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Household environmental protection and the intergenerational transmission of human capital

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Abstract

The estimated discount rate of parents is used to test a choice-based intergenerational model of the contribution of environment to the cognitive skills of a child of a given endowment. A lower parental discount rate is shown to imply higher cognitive skills of the young child. In the context of the model, estimates also imply that environmental conditions and human capital formation are not separable. Lesser environmental quality raises the costs of human capital formation in children and lesser human capital reduces parents' demand for environmental quality. Environmental quality differences among families, just like genetic differences, may persist across generations. © 2000 Published by Elsevier Science B.V. All rights reserved.

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> The difference of natural talents in different men is, in reality, much less than we are aware of; and the very different genius which appears to distinguish men...when grown to maturity, is not...so much the cause, as the effect of the division of labor (Smith, 1937, p. 15).

1. Introduction

The influence of human capital or knowledge about the laws of nature and the nature of man on economic growth and the evolution of income inequality receives increasing attention in both the technical economic literature, e.g., Levy and Murnane (1992), and in popular commentary, e.g., Murray (1984). Human capital is thought to be the primary engine of growth, the major component of wealth in developed economies, to be increased by and to increase the scope of markets, and to play significant roles in fertility choice, socialization, and migration. Little attention has been given, however, to how human capital can affect one's treatment of the natural environment, or how this environment can mold one's accumulation and protection of human capital. Central to any attempt to deal with either of these questions is the extent to which intergenerational redistributions, especially from adults to young children, are influential. Since children do not vote and have only trivial assets or activities over which they can exercise substantial discretion, the practical aspects of the intergenerational redistribution issue revolve around the productivity of parental and social investments in environments that can affect a child's prospective human capital. Given that parents have limited resources, they must often make time and effort choices between their immediate consumption and the provision of environmental enhancements and protections that will advance a child's current health and adult prospects. When approaching adulthood, the child takes what its parents, community, and genes have handed it and sets its course for an adult life.

This study uses an unusual data set to estimate the relationship between the environmental protections that parents offer children and the intergenerational transmission of human capital. We focus on lead, a persistent micropollutant that has become ubiquitous in even remote environments, and which is widely acknowledged in the biomedical literature to produce long-term cognitive skill deficits in young children who are exposed to everyday ambient concentrations common to the world's urban areas (Smith, Grant & Sors, 1989). Following Agee and Crocker (1998), the next section presents a simple model in which changes in parents' demand for own-consumption translate into changes in the environmental quality they provide their children, and hence into changes in the benefits to them of building their children's human capital. The model hinges upon parents having imperfect access to capital markets in that they must either sell assets, increase parental market labor, or reduce household consumption to finance investments in their children which cannot be borrowed and made the children's future obligations. A third section describes the data we employ, while the fourth section presents empirical tests of model propositions. The connection we find between parents' own-consumption and their children's cognitive skills and their home environment leads us to conclude that environmental quality differences among families, just like genetic differences, may persist across generations.

2. Parental investments in children's cognitive skills

Consider a two-period, two-generation lifetime setting in which the generations overlap each period. In period 1, parents with unified preferences derive utility

$$U(s_1, \alpha_1(n)nc_2) \tag{1}$$

in a weakly separable fashion from own-consumption, s_1, over their certain lifespans, and from the current health and thus the expected value, c_2, of the adult prospects in period 2 of their child. $U(\cdot)$ is twice differentiable and concave. So as to remove fertility decisions from the problem, we interpret the parents' number of children, n, to be predetermined. Diminishing marginal utility of children implies that parental first period altruism, α_1, is negatively related to child numbers (Becker, Murphy & Tamura, 1990). Parents have no favorites among their individual children, as is commonly assumed (Wilhelm, 1996). Children are passive with respect to their parents' consumption and investment decisions.

Parents maximize $U(\cdot)$ subject to the constraint

$$X_1 + nc_2(Q_1; E_2) = p_1(Q_1)s_1. \tag{2}$$

The left-hand side of (2) states that parents possess total exogenous money wealth, X_1, and the expected value, c_2, to them in period 2 of their children as adults. This expected value may include consumption support as well as the money equivalent of companionship and emotional support. On the right-hand side, parents allocate this wealth and expected value between period 1 own-consumption, s_1, and the provision of environmental quality, Q_1, for their child. Greater parental provision of period 1 environmental quality progressively increases the unit value, p_1, of own-consumption such that $p_1' > 0$, and $p_1'' > 0$ (primes denoting derivatives). In effect, the quality of the child's environment and the parents' period 1 own-consumption are substitutes.

