Parents' Discount Rates for Child Quality*

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I. Introduction

Contemporary discussions of economic growth make human capital or knowledge accumulation its primary engine [25]. Human capital as the lead component of the stock of wealth defines a developed economy. Becker and Murphy [4] show that human capital both increases and is increased by the scope of the market. Its rate of return rises with the size of its stock [5]. Human capital also plays significant roles in models of human fertility choice [40], population and environmental degradation [11; 34], capital mobility [3], and endogenous technological progress [33].

A substantial portion of an adult's human capital is accumulated during childhood. Children as children, however, cannot independently contract for the resources required to support investments in this human capital. Though nearly every society grants parents wide discretion about the nurture they provide their children, little is understood about what motivates investment by one generation in another, the relative importance of different investment modes, or the discount rates which parents apply. Whatever the motivation and the mode, because of the long time span between birth and adulthood, parents' discount rates potentially exert great leverage upon the investment decisions they make for their children. Knowledge of these discount rates is a prerequisite to acquiring an improved understanding of the internal decision processes of the household, a collective decision unit which economics mostly treats as a black box.¹

Important policy questions, as well as scientific accuracy and logical consistency, demand knowledge of the discount rates parents apply to investments in their children. Healthier, better educated, and wealthier children have a better chance in life. But there is no evident reason to suppose that intrafamily discount rates are socially optimal.² Many of the private reactions and behaviors which reinforce or temper the intended effects of public policies are internal to the household. When these intended effects have a substantial temporal dimension, parental discount rates will be influential. For example, increased public investments in children can be neutralized

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1. Methodological individualism will generally require that the family or household be viewed as a governance structure or institution rather than as a preference ordering.

2. Agee and Crocker [1] show that parents undervalue child health risk information, for example.

by compensatory reductions in children's shares of household budgets. A public investment in children which yields relatively quick payoffs may substitute in the budget for parental investments with longer term payoffs for children. Similarly, publicly provided social security for parents may replace parental investment in children as a source of retirement funds [9]. In addition, for given prices of caregiving alternatives, the extent to which expanded female labor supply opportunities outside the household will increase child care time and effort will vary inversely with the discount rate the family applies to child investments. If these investments enhance the child's adult production and consumption levels, expanded female current employment opportunities combined with sufficiently low familial discount rates could expand future societal wealth and welfare. Lastly, those who question certain environmental and depletable resource policies on the ground that the current adult generation might give insufficient weight to posterity's interests must account for the relative strengths of the intergenerational emotional and material dependencies which different parental discount rates register.³

In this paper, we use parents' decisions to treat their children's body burdens of lead to infer the discount rates parents attach to investments in their children's intellectual and behavioral development. Lead is a persistent micropollutant widely acknowledged in the biomedical literature to have long-lasting neurological consequences when allowed to accumulate in the bodies of young children [44].⁴ The following two sections develop a simple altruistic model of the impact of the endogenous risks posed by a child's body lead burden upon parental utility from child health capital. Section IV describes the data and the setting used in section V to produce estimates of the discount rates which sample parents applied to an investment in the learning capacities and thus the prospective adult production and consumption levels of their children. The paper concludes with a discussion of the implications of our empirical findings for family economics.

II. Parental Altruism and Endogenous Risk

Consider the following parsimonious statement of parental altruism and endogenous risk in a one period lifetime setting.⁵ We ignore the continuous linkages among the generations expressed in dynastic utility formulations [6] in order to focus myopically on a parent-child relationship in which parents make a single, once-and-for-all, tied, inter vivos transfer which they believe influences the child's lifetime prospects. Our model incorporates limited forms of parental altruism, including simple caring about the child's health [49], or strategic interests in the child's adult ability and willingness to protect the parents from the hazards of old age [26]. Adults in multiple adult households are assumed to have identified a cooperative equilibrium with respect to the shared household good which the child represents.

3. The maximum principle of optimal control theory implies that parents will act as if they have the extremely long time horizon which environmentalists advocate even though the parents optimize only over their own consumption and that of their immediate progeny.

4. Environmental and human health damages thought to be caused by persistent micropollutants (PMPs) have become a controversial national and international issue. PMPs degrade slowly and thus accumulate in organisms and ecosystems. Examples of PMPs are too numerous to list exhaustively; however, inorganic compounds such as benzene, polychlorinated biphenyls, halons, chlorofluorocarbons, lead, and mercury are often cited. Needleman et al. [32] were the first to demonstrate that low-level body lead burdens in children are associated with measurable IQ and attention span deficits which plausibly slow intellectual development and thus reduce returns to schooling.

5. Our one period formulation enables us to set aside questions of how the timing of the resolution of uncertainty affects asset choice, including the child health capital asset.

