The Technology of Skill Formation

By Flavio Cunha and James Heckman*

It is well documented that people have diverse abilities, that these abilities account for a substantial portion of the variation across people in socioeconomic success, and that persistent and substantial ability gaps across children from various socioeconomic groups emerge before they start school. The family plays a powerful role in shaping these abilities through genetics, parental investments, and through choice of child environments. From a variety of intervention studies, it is known that ability gaps in children from different socioeconomic groups can be reduced if remediation is attempted at early ages. The remediation efforts that appear to be most effective are those that supplement family environments for disadvantaged children. Cunha et al. (2006), henceforth CHLM, present a comprehensive survey and discussion of this literature.

This paper uses a simple economic model of skill formation to organize this and other evidence summarized here and the findings of related literatures in psychology, education, and neuroscience. The existing economic models of child development treat childhood as a single period (see, e.g., Gary S. Becker and Nigel Tomes 1986; S. Rao Aiyagari, Jeremy Greenwood, and Aranth Seshadri 2002; and Roland Bénabou 2002). The implicit assumption in this approach is that inputs into the production of skills at different stages of childhood are perfect substitutes. We argue that to account for a large body of evidence, it is important to build a model of skill formation with multiple stages of childhood, where inputs at different stages are complements, and where there is self productivity of investment. In addition, in order to rationalize the evidence, it is important to recognize three distinct credit constraints operating on the family and its children. First, the inability of a child to choose its parents. This is the fundamental constraint imposed by the accident of birth. Second, the inability of parents to borrow against their children's future income to finance investments in them. Third, the inability of parents to borrow against their own income to finance investments in their children.

This paper summarizes findings from the recent literature on child development and presents a model that explains them. A model that is faithful to the evidence must recognize that (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. 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 those due to nurture.

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I. Observations about Human Diversity and Human Development and Some Facts Our Model Explains

Any analysis of human development must reckon with three empirically well-established observations about ability. 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. The frenzy generated by Richard J. Herrnstein and Charles A. Murray's book *The Bell Curve*, because of its claims of genetic determinism, obscured its real message, which is that cognitive ability is an important predictor of socioeconomic success (see, e.g., Heckman 1995; and Richard J. Murnane, John B. Willett, and Frank Levy 1995).

A *second observation*, more recently established, is that *abilities are multiple in nature*. Noncognitive abilities (perseverance, motivation, time preference, risk aversion, self-esteem, self-control, preference for leisure) have direct effects on wages (controlling for schooling), schooling, teen pregnancy, smoking, crime, performance on achievement tests, and many other aspects of social and economic life. (Samuel Bowles, Herbert Gintis, and Melissa Osborne 2001; Lex Borghans, Angela L. Duckworth, Heckman, and Bas ter Weel, forthcoming; and Heckman, Jora Stixrud, and Sergio Urzua 2006).

The *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 (see, e.g., Michael Rutter 2006 and Peter D. Gluckman and Mark Hanson 2005).[1] 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 (Rutter 2006). Measured abilities are susceptible to environmental influences, including *in utero* experiences, and also have genetic components. These factors interact to produce behaviors and abilities that have both a genetic and an acquired character.[2, 3] Genes and environment cannot be parsed meaningfully by traditional linear models that assign variance to each component.

Taking these observations as established, we develop a simple economic model to explain the following six facts from the recent empirical literature. First, *ability gaps between individuals and across socioeconomic groups open up at early ages, for both cognitive and noncognitive skills*. See Figure 1 for a prototypical figure which graphs a cognitive test score by age of child and socioeconomic status of the family.[4] CHLM present many additional graphs of child cognitive and noncognitive skills by age showing early divergence and then near parallelism during school-going years across children with parents of different socioeconomic status.[5] Levels of child skills are highly correlated with family background factors like parental education and maternal ability, which, when statistically controlled for, largely eliminate these gaps (see Pedro Carneiro and Heckman 2003; CHLM, and our Web site).[6] Experimental interventions with long-term follow-up confirm that changing the resources available to disadvantaged children improves their adult outcomes (see the studies surveyed in CHLM or David Blau and Janet Currie 2006.) Schooling quality and school resources have relatively small effects on ability deficits and have little effect on test scores by age across children from different socioeconomic groups, as displayed in Figure 1 and related graphs (see Heckman,

[1] For example, Becker (1993, 99–100) contrasts the implications for the earnings distribution of ability models of earnings and human capital models, claiming the latter are more consistent with the empirical evidence on earnings. The implicit assumption in his analysis and the literature it spawned is that ability is determined by "nature," i.e., is genetic, and outside the influence of family investment strategies.

[2] There is some evidence that gene expression affected by environment is heritable (see Rutter 2006).

[3] Some recent evidence on gene-environment interactions resulting from child maltreatment is presented in Avshalom Caspi et al. (2002). Rutter (2006) surveys this evidence.

[4] Permanent income is the measure of socioeconomic status in this figure. See CHLM for the source of this figure and the precise definition of permanent income.

[5] These and other figures are posted at our Web site for this paper. See Figures D0–D8 on our Web site.

[6] See Figures D1–D3 on our Web site.

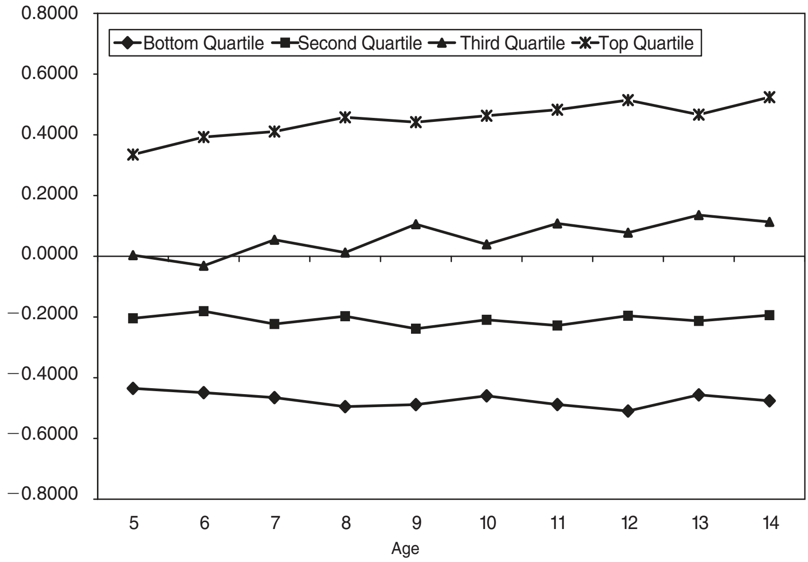

FIGURE 1. CHILDREN OF THE NLSY:
AVERAGE STANDARDIZED SCORE FOR PIAT MATH BY PERMANENT INCOME QUARTILE

Source: Full sample of the Children of the National Longitudinal Survey of Youth. See our Web site for a full explanation of this figure.

Maria Isabel Larenas, and Urzua 2004; Stephen W. Raudenbush 2006).

Second, *in both animal and human species, there is compelling evidence of critical and sensitive periods in the development of the child.* Some skills or traits are more readily acquired at certain stages of childhood than others (see the evidence summarized in Eric I. Knudsen et al. 2006). For example, on average, if a second language is learned before age 12, the child speaks it without an accent (Elissa L. Newport 1990). If syntax and grammar are not acquired early on, they appear to be very difficult to learn later in life (Steven Pinker 1994). A child born with a cataract will be blind if the cataract is not removed within the first year of life.

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 before age 10 (see Kenneth D. Hopkins and Glenn H. Brecht 1975). There is evidence that adolescent interventions can affect noncognitive skills (see CHLM). This evidence is supported by the neuroscience that establishes the malleability of the prefrontal cortex into the early 20s (Ronald E. Dahl 2004). This is the region of the brain that governs emotion and self-regulation.

On average, the later remediation is given to a disadvantaged child, the less effective it is. A study by Thomas G. O'Connor et al. (2000) of adopted Romanian infants reared in severely deprived orphanage environments before being adopted supports this claim. The later the Romanian orphan was rescued from the social, emotional and cognitive isolation of the orphanage, the lower was his or her cognitive performance at the age of six. Classroom remediation programs designed to combat early cognitive deficits have a poor track record.

At historically funded levels, 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 produce meager effects for most people. 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 (Costas Meghir and Mårten Palme 2001; Carneiro and Heckman 2003 and the evidence they cite; and

Carneiro, Heckman, and Edward J. Vytlacil 2006).

The available evidence suggests that for many skills and abilities, later remediation for early disadvantage to achieve a given level of adult performance may be possible but is much more costly than early remediation (Cunha and Heckman 2006). The economic returns to job training, high-school graduation, and college attendance are lower for less able persons (see Carneiro and Heckman 2003 and the studies they cite).

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* (see W. Steven Barnett 2004, the evidence in CHLM, and the papers they cite). This finding is a consequence of dynamic complementarity and self-productivity captured by the technology developed in the next section.

Fourth, *if early investment in disadvantaged children is not followed up by later investment, its effect at later ages is lessened.* Investments appear to be complementary and require follow-up to be effective. Currie and Duncan Thomas (1995) document a decline in the performance of Head Start (a national program that promotes school readiness) minority participants after they leave the program, return to disadvantaged environments, and receive the low levels of investment experienced by many disadvantaged children (see our Web site, CHLM and Blau and Currie 2006 for definitions of this and other early intervention programs).[7]

Fifth, *the effects of credit constraints on a child's outcomes when the child reaches adulthood depend on the age at which they bind for the child's family.* Recent research summarized in Carneiro and Heckman (2002, 2003) and in CHLM demonstrates the quantitative insignificance of family credit constraints in the child's college-going years in explaining a child's enrollment in college. 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, although much public policy is predicated on precisely the opposite point of view. Holding ability fixed, minorities are *more likely* to attend college than others despite their lower family incomes (see Stephen V. Cameron and Heckman 2001 and the references they cite). Augmenting family income or reducing college tuition at the stage of the life cycle when a child goes to college does not go far in compensating for low levels of previous investment.

Carneiro and Heckman present evidence that only a small fraction (at most 8 percent) of the families of adolescents in the United States are credit constrained in making college participation decisions. This evidence is supported by Cameron and Christopher Taber (2004) and Ralph Stinebrickner and Todd R. Stinebrickner (2006). Permanent family income plays an important role in explaining educational choices, insofar as it is a proxy for the high level of investment in abilities and skills that wealthier families provide, but it is not synonymous with family income in the adolescent years, or with tuition and fees.

There is some evidence, however, that credit constraints operating in the *early* years have effects on adult ability and schooling outcomes (Greg J. Duncan and Jeanne Brooks-Gunn 1997; Gordon B. Dahl and Lance J. Lochner 2005; Pamela Morris, Duncan, and Elizabeth Clark-Kaufmann 2005; and Duncan and Ariel Kalil 2006). Carneiro and Heckman (2003) show that controlling for family permanent income reduces the estimated effect of early income on child outcomes. Permanent income has a strong effect on child outcomes. The strongest evidence for an effect of the timing of parental income for disadvantaged children is in their early years. The best documented market failure in the life cycle of skill formation in contemporary American society is the inability of children to buy their parents or the lifetime resources that parents provide and not the inability of families 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.* Emotionally nurturing environments produce more capable learners. The Perry Preschool Program, which was evaluated by random assignment, did not boost participant adult IQ but enhanced performance of participants on

[7] Currie and Thomas (2000) present additional analyses of the Head Start program.

a number of dimensions, including scores on achievement tests, employment, and reduced participation in a variety of social pathologies (see Lawrence J. Schweinhart et al. 2005 and the figures and tables on the Perry program posted at our Web site).[8]

II. A Model of Skill Formation

We now develop a model of skill formation that can explain the six facts just presented, as well as additional findings from the literature on child development. We use the terms "skill" and "ability" interchangeably. Both are produced by environments, investment, and genes.