Q_1 is conditioned on whatever public goods society exogenously provides the child. Parents have no second-period earnings, but the presence of the second term, $c_2(Q_1; E_2)$, on the left-hand side of (2) implies that the parents' lifetime wealth increases with the child's adult prospects. [1] $c_2(\cdot)$ is defined as

$$c_2(Q_1; E_2) \equiv w \cdot z_2(Q_1; E_2) + \varepsilon_2, \tag{3}$$

where z_2 is a continuous concave cognitive skill or adult prospect production function, w the rental rate of these skills, and ε_2 is a stochastic term representing market luck. For simplicity, we assume w equals unity. E_2 is the child's exogenous phenotype, the autonomous background expression of the cultural, environmental,and genetic attributes that the child inherits. We presume as a first approximation that these attributes are transmitted by way of a stochastic linear equation

$$E_2 = \lambda + \theta E_1 + v, \tag{4}$$

where λ denotes the child's community or social endowment (Coleman, 1988), θ represents the degree (or vector of degrees) of "inheritability" of attributes, E_1, that the child's grandparents transmitted to the parents, and $v$measures unsystematic components in heritability. Expression (4) is presumed fixed over the child's lifespan and is shared in common with its siblings. Parents cannot invest in the child's endowment. In sum, $c_2(Q_1; E_2)$ implies that the cognitive skill impact of the child's inheritance is conditioned by the quality of the environment that the child's parents provide.

Parents' equilibrium levels of s_1 and c_2 obtained from the primal optimization problem in expressions (1)–(4) will vary with their demand, Q_1^*, for

[1] Moreover, we assume that parents recognize that children must have enough consumption to survive when they become adults. Formally, we deal with parents' concerns about their child's adult survival level of consumption, X_2^0, by supposing that $\partial U/\partial X_2 \to \infty$ as $X_2 \to X_2^0$, and that $U(X_2)$ is undefined for $X_2 < X_2^0$.

environmental quality. Substitution of Q_1^* into $U(\cdot)$ yields an indirect utility function

$$V = V(p_1(Q_1^*), nc_2(Q_1^*; E_2); X_1), \tag{5}$$

which follows from the primal result that parents produce that level of environmental quality which equates the money equivalents of their marginal utilities of consumption and their child's cognitive skills, given that the parents are wealth-constrained; that is, they cannot borrow for own-consumption and child investments and then make payments on these borrowings the child's adult obligations. Therefore expression (5) implies that parents invest in their child's environment until the marginal rate of return on this investment equals their substitution rate between own-consumption, s_1, and the child's adult prospects (see Appendix A). Becker and Tomes (1986, p. S11) refer to this substitution rate as the parents' rate of discount for these prospects, $\rho \equiv -(\partial U/\partial s_1)(\partial s_1/\partial Q_1)/[\alpha_1(n)n(\partial U/\partial c_2)]$, their "shadow cost" of investing in the child's environmental quality. As in Becker and Tomes, the parents' demand for environmental quality can then be written in terms of the parents' discount rate for developing the child's cognitive skills and hence the expected value of its adult prospects,

$$Q_1^* = Q_1^*(\rho(X_1; n, E_2); E_2) = Q_1^*(\rho(X_1; n); E_2). \tag{6}$$

In expression (6), wealthier parents for whom the left-hand side of (2) is relatively high apply a lower discount rate and consequently provide a better environment for their child, i.e., $(\partial Q_1^*/\partial \rho)(\partial \rho/\partial X_1) > 0$. Note that expression (5) requires $(\partial V/\partial p_1)p_1' + (\partial V/\partial c_2)(\partial c_2/\partial Q_1^*)\alpha_1(n)n = 0$ at equilibrium quality Q_1^*, implying that $\partial c_2/\partial Q_1^* > 0$ since, by construction, $p_1' > 0$, $\partial V/\partial p_1 < 0$ and $\partial V/\partial c_2 > 0$. Thus, increases in environmental quality increase the value parents attach to the child's cognitive skills.

To see the impact of a change in environmental quality upon parents' own-consumption, s_1, totally differentiate the Marshallian demand $s_1^*(p_1(Q_1^*), c_2(Q_1^*; E_2), X_1)$ to obtain

$$\frac{\partial s_1^*}{\partial Q_1^*} = \frac{\partial s_1^*}{\partial p_1} p_1' + \frac{\partial s_1^*}{\partial c_2} \frac{\partial c_2}{\partial Q_1^*}. \tag{7}$$

This expression says that the demand for own-consumption arises from the impact of environmental quality provision upon the parental benefits of improving the child's adult prospects as well as upon the unit value of own-consumption. By construction, $p_1' > 0$, and by implication, $\partial c_2/\partial Q_1^* > 0$. Also, $\partial s_1^*/\partial p_1 < 0$, since an increase in unit value of own-consumption is consistent with a reduction in quality demanded. Given that the budget constraint in expression (2) makes parents' own-consumption and the child's adult prospects substitutes such that $\partial s_1^*/\partial c_2 < 0$, it then follows that $\partial s_1^*/\partial Q_1^* < 0$.