Let the parents' utility be a quasi-concave, weakly separable, homothetic function of a vector, $\mathbf{X}$, whose components represent the quantities of non-child health commodities consumed and of parents' perceived risk, R , that their child will develop chronic lead-induced health effects,

$$U = U(\mathbf{X}, R), \quad (1)$$

with $U_{\mathbf{X}} > 0$ and $U_R < 0$. R is a measure on a real interval that could be either the perceived probability or the expected severity of the child's ill-health. The child's siblings are included in $\mathbf{X}$ and their numbers are predetermined. Perceived risk, R , admits that the child's adult intellectual, physical, social and moral endowments are not yet fully revealed to the parents. Risk perceived to be posed by body burdens of lead is endogenous because parents are aware that they can influence it by reducing exposures, $\mathbf{A}$, and by the use of medical treatment, L :

$$R = R(\mathbf{A}, L; \ell, \gamma), \quad (2)$$

where ℓ is the child's body lead burden, and γ is any predetermined family characteristics such as parents' educations which influence risk perception. Reduced exposures to lead can be achieved by using market goods to prevent or correct hazards (mainly interior paint and plumbing) in the home and increased time spent on child supervision [28]. Chelation therapy is the standard medical procedure for treating elevated body burdens of lead [44].⁶ Expenditures on chelation therapy produce nothing of value other than reductions in R .

Given smooth substitutability between parental work and other activities, the full-income budget constraint faced by households can be written as

$$r_{\mathbf{X}}\mathbf{X} + r_{\mathbf{A}}\mathbf{A} + r_L L = Y, \quad (3)$$

with $r_j = (p_j + wt_j)$, $Y = I + w(T - t_s)$, and $j \in \mathbf{X}, \mathbf{A}, L$. p_j is the parametric money price of commodity j , w is the parametric opportunity cost of parental time, t_j is the time required to consume one unit of commodity j , and t_s is time spent away from the workplace. Full income, Y , is the sum of nonlabor income, I , and labor income, $w(T - t_s)$. Equation (3) requires that total time available be allocated among all possible uses of time, including child care and chelation activities.⁷ Full income must equal total expenditures. Parents allocate their time between work and consumption activities; their income is allocated between child health-related expenditures and expenditures on other goods.

Under local nonsatiation, we define the parents' indirect utility function, V , as the solution to the above utility maximization problem with wage-price vector $\mathbf{r} = (w, \mathbf{p})$:

$$V \equiv \max \{U[\mathbf{X}, R(\mathbf{A}, L; \ell, \gamma)] \mid r_{\mathbf{X}}\mathbf{X} + r_{\mathbf{A}}\mathbf{A} + r_L L = Y\}. \quad (4)$$

Utility is a function of full income, Y , full prices, $\mathbf{r}$, and a contingent claim which specifies the conditions under which a given child body lead burden will confront the parents; that is,

6. Treatment consists of a series of chemical injections which react to bind metals and accelerate their urinary excretion [39; 41].

7. Hotz and Miller [17] estimate that parents provide about 660 hours caring for a child in its first year. This time input declines at a 12 percent annual rate. They also could not reject the hypothesis that the goods input for child care exhibited a constant time profile in money terms. Johnson and Pencavel [19] find that the time costs of children are greater than the money costs.

$V = V(Y, \ell, \mathbf{r})$. For a given reduction in perceived risk associated with a guaranteed reduction, $\ell - \bar{\ell}$, of child body lead burden, the parents' indirect utility function in (4) can be defined in annualized terms as

$$V(Y - \delta CS, \ell - \bar{\ell}, \mathbf{r}) = V(Y, \ell, \mathbf{r}), \quad (5)$$

where CS is the Hicksian compensating surplus. The parents' rate of time preference, ρ , generates a discount term, δ , equal to $\rho/(1 + \rho)$. CS is the maximum wealth the parents are willing to forego to reduce perceived risks from their child's lead burden while maintaining their original utility level, V . Given that parents perceive the effects of the lead burden to be lifelong for their child and thus (roughly) infinite in length for the parents, the compounded sum of instantaneous parental compensating surpluses is

$$\sum_{\tau=0}^{\infty} CS(1 + \rho)^{\tau} \quad (6)$$

and the present value of this sum is

$$CS/[(1 + \rho)(1 - (1 + \rho)^{-\tau})].^8 \quad (7)$$

Since (5) constitutes an exact index of lifetime utility and since the parents' horizon is infinite, expression (7) simplifies to $CS/(1 + \rho)$, and annualized compensating surplus can be written as

$$\delta CS = [\rho/(1 + \rho)]CS. \quad (8)$$

A small reduction in the child's body lead burden can thus be valued in terms of the parents' annualized marginal willingness-to-pay ($MWTP_{\ell}$). $MWTP_{\ell}$ is obtained by totally differentiating the indirect utility function in (5) with respect to ℓ and setting the result equal to zero:

$$\delta MWTP_{\ell} \equiv \delta(-dCS/d\ell) = -(\partial V/\partial \ell)/(\partial V/\partial Y) \equiv -V_{\ell}/V_Y. \quad (9)$$