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, and time preference). These abilities are used with different weights in different tasks in the labor market and in social life more generally.[9] Achievement test scores, sometimes confused with IQ scores (e.g., Herrnstein and Murray 1994), are not pure measures of ability and are affected by cognitive, noncognitive, and environmental inputs (see, e.g., Karsten T. Hansen, Heckman, and Kathleen J. Mullen 2004; and Cunha and Heckman, 2007).

The human skill formation process is governed by a multistage technology. Each stage corresponds to a period in the life cycle of a child. While the child development literature recognizes stages of development (see, e.g., Erik H. Erikson 1950), the economics of child development does not. Inputs or investments at each stage produce outputs at the next stage. Like Yoram Ben-Porath (1967), we use a production function to determine the relationship between inputs and the output of skill. Unlike Ben-Porath, in our model, qualitatively different inputs can be used at different stages, and the technologies can be different at different stages of child development.[10]

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 technology 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. The 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.

An important feature of our technology is that the skills produced at one stage augment the skills attained at later stages. This effect is termed *self-productivity.* It embodies the idea that skills acquired in one period persist into future periods. It also embodies the idea that skills are self-reinforcing and cross fertilizing. For example, emotional security fosters child exploration and more vigorous learning of cognitive skills. This has been found in animal species (Stephen J. Suomi 1999; Michael J. Meaney 2001; and Judy Cameron 2004) and in humans (Duncan et al. 2006; C. Cybele Raver, Pamela W. Garner, and Radiah Smith-Donald 2007, interpreting the ability of a child to pay attention as a socioemotional skill). A higher stock of cognitive skills in one period raises the stock of cognitive skills in the next period. A second key feature of skill formation is *dynamic complementarity.* Skills produced at one stage raise the productivity of investment at subsequent stages. In a multistage technology, complementarity implies that levels of skill investments at different ages bolster each other. They are synergistic. Complementarity also implies that early investment should be followed up by later investment in order for the early investment to be productive. 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 from the recent literature summarized in the previous section. These features of the technology of skill formation have

[8] See the Figure D9 series.

[9] CHLM briefly discuss the evidence on this point and suggest a model of comparative advantage in occupational choice to supplement their model of skill formation.

[10] We discuss the comparison between our technology and that of Ben-Porath (1967) in Section B of our Web site.

consequences for the design and evaluation of public policies toward families. In particular, they show why the returns to late childhood investment and remediation for young adolescents from disadvantaged backgrounds are so low, while the returns to early investment in children from disadvantaged environments are so high.

We now formalize these concepts in an overlapping generations model. An individual lives for $2T$ years. The first T years the individual is a child of an adult parent. From age $T + 1$ to $2T$ the individual lives as an adult and is the parent of a child. The individual dies at the end of the period in which he is $2T$ years old, just before his child's child is born. At every calendar year there are an equal and large number of individuals of every age $t \in \{1, 2, \ldots, 2T\}$.[11] To simplify the notation, we do not explicitly subscript generations.

A household consists of an adult parent and his child. Parents invest in their children because of altruism. They have common preferences and supply labor inelastically. Let I_t denote parental investments in child skill when the child is t years old, where $t = 1, 2, \ldots, T$. The output of the investment process is a skill vector. The parent is assumed to fully control the investments in the skills of the child, whereas in reality, as a child matures, he gains much more control over the investment process.[12] We ignore investments in the child's adult years to focus on new ideas in this paper. We also keep government inputs (e.g., schooling) implicit. They can be modeled as a component of I_t.

We now describe how skills evolve over time. Assume that each agent is born with initial conditions θ_1. Let h denote parental characteristics (e.g., IQ, education, etc.). At each stage t, let θ_t denote the vector of skill stocks. The technology of production of skill when the child is t years old is

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

for $t = 1, 2, \ldots, T$. We assume that f_t is strictly increasing and strictly concave in I_t, and twice continuously differentiable in all of its arguments.[13]

Technology (1) is written in recursive form. Substituting in (1) for $\theta_t, \theta_{t-1}, \ldots$, repeatedly, one can rewrite the stock of skills at stage $t + 1$, θ_{t+1}, as a function of all past investments:[14]

$$\theta_{t+1} = m_t(h, \theta_1, I_1, \ldots, I_t), \; t = 1, \ldots, T. \tag{2}$$

Dynamic complementarity arises when $\partial^2 f_t(h, \theta_t, I_t)/\partial\theta_t \partial I_t' > 0$, i.e., when stocks of skills acquired by period $t - 1$ (θ_t) make investment in period t (I_t) more productive. Such complementarity explains why returns to educational investments are higher at later stages of the child's life cycle for more able children (those with higher θ_t). Students with greater early skills (cognitive and noncognitive) are more efficient in later learning of both cognitive and noncognitive skills. The evidence from the early intervention literature suggests that the enriched early preschool environments provided by the Abecedarian, Perry, and CPC interventions promote greater efficiency in learning in school and reduce problem behaviors (see Blau and Currie 2006, CHLM, and our Web site for this evidence and descriptions of these early intervention programs).

Self-productivity arises when $\partial f_t(h, \theta_t, I_t)/\partial\theta_t > 0$, i.e., when higher stocks of skills in one period create higher stocks of skills in the next period. For the case of skill vectors, this includes own and cross effects. The joint effects of self-productivity and dynamic complementarity help to explain the high productivity of investment in disadvantaged young children, and the lower return to investment in disadvantaged adolescent children for whom the stock of skills is low and hence the complementarity effect is lower. These are facts two and three presented in Section I.

This technology is sufficiently rich to describe learning in rodents and macaque monkeys. More emotionally secure young animals explore their environments more actively and learn more quickly. This technology also explains the

[11] We develop our formal overlapping generations (OLG) model in Section C of our Web site.

[12] A sketch of such a model is discussed in Carneiro, Cunha, and Heckman (2003).

[13] These conditions are sufficient. There is no need for a differentiability requirement for h, and the differentiability requirement with respect to θ_t can be weakened.

[14] Examples are developed in Section A of our Web site.

evidence that the ability of the child to pay attention affects subsequent academic achievement. Cross-complementarity serves to explain fact six. This technology also captures the critical and sensitive periods in humans and animals documented by Knudsen et al (2006). We now define these concepts precisely.

Period t^* is a critical period for θ_{t+1} if

$$\frac{\partial \theta_{t+1}}{\partial I_s} = \frac{\partial m_t(h, \theta_1, I_1, \ldots, I_t)}{\partial I_s} \equiv 0$$

for all $h, \theta_1, I_1, \ldots, I_t, s \neq t^*$,

$$\text{but} \qquad \frac{\partial \theta_{t+1}}{\partial I_{t^*}} = \frac{\partial m_t(h, \theta_1, I_1, \ldots, I_t)}{\partial I_{t^*}} > 0$$

for some $h, \theta_1, I_1, \ldots, I_t$.

This condition says that investments in θ_{t+1} are productive in period t^* but not in any other period $s \neq t^*$. Period t^* is a sensitive period for θ_{t+1} if

$$\left.\frac{\partial \theta_{t+1}}{\partial I_s}\right|_{h = \bar{h},\, \theta_1 = \theta,\, I_1 = i_1, \ldots, I_t = i_t} < \left.\frac{\partial \theta_{t+1}}{\partial I_{t^*}}\right|_{h = \bar{h},\, \theta_1 = \theta,\, I_1 = i_1, \ldots, I_t = i_t}.$$

In words, period t^* is a sensitive period relative to period s if, at the same level of inputs, investment is more productive in stage t^* than in another stage $s \neq t^*$.[15]

Suppose for simplicity that $T = 2$. In reality, there are many stages in childhood, including *in utero* experiences.[16] Assume that θ_1, I_1, I_2 are scalars.[17] The adult stock of skills, h' $(= \theta_3)$, is a function of parental characteristics, initial conditions and investments during childhood I_1 and I_2:

$$(3) \qquad h' = m_2(h, \theta_1, I_1, I_2).$$

The literature in economics assumes only one period of childhood. It does not distinguish between early investment and late investment. This produces the conventional specification which is a special case of technology (3), where

$$(4) \qquad h' = m_2(h, \theta_1, \gamma I_1 + (1 - \gamma) I_2)$$

and $\gamma = ½$. In this case, adult stocks of skills do not depend on how investments are distributed over different periods of childhood. For example, take two children, A and B, who have identical parents and the same initial condition θ_1, but have different investment profiles: child A receives no investment in period one and receives I units of investment in period two, $I_1^A = 0$, $I_2^A = I$, while child B receives I units of investment in period one and zero units of investment in period two, $I_1^B = I$, $I_2^B = 0$. According to (4), when $\gamma = {}^1/_2$, children A and B will have the same stocks of skills as adults. The timing of investment is irrelevant. Neither period one nor period two is critical.

The polar opposite of perfect substitution is perfect complementarity:

$$(5) \qquad h' = m_2(h, \theta_1, \min\{I_1, I_2\}).$$

Technology (5) has the feature that adult stocks of skills critically depend on how investments are distributed over time. For example, if investment in period one is zero, $I_1 = 0$, then it does not pay to invest in period two. If late investment is zero, $I_2 = 0$, it does not pay to invest early. For the technology of skill formation defined by (5), the best strategy is to distribute investments evenly, so that $I_1 = I_2$. Complementarity has a dual face. It is essential to invest early to get satisfactory adult outcomes. But it is also essential to invest late to harvest the fruits of the early investment.[18] Such dynamic complementarity helps to explain the evidence by Currie and

[15] See CHLM for a definition of critical and sensitive periods in terms of technology (1). These definitions are developed further in Section B of our Web site.

[16] Our technology applies to *in utero* and post-natal investments as well. See Jack P. Shonkoff and Deborah Phillips (2000) for evidence on the importance of such investments.

[17] CHLM analyze the vector case. See also the supporting material on our Web site.

[18] Both periods are critical. Note that, in this case, the production function is not strictly differentiable as required in our definition. Our definition can be extended to deal with this limit case.

Thomas (1995) that for disadvantaged minority students, early investments through Head Start have weak effects in later years if not followed up by later investments. This is fact four on our list. Our explanation is in sharp contrast to the one offered by Becker (1991) who explains weak Head Start effects by crowding out of parental investment by public investment. That is a story of substitution against the child who receives investment in a one-period model of childhood. Ours is a story of dynamic complementarity.[19]

A more general technology that captures technologies (4) and (5) as special cases is a standard CES:

$$(6)\quad h' = m_2\Big(h, \theta_1, [\gamma(I_1)^{\phi} + (1-\gamma)(I_2)^{\phi}]^{1/\phi}\Big)$$

for $\phi \leq 1$ and $0 \leq \gamma \leq 1$. The CES share parameter γ is a *skill multiplier*. It reveals the productivity of early investment not only in directly boosting h' (through self-productivity), but also in raising the productivity of I_2 by increasing θ_2 through first-period investments. Thus, I_1 directly increases θ_2, which, in turn, affects the productivity of I_2 in forming h'; γ captures the net effect of I_1 on h' through both self-productivity and direct complementarity.[20]

The elasticity of substitution $1/(1-\phi)$ is a measure of how easy it is to substitute between I_1 and I_2. For a CES technology, ϕ represents the degree of complementarity (or substitutability) between early and late investment in producing skills. The parameter ϕ governs how easy it is to compensate for low levels of stage 1 skills in producing later skills.