Now consider how a change in the child's autonomous inheritance will affect parents' demands for own-consumption and hence their investment in their child's environment. Substitute Q_1^* from (6) into the parents' equilibrium level of own-consumption and differentiate to obtain

$$\frac{\mathrm{d}s_1^*}{\mathrm{d}E_2} = \left[\left(\frac{\partial s_1^*}{\partial p_1}\right)p_1' + \left(n\frac{\partial s_1^*}{\partial c_2}\right)\frac{\partial c_2}{\partial Q_1^*}\right]\left[\left(\frac{\mathrm{d}Q_1^*}{\mathrm{d}\rho}\right)\frac{\partial \rho}{\partial E_2} + \frac{\partial Q_1^*}{\partial E_2}\right]. \tag{8}$$

The first bracketed term on the right-hand side of (7) is the effect of any change in environmental quality upon parents' willingness to invest in developing the child's cognitive skills. Q_1^* must change as E_2 changes. The second right-hand side term reflects the indirect and direct effect of a change in E_2 upon the parents' demand for environmental quality. Not surprisingly, parents' own-consumption and children's endowments are indirectly linked through ρ; that is, constraints on financing investments in children introduce an accentuating positive effect of parents' wealth on children's adult prospects. [2]

3. Data

The foregoing model carries precise implications for the quality of the environment that parents choose for their children: they equate the marginal rate of return to investments in the child's skills to their marginal rate of substitution between own-consumption and the child's skills. Data on parents' equilibrium return rates for investing in these environments would thus enable us to distinguish the determinants among families of parental investments in their children and the distribution of skills among these children. We have no observed data on parents' equilibrium return rates for their children. However, in Agee and Crocker (1996), we use data on screening for children's body burdens of lead to estimate the discount rates that parents attach to investments in avoiding risks of their child developing long-term

[2] Although imperfect access to capital market financing raises the positive effect of parents' earnings on children's adult prospects, Becker and Tomes (1986) show that this introduces a possible negative relation between the earnings of grandparents and grandchildren, such as is found in Wahl (1986).

cognitive deficits from low-level lead exposure. This section describes the lead screening data and the Agee and Crocker framework used to estimate parental discount rates from this data. Together with information in the same data set on the assessed intelligence (IQ) of parents and children, these estimated discount rates allow us to test the foregoing choice-based, intergenerational model of the contribution of environment to the cognitive skills (as measured by assessed IQ) of a child of a given endowment.

3.1. The lead screening data

Our data were originally gathered for Needleman et al. (1979) and Needleman, Schell, Bellinger, Leviton, and Allred (1990). They involve observations on 256 children each from separate families in two adjoining Boston, Massachusetts area communities in 1975–78, and again in 1985. Each household had an own child who attended the first or second grades between 1975 and 1978. Thus these children were very unlikely to be old enough to reflect meaningfully about the effect of their cognitive development choices upon their parents' altruism toward them. Information on each child's medical history and current health status, and the parents' time allocations, employment, and a variety of personal characteristics was gathered in the 1975–78 survey. The lead content of shed teeth was used to measure each child's body lead burden. All sample children had a birth weight above 2500 g, were discharged from a medical facility following birth at the same time as the mother, had not previously received medical treatment for lead-related health effects, did not have a history of noteworthy head injury, and were not retarded (i.e., $IQ > 70$).

While parents completed a Peabody Picture Vocabulary IQ Test (Dunn, 1959), their child was given the Wechsler Intelligence Scale for Children-Revised (Wechsler, 1974). We presume that cognitive skills are measurable without systematic error in terms of assessed intelligence (IQ). After completion of these IQ examinations, a child psychiatrist informed the parents of their child's lead status, its expected consequences, and medically appropriate courses of action for the child. Over the next few years, parents then had to make a choice between doing nothing for the child or investing in changing its environment, i.e., its lead burden. In 1985, the original data set was supplemented by information about 1985 parental wage levels and the medical treatments, if any, which the child had undergone in the interim.

3.2. Parents' discount rates

Agee and Crocker (1996) used parents' implicit valuations of their children's reduced body lead burdens to infer the subjective discount rates they applied to their children. The inferences were based upon a model of ex ante endogenous risk. That is, parents' perceived risk – of their child developing lead-induced neurological deficits – varied with their choices of medical treatments and reductions of the child's exposures to lead in the home environment. Perceived risk represented a continuous measure over a real interval of parents's perceived probability or expected severity of their child's neurological deficits. For a reduction in perceived risk associated with a reduction, $\lambda - \bar{\lambda}$, of the child's body lead burden, λ, the parents' indirect utility function, $V(\cdot)$, was defined in annualized terms as

$$\bar{V} = V\left(Y_1 - \delta CS, \lambda - \bar{\lambda}, q\right), \tag{9}$$

where Y_1, is annual income, q real prices, and δCS is the annualized Hicksian compensating surplus. δCS is the maximum income in annualized terms that parents are willing to forego in order to reduce perceived risks to their child while maintaining their original utility level, $\bar{V}$. The parents' rate of discount, ρ, generates an annualizing term, δ, equal to $\rho/(1+\rho)$. [3] A small reduction in the child's lead burden was thus valued in terms of the parents' annualized marginal implicit price of risk P_λ. P_λ was obtained by totally differentiating (9) with respect to λ and setting the result equal to zero:

$$P_\lambda \equiv -\left(\frac{\mathrm{d}CS}{\mathrm{d}\lambda}\right) = -\frac{(1/\delta)(\partial V/\partial \lambda)}{(\partial V/\partial Y_1)}. \tag{10}$$

