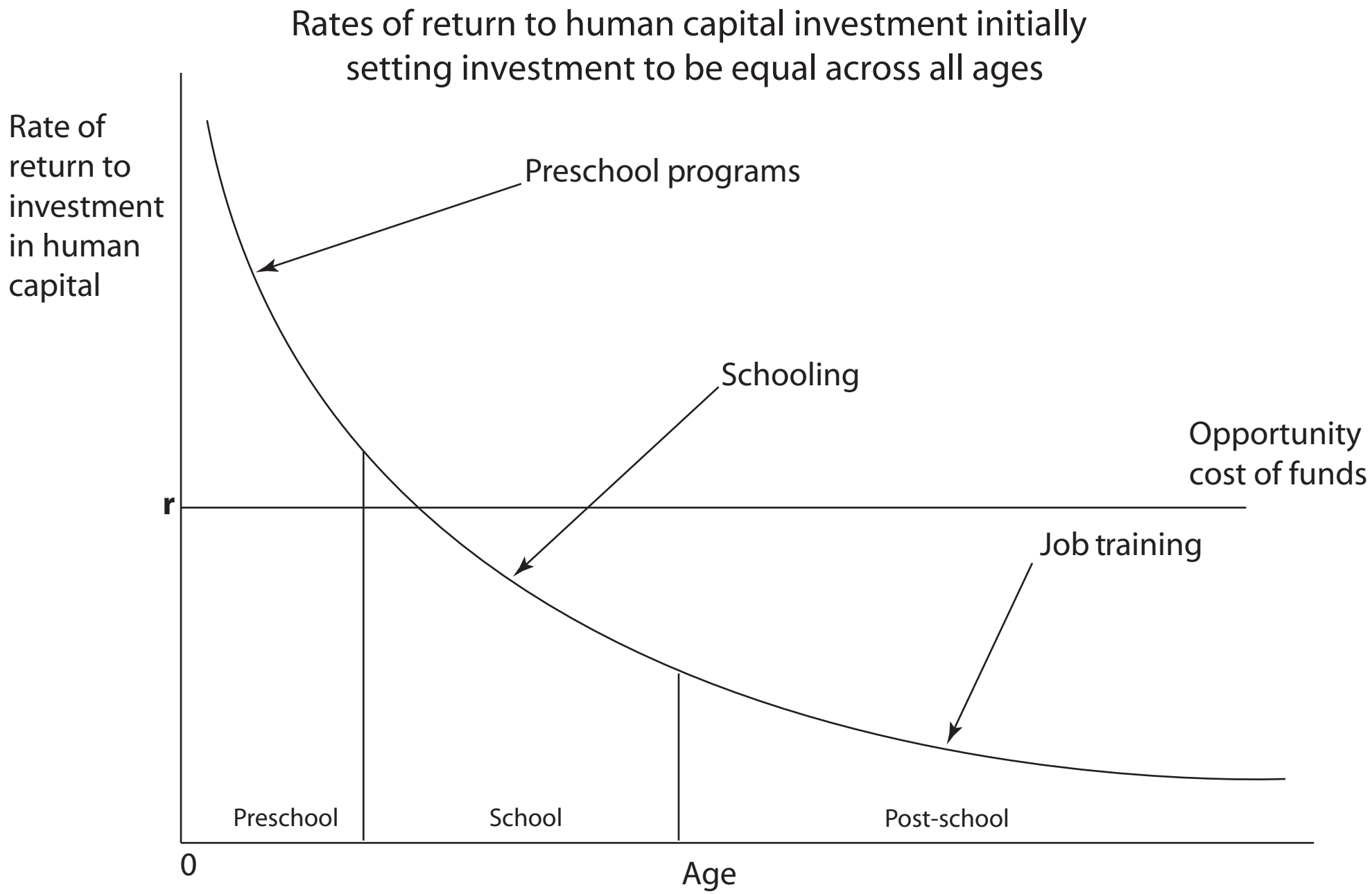
# Figure 8

**Global Cognitive Index (GCI) at 6 years of age as a function of group (age at entry). The means (*SD*) for the U.K., 0- to <6-month Romanian, 6- to <24-month Romanian, and 24- to 42-month Romanian groups were, respectively, 117 (17.8), 114 (18.3), 99 (19.2), and 90 (23.8). U.K. = United Kingdom adoptees; ROM = Romanian adoptees.**




Source: O'Connor et al., 2000.