When ϕ is small, low levels of early investment I_1 are not easily remediated by later investment I_2 in producing human capital. The other face of CES complementarity is that when ϕ is small, high early investment should be followed with high late investment if the early investment is to be harvested. In the extreme case when $\phi \to -\infty$, (6) converges to (5). This technology explains facts two and three—why returns to education are low in the adolescent years for disadvantaged (low h, low I_1, low θ_2) adolescents but are high in the early years. Without the proper foundation for learning (high levels of θ_2) in technology (1), adolescent interventions have low returns.

In a one-period model of childhood, inputs at any stage of childhood are perfect substitutes. Application of the one-period model supports the widely held but empirically unsupported intuition that diminishing returns make investment in less advantaged adolescents *more* productive. As noted in fact two of Section I, the evidence suggests that just the opposite is true. We next embed the technology in a market environment with parental choice of inputs.

III. The Optimal Life-Cycle Profile of Investments

Using technology (6), we now show how the ratio of early to late investments varies as a function of ϕ and γ as a consequence of parental choices in different market settings. Let w and r denote the wage and interest rates, respectively, in a stationary environment. At the beginning of adulthood, the parent draws the initial level of skill of the child, θ_1, from the distribution $J(\theta_1)$. Upon reaching adulthood, the parent receives bequest b. The state variables for the parent are the parental skills, h, the parental financial resources, b, and the initial skill level of the child, θ_1. Let c_1 and c_2 denote the consumption of the household in the first and second period of the life cycle of the child, respectively. The parent decides how to allocate the resources among consumption and investments at different periods, as well as bequests b', which may be positive or negative. Assuming that human capital (parental and child) is scalar, the budget constraint is

$$(7)\quad c_1 + I_1 + \frac{c_2 + I_2}{(1+r)} + \frac{b'}{(1+r)^2} = wh + \frac{wh}{(1+r)} + b.$$

[19] We offer another explanation of the apparently weak Head Start effects below.

[20] Consider an example in which $f_t(h, \theta_t, I_t) = [\eta_{1,t}(\theta_t)^{\phi_t} + \eta_{2,t}(I_t)^{\phi_t} + \eta_{3,t}(h)^{\phi_t}]^{(\rho_t/\phi_t)}$ for $t = 1,2$; $\rho_1 = 1$, $\rho_2 < 1$; and $\eta_{1,t} + \eta_{2,t} + \eta_{3,t} = 1$. Then, substituting for θ_2, we obtain $m_2(h,\theta_1,I_1,I_2) = [\eta_{1,2}(\eta_{1,1}(\theta_1)^{\phi_1} + \eta_{2,1}(I_1)^{\phi_1} + \eta_{3,1}(h)^{\phi_1})^{(\phi_2/\phi_1)} + \eta_{2,2}(I_2)^{\phi_2} + \eta_{3,2}(h)^{\phi_2}]^{(\rho_2/\phi_2)}$. The parameter ϕ_2 describes how easy it is to compensate early neglect with second-period investment. The parameter ϕ_1 describes the compensation possibilities for overcoming adverse initial conditions θ_1 with first-period investment. The technology in the text is obtained by setting $\phi_1 = \phi_2$, $\eta_{3,1} = \eta_{3,2} = \eta_{1,1} = 0$, so that $\gamma = \eta_{1,2}\,\eta_{2,1}$ and $\eta_{2,2} = 1 - \gamma$. See Section A.1 on our Web site for further analysis of this and related cases.

Let β denote the utility discount factor and δ denote the parental altruism toward the child. Let $u(\cdot)$ denote the utility function. The recursive formulation of the problem of the parent is

$$V(h,b,\theta_1) = \max\{u(c_1) + \beta u(c_2) + \beta^2 \delta E[V(h',b',\theta_1')]\}. \tag{8}$$

The problem of the parent is to maximize (8) subject to (7) and technology (6).[21]

When $\phi = 1$, so early and late investment are perfect CES substitutes, the optimal investment strategy is straightforward. The price of early investment is \$1. The price of late investment is $\$1/(1 + r)$. Thus, the parent can purchase $(1 + r)$ units of I_2 for every unit of I_1. The amount of human capital produced from one unit of I_1 is γ, while $\$(1 + r)$ of I_2 produces $(1 + r)(1 - \gamma)$ units of human capital. Thus, two forces act in opposite directions. High productivity of initial investment (the skill multiplier γ) drives the parent toward making early investments. The interest rate drives the parent to invest late. It is optimal to invest early if $\gamma > (1 - \gamma)(1 + r)$.

As $\phi \to -\infty$, the CES production function converges to the Leontief case and the optimal investment strategy is to set $I_1 = I_2$. In this case, investment in the young is essential. At the same time, later investment is needed to harvest early investment. On efficiency grounds, early disadvantages should be perpetuated, and compensatory investments at later ages are economically inefficient.

For $-\infty < \phi < 1$, the first-order conditions are necessary and sufficient given concavity of the technology in terms of I_1 and I_2. For an interior solution, we can derive the optimal ratio of early to late investment:

$$\frac{I_1}{I_2} = \left[\frac{\gamma}{(1 - \gamma)(1 + r)}\right]^{\frac{1}{1-\phi}}. \tag{9}$$

Figure 2 plots the ratio of early to late investment as a function of the skill multiplier γ under different values of the complementarity parameter ϕ, assuming $r = 0$. When $\phi \to -\infty$, the ratio is not sensitive to variations in γ. When $\phi = 0$, the function (6) is

$$h' = m_2(h,\theta_1,I_1,I_2) = m_2(h,\theta_1,I_1^{\gamma} I_2^{1-\gamma}).$$

In this case, from equation (9), the optimal I_1/I_2 is close to zero for low values of γ, but explodes to infinity as γ approaches one.[22]

When CES complementarity is high, the skill multiplier γ plays a limited role in shaping the ratio of early to late investment. High early investment should be followed by high late investment. As the degree of CES complementarity decreases, the role of the skill multiplier increases, and the higher the multiplier, the more investment should be concentrated in the early ages.

In a perfect credit market model, optimal investment levels are not affected by parental wages or endowments, or the parameters that characterize the utility function $u(\cdot)$.[23] Note, however, that even in this "perfect" credit market setting, parental investments depend on parental skills, h, because these characteristics affect the returns to investment. From the point of view of the child, this is a market failure due to the accident of birth. Children would like to choose the optimal amount of parental characteristics h to complement their initial endowment, θ_1.[24]

Consider the second credit constraint mentioned in the introduction, parental bequests must be nonnegative, i.e., parents cannot leave debts to their children. The problem of the parent is to maximize (8) subject to (7), technology (6), and the liquidity constraint

$$b' \geq 0. \tag{10}$$

If constraint (10) binds, then early investment under lifetime liquidity constraints, $\hat{I}_1$, is lower than the early investment under the perfect credit market model, denoted I_1^*. The same is true for

[21] Section C of our Web site develops this analysis for an overlapping-generations model.

[22] Table A1 on our Web site concisely summarizes this analysis.

[23] We refer to parental resources specific to a given generation.

[24] This thought experiment is whimsical. If parents create the child through genes and environment, the child is not an independent actor. Under a homunculus theory, the child would have an identity independent of the parent.

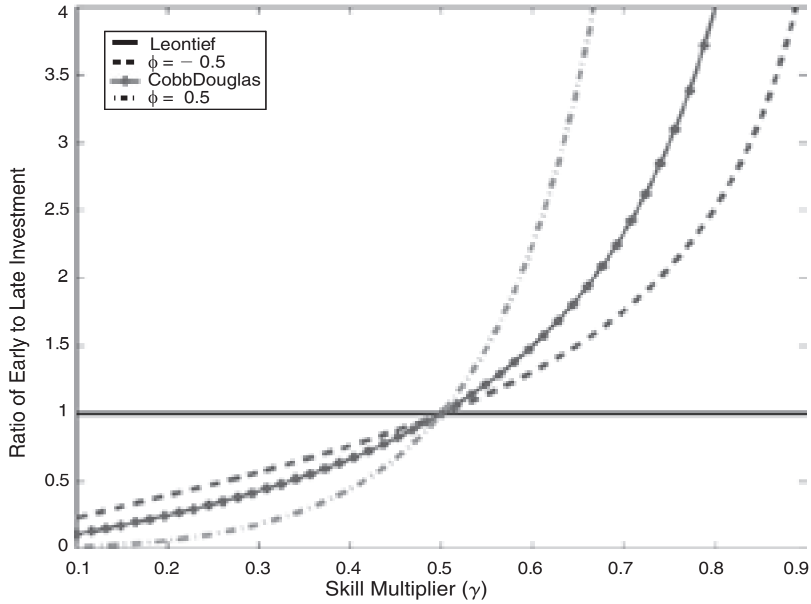

Figure 2. Ratio of Early to Late Investment in Human Capital as a Function of the Skill Multiplier for Different Values of Complementarity

Notes: Assumes $r = 0$.
Source: Cunha, Heckman, Lochner, and Masterov (2006).

late investment, $\hat{I}_2 < I_2^*$. Under this type of market imperfection, underinvestment in skills starts at early ages and continues throughout the life cycle of the child. This explains fact one—that skill gaps open up early and are perpetuated.[25]

In this second case, both early and late investment depend on parental initial wealth b for the families for whom the liquidity constraint (10) binds. Children who come from constrained families with lower b will have lower early *and* late investment. Interventions that occur at early stages would exhibit high returns, especially if they are followed up with resources to supplement late investment. Once the early stage investment is realized, however, late remediation for disadvantaged children would produce lower returns if early and late investment are not perfect substitutes, and late investment is more productive the higher the level of early investment. This helps to explain fact five in Section I.

The effects of government policies on promoting the accumulation of human capital depend on the complementarity between early and late investment, as well as on whether the policies were anticipated by parents or not. For example, the short-run effects of an unanticipated policy that subsidizes late investment will have weaker effects the greater the complementarity between early and late investment. If the technology is Leontief, there is no short-run impact of the policy on adolescent investment. At the time the policy is announced, poor parents have already made their early investment decisions and, in the Leontief case, it is not possible to compensate by increasing late investment as a response to the subsidy.

There is, however, a long-run effect of the policy. If the policy is a permanent change announced before the child is born, new parents will adjust both early and late investment in response to the subsidy to late investment. Note that the same is true for an exogenous increase in the return to education. If there is strong

[25] Of course, other reasons why skill gaps open up early and are perpetuated are variation in h and θ_1, the parental environmental and initial endowment variables, respectively.

complementarity between early and late investment, in the short run we would expect weak reactions to the increase in returns to education as gauged by adolescent investment decisions for the children from very poor family backgrounds, but stronger reactions in the long run. This analysis provides an explanation for why the college enrollment response to unanticipated increases in the returns to college were initially so strong for adolescents from advantaged families and initially so weak for adolescents from less advantaged families. Adolescents from less advantaged families are more likely to lack the foundational skills that make college going productive, compared to adolescents from more advantaged families (see Figure D10 on our Web site).