Agee and Crocker (1996) estimate expression (10) by deriving an observable expression for the endogenous implicit price variable, P_λ, and by specifying

[3] See, for example, Hausman (1979, p. 35), and Viscusi and Moore (1989). The parents' present value of compensating surplus for a reduction their child's lead burden is

$$\frac{CS}{\{(1+\rho)[1-(1+\rho)^{-\tau}]\}},$$

where τ is the perceived duration in years of the child's lead-induced health effects. Assuming that parents perceive the effects to be lifelong for their child and thus roughly infinite in duration, the above expression reduces to $CS/(1+\rho)$. Thus in annualized terms, parental compensating surplus is

$$\delta CS = \left[\frac{\rho}{(1+\rho)}\right] CS.$$

$V(\cdot)$ with an indirect addilog utility function (Parks, 1969). The empirical version of (10) also specified the function

$$\frac{1}{\delta} = (\text{INCOME, DADPRSNT, MOMAGE, MOMEDUC, DADEDUC, SEX, NUMCHLD}) \tag{11}$$

as a log-linear combination of observable variables to explain differences in parental discount rates from differences in family characteristics. Annual parental income (INCOME), presence of the father in the household (DADPRSNT), the mother's age (MOMAGE), and educational attainments of parents (MOMEDUC, DADEDUC) combined to measure household differences in wealth. The child's gender (SEX) and number of siblings (NUMCHILD) measured sources of differences in parental altruism per child. The variables in (11) were assumed determined prior to rather than contemporaneously with the parents' demands to reduce their children's body lead burdens.

The adjusted R^2 for the estimate of expression (10) was 0.90, a coefficient which we presume to be large enough to allay the concerns of Bound, Jaeger and Baker (1995) and Nelson and Startz (1990) about inconsistency of estimates whenever the correlation between instruments and the unobserved variable $(1/\delta)$ is low. More parental income, maternal education, and presence of the father reduced the discount rate that parents applied to investments in their children's cognitive skills (see also Parsons & Goldin, 1989), while more paternal education increased this rate. Consistent with expression (1), no gender preference appeared. The parental discount rate increased with the number of the child's siblings.

Table 1 supplies descriptive statistics of sample parents' discount rates, $\hat{\rho}$, calculated from the fitted values for expression (11). The mean implicit discount rate for the entire sample is 4.7%, with a 2.2% standard error. The table shows that sample parents with annual incomes below the 1979 US median of $16,841 applied discount rates of approximately 7.2% on average, while those above the median applied rates of 3.2%. [4] Children in families without a high school diploma were discounted at about 7%, while families with both parents having had at least some college were discounted at about 2.6% which,

[4] Relative to US adults over age 25 (US census, 1982), sample parents have a higher mean number of years of schooling completed; 81% of sample parents completed high school and 16% have graduated from college compared to 1980 US percentages of 66.3 and 16.3 (72.7 and 20.0 in Massachusetts). Sample households' median income of $17,000 is slightly higher than the 1979 US median of $16,841.

Table 1
Acronyms, definitions, sample means, and standard deviations

Variable	Definition	Mean (S.D.) ($N=256$)
Endogenous variables		
FULSCLIQ	Age standardized Full-scale IQ measured by the Wechsler Intelligence Scale for Children-Revised	104.88 (13.28)
VERBALIQ	Age standardized Verbal IQ measured by the Weschler Intelligence Scale for Children-Revised	101.87 (13.54)
Explanatory variables		
$\hat{\rho}$	Parent's implicit discount rate in percent for their child's cognitive development	4.70 (2.2)
	(i) *By household income*:	
	Below 1979 US median ($N = 107$)	7.2 (2.8)
	Above 1979 US median ($N = 149$)	3.2 (0.05)
	(ii) *By education*:	
	Both parents without HS diploma ($N = 49$)	7.0 (0.07)
	Both parents with some college or more ($N = 21$)	2.6 (0.7)
	(iii) *By number of children*:	
	One or two children ($N = 97$)	4.3 (1.9)
	Four or more children ($N = 41$)	5.0 (2.5)
	(iv) *By the subject child's body lead burden*:	
	Low ($N = 61$)	4.3 (2.2)
	Moderate ($N = 136$)	4.7 (2.4)
	High ($N = 59$)	4.9 (1.9)
PBLEVEL	Subject child's dentine lead level in arithmetic mean ppm over three shed teeth	15.055 (11.99)
$\hat{\rho}$ * PBHIGH	Subject child's body lead burden is in excess of a mean of 6 ppm taken over three shed teeth (1 – yes, 0 – no)	3.63 (2.83)
BIRTHWT	Subject child's birth weight in ounces	116.84 (19.14)
DADEDUC	Father's education in grades completed as of 1978	11.92 (2.57)
DADPRSNT	Father lives with the mother and child(ren); 1 – yes, 0 – no	0.72 (0.48)
HOSPINF	Number of days subject child was in hospital after birth	5.62 (7.17)
INCOME	Annual wage income of parents in 1980 dollars: $1 =$ INCOME $< \$7000$, $2 = \$7000 \leqslant$ INCOME $< \$8500\ldots$, $14 =$ INCOME $> \$25,000$	8.73 (2.30)
MOMAGE	Mother's age in years in 1978	30.24 (4.76)
MOMEDUC	Mother's education in grades completed as of 1978	11.61 (2.17)
MOMWRKS	Mother works; 1 – yes, 0 – no	0.81 (0.40)
NUMCHLD	Number of children in family in 1978	2.94 (1.13)
NUMHDINJ	Subject child's number of lifetime head injuries	0.07 (0.35)
ORDENGL	Order in which the subject child learned the English language	1.16 (0.59)
PARENTIQ	Mean parental IQ measured by the Peabody Picture Vocabulary Test	110.83 (13.93)
SEX	Gender of the subject child; 1 – male, 0 – female	0.50 (0.50)