Expression (9) portrays parents' marginal rate of substitution, $-V_{\ell}/V_Y$, between their child's body lead burden and their wealth. This is the annualized implicit price of risk, $\delta(-dCS/d\ell)$, parents perceive to be associated with their child's body lead burden. Derivation of the parents' discount term, δ , implied through their valuation of reduced lead burden in their child requires that (9) be specified in terms of observable variables. To do this, we derive an alternative but equivalent expression for $MWTP_{\ell}$ in (9), assume a tractable and oft-used functional form for the indirect utility function in (4), and allow the discount term, δ , to vary according to differences in predetermined parental attributes and individual effects.

8. Blackorby, Donaldson, and Moloney [8] refer to equation (7) as the present value of the sum of instantaneous compensating surpluses, an exact index of instantaneous welfare change at any time τ . They show that there do not exist intertemporal preferences for which this sum of instantaneous surpluses is an exact measure of welfare change unless individuals are concerned only with consumption in a single period.

III. Arriving at Observables

As in Ehrlich and Becker [12, 640] and Shogren and Crocker [42], the preceding derivation of $MWTP_\ell$ implies that perceptions of child health risks are influenced by the same parameters which shape consumption and investment plans. $MWTP_\ell$ can be defined in terms of observables by defining the pseudo-expenditure function as the minimum value of nonlabor income necessary to sustain utility at U^0 with wage-price vector $\mathbf{r} = (w, \mathbf{p})$:

$$S^* \equiv \min \{r_X \mathbf{X} + r_A \mathbf{A} + r_L L + \mu(U[\mathbf{X}, R(\mathbf{A}, L; \ell, \gamma)] - U^0)\}. \quad (10)$$

The pseudo-expenditure function is used in place of the traditional expenditure function when consumers are also labor suppliers. Key properties of the pseudo-expenditure function are identical to those of the expenditure function [20, 390].

First order necessary conditions from the expenditure minimization problem are

$$\mathbf{X} : \mathbf{r}_X + \mu U_X = 0 \quad (11)$$

$$\mathbf{A} : \mathbf{r}_A + \mu U_R R_A = 0 \quad (12)$$

$$L : r_L + \mu U_R R_L = 0, \quad (13)$$

plus the utility constraint, $U(\cdot) - U^0 = 0$, where μ is the Lagrangian multiplier denoting the shadow price of utility. Expressions (11) through (13) require the value of each commodity or state in marginal utility terms to equal its respective full price.

Upon applying the Envelope Theorem to expression (10) and substituting from (13), parents' $MWTP_\ell$ can be stated as

$$MWTP_\ell \equiv \partial S^* / \partial \ell = \mu U_R R_\ell = -r_L R_\ell / R_L. \quad (14)$$

As in Berger et al. [7], $MWTP_\ell$ can be expressed as the marginal rate of substitution between the child's body lead burden and medical treatment (chelation therapy).⁹ With quasi-concavity of the utility function in (1),

$$\begin{aligned} \partial L / \partial \ell &\equiv L_\ell = [\mathbf{b}_{31}(\mu U_{XR} R_\ell) + \mathbf{b}_{32}(\mu U_{RR} R_A R_\ell) + \mathbf{b}_{33}(\mu U_{RR} R_L R_\ell) + \mathbf{b}_{34}(U_R R_\ell)] / \det \mathbf{B} \\ &= -R_\ell / R_L, \end{aligned} \quad (15)$$

by the Implicit Function Theorem, where $\mathbf{b}_{ik}$ is the cofactor of the i - k element of the bordered hessian, $\mathbf{B}$, and $\det \mathbf{B}$ is the determinant of $\mathbf{B}$. When (15) is multiplied by the full price of chelation therapy, $MWTP_\ell$ of expression (14) is obtained. Substituting this latter result into (9) yields

$$\delta r_L L_\ell = -V_\ell / V_Y, \quad (16)$$

which contains an unspecified form of the indirect utility function in (4).

9. The medical manipulation of lead via chelation therapy rather than exposure reductions via goods purchases and increased parental time expenditures is used to estimate $MWTP_\ell$ because the latter activities can have joint products such as improved housing appearance and more parental leisure. Parental time and budget allocations to chelation therapy are very unlikely to be a direct source of parental utility nor to serve the dual purposes of increased parental leisure or income and reduced child body lead burden.