There is no trade-off between equity and efficiency in *early* childhood investment. Government policies to promote early accumulation of human capital should be targeted to the children of poor families. However, the optimal second-period intervention for a child from a disadvantaged environment depends critically on the nature of technology (6). If I_1 and I_2 are perfect CES complements, then a low level of I_1 cannot be compensated at any level of investment by a high I_2. On the other hand, suppose that $\phi = 1$, so the technology m_2 can be written with inputs as perfect CES substitutes. In this case, a second-period intervention can, in principle, eliminate initial skill deficits (low values of I_1). At a sufficiently high level of second-period investment, it is technically possible to offset low first-period investment, but it may not be cost effective to do so. If γ is sufficiently low relative to r, it is more efficient to postpone investment.

The concepts of critical and sensitive periods are defined in terms of the technical possibilities of remediation. Many noneconomists frame the question of remediation for adverse environments in terms of what is technically possible, not what is economically efficient. Our analysis considers both technological possibilities and costs. From an economic point of view, critical and sensitive periods should be defined in terms of the costs and returns of remediation, and not solely in terms of technical possibilities.

Another source of market failure arises when parents are subject to lifetime liquidity constraints and constraints that prevent parents from borrowing against their own future labor income, which may affect their ability to finance investment in the child's early years.[26] This is the third constraint considered in the introduction. To analyze this case, assume that parental productivity grows exogenously at rate α. Let s denote parental savings. We write the constraints facing the parent at each stage of the life cycle of the child as:

(first stage)

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

(second stage)

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

where $s \geq 0$ and $b' \geq 0$. The restriction $s \geq 0$ says that the parent cannot borrow income from their old age to finance consumption and investment when the child is in the first stage of the life cycle. Some parents may be willing to do this, especially when α is high. In the case when $s \geq 0$ and $b' \geq 0$ bind, and investments in different periods are not perfect substitutes, the timing of income matters. To see this, note that if $u(c) = (c^\sigma - 1)/\sigma$, the ratio of early to late investment is

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

If early income is low with respect to late income, the ratio I_1/I_2 will be lower than the optimal ratio. The deviation from the optimal ratio will be larger the lower the elasticity of intertemporal substitution of consumption (captured by the parameter σ). Early income would not matter if $\sigma = 1$, which would be the case when consumption in stage one is a perfect substitute for consumption in stage two. Substitutability through

[26] This type of constraint is also analyzed by Elizabeth Caucutt and Lance J. Lochner (2004).

parental preferences can undo lack of substitutability in the technology of skill formation.

Our analysis of credit-constrained families, joined with a low value of ϕ, interprets the evidence presented by Duncan and Brooks-Gunn (1997); Morris, Duncan, and Clark-Kaufmann (2005); Duncan and Kalil (2006); and Dahl and Lochner (2005) that the level of family income in the early stages of childhood has some effect on the level of ability and achievement of the children. This is fact five of Section I. Our analysis also interprets the evidence of Carneiro and Heckman (2002) and Cameron and Taber (2004) that, conditioning on child ability, family income in the adolescent years has only a minor effect on adolescent schooling choices.

IV. Cognitive and Noncognitive Skill Formation

A large body of research documents the socioemotional basis of reason (see Antonio R. Damasio 1994; Joseph E. LeDoux 1996). Our analysis goes beyond this literature to formalize a body of evidence that emotional skills promote learning. Mechanisms relating cortisol to stress and the effects of cortisol on the brain development of animals have been documented by Suomi (1999) and Meaney (2001). Duncan et al. (2006) and Raver, Garner, and Smith-Donald (2007) show that a child's ability to pay attention facilitates later learning.

The framework developed in Section II readily accommodates skill vectors.[27] The evidence summarized in Section I shows the importance of both cognitive and noncognitive skills in determining adult outcomes. Child development is not just about cognitive skill formation, although a lot of public policy analysis focuses solely on cognitive test scores. Let θ_t denote the vector of cognitive and noncognitive skills: $\theta_t = (\theta_t^C, \theta_t^N)$. Let I_t denote the vector of investment in cognitive and noncognitive skills: $I_t = (I_t^C, I_t^N)$. We use $h = (h^C, h^N)$ to denote parental cognitive and noncognitive skills. At each stage t, we can define a recursive technology for cognitive skills $(k = C)$, and noncognitive skills, $(k = N)$:

$$\theta_{t+1}^k = f_t^k(\theta_t^C, \theta_t^N, I_t^k, h^C h^N), k \in \{C, N\}. \tag{11}$$

Note that technology (11) allows for cross-productivity effects—cognitive skills may affect the accumulation of noncognitive skills and vice versa. They also allow for critical and sensitive periods to differ by skill, as is required to account for fact two.

If cognitive and/or noncognitive skills determine costs of effort, time preference, or risk aversion parameters, parental investments affect child and adult behavior. Our analysis of preference formation contrasts with the analyses of Hideo Akabayashi (1996) and Bruce A. Weinberg (2001). Those authors build principal-agent models where the parent (the principal) and the child (the agent) agree on contracts in which parents' financial transfers are conditional on observable measures of effort (e.g., test scores in school). These contracts are designed so that the children are driven toward the level of effort desired by the parents. In our model, parents directly shape child preferences.

Accounting for preference formation enables us to interpret the success of many early childhood programs targeted to disadvantaged children that do not permanently raise IQ, but permanently boost social performance.[28] This is fact six of Section I. The controversy over Head Start fadeout may have been a consequence of relying only on cognitive measures to gauge performance. The Perry Preschool Program had an IQ fadeout but a lasting effect on a variety of participants through age 40. They work harder, are less likely to commit crime, and participate in fewer social pathologies than do control group members.[29]

V. Estimates of the Technology

Cunha and Heckman (2007) and Cunha, Heckman, and Schennach (2007) estimate recursive multistage technology (6) with cognitive and noncognitive skills generating adult outcomes like schooling, earnings, and occupational

[27] See Section B on our Web site.

[28] The Abecedarian early intervention program permanently boosted adult IQ (see CHLM).

[29] See the D9 series on our Web site. The exact mechanism by which noncognitive skills are boosted is not yet established. It could be that noncognitive skills are created directly in the early years and persist. It could also be that the higher early cognitive skills that fade out foster noncognitive skills that persist. Both channels of influence could be in operation.

choice.[30] They develop new econometric methods that extend factor analysis to a nonlinear setting. We refer the reader to those papers for econometric details and discussions of the rich panel data on child development that makes such estimation possible.

They find strong evidence of self-productivity and complementarity. Their evidence is consistent with the literature demonstrating malleability of the prefrontal cortex governing executive function and socioeconomic development, as well as the stability of IQ measures after age 10 cited in Section I. They find higher substitutability of early and late investment in producing noncognitive skills and lower substitutability of early investment in producing cognitive skills. Higher stocks of noncognitive skills promote the self-productivity of cognitive skills; cognitive skill stocks promote the self-productivity of noncognitive skills. Higher levels of both cognitive and noncognitive skills raise the productivity of subsequent investment. There is evidence of sensitive periods for parental investment. The productivity of parental investment is higher in early stages for cognitive skills with a fall off in their productivity in later years. The productivity of parental investment is higher at later stages for noncognitive skills. This evidence is consistent with greater malleability of the prefrontal cortex governing socioemotional development into the early 20s, documented by Dahl (2004).

Cunha, Heckman, and Schennach (2007) estimate a strong interaction between initial endowments and parental investments that calls into question the conventional additive model of nature versus nurture. This evidence is consistent with the modern literature on epigenetics. Nature and nurture interact to produce child outcomes and environmental effects that last across generations. Even θ_1, endowment at birth, is affected by environmental factors as a large literature documents (see, e.g., Shonkoff and Phillips 2000).

VI. Lessons for the Design of Policies

Cunha and Heckman (2006) simulate the nonlinear model of skill formation estimated by Cunha, Heckman, and Schennach (2007) to show the importance of self-productivity and complementarity for designing policies to reduce inequality. We focus our analysis on children from disadvantaged backgrounds because at current levels of social inequality they benefit the most from policies that supplement early environments.[31] Disadvantaged children are at risk of being permanently poor and uneducated, and of participating in crime. In our simulation, disadvantaged children come from a background where mothers are in the first (lowest) decile in the distribution of parental skills. If no intervention occurs, the children receive investments equivalent to the first decile of the distribution of parental investments.

Consider three different policies. The first policy is a Perry Preschool–like policy. It provides investment at early ages that moves children from the first decile of child cognitive skills at entry age to the fourth decile of child skills at the age of exit from the program. This gain can be achieved by moving parental investment from the bottom decile to around the seventh decile of the family investment distribution. In this policy, there is no follow-up investment. We also consider a second policy for the same target population that postpones remediation until adolescence. It compensates early shortfalls by investing larger amounts in adolescent stages of the life cycle to produce approximately the same high-school graduation rates that are observed in the Perry program.

College tuition programs, adolescent literacy programs, and mentoring programs are examples of such a policy. To achieve Perry-like outcomes for this population through adolescent investment, it is necessary to move adolescent investment to the ninth decile of the parental investment distribution. The present value of the costs of the investment in this adolescent remediation program is more than 35 percent larger than in the Perry Preschool program. Late remediation is possible, but it is costly. The case for early childhood intervention is based more on the importance of sensitive periods in the life cycle of the child than on the importance of critical periods. We contrast early-only and late-only investment policies with a third policy that optimally distributes the resources spent

[30] Anchoring test score outcomes in behavior avoids reliance on arbitrarily scaled test scores as a measure of output (see Cunha and Heckman 2007 and Cunha et al. 2007).

[31] This is fact three of Section I.

Table 1—Comparison of Different Investment Strategies

(Disadvantaged children: First decile in the distribution of cognitive and noncognitive skills at age 6; mothers are in first decile in the distribution of cognitive and noncognitive skills at ages 14–21)

	Baseline	Changing initial conditions: Moving children to the 4th decile of distribution of skills only through early investment	Adolescent intervention: Moving investments at last transition from 1st to 9th decile	Changing initial conditions and performing a balanced intervention
High-school graduation	0.4109	0.6579	0.6391	0.9135
Enrollment in college	0.0448	0.1264	0.1165	0.3755
Conviction	0.2276	0.1710	0.1773	0.1083
Probation	0.2152	0.1487	0.1562	0.0815
Welfare	0.1767	0.0905	0.0968	0.0259

Note: The adolescent-only and balanced intervention programs cost 35 percent more than the Perry program.
Source: Cunha and Heckman (2006).

in the second policy over the full life cycle of the child. A balanced investment strategy is the most efficient.

The first column of numbers in Table 1 reports high-school graduation, college enrollment, conviction, probation, and use of welfare if no intervention is made. Our model predicts a 41 percent high-school graduation rate for this group, compared to 41.4 percent found in the Perry control group. Only 4.5 percent of the control group ever enrolls in college. Around 22 percent of them will be convicted of a crime or be on probation at some point in their adult lives. About 18 percent will make use of welfare programs in their adult years.