incidentally, is fairly close to the Viscusi and Moore (1989) estimate of the long-term AAA bond rate of 3.2%.

4. Parents' environmental investments and children's IQs

In Section 2 the distribution across families of wealth and children's endowments determines the distribution of equilibrium parental investments for their children's environments. Substituting the Q_1^* in expression (6) into the cognitive skill production function in expression (3) yields

$$z_2^* = z_2^*(Q_1^*(\rho; E_2); E_2) = \varphi_2(\rho; E_2). \qquad (12)$$

A linear approximation to this relation is

$$z_2 = a + b\rho + cE_2 + \eta_2, \qquad (13)$$

where η_2 measures unsystematic components of the determinants of the child's cognitive skills. Our interest focuses on the marginal contribution to the child's cognitive skills of the systematic parent–child connections expressed in ρ, the discount rate that parents applied to their investments in reducing the child's body burden of lead. Given that parents apply a weakly positive discount rate and that increased child endowments raise the marginal productivity of parents' time and money expenditures on these environmental investments we expect our estimate of the b parameter to be negative.

The unobservability of E_2 complicates the straightforward estimation of (13). If E_2 were correlated with ρ, a failure to include some measure of E_2 would bias any estimate of the coefficient of ρ. We therefore postulate an incidental equation to describe the relation between the unobserved E_2 and an observable variable, the average of the assessed IQs of the child's parents (PARENTIQ). To derive this equation, we lag expression (13) by one generation and substitute from (4) to obtain (Behrman & Taubman, 1985):

$$\text{PARENTIQ} = A + BE_2 + \mu, \qquad (14)$$

where $A = a - (c\lambda/\theta)$, $B = c/\theta$, and $\mu = b\rho_0 - (cv_2/\theta) + \eta_1$ (0 denotes grandparents). This expression recognizes that a child does not inherit an IQ from its parents. Instead, the child inherits a set of cultural and genetic attributes, as well as grandparent-to-parent nurturance. The expression of that inheritance, called the *phenotype* (the observable cognitive skills of a child), results from the interaction of the inheritance with current environmental influences. Expression (14) is therefore to be interpreted as the child's inheritance measured in terms of parental phenotype. Substitution of expression (14) into (13) yields

$$z_2 = \bar{a} + \psi(\text{PARENTIQ}) + b\rho + \bar{\eta}_2, \tag{15}$$

where $\bar{a} = a(1-\theta) + c\lambda$, and $\bar{\eta}_2 = cv_2 - \theta(b\rho_0 + \eta_1) + \eta_2$. However, since PARENTIQ and $+\bar{\eta}_2$ in expression (15) are correlated, the ordinary least squares (OLS) estimator of b and ψ will be biased and inconsistent. Specifically, if E_2 and ρ are negatively correlated, measurement error introduced by way of (14) will impart a downward asymptotic bias to b (Garber & Klepper, 1980). In effect, ρ will pick up some of the positive effects of E_2 which, because of measurement error, are not attributed to the PARENTIQ surrogate. As is well known, this same error will cause the estimated coefficient for PARENTIQ to be biased toward zero. Consequently, we interpret our estimates of b and ψ in Tables 2 and 3 as lower bounds on the true influences of the parental discount rate for body lead burden reducing investments and heritability of family endowments upon the development of a young child's cognitive skills.