Any continuous, nonincreasing, quasi-concave function of prices specifies an indirect utility function for some direct utility function. We wish to use a functional form for indirect utility which embodies the restrictions of classical demand theory but which does not unduly prejudice the set of admissible demand expressions. Yoshihara [53] and Parks [36] show that the indirect addilog utility function is homogeneous of degree zero in prices and income and satisfies the adding-up criterion and the Slutsky symmetry condition. This function imposes severe restrictions on cross-price terms but is widely regarded as adequate when dealing with cross-sectional household budget data involving highly aggregated commodities such as $\mathbf{X}$ and $\mathbf{A}$. Substitution and complementarity effects are likely to be small among broad commodity categories [38].¹⁰

The indirect addilog utility function can be expressed as

$$V(Y, \ell, \mathbf{r}) = \alpha(Y/\ell)^\beta + \sum_{j=1}^n \alpha_j(Y/r_j)^{\beta_j} \quad (17)$$

which implies that the demand for each commodity can be written as a function of the normalized price of that good and a single index function which appears in every demand function. Parks [36] describes the α_j as preference indicators and the β_j as reaction coefficients.

Differentiating (17) with respect to Y and ℓ and substituting the results into (16) yields

$$\delta r_L L_\ell = (\alpha \beta \ell^{-\beta-1} Y^\beta) / (\alpha \beta Y^{\beta-1} \ell^{-\beta} + \sum_{j=1}^n \alpha_j \beta_j Y^{\beta_j-1} r_j^{-\beta_j}), \quad (18)$$

which is highly awkward to estimate with linear techniques. However, the ratio of $-V_\ell/V_Y$ and the Marshallian demand function for chelation therapy, L^m yields a more convenient form. Applying Roy's Identity, setting $K = \alpha\beta/\alpha_L\beta_L$, and rearranging terms, we have

$$L_\ell/(\ell/L^m) = (K/\delta)(Y^{\beta-\beta_L} \ell^{-\beta} r_L^{\beta_L}). \quad (19)$$

IV. Empirical Model

There are two important problems which must be addressed in order to implement expression (19) empirically. First, the intertemporal market for child health may be incomplete in varying degrees among families.¹¹ Risk aversion may also differ. Families may therefore differ in their opportunities and their desires to reallocate resources from the parents' present to their child's future. Expression (19) presumes that all parents possess the same rate of time preference. We relax this presumption by allowing parents' inverse discount term, $1/\delta$, to vary multiplicatively according to a vector, $\mathbf{Z}$, consisting of predetermined levels of parental educational attainments, household income and composition, gender of the subject child, and unobserved family effects, ϵ . Time preference rates play a major role in determining household attributes such as parental educational attainments. However, the levels of these attributes that we observe here are determined prior to rather than coincidental with the demand for chelation therapy. We thus write

10. Houthakker [18, 246] remarks that "The interrelations between such aggregates probably follow largely from their competition for the consumer's dollar rather than from any more specific substitution or complementarity connection. . ."

11. Because our sample households possessed insurance, they were unlikely to be liquidity constrained. The sample is therefore unlikely to be susceptible to unobserved heterogeneity in credit markets for medical care.

$$1/\delta = \prod_h Z_h^{1/\delta_h} e^\epsilon, \quad (20)$$

where e is the base of the natural logarithms. Substituting (20) into (19), taking the natural logarithm of each side, and rearranging terms yields

$$\begin{aligned} \ln[L_\ell(\ell/L^m)] &= \ln(K) + \sum_h (1/\delta_h) \ln(Z_h) + \beta[\ln(Y) - \ln(\ell)] \\ &\quad + \beta_L[\ln(r_L) - \ln(Y)] + \epsilon. \end{aligned} \quad (21)$$

The second problem is that the quantity $L_\ell(\ell/L^m)$ contains unobservable utility levels through the endogenous variable L_ℓ , the marginal effect of the child's body lead burden upon the parents' compensated demand for chelation therapy. In order to give empirical content to (21), we will employ a method originally developed by Small and Rosen [43] from which we derive a first stage estimate of L_ℓ/L^m from parents' conditional Marshallian demand for chelation therapy. To do this, we view parents' decision to seek chelation therapy as a discrete choice based upon information made available to parents (via lead screening) about the relation between their child's observed body lead burden and the likelihood of future cognitive or adaptive behavior disorders [1].