The second column in Table 1 reports the performance of our Perry-like early intervention policy. This policy increases high-school graduation and college enrollment rates to more than 65 percent and 12 percent, respectively. It reduces participation in crime. It makes the children more productive when they are adults. It cuts in half the probability that the child collects welfare benefits in his/her early adult years. These effects are comparable to those reported in the Perry preschool intervention (see, e.g., Schweinhart et al. 2005). Thus, with our technology, we can rationalize the results found in the Perry program as an intervention that boosts parental investments (but not parental characteristics) from the first decile of investment in children to the fourth decile.

The third column in Table 1 displays the performance of a 35 percent more costly policy that produces comparable educational outcomes for those obtained in the Perry-like intervention. Adolescent interventions can be effective, but they are more costly than early interventions. The greater cost associated with later remediation arises from lost gains in self-productivity and dynamic complementarity from early investment that are key features of our model.

The empirical importance of dynamic complementarity—the fact that the marginal productivity of investment depends on the level of skills produced by previous investments—generates an important insight for the design of policies. For a fixed expenditure, policies that are balanced increase returns and are more productive than policies tailored to one segment of the life cycle of the child. The returns to later investment are greater if higher early investment is made. Perry children made less use of remedial education than peers who did not receive treatment. The intervention made later schooling more effective. If early interventions are followed up with later interventions in an optimal fashion, outcomes can be considerably improved.

The fourth column in Table 1 presents the results from a balanced policy. It displays the outcomes that can be produced by an intervention that distributes the funds spent on the adolescent-only intervention in an optimal way. For a balanced program, high-school graduation and college enrollment rates are 91 percent and 37 percent, respectively. The reduction in conviction and probation rates is better than what is obtained from an adolescent-only policy, and welfare use is reduced to a low rate of 2.6 percent. Complementarity implies that early investment is more productive if it is followed up with late investment. And late investment is more productive if it is preceded by early investment. The mechanism that makes the balanced intervention more effective has a very simple economic interpretation. When adolescent-only interventions are made, baseline skills are low and, consequently, so is the marginal productivity of later investment. A balanced investment program increases the stock of skills of the child coming into adolescence. Because the marginal productivity of later investment depends on the level of skills acquired prior to adolescence, the investment in the last period is more productive. Thus, the same amount of total investment distributed more evenly over the life cycle of the child produces more adult skills than a policy that concentrates attention on only one part of the child's life cycle.

VII. Summary and Extensions

A technology of cognitive and noncognitive skill formation that features self-productivity, dynamic complementarity, and skill multipliers explains a variety of findings established in the child development and child intervention literatures. Although we have focused on cognitive and noncognitive skills, our analysis also applies to the formation of physical health capital (see Heckman 2007). The evidence on the importance of early childhood environments on adult health (David J. P. Barker 1998; and Anne Case, Angela Fertig, and Christina Paxson 2005) can be rationalized by our technology. Stocks of cognitive and noncognitive skills facilitate the accumulation of health capital through self-regulation and choices. Stocks of health skills also raise the productivity of schooling (Alok Bhargava 2008).

REFERENCES

Aiyagari, S. Rao, Jeremy Greenwood, and Ananth Seshadri. 2002. "Efficient Investment in Children." *Journal of Economic Theory*, 102(2): 290–321.

Akabayashi, Hideo. 1996. "On the Role of Incentives in the Formation of Human Capital in the Family." PhD dissertation. University of Chicago.

Barker, David J. P. 1998. *Mothers, Babies and Health in Later Life*. Edinburgh: Churchill Livingstone.

Barnett, W. Steven. 2004. "Benefit-Cost Analysis of Preschool Education." http://nieer.org/resources/files/BarnettBenefits.ppt.

Becker, Gary S. 1991. *A Treatise on the Family.* Cambridge, MA: Harvard University Press.

Becker, Gary S. 1993. *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education*. 3rd ed. Chicago: University of Chicago Press.

Becker, Gary S., and Nigel Tomes. 1986. "Human Capital and the Rise and Fall of Families." *Journal of Labor Economics*, 4(3, Part 2): S1–39.

Bénabou, Roland. 2002. "Tax and Education Policy in a Heterogeneous-Agent Economy: What Levels of Redistribution Maximize Growth and Efficiency?" *Econometrica*, 70(2): 481–517.

Ben-Porath, Yoram. 1967. "The Production of Human Capital and the Life Cycle of Earnings." *Journal of Political Economy*, 75(4, Part 1): 352–65.

Bhargava, Alok. Forthcoming. *Food, Economics and Health*. Oxford: Oxford University Press.

Blau, David, and Janet Currie. 2006. "Preschool, Daycare, and Afterschool Care: Who's Minding the Kids?" In *Handbook of the Economics of Education*. Vol. 2, *Handbooks in Economics*, ed. Eric Hanushek and Finis Welch, 1163–1278. Amsterdam: North-Holland.

Borghans, Lex, Angela L. Duckworth, James J. Heckman, and Bas ter Weel. Forthcoming. "The Economics of Noncognitive Skills." *Journal of Human Resources*.

Bowles, Samuel, Herbert Gintis, and Melissa Osborne. 2001. "The Determinants of Earnings: A Behavioral Approach." *Journal of Economic Literature*, 39(4): 1137–76.

Cameron, Judy. 2004. "Evidence for an Early Sensitive Period for the Development of Brain Systems Underlying Social Affiliative Behavior." Unpublished.

Cameron, Stephen V., and James J. Heckman. 2001. "The Dynamics of Educational Attainment for Black, Hispanic, and White Males." *Journal of Political Economy*, 109(3): 455–99.

Cameron, Stephen V., and Christopher Taber. 2004. "Estimation of Educational Borrowing Constraints Using Returns to Schooling." *Journal of Political Economy*, 112(1): 132–82.

Carneiro, Pedro, Flavio Cunha, and James J. Heckman. 2003. "Interpreting the Evidence of Family Influence on Child Development." Paper presented at the Economics of Early Childhood Development: Lessons for Economic Policy Conference, Minneapolis, MN.

Carneiro, Pedro, and James J. Heckman. 2002. "The Evidence on Credit Constraints in Post-Secondary Schooling." *Economic Journal*, 112(482): 705–34.

Carneiro, Pedro, and James J. Heckman. 2003. "Human Capital Policy." In *Inequality in America: What Role for Human Capital Policies?*, ed. James J. Heckman, Alan B. Krueger and Benjamin M. Friedman. Cambridge, MA: MIT Press.

Carneiro, Pedro, James J. Heckman, and Edward J. Vytlacil. 2006. "Estimating Marginal and Average Returns to Education." Unpublished.

Case, Anne, Angela Fertig, and Christina Paxson. 2005. "The Lasting Impact of Childhood Health and Circumstance." *Journal of Health Economics*, 24(2): 365–89.

Caspi, Avshalom, Joseph McClay, Terrie E. Moffitt, Jonathan Mill, Judy Martin, Ian W. Craig, Alan Taylor, and Richie Poulton. 2002. "Role of Genotype in the Cycle of Violence in Maltreated Children." *Science*, 297(5582): 851–54.

Caucutt, Elizabeth, and Lance J. Lochner. 2004. "Early and Late Human Capital Investments, Credit Constraints, and the Family." Unpublished.

Cunha, Flavio, and James J. Heckman. 2006. "Investing in Our Young People." Unpublished.

Cunha, Flavio, and James J. Heckman. Forthcoming. "Formulating, Identifying and Estimating the Technology of Cognitive and Noncognitive Skill Formation." *Journal of Human Resources.*

Cunha, Flavio, James J. Heckman, Lance J. Lochner, and Dimitriy V. Masterov. 2006. "Interpreting the Evidence on Life Cycle Skill Formation." In *Handbook of the Economics of Education*, ed. Eric A. Hanushek and Frank Welch, 697–812. Amsterdam: North-Holland: Elsevier.

Cunha, Flavio, James J. Heckman, and Susanne M. Schennach. 2006. "Estimating the Technology of Cognitive and Noncognitive Skill Formation." Unpublished.

Currie, Janet, and Duncan Thomas. 1995. "Does Head Start Make a Difference?" *American Economic Review*, 85(3): 341–64.

Currie, Janet, and Duncan Thomas. 2000. "School Quality and the Longer-Term Effects of Head Start." *Journal of Human Resources*, 35(4): 755–74.

Dahl, Gordon B., and Lance J. Lochner. 2005. "The Impact of Family Income on Child Achievement." National Bureau of Economic Research Working Paper 11279.

Dahl, Ronald E. 2004. "Adolescent Brain Development: A Period of Vulnerabilities and Opportunities." In *Annals of the New York Academy of Sciences*, ed. Ronald E. Dahl and Linda Patia Spear, 1–22. New York: New York Academy of Sciences.

Damasio, Antonio R. 1994. *Descartes' Error: Emotion, Reason, and the Human Brain*. New York: Putnam.

Duncan, Greg J., and Jeanne Brooks-Gunn. 1997. "Income Effects across the Life Span: Integration and Interpretation." In *Consequences of Growing Up Poor,* ed. Greg J. Duncan and Jeanne Brooks-Gunn, 596–610. New York: Russell Sage Foundation.

Duncan, Greg J., Chantelle J. Dowsett, Amy Claessens, Katherine Magnuson, Aletha C. Huston, Pamela Klebanov, Linda Pagani, Leon Feinstein, Mimi Engel, Jeanne Brooks-Gunn, Holly Sexton, Kathryn Duckworth, and Crista Japeli. 2006. "School Readiness and Later Achievement." Unpublished.

Duncan, Greg J., and Ariel Kalil. 2006. "The Effects of Income in the Early Years on Child Outcomes." Unpublished.

Erikson, Erik H. 1950. *Childhood and Society.* New York: Norton.

Gluckman, Peter D. and Mark Hanson. 2005. *The Fetal Matrix: Evolution, Development, and Disease*. Cambridge: Cambridge University Press.

Hansen, Karsten T., James J. Heckman, and Kathleen J. Mullen. 2004. "The Effect of Schooling and Ability on Achievement Test Scores." *Journal of Econometrics*, 121(1-2): 39–98.

Heckman, James J. 1995. "Lessons from *The Bell Curve*." *Journal of Political Economy*, 103(5): 1091–1120.

Heckman, James J. Forthcoming. "The Technology and Neuroscience of Capacity Formation." *Proceedings of the National Academy of Sciences.*

Heckman, James J. 2006. "The Technology and Neuroscience of Capacity Formation."

Presented at the Economic Causes and Consequences of Population Aging, Robert Fogel 80th Birthday Celebration, Nov. 18.

Heckman, James J., Maria Isabel Larenas, and Sergio Urzua. 2004. "Accounting for the Effect of Schooling and Abilities in the Analysis of Racial and Ethnic Disparities in Achievement Test Scores." Unpublished.

Heckman, James J., Jora Stixrud, and Sergio Urzua. 2006. "The Effects of Cognitive and Noncognitive Abilities on Labor Market Outcomes and Social Behavior." *Journal of Labor Economics*, 24(3): 411–82.

Herrnstein, Richard J., and Charles A. Murray. 1994. *The Bell Curve: Intelligence and Class Structure in American Life.* New York: Free Press.

Hopkins, Kenneth D., and Glenn H. Bracht. 1975. "Ten-Year Stability of Verbal and Nonverbal IQ Scores." *American Educational Research Journal*, 12(4): 469–77.