Table 2 reports OLS estimates of expression (15) using assessed Full-scale and Verbal IQ scores as measures of children's cognitive skills. Both sets of estimates include as predetermined covariates the child's birth weight (BIRTHWT), length of hospital stay after birth (HOSPINF), order in which English was learned (ORDENGL), and number of head injuries (NUMHDINJ) to control for exogenous, strictly post-natal factors that do not influence ρ but which representative biomedical thinking (e.g., Needleman et al., 1990) believes are associated with differences in children's assessed IQ's. Also predetermined are the indirect influences in (11) which we postulate operate on IQ recursively through their effects upon the estimated discount rate, $\hat{\rho}$, that parents apply to investments in reducing their child's body lead burden. That is, as our analytical framework commands, we treat the parental discount rate as a price that intervenes between the child's cognitive skills and factors that, with little or no theoretical justification, nearly all cognitive skill studies maintain directly influence these skills. A dichotomous measure of whether the sample child's mother works outside the home (MOMWRKS) is also treated as predetermined. Some recent research suggests that the young children of working mothers develop cognitive skill deficits, e.g., Hill and O'Neill (1994).

In the first and third columns of Table 2, coefficients for the PARENTIQ and $\hat{\rho}$ covariates have the expected signs and provide statistically significant explanations of the variations in children's assessed Full-scale and Verbal

Table 2
OLS estimates of child IQ production functions ($N = 256$)

Variable	Full-scale IQ[a]		Verbal IQ[a]	
	(1)	(2)	(3)	(4)
Constant	69.48	70.23	73.09	73.82
	(7.70)	(7.83)	(7.82)	(7.93)
$\hat{\rho}$	−0.77	−1.54	−0.76	−1.51
	(−2.04)	(−2.87)	(−1.95)	(−2.73)
PBLEVEL	−0.17	−0.23	−0.18	−0.24
	(−2.04)	(−3.25)	(−2.74)	(−3.31)
$\hat{\rho}$ ∗ PBHIGH		0.85		0.84
		(2.01)		(1.91)
BIRTHWT	0.05	0.05	0.06	0.06
	(1.15)	(1.24)	(1.35)	(1.43)
HOSPINF	0.007	0.06	0.07	0.07
	(0.60)	(0.53)	(0.61)	(0.55)
MOMWRKS	1.51	1.59	2.69	2.76
	(0.79)	(0.83)	(1.35)	(1.39)
NUMHDINJ	−2.50	−2.53	−2.97	−3.00
	(−0.22)	(−1.16)	(−1.30)	(−1.32)
ORDENGL	−0.51	−1.07	−2.81	−1.25
	(−0.22)	(0.44)	(−1.16)	(0.49)
PARENTIQ	0.32	0.30	0.26	0.25
	(5.55)	(5.29)	(4.45)	(4.20)
$\bar{R}^2$	0.18	0.19	0.15	0.16
X^2 (8)	58.01	62.15	49.37	53.09

IQs. For the intervals to which our sample refers, the table suggests that if parents' discount rates increase from roughly 3–7% (the average difference in Table 1 between lower and higher income and educated parent subsamples) the IQs of sample children decrease by about 3 points. [5] This can be compared to the 9 point decrease in PARENTIQ that is associated, on average, with a 3 point decrease in each of the child's Fullscale and Verbal IQ's.

Table 1 reports that the discount rate Agee and Crocker, 1996 estimated which parents applied to investments in reducing their child's body lead burden increased slightly with this burden. Because parents were ignorant

[5] This lower bound estimate fits well with existing social psychology research on class differences in assessed IQs. For example, in a sample of 261 adopted children, Scarr and Weinberg (1983) found that children with natural parents in the lowest third of sample parent educational attainments who were adopted by parents in the highest third of educational attainments scored an average of 6.7 points higher on IQ tests than did comparable children who remained with their natural parents. Likewise, children with natural parents in the highest third of sample parent educational attainments who were adopted by parents in the lowest third of educational attainments scored an average of 3.5 points lower.

about its presence prior to the physician consultation (Needleman et al., 1979), this burden was part of the child's autonomous inheritance. In accordance with expression (8), one possible interpretation of these higher estimated rates is that a greater burden reduced parents' perceived effectiveness of investments in their child's cognitive skills, thereby increasing parents' propensity to consume and accentuating the effect that the inherited burden poses upon the child's adult prospects. The choice that parents made about own-consumption affected their child's environment and, in turn, the expected consequences of the environment affected their choices. Here we test the empirical validity of this interpretation. The alternative hypotheses are that only the autonomous body lead burden or only parents' investments and not the effect of autonomous lead upon the mix of parents' own-consumption and investments in reducing the child's lead burden as reflected in the parents' discount rate influenced the child's cognitive skills. [6] We now test these three distinct hypotheses by linearly approximating (15) as

$$Z_2 = \bar{a} + \psi(\text{PARENTIQ}) + b\rho + e\rho * \lambda + \eta_2, \tag{16}$$

where ρ captures the willingness of the parents to invest in reducing the child's lead burden, λ represents its inherited body lead burden, and $\rho * \lambda$ is the interaction between the parent-supplied environment and the inheritance. The second and fourth columns of Table 2 report OLS estimates of expression (16), again using Full-scale and Verbal IQs as measures of children's cognitive skills.