In accordance with the utility maximization problem in (4), let $\tilde{v}_L$ define parents' maximum attainable utility if chelation therapy is chosen, and $\tilde{v}_0$ define parents' maximum attainable utility if chelation therapy is not chosen. For households characterized by γ and ℓ , the choice of whether to chelate is made by comparing utility level $\tilde{v}_L$ with $\tilde{v}_0$, given income, Y , and wage-price vector, $\mathbf{r} = (w, \mathbf{p})$:

$$\begin{aligned} L &= 1 \quad \text{if } \tilde{v}_L(\mathbf{r}_X, \mathbf{r}_A, r_L, \ell, \gamma, Y) - \tilde{v}_0(\mathbf{r}_X, \mathbf{r}_A, \ell, \gamma, Y) > 0 \\ &= 0 \quad \text{otherwise.} \end{aligned} \quad (22)$$

Following Small and Rosen [43], let household j 's conditional indirect utility function for chelation therapy be expressed as a sum of two components:

$$\tilde{v}_{jL} = v_{jL}(\mathbf{r}_X, \mathbf{r}_A, r_L, \ell, \gamma, Y) + \epsilon_{jL}, \quad (23)$$

where $v_{jL}(\cdot)$ is a "universal" utility function whose form is identical for all consumers, and ϵ_{jL} measures the effects of unobservable family-specific influences which are independent of v_{jL} . The vector γ contains observable attributes of the chelation therapy choice in addition to characteristics of the household. Household j will choose chelation therapy following screening if $\tilde{v}_{jL} > \tilde{v}_{j0}$. The probability that household j will choose chelation therapy, conditional on prices, income and observable household characteristics is

$$\pi_{jL} = \Pr\{\epsilon_{j0} - \epsilon_{jL} < v_{jL} - v_{j0}\}. \quad (24)$$

Assuming that $\epsilon_0 - \epsilon_L$ is a standard normal variate, consistent estimates of π_L in (24) can be obtained by means of a binary probit model. For cases in which the conditional indirect utility function in (23) is specified as linear in its explanatory variables, the choice probability analogue of the continuous quantity L_ℓ/L^m in (21) is approximated by the expression

$$L_\ell/L^m = \phi(v)[\theta_\ell - \theta_{r_L}\Phi(v)]/\Phi(v), \quad (25)$$

where Φ and ϕ are respectively the cumulative distribution and probability density functions of the standard normal distribution, $v = v_{jL} - v_{j0}$, and θ_ℓ and θ_{r_L} are the coefficients for child body lead burden and the full price of chelation therapy from the econometric estimation of $v(r_X, r_A, r_L, \ell, \gamma, Y)$.¹²

In summary, the empirical model consists of two equations: (i) the chelation choice function in (24) describing parents' probability of choosing chelation therapy, and (ii) the annualized implicit price of risk expression in (21) specifying parents' substitution rate between full income and their child's body lead burden. The estimation strategy proceeds by estimating (24) via binary probit, and applying the fitted values for L_ℓ/L^m in the least squares estimation of equation (21).

V. Data and Empirical Implementation

Data were obtained from a sample of 256 children from separate households in two Boston, Massachusetts area communities in 1978 and 1985. The 256 households, all of whom had an own child who attended the first and second grades between 1975 and 1978, were taken from the population of 3,329 first and second grade attendees. In both surveys, parents and clinical tests provided detailed information on the child's medical history and current health state, and the parents' time allocations, employment, and a variety of personal characteristics. The lead content of shed teeth was used to measure each child's body lead burden.

In the 1978 survey, parents of subject children with confirmed high and low levels of body lead burden were invited to participate in the further neuropsychologic evaluation of their child [32; 2]. Excluded, usually by telephone interview, were children from homes in which English was not the first language, or whose parents either did not wish or were not able to participate. Also excluded after a medical history was obtained, were children whose birth weight was below 2500 grams, who were not discharged at the same time as their mother after birth, or who had a history of noteworthy head injury. While the parents of remaining children filled out a comprehensive medical and social history, the child received a comprehensive battery of neuropsychologic tests. After each examination was completed, a child psychiatrist, Herbert Needleman, M.D., informed the parents of their child's lead status and the consequences of this status. The parents were then counseled at no cost about a medically appropriate course of action.¹³ In 1985, the original data set was supplemented by information about 1985 parental wage levels and chelation therapy, if any, which the child had undergone in the interim. Table I presents variable definitions, means, and standard deviations.¹⁴

12. Given that the utility function in (1) is both continuous and strictly increasing in the consumption good, $\mathbf{X}$, and nondecreasing in the child-protection goods $\mathbf{A}$ and L , the following Slutsky-like equation [43, 117] links parents' continuous compensated demand function for chelation therapy to the discrete choice case:

$$L_\ell = \tilde{L}^m(\partial\pi_L/\partial\ell) + \pi_L(\partial\tilde{L}^m/\partial\ell) + L^m(\partial\tilde{L}^m/\partial Y + \partial\pi_L/\partial Y),$$

where $\tilde{L}^m = -(\partial\tilde{v}_L/\partial r_L)/(\partial\tilde{v}_L/\partial Y)$ is the conditional Marshallian demand function for chelation therapy, and $L^m = \pi_L\tilde{L}^m$.

