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    AN ECONOMIC ANALYSIS OF CHILDREN'S HEALTH
        AND INTELLECTTUAL DEVELOPMENT
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## AN ECONOMIC ANALYSIS OF CHILDREN'S HEALTH AND INTELLECTUAL DEVELOPMENT

Linda Nasif Edwards and Michael Grossman*

The role of health and intellectual development in the determination of economic and social well-being is a subject of increasing concern for both social science and public policy. Numerous studies have demonstrated that adults' earnings and life expectancy depend on their schooling, health, and ability. ${ }^{1}$ Others suggest important causal relationships running from health and intelligence at early stages in the life cycle to years of formal schooling completed and from schooling to adults' health. A common theme in these studies as well as in the massive literature on the effects of home environmental variables on children's cognitive development is that well-being at later stages in the life cycle depends on well-being at early stages.

The basic purpose of our research is to contribute to an understanding of the joint determination of children's cognitive development and their health. Although there is a large literature concerning the first

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[^0]of these issues, there has been little work on the latter. ${ }^{2}$ we also explore interrelationships between various aspects of children's physical health and their intellectual development and, in particular, attempt to answer the important question of whetiner poor health retards the cognitive development of children. ${ }^{3}$

More specifically, this paper, which is part of a larger project, examines the determinants of cognitive development and health of children from six to eleven years of age in Cycle II of the U.S. Health Examination Survey, We focus on the roles of home environmental variables and proxies for the endowed (initial or inherited) level of health in the current nealth and development functions with a view toward uncovering similarities in or differences between health and development effects. The empirical work is guided by an insight provided by a theoretical model of intergenerational transfers of human and non-human wealth: namely, to understand the behavior of parents with respect to their children's health and development, it is important to distinguish
${ }^{2}$ Starfield (1975) emphasizes that, although many persons have studied the effects of medical care and socioeconomic characteristics on infant mortality, relatively few have examined the effects of these variables on the nealth of children who survive the first year of life. For a few recent exceptions, see, for example, Kaplan, Lave, and Leinhardt (1972); Hu (1973): Kessner (1974); Haggerty, Roghmann, and Pless (1975); and Inman (1976).

Birch and Gussow (1970), whose entire book focuses on the effects of health on learning, point out that most of the evidence they bring to bear on the issue is indirect because "... there has been little investigation of the specific relationships between the physical status of poor children and their later development ( $D .10$ )." For one attempt to investigate these relationships in a sample of very young children, see Broman, Nichols, and Kennedy (1975).
low income families from high income families. Clearly, this is a policy relevant insight, for public policy often is aimed at low income groups. Our results indicate that it would be incorrect to formulate policies directed at improving the welfare of children in low income families on the basis of empirical results derived from examining the population at large.

## I. The Model

In this section we outline an economic model of children's health and intellectual development. The model serves as a vehicle for organizing and interpreting empirical research with a data set as complex as the Health Examination Survey. While our model draws jeavily on analyses of intergenerational transfers by Becker (1967, 1974); Eriedman and Leibowitz (1975); Ishikawa (1975); Becker and Tomes (1976); and Tomes (1977), one of its novel aspects is that it suggests appropriate ways to estimate the effects of parents' income and other variables on children's health and development.
A. General Analytical Framework

To start the analysis, assume that parents make decisions over two periocis $(0,1)$ or stages in their life cycle. In period 0 their children are completely dependent upon them for financial support, while in period 1 the childzen become financially independent. ${ }^{1}$ The oarents' utility function can be specified as

$$
\begin{equation*}
U=U\left(C_{0}, C_{1}, N, Q\right), \tag{1}
\end{equation*}
$$

where $C_{0}$ and $C_{1}$ represent their consumption in each period, $N$ is their total number of children, and $Q$ is quality per child. This utility
${ }^{1}$ For a model of intergenerational transfers in which the period of dependency is treated as an endogenous variable and associated with years of formal schooling completed by children, see Ishikawa (1975).
function embodies the assumption that within a given family tie quality
of each child is the same.

In a general model, child quality would depend on the child's expected lifetime wealth, health, intellectual development, and perhaps other factors, so that these variables would enter the utility function as separate arguments. To simplify the analysis and to obtain testable propositions, we assume, however, that child quality is determined solely by the child's lifetime wealth or, equivalently, by the present value of earned and nonearned income in the period of independence:

$$
\begin{equation*}
Q=B+W(H, D) \tag{2}
\end{equation*}
$$

In this equation $B$ is a financial transfer or becuest made by parents to the child at the beginning of the period of independence ${ }^{3}$ and $W$ is the present value of earninqs. Earnings are assumed to depend on the stocks of physical health capital $(H)$ and knowledae or cognitive development capital \{D); which are two components of human capital, In farticular, the marginal

2
For a model in which the quality of each child in the family can differ, see Becker and Tomes (1976). They show that quality would tend to be equalized across children in the same family as a result of the first-order equilibrium conditions in their model.