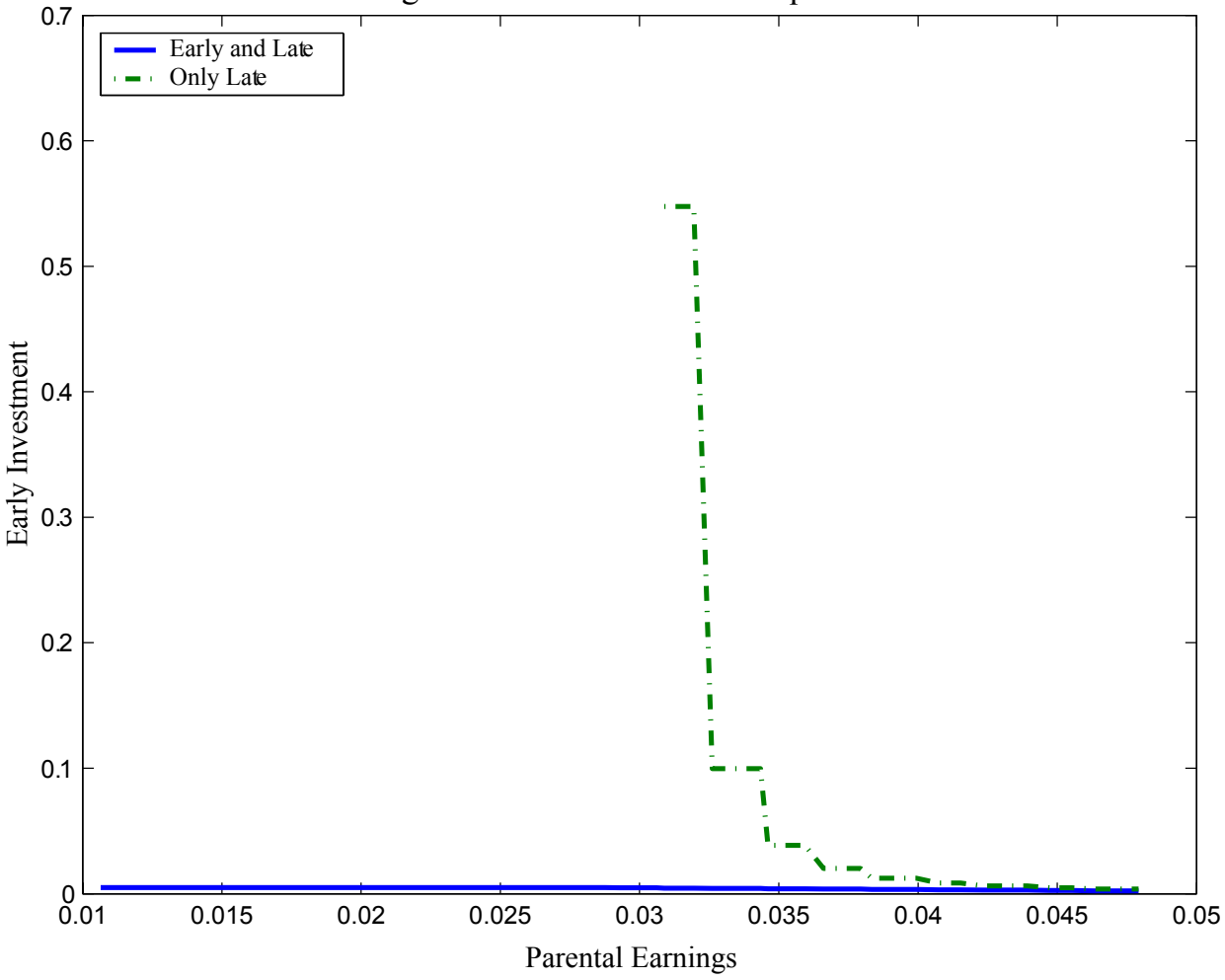
# Figure 9




Rates of return to human capital investment initially setting investment to be equal across all ages

Figure 10

The Costs of Remediation
Late vs. Early and Late Remediation
Agents that Receive Zero Bequests




Let $y$ denote parental earnings. Let $x^*$, $z^*$ denote the early and late investments in a complete markets economy. Let $x(y)$, $z(y)$ denote the early and late investments in the Aiyagari/Laitner economy for agents with zero bequests. This economy restricts the ability of families to borrow freely. The early and late remediation are values $\Delta x(y)$ and $\Delta z(y)$ where $\Delta x(y) = x^* - x(y)$ and $\Delta z(y) = z^* - z(y)$. The cost of the early remediation is $C_1 = \Delta x(y) + \Delta z(y)/(1+r)$, where $r$ is the steady state equilibrium interest rate of the Aiyagari/Laitner economy. Let $h^*$ denote the steady state stock of human capital in the complete markets economy. The late remediation is the value $\delta$ that solves $g(\delta) = h^* - (\gamma x(y)^{\phi} + (1-\gamma)\delta^{\phi})^{\rho/\phi}$, where the second term is the production function for human capital ($\phi$ is the subsitution parameter, $1/(1-\phi)$ is the elasticity of substitution, and $\rho$ is the scale parameter as estimated in Cunha and Heckman (2003, 2004). The cost of late remediation is $C_2 = \delta/(1+r)$

Source: Cunha and Heckman (2003)