The coefficients for the discount rate and the body lead burden covariates in the second and fourth columns of Table 2 have the expected signs and provide qualitatively significant explanations of variations in the child IQ measures. We cannot therefore reject either the autonomous economy (discount rate) or the autonomous nature (body lead burden) conjectures. Note, however, that the term, $\hat{\rho} * \text{PBHIGH}$, which represents interaction between the parental investments and the child's body lead burden, is also significant.

For the interaction term, $\hat{\rho} * \mathit{PBHIGH}$, lead is set equal to one and defined as high ($N = 195$) if the child's lead burden is in excess of 6 ppm. Otherwise the term is set equal to zero and defined as low ($N = 61$). The derivative

$$\frac{\partial \text{ Full Scale IQ}}{\partial \hat{\rho}} = -1.54 + 0.85 = -0.69 \tag{17}$$

[6] In the child lead exposure literature, these hypotheses can be found respectively in Needleman et al. (1990), Milar, Schroeder, Mushak, Dolcourt and Grant (1980), and Werner, Honzik and Smith (1968).

for high lead children, and the derivative

$$\frac{\partial \text{ Full Scale IQ}}{\partial \hat{\rho}} = -1.54 \tag{18}$$

for low lead children suggest that low lead children are more sensitive than the high lead children to changes in the caregiving environment as registered in parents' discount rates. That is, neither the body lead burden nor the caregiving environment conjectures alone are sufficient to explain variations in the Full-scale IQs of our sample children. Similar results apply to their verbal IQs.

Agee and Crocker (1996) showed that the discount rates applied to children in this sample varied inversely with the parents' socioeconomic status or human capital stock. Elevated body lead burdens in this sample and in the general American population (Schwartz & Levin, 1992) are associated with lower socioeconomic status. Hence, given that these associations are durable, natural conditions and human capital formation are not separable. Lesser environmental quality raises the costs of human capital formation and lesser human capital reduces the demand for environmental quality. Thus human capital differences are not so much the cause of environmental quality differences but are rather the intervening bridge by which parents' discount rates and all the economic factors and social ties that induce them are transformed into choices for different environments. Environmental quality differences among families, just like genetic differences, may then persist across generations if the factors that influence parents' discount rates are unchanged.

5. Conclusions

This paper qualitatively demonstrates that the discount rates that a set of American parents applied to own-investments in their young children's adult prospects influenced those children's cognitive skills. Construction and interpretation of the estimates is guided by an intergenerational utility maximization framework in which the development of cognitive skills is dependent in part upon the specific environment in which the skills are nurtured. Lower discount rates imply that parents make greater investments in improving their children's environments. Improved environments enhance the children's cognitive skills. The policy implications are plain: a high parental discount rate applied to environmental investments in children today implies that these children when adults will apply a high discount rate tomorrow, in the absence of some compensating activity. Given that higher cognitive skills lead directly to better adult prospects and indirectly to better prospects through increased learning and additional years of schooling, reduced parental incentives to nurture the cognitive skills of their children perpetuate lesser cognitive skills through the generations. Environmental differences among families, just like genetic differences, may persist across generations.

Some caveats are in order. First, if the parents' net rate of return to nonchild (financial) investments were positively related to their earnings and education, our findings would be confounded by a price effect masquerading as a wealth effect. Second, the durability of the effects we have identified cannot be determined from our data. We do not allow differences in families' fertility decisions to appropriate the cognitive skills effects of the differences in their discount rates. Finally, the major limitation in our approach is that we cannot control for variations in cognitive skills that are not reflected in the IQ test scores we use as indicators of these skills.

Appendix A

To show that parents invest in the child's environment until their marginal rate of return equals their substitution rate between own-consumption and the child's adult prospects, define the rate of return, $1 + r$, as

$$1 + r(Q_1; E_2) = \partial c_2 / \partial Q_1. \tag{A.1}$$

From expression (2) in the text

$$s_1 = \frac{X_1 + nc_2(Q_1; E_2)}{p_1(Q_1)}, \tag{A.2}$$

which, when (A.2) is substituted into expression (1) of the text, means that the parents' primal optimization problem can be written as

$$\operatorname*{Max}_{Q_1} \; U(s_1(Q_1; E_2, X_1), \alpha(n) nc_2(Q_1; E_2)). \tag{A.3}$$

The first-order condition is

$$\frac{\partial U}{\partial s_1}\frac{\partial s_1}{\partial Q_1} + \alpha_1(n) n \frac{\partial U}{\partial c_2}\frac{\partial c_2}{\partial Q_1} = 0. \tag{A.4}$$

Rearranging (A.4), we get

$$\frac{\partial s_1/\partial Q_1}{\partial c_2/\partial Q_1} = -\frac{\alpha_1(n)n(\partial U/\partial c_2)}{\partial U/\partial s_1}, \tag{A.5}$$

or

$$1 + r = -\frac{(\partial U/\partial s_1)(\partial s_1/\partial Q_1)}{\alpha_1(n)n(\partial U/\partial c_2)} = -\frac{\partial U/\partial Q_1}{\alpha_1(n)n(\partial U/\partial c_2)}. \tag{A.6}$$

References

Agee, M. D., & Crocker, T. D. (1996). Parents' discount rates for child quality. *Southern Economic Journal*, *63*, 36–50.