Knudsen, Eric I., James J. Heckman, Judy Cameron, and Jack P. Shonkoff. 2006. "Economic, Neurobiological, and Behavioral Perspectives on Building America's Future Workforce." *Proceedings of the National Academy of Sciences*, 103(27): 10155–62.

LeDoux, Joseph E. 1996. *The Emotional Brain: The Mysterious Underpinnings of Emotional Life*. New York: Simon and Schuster.

Meaney, Michael J. 2001. "Maternal Care, Gene Expression, and the Transmission of Individual Differences in Stress Reactivity across Generations." *Annual Review of Neuroscience,* 24(1): 1161–92.

Meghir, Costas, and Mårten Palme. 2001. "The Effect of a Social Experiment in Education." Institute for Fiscal Studies Working Paper W01/11.

Morris, Pamela, Greg J. Duncan, and Elizabeth Clark-Kaufmann. 2005. "Child Well-Being in an Era of Welfare Reform: The Sensitivity of Transitions in Development to Policy Change." *Developmental Psychology*, 41(6): 919–32.

Murnane, Richard J., John B. Willett, and Frank Levy. 1995. "The Growing Importance of Cognitive Skills in Wage Determination." *Review of Economics and Statistics*, 77(2): 251–66.

Newport, Elissa L. 1990. "Maturational Constraints on Language Learning." *Cognitive Science*, 14(1):11–28.

O'Connor, Thomas G., Michael Rutter, Celia Beckett, Lisa Keaveney, Jana M. Kreppner, and the English and Romanian Adoptees Study Team. 2000. "The Effects of Global Severe Privation on Cognitive Competence: Extension and Longitudinal Follow-Up." *Child Development,* 71(2): 376–90.

Pinker, Steven. 1994. *The Language Instinct: How the Mind Creates Language*. New York: W. Morrow and Co.

Raudenbush, Stephen W. 2006. "Schooling, Statistics and Poverty: Measuring School Improvement and Improving Schools." Paper presented at the University of Chicago Division of Social Sciences Inaugural Lecture, Chicago, IL.

Raver, C. Cybele, Pamela W. Garner, and Radiah Smith-Donald. 2007. "The Roles of Emotion Regulation and Emotion Knowledge for Children's Academic Readiness: Are the Links Causal?" In *School Readiness and the Transition to Kindergarten in the Era of Accountability,* ed. Robert C. Pianta, Martha J. Cox and Kyle L. Snow. Baltimore: Brookes Publishing.

Rutter, Michael. 2006. *Genes and Behavior: Nature-Nurture Interplay Explained*. Oxford: Blackwell Publishing.

Schweinhart, Lawrence J., Jeanne Montie, Zongping Xiang, W. Steven Barnett, Clive R. Belfield, and Milagros Nores. 2005. *Lifetime Effects: The High/Scope Perry Preschool Study Through Age 40*. Ypsilanti, MI: High/Scope Press.

Shonkoff, Jack P., and Deborah Phillips. 2000. *From Neurons to Neighborhoods: The Science of Early Childhood Development*. Washington, DC: National Academy Press.

Stinebrickner, Ralph, and Todd R. Stinebrickner. 2006. "Credit Constraints and College Attrition." Unpublished.

Suomi, Stephen J. 1999. "Development Trajectories, Early Experiences, and Community Consequences: Lessons from Studies with Rhesus Monkeys." In *Developmental Health and the Wealth of Nations: Social, Biological, and Educational Dynamics,* ed. Daniel P. Keating and Clyde Hertzman, 185–200. New York: The Guilford Press.

Weinberg, Bruce A. 2001. "An Incentive Model of the Effect of Parental Income on Children." *Journal of Political Economy*, 109(2): 266–80.

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1. Søren Dalsgaard, Helena Skyt Nielsen, Marianne Simonsen. 2014. Consequences of ADHD medication use for children's outcomes. *Journal of Health Economics* **37**, 137-151. [CrossRef]
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3. Daniel Kuehnle. 2014. The causal effect of family income on child health in the UK. *Journal of Health Economics* **36**, 137-150. [CrossRef]
4. Jamie Emerson, Brian Hill. 2014. Gender Differences in Competition: Running Performance in 1,500 Meter Tournaments. *Eastern Economic Journal* . [CrossRef]
5. Kåre Moberg. 2014. Two approaches to entrepreneurship education: The different effects of education for and through entrepreneurship at the lower secondary level. *The International Journal of Management Education* . [CrossRef]
6. A. Aizer. 2014. Rising Inequality and Intergenerational Mobility: The Role of Public Investments in Human Capital. *CESifo Economic Studies* **60**:2, 280-311. [CrossRef]
7. E. Mork, A. Sjogren, H. Svaleryd. 2014. Parental Unemployment and Child Health. *CESifo Economic Studies* **60**:2, 366-401. [CrossRef]
8. Kevin Denny, Orla Doyle, Patricia McMullin, Vincent O'Sullivan. 2014. Money, mentoring and making friends: The impact of a multidimensional access program on student performance. *Economics of Education Review* **40**, 167-182. [CrossRef]
9. M. J. Kottelenberg, S. F. Lehrer. 2014. Do the Perils of Universal Childcare Depend on the Child's Age?. *CESifo Economic Studies* **60**:2, 338-365. [CrossRef]
10. M. J. Bailey, O. Malkova, J. Norling. 2014. Do Family Planning Programs Decrease Poverty? Evidence from Public Census Data. *CESifo Economic Studies* **60**:2, 312-337. [CrossRef]
11. T. Falch, O. H. Nyhus, B. Strom. 2014. Performance of Young Adults: The Importance of Different Skills. *CESifo Economic Studies* **60**:2, 435-462. [CrossRef]
12. Thomas Dohmen. 2014. Behavioural Labour Economics: Advances and Future Directions. *Labour Economics* . [CrossRef]
13. Ana Susac, Sven Braeutigam. 2014. A case for neuroscience in mathematics education. *Frontiers in Human Neuroscience* **8**. . [CrossRef]
14. Stephanie von Hinke Kessler Scholder, George L. Wehby, Sarah Lewis, Luisa Zuccolo. 2014. Alcohol Exposure In Utero and Child Academic Achievement. *The Economic Journal* **124**:576, 634-667. [CrossRef]
15. Duncan Pieterse. 2014. CHILDHOOD MALTREATMENT AND EDUCATIONAL OUTCOMES: EVIDENCE FROM SOUTH AFRICA. *Health Economics* n/a-n/a. [CrossRef]
16. Richard Blundell. 2014. Income Dynamics and Life-cycle Inequality: Mechanisms and Controversies. *The Economic Journal* **124**:576, 289-318. [CrossRef]
17. Owen Thompson. 2014. Genetic mechanisms in the intergenerational transmission of health. *Journal of Health Economics* **35**, 132-146. [CrossRef]
18. Maria Fernanda Rosales. 2014. Family Investment Responses to Childhood Health Conditions: Intrafamily Allocation of Resources. *Journal of Health Economics* . [CrossRef]
19. Sonia Bhalotra, Thomas PoggeEthical and Economic Perspectives on Global Health Interventions 209-227. [CrossRef]
20. Miriam Wüst. 2014. MATERNAL EMPLOYMENT DURING PREGNANCY AND BIRTH OUTCOMES: EVIDENCE FROM DANISH SIBLINGS. *Health Economics* n/a-n/a. [CrossRef]

21. Mark Taylor, Tina Rampino. 2014. Educational Aspirations and Attitudes over the Business Cycle. *Economica* n/a-n/a. [CrossRef]
22. Alessandra Casarico, Luca Micheletto, Alessandro Sommacal. 2014. Intergenerational transmission of skills during childhood and optimal public policy. *Journal of Population Economics* . [CrossRef]
23. Dante Contreras, Osvaldo Larrañaga, Esteban Puentes, Tomás Rau. 2014. Improving the Measurement of the Relationship between Opportunities and Income: Evidence from Longitudinal Data from Chile. *Development Policy Review* **32**:2, 219-237. [CrossRef]
24. Matthias Rieger, Natascha Wagner. 2014. Child health, its dynamic interaction with nutrition and health memory – Evidence from Senegal. *Economics & Human Biology* . [CrossRef]
25. Christian Helmers, Manasa Patnam. 2014. Does the rotten child spoil his companion? Spatial peer effects among children in rural India. *Quantitative Economics* **5**:1, 67-121. [CrossRef]
26. Kai-Uwe Müller,, C. Katharina Spieß,, Katharina Wrohlich. 2014. Kindertagesbetreuung: Wie wird ihre Nutzung beeinflusst und was kann sie für die Entwicklung von Kindern bewirken?. *Vierteljahrshefte zur Wirtschaftsforschung* **83**:1, 49-67. [CrossRef]
27. Massimiliano Bratti, Mariapia Mendola. 2014. Parental Health and Child Schooling. *Journal of Health Economics* . [CrossRef]
28. Marc Piopiunik, Ludger Wößmann. 2014. Volkswirtschaftliche Erträge wirksamer Bildungsreformen zur Reduktion der Zahl der Risikoschüler. *Zeitschrift für Erziehungswissenschaft* **17**:S2, 393-416. [CrossRef]
29. Sarah Brown, Jolian McHardy, Karl Taylor. 2014. Intergenerational Analysis of Social Interaction and Social Skills: An Analysis of U.S. and U.K. Panel Data. *Economics of Education Review* . [CrossRef]
30. Jonas Helgertz, Mats R. Persson. 2014. Early life conditions and long-term sickness absence during adulthood – A longitudinal study of 9000 siblings in Sweden. *Social Science & Medicine* . [CrossRef]
31. Enrico Spolaore, Romain WacziargLong-Term Barriers to Economic Development 121-176. [CrossRef]
32. Harold Alderman, Jere R. Behrman, Sally Grantham-McGregor, Florencia Lopez-Boo, Sergio Urzua. 2014. Economic perspectives on integrating early child stimulation with nutritional interventions. *Annals of the New York Academy of Sciences* n/a-n/a. [CrossRef]
33. Christopher M. Napolitano, Edmond P. Bowers, Miriam R. Arbeit, Paul Chase, G. John Geldhof, Jacqueline V. Lerner, Richard M. Lerner. 2014. The GPS to Success Growth Grids: Measurement Properties of a Tool to Promote Intentional Self-Regulation in Mentoring Programs. *Applied Developmental Science* **18**:1, 46-58. [CrossRef]
34. Vittorio Daniele, Nicola Ostuni. 2013. The burden of disease and the IQ of nations. *Learning and Individual Differences* **28**, 109-118. [CrossRef]
35. Katrin John, Stephan L. Thomsen. 2013. Heterogeneous returns to personality: the role of occupational choice. *Empirical Economics* . [CrossRef]
36. Iryna Rud, Chris Van Klaveren, Wim Groot, Henriëtte Maassen van den Brink. 2013. The externalities of crime: The effect of criminal involvement of parents on the educational attainment of their children. *Economics of Education Review* . [CrossRef]
37. Mark D. Agee, Thomas D. Crocker. 2013. Operationalizing the capability approach to assessing well-being. *The Journal of Socio-Economics* **46**, 80-86. [CrossRef]
38. C. KIRABO JACKSON. 2013. DO COLLEGE-PREPARATORY PROGRAMS IMPROVE LONG-TERM OUTCOMES?. *Economic Inquiry* no-no. [CrossRef]
39. Eric Johnson, C. Lockwood Reynolds. 2013. The effect of household hospitalizations on the educational attainment of youth. *Economics of Education Review* . [CrossRef]