13. Information provided to parents about the consequences of their child's body lead burden is information about a point on the dose-response function corresponding to their child's body lead level and not the entire dose-response curve.

14. The sample selection factors used by Needleman et al. [32] to assess the effects of low-level lead exposure on children's cognitive functioning bring to question the comparability of socioeconomic characteristics and behaviors

Table I. Acronyms, Definitions, Sample Means and Standard Deviations

Acronym	Definition	Mean	Standard Deviation
Endogenous Variables			
<i>CHELATED</i>	Child was chelated: 1 = yes; 0 = no.	0.063	0.243
Child Variables			
<i>PICA</i>	Parents reported pica behavior in the subject child: 1 = yes; 0 = no.	0.137	0.344
<i>PBLEVEL</i>	Dentine lead content in arithmetic mean ppm over 3 shed teeth.	15.055	11.993
<i>SEX</i>	Gender of the subject child: 1 = male; 0 = female.	0.504	0.501
Parent Variables			
<i>DADEDUC</i>	Father's education in grades completed as of 1978.	11.918	2.574
<i>DADPRSNT</i>	Father lives with the mother and child: 1 = yes; 0 = no.	0.715	0.478
<i>MOMAGE</i>	Mother's age in years in 1978.	30.241	4.762
<i>FPCHEL</i>	Expected full price to parents of chelation therapy, net of insurance, in 1980 dollars.	47.013	9.579
<i>MOMEDUC</i>	Mother's education in grades completed as of 1978.	11.605	2.169
<i>NUMCHILD</i>	Number of children in the family.	2.961	1.134
<i>INCOME</i>	Parents' annual wage income in 1980 dollars: 1 = $INCOME < 7,000$ 2 = $7,000 \leq INCOME < 8,500$... 14 = $INCOME > 25,000$.	8.73	2.3

n = 256

Following Agee and Crocker [1], the functional form for the chelation choice function is linear in its explanatory variables. The implicit price of risk expression is log-linear in its explanatory variables.

Several variables present in the theoretical specification of (24) are excluded in its estimation. Since respondents came from the same locale and presumably confront similar prices for similar market goods, prices comprising the composite good, **X**, and avoidance goods, **A**, are assumed to

among sample parents with corresponding distributions for other groups. Compared to U.S. adults over age 25 [46], sample parents have a higher mean number of years of schooling completed; 81 percent of sample parents have completed high school and 16 percent have graduated from college compared to 1980 U.S. percentages of respectively 66.3 and 16.3 (72.7 and 20.0 in Massachusetts). Sample households' median income of \$17,000 (mean = \$17,100) is slightly higher than the 1979 U.S. median household income of \$16,841. In 1979, approximately 45 percent of U.S. households reported incomes of less than this median (42 percent in Massachusetts). Table IV shows that 42 percent of sample parents reported incomes of less than the sample mean.

Another relevant comparison exists regarding the proportion of sample parents who chose chelation therapy for their child. The U.S. Environmental Protection Agency estimated that between 1976 and 1980 approximately 4 percent of U.S. children aged 0.5 to 7 had lead levels above the cutoff point said to warrant medical intervention [48, IV-4]. Children living in metropolitan areas of 1 million or more had a 45 percent higher incidence than those in the general population [47, 1]. This U.S. metropolitan incidence is close to the 6.2 percent of children chelated in our Boston area sample.

be identical across households. The time required to consume one unit of $\mathbf{X}$ or $\mathbf{A}$ is assumed to be identical across households as well. Thus, $\mathbf{r}_X$ and $\mathbf{r}_A$ are excluded because they vary only with the opportunity cost of parental time, a variable included in the full price of chelation therapy.

All current health benefit assessments of reducing child lead exposure include, as a component of total expenditures, time costs to parents associated with medical treatments or enhanced child supervision [44; 37; 27]. The majority of this cost is accounted for by the primary caregiver's opportunity cost of time. Gronau [13] identified the mother's reservation wage as a major determinant of the time a mother makes available for child care activity. He found that full-time homemakers valued their time by 13 to 22 percent more than their offer wages. But a relatively high reservation wage need not imply that the quality of child care increases [31]. Working mothers may choose to substitute increased attentiveness in care for time in care, while nonworking mothers may do the opposite.

Most of the primary care-givers in our sample were full-time homemakers. Because accurate wage measures for full-time homemakers are unavailable, following Mincer [29], we presume that preferences regarding reservation wages of primary care-givers in our sample are explained by the educational attainments of parents, household composition, and the age of the mother. We also presume that these measures adequately reflect the variation in nonlabor income across households, a variable that was not measured in the survey.