Agee, M. D., & Crocker, T. D. (1998). Economies, human capital, and natural assets: Forming empirical linkages. *Environmental and Resource Economics*, *11*, 261–271.

Becker, G. S., & Tomes, N. (1986). Human capital and the rise and fall of families. *Journal of Labor Economics*, *4*, Sl–S39.

Becker, G. S., Murphy, K. M., & Tamura, R. (1990). Human capital, fertility, and economic growth. *Journal of Political Economy*, *98*, S12–S37.

Behrman, J., & Taubman, P. (1985). Intergenerational earnings and mobility in the United States: Some estimates and a test of Becker's intergenerational endowments model. *The Review of Economics and Statistics*, *67*, 144–151.

Bound, J., Jaeger, D. A., & Baker, R. M. (1995). Problems with instrumental variables estimation when the correlation between the instruments and the endogenous explanatory variable is weak. *Journal of the American Statistical Association*, *90*, 443–450.

Coleman, J. S. (1988). Social capital in the creation of human capital. *American Journal of Sociology*, *94*, S95–S120.

Dunn, L. M. (1959). *Peabody picture vocabulary test*. Circle Pines, MN: American Guidance Service.

Garber, S. G., & Klepper, S. I. (1980). Extending the classical normal errors-in variables model. *Econometrica*, *48*, 1541–1546.

Hausman, J. A. (1979). Individual discount rates and the purchase and utilization of energy using durables. *Bell Journal of Economics*, *10*, 33–54.

Hill, M. A., & O'Neill, J. (1994). Family endowments and the achievement of young children with special reference to the underclass. *Journal of Human Resources*, *29*, 1064–1100.

Levy, F., & Murnane, R. J. (1992). US earnings levels and earnings inequality: A review of recent trends and proposed explanations. *Journal of Economic Literature*, *30*, 1332–1381.

Milar, C., Schroeder, S., Mushak, P., Dolcourt, J., & Grant, L. (1980). Contributions of the caregiving environment to increased lead burden of children. *American Journal of Mental Deficiency*, *84*, 339–344.

Murray, C. (1984). *Losing ground: American social policy 1950–1980*. New York: Basic Books.

Needleman, H. L., Schell, A., Bellinger, D., Leviton, A., & Allred, E. (1990). The long-term effects of exposure to low doses of lead in childhood. *New England Journal of Medicine*, *322*, 83–88.

Needleman, H. L., Gunnoe, C., Leviton, A., Reed, R., Peresie, H., Maher, C., & Barrett, P. (1979). Deficits in psychologic and classroom performance of children with elevated dentine lead levels. *New England Journal of Medicine*, *300*, 689–695.

Nelson, C. R., & Startz, R. (1990). The distribution of the instrumental variables estimator and the *T*-ratios when the instrument is a poor one. *Journal of Business*, *63*, S125–S140.

Parks, R. W. (1969). "Systems of demand equations": An empirical comparison of alternative functional forms. *Econometrica*, *37*, 639–650.

Parsons, D., & Goldin, C. (1989). Parental altruism and self-interest: Child labor among late nineteenth century American families. *Economic Inquiry*, *27*, 637–659.

Scarr, S., & Weinberg, R. (1983). The Minnesota adoption studies: Genetic differences and malleability. *Child Development*, *54*, 260–267.

Schwartz, L., & Levin, R. (1992). Lead: Example of the job ahead. *EPA Journal*, *8*, 42–54.

Smith, A. (1937). In E. Cannon (Ed.), *The wealth of nations*. New York: The Modern Library ([1776]).

Smith, M. A., Grant, L. D., Sors, A. I. (Eds.) (1989), *Lead exposure and child development: An international assessment*. Amsterdam: Elsevier.

US Bureau of the census, 1980 (1982). *Census of population*. Washington, DC: US Government Printing Office.

Viscusi, W. K., & Moore, M. J. (1989). Rates of time preference and valuations of the duration of life. *Journal of Public Economics*, *38*, 297–317.

Wahl, J. B. (1986). New results on the decline in household fertility in the United States from 1750 to 1900. *Studies in Income and Wealth Series, 51*, 391–425. Chicago, IL: University of Chicago Press.

Wechsler, D. (1974). *The Wechsler intelligence scale for children revised*. San Antonio, TX: Psychological Corporation.

Werner, E., Honzik, M., & Smith, R. (1968). Predictions of intelligence and achievement at ten years from twenty months pediatric and psychological examinations. *Child Development*, *39*, 1063–1075.

Wilhelm, M. O. (1996). Bequest behaviors and the effect of Heirs' earnings: Testing the altruistic model of bequests. *The American Economic Review*, *86*, 874–892.