40. Joshua Graff Zivin,, Matthew Neidell. 2013. Environment, Health, and Human Capital. *Journal of Economic Literature* **51**:3, 689-730. [Abstract] [View PDF article] [PDF with links]
41. Guozhong Zhu, Gulfer Vural. 2013. Inter-generational effect of parental time and its policy implications. *Journal of Economic Dynamics and Control* **37**:9, 1833-1851. [CrossRef]
42. Xianhua Dai, James J. Heckman. 2013. Older siblings' contributions to young child's cognitive skills. *Economic Modelling* **35**, 235-248. [CrossRef]
43. John Ermisch, Marco Francesconi. 2013. THE EFFECT OF PARENTAL EMPLOYMENT ON CHILD SCHOOLING. *Journal of Applied Econometrics* **28**:5, 796-822. [CrossRef]
44. Grace Lordan, Paul Frijters. 2013. UNPLANNED PREGNANCY AND THE IMPACT ON SIBLING HEALTH OUTCOMES. *Health Economics* **22**:8, 903-914. [CrossRef]
45. Donna S. Rothstein. 2013. Breastfeeding and Children's Early Cognitive Outcomes. *Review of Economics and Statistics* **95**:3, 919-931. [CrossRef]
46. Richard J. Murnane. 2013. U.S. High School Graduation Rates: Patterns and Explanations. *Journal of Economic Literature* **51**:2, 370-422. [Abstract] [View PDF article] [PDF with links]
47. Enrico Spolaore,, Romain Wacziarg. 2013. How Deep Are the Roots of Economic Development?. *Journal of Economic Literature* **51**:2, 325-369. [Abstract] [View PDF article] [PDF with links]
48. Darragh Flannery, Cathal O'Donoghue. 2013. The demand for higher education: A static structural approach accounting for individual heterogeneity and nesting patterns. *Economics of Education Review* **34**, 243-257. [CrossRef]
49. Tim Lohse, Peter F. Lutz, Christian Thomann. 2013. Redistributional consequences of early childhood intervention. *The European Journal of Health Economics* **14**:3, 373-381. [CrossRef]
50. Diether W. Beuermann, Emma Naslund-Hadley, Inder J. Ruprah, Jennelle Thompson. 2013. The Pedagogy of Science and Environment: Experimental Evidence from Peru. *Journal of Development Studies* **49**:5, 719-736. [CrossRef]
51. Friedhelm Pfeiffer,. 2013. On the Power of Childhood Impressions for Skill Formation. Initial Evidence and Unsettled Questions. *Sozialer Fortschritt* **62**:5, 131-139. [CrossRef]
52. Eamonn Ferguson, Jane W. Ward, Anya Skatova, Helen J. Cassaday, Peter A. Bibby, Claire Lawrence. 2013. Health specific traits beyond the Five Factor Model, cognitive processes and trait expression: replies to Watson (2012), Matthews (2012) and Haslam, Jetten, Reynolds, and Reicher (2012). *Health Psychology Review* **7**:sup1, S85-S103. [CrossRef]
53. Casey Abington, William Blankenau. 2013. Government education expenditures in early and late childhood. *Journal of Economic Dynamics and Control* **37**:4, 854-874. [CrossRef]
54. Hendrik Thiel, Stephan L. Thomsen. 2013. Noncognitive skills in economics: Models, measurement, and empirical evidence. *Research in Economics* . [CrossRef]
55. Stefan Dercon, Alan Sánchez. 2013. Height in mid childhood and psychosocial competencies in late childhood: evidence from four developing countries. *Economics & Human Biology* . [CrossRef]
56. Greg J. Duncan,, Katherine Magnuson. 2013. Investing in Preschool Programs. *Journal of Economic Perspectives* **27**:2, 109-132. [Abstract] [View PDF article] [PDF with links]
57. Lídia Farré, Roger Klein, Francis Vella. 2013. A parametric control function approach to estimating the returns to schooling in the absence of exclusion restrictions: an application to the NLSY. *Empirical Economics* **44**:1, 111-133. [CrossRef]
58. Liam Delaney, Colm Harmon, Martin Ryan. 2013. The role of noncognitive traits in undergraduate study behaviours. *Economics of Education Review* **32**, 181-195. [CrossRef]

59. Haroon Chowdry, Claire Crawford, Lorraine Dearden, Alissa Goodman, Anna Vignoles. 2013. Widening participation in higher education: analysis using linked administrative data. *Journal of the Royal Statistical Society: Series A (Statistics in Society)* **176**:2, 431-457. [CrossRef]
60. Juergen Jung, Diane M. Harnek Hall, Thomas Rhoads. 2013. Does the availability of parental health insurance affect the college enrollment decision of young Americans?. *Economics of Education Review* **32**, 49-65. [CrossRef]
61. George L. Wehby, Ann Marie McCarthy. 2013. Economic gradients in early child neurodevelopment: A multi-country study. *Social Science & Medicine* **78**, 86-95. [CrossRef]
62. Samuel K. Ampaabeng, Chih Ming Tan. 2013. The long-term cognitive consequences of early childhood malnutrition: The case of famine in Ghana. *Journal of Health Economics* . [CrossRef]
63. Günther Fink, Analia Olgiati, Moonga Hawela, John M Miller, Beatrice Matafwali. 2013. Association between early childhood exposure to malaria and children's pre-school development: evidence from the Zambia early childhood development project. *Malaria Journal* **12**:1, 12. [CrossRef]
64. Paul Bingley, Alessandro Martinello. 2013. Mental retirement and schooling. *European Economic Review* . [CrossRef]
65. Pedro Carneiro, Costas Meghir, Matthias Parey. 2013. MATERNAL EDUCATION, HOME ENVIRONMENTS, AND THE DEVELOPMENT OF CHILDREN AND ADOLESCENTS. *Journal of the European Economic Association* **11**, 123-160. [CrossRef]
66. Justine S. Hastings, Brigitte C. Madrian, William L. Skimmyhorn. 2013. Financial Literacy, Financial Education, and Economic Outcomes. *Annual Review of Economics* **5**:1, 347-373. [CrossRef]
67. Michela Braga, Daniele Checchi, Elena Meschi. 2013. Educational policies in a long-run perspective. *Economic Policy* **28**:73, 45-100. [CrossRef]
68. Eric A. Hanushek, Ludger Woessmann. 2012. Do better schools lead to more growth? Cognitive skills, economic outcomes, and causation. *Journal of Economic Growth* **17**:4, 267-321. [CrossRef]
69. Jacob Nielsen Arendt. 2012. The effect of public financial aid on dropout from and completion of university education: evidence from a student grant reform. *Empirical Economics* . [CrossRef]
70. Elizabeth R. Kazakoff, Amanda Sullivan, Marina U. Bers. 2012. The Effect of a Classroom-Based Intensive Robotics and Programming Workshop on Sequencing Ability in Early Childhood. *Early Childhood Education Journal* . [CrossRef]
71. Antonio Filippin, Marco Paccagnella. 2012. Family background, self-confidence and economic outcomes. *Economics of Education Review* **31**:5, 824-834. [CrossRef]
72. Miriam Wüst. 2012. Early interventions and infant health: Evidence from the Danish home visiting program. *Labour Economics* **19**:4, 484-495. [CrossRef]
73. James J. Heckman, Tim Kautz. 2012. Hard evidence on soft skills. *Labour Economics* **19**:4, 451-464. [CrossRef]
74. Limor Hatsor. 2012. Occupational choice: Teacher quality versus teacher quantity. *Labour Economics* **19**:4, 608-623. [CrossRef]
75. Mario Fiorini. 2012. FOSTERING EDUCATIONAL ENROLMENT THROUGH SUBSIDIES: THE ISSUE OF TIMING. *Journal of Applied Econometrics* **27**:5, 741-772. [CrossRef]
76. Guido Schwerdt, Dolores Messer, Ludger Woessmann, Stefan C. Wolter. 2012. The impact of an adult education voucher program: Evidence from a randomized field experiment. *Journal of Public Economics* **96**:7-8, 569-583. [CrossRef]
77. Elly-Ann Lindström. 2012. Gender Bias in Parental Leave: Evidence from Sweden. *Journal of Family and Economic Issues* . [CrossRef]

78. SATOSHI OKABE. 2012. Family Background and the Process of Ability Formation*. *International Journal of Japanese Sociology* no-no. [CrossRef]
79. Lance Lochner, Alexander Monge-Naranjo. 2012. Credit Constraints in Education. *Annual Review of Economics* **4**:1, 225-256. [CrossRef]
80. Maria Arbatskaya, Hugo M. Mialon. 2012. Dynamic Multi-Activity Contests*. *The Scandinavian Journal of Economics* **114**:2, 520-538. [CrossRef]
81. Richard Akresh,, Sonia Bhalotra,, Marinella Leone,, Una Okonkwo Osili. 2012. War and Stature: Growing Up during the Nigerian Civil War. *American Economic Review* **102**:3, 273-277. [Abstract] [View PDF article] [PDF with links]
82. Fabrizio Mazzonna, Franco Peracchi. 2012. Ageing, cognitive abilities and retirement. *European Economic Review* **56**:4, 691-710. [CrossRef]
83. Gregory Gilpin, Michael Kaganovich. 2012. The quantity and quality of teachers: Dynamics of the trade-off. *Journal of Public Economics* **96**:3-4, 417-429. [CrossRef]
84. Vijay Reddy, Servaas Van der Berg, Dean Janse van Rensburg, Stephen Taylor. 2012. Educational outcomes: Pathways and performance in South African high schools. *South African Journal of Science* **108**:3/4. . [CrossRef]
85. Martin Ravallion. 2012. Why Don't We See Poverty Convergence?. *American Economic Review* **102**:1, 504-523. [Abstract] [View PDF article] [PDF with links]
86. Wolfram F. Richter, Berthold U. Wigger. 2012. Besteuerung des Humanvermögens. *Perspektiven der Wirtschaftspolitik* **13**:1-2, 82-102. [CrossRef]
87. James Banks, Fabrizio Mazzonna. 2012. The Effect of Education on Old Age Cognitive Abilities: Evidence from a Regression Discontinuity Design*. *The Economic Journal* no-no. [CrossRef]
88. Ross Finnie. 2012. Access to post-secondary education: The importance of culture. *Children and Youth Services Review* . [CrossRef]
89. James J. Heckman. 2012. The developmental origins of health. *Health Economics* **21**:1, 24-29. [CrossRef]
90. Marco Caliendo, Jens Hogenacker. 2012. The German labor market after the Great Recession: successful reforms and future challenges. *IZA Journal of European Labor Studies* **1**:1, 3. [CrossRef]
91. Greg J. Duncan. 2012. Give Us This Day Our Daily Breadth. *Child Development* **83**:1, 6-15. [CrossRef]
92. Sarah-Jayne Blakemore, Silvia A. Bunge. 2012. At the nexus of neuroscience and education. *Developmental Cognitive Neuroscience* . [CrossRef]
93. Edmond P. Bowers, Steinunn Gestsdottir, G. John Geldhof, Jana Nikitin, Alexander von Eye, Richard M. Lerner. 2011. Developmental trajectories of intentional self regulation in adolescence: The role of parenting and implications for positive and problematic outcomes among diverse youth. *Journal of Adolescence* **34**:6, 1193-1206. [CrossRef]
94. P.A. Howard-Jones, E.V. Washbrook, S. Meadows. 2011. The timing of educational investment: A neuroscientific perspective. *Developmental Cognitive Neuroscience* . [CrossRef]
95. Raul Caruso. 2011. Crime and sport participation: Evidence from Italian regions over the period 1997–2003. *The Journal of Socio-Economics* **40**:5, 455-463. [CrossRef]
96. Augustin de Coulon, Elena Meschi, Anna Vignoles. 2011. Parents' skills and children's cognitive and non-cognitive outcomes. *Education Economics* 1-24. [CrossRef]
97. Hirokazu Yoshikawa, Ariel Kalil. 2011. The Effects of Parental Undocumented Status on the Developmental Contexts of Young Children in Immigrant Families. *Child Development Perspectives* no-no. [CrossRef]