The full, uninsured price of chelation therapy was calculated according to the recommendations of Piomelli [37]. In general, the required intensity of chelation therapy, defined as numbers of treatments, and child body lead burden move concurrently. Of those children receiving one treatment, 50 percent would require a second treatment, and 25 percent would require a third treatment. Each treatment involves five days in the hospital, several physician visits, laboratory work, and a neuropsychological evaluation for a total 1980 cost of \$1945, including transportation.¹⁵ In addition, each treatment requires a minimum of 8 hours of parental time expenditure for visitation and accompaniment while the child is hospitalized, subsequent physician's visits, and neuropsychological evaluations. Though each household in our sample was insured, we lack data on differences, if any, in copayment terms among sample households. We have therefore calculated *FPCHL*, the full insured price, in terms of these time expenditures multiplied by the 1985 hourly wages of employed mothers in the sample.¹⁶ Thus we presume that the money equivalent of these time expenditures is highly correlated with the payments for which sample households would be held responsible net of insurance payments for chelation, and that these expenditures are uncorrelated with the stochastic disturbance in the chelation choice expression.¹⁷

PICA is a dummy variable in the chelation choice function that accounts for parental reports of the child's inappropriate mouthing behavior. Pica is important in a variety of accidental poisonings in young children, especially lead poisoning [45]. In our sample, pica was reported

15. Chelation therapy is not taken beyond three treatments because of the potential for adverse health effects, including removal of necessary minerals, kidney damage, and pain [10]. Since only a small percentage of children classified by Needleman et al. [32] as low lead burden ever received one treatment, and an even smaller proportion of these children required further treatments, we assumed that children with low body lead burdens faced a minimum full, uninsured price of \$1945. Children classified as moderate to high body lead burden were assumed to face an expected full, uninsured price of \$3403.75 for 1.75 treatments.

16. In 1985, the employed mothers in our sample had an average hourly wage of \$3.74 with a standard deviation of \$3.03. The 14 hours of parental time expenditure required for the 1.75 treatments of chelated children with moderate and high body lead burdens cost \$52.36. Parental time expenditures for children with low body lead burdens are assumed not to exceed 8 hours for a total cost of \$29.92.

17. See Yatchew and Griliches [52] and Hausman, Newey, and Powell [16] for the properties of instrumental variables in nonlinear regression.

Table II. Probit Estimates of the Chelation Choice Function Dependent Variable: *CHELATED*

Explanatory Variable	Coefficient	Asymptotic <i>t</i> -Statistic
<i>PICA</i>	0.5758	1.507
<i>PBLEVEL</i>	0.0785	4.107
<i>DADEDUC</i>	0.0799	1.026
<i>MOMEDUC</i>	-0.3566	-3.754
<i>DADPRSNT</i>	-1.3328	-2.579
<i>MOMAGE</i>	0.0028	0.137
<i>FPCHEL</i>	-0.0107	-2.40
<i>INCOME</i>	1.2657	2.311

n = 256

Log-Likelihood at zero = -59.851

Log-Likelihood at convergence = -41.869

 $\chi^2(7) = 35.963$ **Table III.** Least Squares Estimates of the Implicit Price Expression Dependent Variable: $\ln(L_\ell/L^m) + \ln(\ell)$

Explanatory Variable	Coefficient	Asymptotic <i>t</i> -Statistic
<i>CONSTANT</i>	-3.0858	-8.766
$\ln(\text{INCOME})$	0.0796	6.369
$\ln(\text{DADEDUC})$	-0.2055	-3.794
$\ln(\text{MOMEDUC})$	1.4027	15.803
<i>DADPRSNT</i>	0.2839	7.316
$\ln(\text{MOMAGE})$	-0.0096	-0.140
$\ln(\text{NUMCHILD})$	-0.039	-1.873
<i>SEX</i>	-0.0093	-0.395
$\ln(\text{INCOME}) - \ln(\text{PBLEVEL})$	-0.6587	-28.984
$\ln(\text{FPCHEL}) - \ln(\text{INCOME})$	0.0007	0.090

n = 256Adjusted $R^2 = .90$ $\chi^2(9) = 601.92$

by 11 percent of parents of children that Needleman et al. [32] classified as low lead, 13.6 percent of moderate lead children, and 13.8 percent of high lead children. Although pica was found to be significantly related to body lead burden in the sample ($r = .16, p < .01$), it was not found to be significantly related to the outcome measures of assessed intelligence in the subject children.

Estimated coefficients for the chelation choice function and implicit price expression are reported in Tables II and III. A likelihood ratio statistic was used to test richer specifications of the chelation choice function involving interactions between child body lead burden and parental income and educational attainments. Test statistics failed to reject the null hypothesis of no interactions present at the 5 percent significance level. However, even though the chelation choice function in Table II is linear, the nonlinear form of (25) and the 256 distinct household markets for chelation therapy provide sufficient exogenous marginal price variation to identify the system in Tables II and III [35].

Table II indicates that child body lead burden, full price of chelation therapy, presence of a father, and mother's education are statistically significant determinants of the direct benefits that households perceive from choosing chelation therapy. The coefficients for child lead burden and full price of therapy have the anticipated positive and negative signs. In addition, parents are less likely to choose chelation if the mother and father reside together and as the mother's education

increases. This is consistent with the predictions of human-capital-based models that focus on the relation of efficiency in raising children to maternal schooling as formulated by Leibowitz [24]. Thus an increase in the mother's education or the presence of her spouse might be interpreted as raising her marginal productivity of time as primary care-giver, thereby reducing parental demand to complement exposure reduction with chelation therapy.

Table III reports estimates of the annualized implicit price of risk expression (21).¹⁸ Coefficients on the log implicit price variables *INCOME*, *DADEDUC*, *MOMEDUC*, *DADPRSNT*, *MOMAGE*, *NUMCHILD*, and *SEX* yield fitted values for the discount term $\ln(1/\delta)$ equal to $\ln[(1 + \rho)/\rho]$. Parental income, education, and household composition act as significant determinants of intergenerational time preference. In particular, two parent households with higher income and more maternal education discount that child's adult prospects at lower rates.¹⁹ No gender preference appears. There is some tendency for the discount rate parents apply to a child to increase with the number of the child's siblings.

The mean implicit discount rate for the entire sample is 4.7 percent with a 2.2 percent standard error. By comparison, Viscusi and Moore [50] calculate the long-term financial market interest rate for 1981 (Aaa bond rate) adjusted for 8.8 percent expected inflation (1980 GNP deflator) as 3.2 percent.

Table IV reports mean discount rates with standard errors for specific subsamples. The table shows that there exist wide differences across sample households in the discount rates parents apply to their children's futures. Parents with incomes below the sample mean apply discount rates of about 6.8 percent while those above the mean exhibit 3.2 percent rates. The futures of children in households without a high school diploma are discounted at 6.9 percent while households with both parents having had at least some college discount at 2.6 percent. This 2.6 percent rate approximates the Viscusi and Moore [50] real market rate of 3.2 percent.

VI. Conclusions

Within the context of an explicit model of endogenous risk, we have presented the first empirical evidence that parents discount investments which affect the adult prospects of their children. These rates, which numerous authors show affect the intergenerational transmission of human capital, are strongly influenced by household circumstances. The discount rates which the better-off and well-educated apply approximate the real market rate for financial instruments; the discount rates which the worse-off and ill-educated apply are more than twice the real market rate. Regardless of their incomes and educations, the parents in our sample discounted investments in their children's adult prospects much more lightly than the 20 to 50 percent rates the literature [15; 14] says they are likely to apply to household durables. Altruism, or at least an unwillingness of parents to treat the self differently from the child, must enter. The rates which we estimate parents apply to the futures of their children are well within the 2.0 to 12.0 percent rates that Kashner [21], Viscusi

18. White's [51] general heteroskedasticity test rejected the null hypothesis of homoskedasticity at the 1 percent level of significance when applied to the implicit price estimates. White's [51] heteroskedasticity-consistent covariance matrix was then used for hypothesis tests of the coefficients in Table III.

19. Evidence of strong negative associations between time preference rates in other contexts and measures of labor income and education have been documented elsewhere, e.g., Lawrance [22], and Viscusi and Moore [50]. Several explanations for these associations have been offered, including differential access to capital markets, preference differences, and differences in expectations about future incomes.

Table IV. Implicit Discount Rates by Sample Classification^a

1. By Household Income:

Below Mean ($n = 107$)	Above Mean ($n = 149$)
6.8%	3.2%
(1.9)	(0.5)

2. By Education:

Both Parents w/o H.S. Diploma ($n = 49$)

6.9%

(2.7)

At Least One Parent w/ H.S. Diploma or More ($n = 207$)

4.2%

(1.7)

At Least One Parent w/ Some College or More ($n = 78$)

3.7%

(1.5)

Both Parents w/ Some College or More ($n = 21$)

2.6%

(0.7)

3. By Number of Children:

One or Two Children ($n = 97$)

4.3%

(1.9)

Four or More Children ($n = 41$)

5.0%

(2.5)

4. By Child Body Lead Burden:

Low ($n = 61$)	Moderate ($n = 136$)	High ($n = 59$)
4.3%	4.7%	4.9%
(2.2)	(2.4)	(1.9)

Overall Mean = 4.7% (2.2%)

a. Standard errors in parentheses.

and Moore [50], and Moore and Viscusi [30] estimate adults apply to their own health, and that Lang and Ruud [23] estimate they applied to their schooling.

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