98. David Frisvold, Ezra Golberstein. 2011. School quality and the education–health relationship: Evidence from Blacks in segregated schools. *Journal of Health Economics* . [CrossRef]
99. Eamonn Ferguson, James J. Heckman, Philip Corr. 2011. Personality and economics: Overview and proposed framework. *Personality and Individual Differences* **51**:3, 201-209. [CrossRef]
100. Michele Pellizzari, Francesco C. Billari. 2011. The younger, the better? Age-related differences in academic performance at university. *Journal of Population Economics* . [CrossRef]
101. Björn Bartling, Ernst Fehr, Daniel Schunk. 2011. Health effects on children's willingness to compete. *Experimental Economics* . [CrossRef]
102. Niklas Hanes, Erik Norlin. 2011. Psychological Traits and Earnings Differentials among Men: A Study of Second-generation Immigrants in Sweden*. *Scandinavian Journal of Economics* **113**:2, 318-341. [CrossRef]
103. Flávio Cunha. 2011. Recent Developments in the Identification and Estimation of Production Functions of Skills*. *Fiscal Studies* **32**:2, 297-316. [CrossRef]
104. Vincenzo Caponi. 2011. INTERGENERATIONAL TRANSMISSION OF ABILITIES AND SELF-SELECTION OF MEXICAN IMMIGRANTS*. *International Economic Review* **52**:2, 523-547. [CrossRef]
105. Simon Schwartzman. 2011. La tendencia academicista en la educación brasilera. *Pensamiento Educativo: Revista de Investigación Educacional Latinoamericana* **48**:1, 15-27. [CrossRef]
106. Olof Åslund,, Per-Anders Edin,, Peter Fredriksson,, Hans Grönqvist. 2011. Peers, Neighborhoods, and Immigrant Student Achievement: Evidence from a Placement Policy. *American Economic Journal: Applied Economics* **3**:2, 67-95. [Abstract] [View PDF article] [PDF with links]
107. Franco Peracchi, Emilia Arcaleni. 2011. Early-life environment, height and BMI of young adult males in Italy. *Economics & Human Biology* . [CrossRef]
108. Fabio D'Orlando, Francesco Ferrante, Gabriele Ruiu. 2011. Culturally based beliefs and labor market institutions. *The Journal of Socio-Economics* **40**:2, 150-162. [CrossRef]
109. Sarah Brown, Steven Mcintosh, Karl Taylor. 2011. Following in Your Parents' Footsteps? Empirical Analysis of Matched Parent-Offspring Test Scores*. *Oxford Bulletin of Economics and Statistics* **73**:1, 40-58. [CrossRef]
110. Katja Coneus, Manfred Laucht, Karsten Reuß. 2011. The role of parental investments for cognitive and noncognitive skill formation—Evidence for the first 11 years of life. *Economics & Human Biology* . [CrossRef]
111. Erik Lindqvist,, Roine Vestman. 2011. The Labor Market Returns to Cognitive and Noncognitive Ability: Evidence from the Swedish Enlistment. *American Economic Journal: Applied Economics* **3**:1, 101-128. [Abstract] [View PDF article] [PDF with links]
112. Eduardo de Carvalho Andrade, Luciano I. de Castro. 2011. Tougher Educational Exam Leading to Worse Selection. *Economics: The Open-Access, Open-Assessment E-Journal* **5**:2011-17, 1. [CrossRef]
113. Mathilde Almlund, Angela Lee Duckworth, James Heckman, Tim KautzPersonality Psychology and Economics 1-181. [CrossRef]
114. Christopher M. Napolitano, Edmond P. Bowers, Steinunn Gestsdóttir, Paul A. ChaseThe development of intentional self-regulation in adolescence 19-38. [CrossRef]
115. Lawrence E. Blume, William A. Brock, Steven N. Durlauf, Yannis M. IoannidesIdentification of Social Interactions 853-964. [CrossRef]
116. Anders Björklund, Kjell G. SalvanesEducation and Family Background 201-247. [CrossRef]
117. Janet Currie, Douglas AlmondHuman capital development before age five 1315-1486. [CrossRef]

118. Ana Rute Cardoso, Elsa Fontainha, Chiara Monfardini. 2010. Children's and parents' time use: empirical evidence on investment in human capital in France, Germany and Italy. *Review of Economics of the Household* **8**:4, 479-504. [CrossRef]
119. Tullio Jappelli. 2010. Economic Literacy: An International Comparison*. *The Economic Journal* **120**:548, F429-F451. [CrossRef]
120. Paolo Naticchioni, Andrea Ricci, Emiliano Rustichelli. 2010. Far away from a skill-biased change: falling educational wage premia in Italy. *Applied Economics* **42**:26, 3383-3400. [CrossRef]
121. Richard E. Nelson. 2010. Testing the Fetal Origins Hypothesis in a developing country: evidence from the 1918 Influenza Pandemic. *Health Economics* **19**:10, 1181-1192. [CrossRef]
122. Pilar García-Gómez, Hans-Martin Gaudecker, Maarten Lindeboom. 2010. Health, disability and work: patterns for the working age population. *International Tax and Public Finance* . [CrossRef]
123. Tobias Effertz, Thorsten Teichert. 2010. Kindermarketing aus neurologischer Sicht: Empfehlungen für ethisch korrekte Gestaltungen des Marketing-Mix. *Journal für Betriebswirtschaft* **60**:3, 203-236. [CrossRef]
124. Oliver Falck, Stephan Heblich, Elke Luedemann. 2010. Identity and entrepreneurship: do school peers shape entrepreneurial intentions?. *Small Business Economics* . [CrossRef]
125. Silke Anger, Guido Heineck. 2010. Do smart parents raise smart children? The intergenerational transmission of cognitive abilities. *Journal of Population Economics* **23**:3, 1105-1132. [CrossRef]
126. Claudio Sapelli. 2010. Some Thoughts on the Evaluation of the Chilean Voucher System. *Journal of School Choice* **4**:2, 222-231. [CrossRef]
127. Christian Helmers, Manasa Patnam. 2010. The formation and evolution of childhood skill acquisition: Evidence from India. *Journal of Development Economics* . [CrossRef]
128. Susann Rohwedder,, Robert J. Willis,. 2010. Mental Retirement. *Journal of Economic Perspectives* **24**:1, 119-138. [Abstract] [View PDF article] [PDF with links]
129. Marigee Bacolod, Bernardo S. Blum, William C. Strange. 2010. ELEMENTS OF SKILL: TRAITS, INTELLIGENCES, EDUCATION, AND AGGLOMERATION. *Journal of Regional Science* **50**:1, 245-280. [CrossRef]
130. Valentino Dardanoni, Mario Fiorini, Antonio Forcina. 2010. Stochastic monotonicity in intergenerational mobility tables. *Journal of Applied Econometrics* n/a-n/a. [CrossRef]
131. Atheendar S. Venkataramani. 2010. The intergenerational transmission of height: evidence from rural Vietnam. *Health Economics* n/a-n/a. [CrossRef]
132. Mara Violato, Stavros Petrou, Ron Gray, Maggie Redshaw. 2010. Family income and child cognitive and behavioural development in the United Kingdom: does money matter?. *Health Economics* n/a-n/a. [CrossRef]
133. C. Katharina Spieß. 2010. Was verspricht der Koalitionsvertrag der schwarz-gelben Bundesregierung im Bereich der Bildungs- und Familienpolitik? Eine Bewertung ausgewählter Aspekte. *Vierteljahrshefte zur Wirtschaftsforschung* **79**:1, 101-116. [CrossRef]
134. Francesco Ferrante. 2009. Education, Aspirations and Life Satisfaction. *Kyklos* **62**:4, 542-562. [CrossRef]
135. Lindsey Jeanne Leininger, Ariel Kalil. 2009. Cognitive and non-cognitive predictors of success in adult education programs: Evidence from experimental data with low-income welfare recipients. *Journal of Policy Analysis and Management* **27**:3, 521-535. [CrossRef]
136. David Deming. 2009. Early Childhood Intervention and Life-Cycle Skill Development: Evidence from Head Start. *American Economic Journal: Applied Economics* **1**:3, 111-134. [Abstract] [View PDF article] [PDF with links]

137. Abdurrahman Aydemir, Wen-Hao Chen, Miles Corak. 2009. Intergenerational Earnings Mobility among the Children of Canadian Immigrants. *Review of Economics and Statistics* **91**:2, 377-397. [CrossRef]

138. Elise Huillery. 2009. History Matters: The Long-Term Impact of Colonial Public Investments in French West Africa. *American Economic Journal: Applied Economics* **1**:2, 176-215. [Abstract] [View PDF article] [PDF with links]

139. Giorgio Brunello, Margherita Fort, Guglielmo Weber. 2009. Changes in Compulsory Schooling, Education and the Distribution of Wages in Europe. *The Economic Journal* **119**:536, 516-539. [CrossRef]

140. Daniel McFadden. 2008. Human Capital Accumulation and Depreciation*. *Review of Agricultural Economics* **30**:3, 379-385. [CrossRef]

141. JAMES J. HECKMAN. 2008. SCHOOLS, SKILLS, AND SYNAPSES. *Economic Inquiry* **46**:3, 289-324. [CrossRef]

142. Manfred Weiß. 2008. Stichwort: Bildungsökonomie und Qualität der Schulbildung. *Zeitschrift für Erziehungswissenschaft* **11**:2, 168-182. [CrossRef]

143. Ludger Wößmann. 2008. Die Bildungsfinanzierung in Deutschland im Licht der Lebenszyklusperspektive: Gerechtigkeit im Widerstreit mit Effizienz?. *Zeitschrift für Erziehungswissenschaft* **11**:2, 214-233. [CrossRef]

144. James J. Heckman. 2008. Role of Income and Family Influence on Child Outcomes. *Annals of the New York Academy of Sciences* **1136**:1, 307-323. [CrossRef]

145. James J. Heckman, Dimitriy V. Masterov. 2007. The Productivity Argument for Investing in Young Children. *Review of Agricultural Economics* **29**:3, 446-493. [CrossRef]

146. J. J. Heckman. 2007. The economics, technology, and neuroscience of human capability formation. *Proceedings of the National Academy of Sciences* **104**:33, 13250-13255. [CrossRef]

147. Lina Dunnzlaff, Dirk Neumann, Judith Niehues, Andreas PeichlChapter 5 Equality of Opportunity and Redistribution in Europe 99-129. [CrossRef]