3
A more plausible assumption is that financial transfers are made during the period of independence rather than at its beginning. This, however, does not affect the analysis if the tax treatment of the transfers are unchanged and if individuals face "good" capital markets. See, for example, Blinder (1973).
products of these stocks $\left(W_{H}=Q_{H}\right.$ and $\left.W_{D}=Q_{D}\right)$ are positive. 4
The amount of health and development are given by the following identities (in the aosence of depreciation):

$$
\begin{align*}
& H=H_{0}+I  \tag{3}\\
& D=D_{0}+G \tag{4}
\end{align*}
$$

where $H_{0}$ is the initial or inherited stock of health (genetic endowment of health), I is net investment in health, $D_{0}$ is the initial or inherited stock of development, and $G$ is net investment in development. 5 To complete the rudiments of the model, we specify production functions of investments in health and development as

$$
\begin{align*}
& I=I\left(M, F, H_{0}, D_{0}\right)  \tag{5}\\
& G=G\left(X, F^{\prime}, H_{0}, D_{0}\right) \tag{6}
\end{align*}
$$

4
Throughout this paper, a single capital letter subscript denotes a first-order partial derivative, while a double subscript denotes a secondorder partial derivative. Thus,

$$
W_{H} \equiv \partial W / \partial H, W_{H H} \equiv \partial^{2} W / \partial H^{2}, \quad W_{D H} \equiv \partial^{2} W / \partial D \partial H
$$

etcetera. In Edwards and Grossman (1976), we discuss plausible signs of the second derivatives of the earnings function, but we make no assumption about these signs in this paper. Note that the marginal product of $B$ in equation (2) is constant $\left(Q_{B}=I\right)$ and independent of $H$ and $D\left(Q_{B B}=Q_{B H}=\right.$
$\left.Q_{B D}=0\right)$.
${ }^{5}$ We treat $H_{0}$ and $D_{0}$ as exogenous variables. In a full model they would have endogenous components that would be determined by factors such as prenatal medical care and parental characteristics.

In equations (5) and (6), $M$ is a vector of endogenous inputs in the health production function, $X$ is a vector of endogenous inputs in the development production function, and $F$ and $F^{\prime}$ are vectors of exogenous variables that affect the efficiency of the production process. Examples of elements in the $M$ vector include medical care, nutrition, housing quality, and parents' time; while examples of elements in the $x$ vector include school quality, home learning aids, and parents' time. Examples of elements in $F$ and $F^{\prime}$ are parents' schooling and parents' age. 6 We assume that equations (5) and (6) do not vary among children in a given family and further that all children in a given family have identical endowments ( $H_{0}$ and $D_{0}$ ). These assumptions insure that the optimal amounts of $B, H$, and $D$ as well as $Q$ will be the same for all children in the family. ${ }^{7}$

Note that the initial stocks of health and development ( $H_{0}, D_{0}$ ) are included in the production functions of both $I$ and $G$. While no assumption is made at this time with respect to the directional effects of these initial stocks on $I$ and $G$, this flexible specification allows for a number of possibilities. For example, the effect of medical care inputs on changes in health may be greater when an individual's stock of health is at a lower level (i.e. $\left.\partial I / \partial H_{0}<0\right)$. Or, children with greater inherited intellectual ability may augment that ability more easily (i.e.

6The vectors $F$ and $F^{\prime}$ might or might not be identical.
7
If the production functions and/or initial endowments of children vary, $B, D$, and $H$ would tend to differ among children but $Q$ would not (see Becker and Tomes 1976). In future work we may pursue theoretical and empirical analyses in which endowments vary among children in the same family.
$\left.\partial G / \partial D_{0}>0\right)^{8}$ Further, this specification allows for an interplay between health and development, and in particular, it allows for the possibility that low initial health levels will affect realized intellectual ability. 9 Parents maximize the utility function given by equation (1) subject to the children's quality function [equation (2)], the initial stocks of health and development, the production functions of health and development [equations (5) and (6)], and their wealth constraint. The last constraint has the form

$$
\begin{equation*}
s=c_{0}+c_{1}(1+r)^{-1}+N\left[B(1+r)^{-1}+p M+q X\right] \tag{7}
\end{equation*}
$$

where $r$ is the rate of interest, $p$ is the price of $M$, $q$ is the price of $X$, and the quantity $B(1+r)^{-1}+p M+q X$ is the present value of expenditures per child. ${ }^{10}$
${ }^{8}$ This assumption is made by Becker and Tomes (1976). On the other hand, Eloom's (1964) findings suggest that the initial level of measures such as height, IO, and school achievement does not affect the rate at which a child augments these measures.
${ }^{9}$ Most of the literature on the interaction between child health and development emphasizes the impact of low levels of investments in health at the preschool stage of the child's life cycle on subsequent cognitive development (for example, Birch and Gussow 1970; Broman, Nichols, and Kennedy 1975). To examine the impact of both current and initial health on development or to allow for full simultaneity between health and development, it would be necessary to introduce more than one period of dependency.

10
From now on we treat $M$ and $X$ as scalars rather than vectors.

From the first-order conditions for the maximization of utility with respect to $C_{0}, C_{1}, N, B, M$, and $X, 11$ we obtain

$$
\begin{equation*}
\left(p / Q_{M}\right)=\left(q / Q_{X}\right)=(1+r)^{-1} \tag{8}
\end{equation*}
$$

This is the familiar result (which can be obtained directly by minimizing the cost of producing a given amount of $Q$ ) that the ratio of a price of an input to its marginal product in the $Q$ function must be equal for all inputs. In the case of $B$, the price of $B$ relative to the price of parents, current consumption $\left(C_{0}\right)$ is $(1+r)^{-1}$ because in order to raise $B$, and hence $Q$, by one dollar, $C_{0}$ must fall by $(1+r)^{-1}$ dollars. The marginal product of $B$ is constant at one dollar. The common value of the two equalities in ( 8 ) may be interpreted as the marginal cost of quality, which is completely determined by the interest rate once the optimal

11
The first-order conditions are

$$
\begin{aligned}
& U_{0}=\lambda \\
& U_{1}=\lambda(1+r)^{-1} \\
& U_{N}=\lambda z \\
& U_{Q}=\lambda N(1+r)^{-1} \\
& U_{Q} Q_{M}=\lambda N p \\
& U_{Q} Q_{X}=\lambda N q
\end{aligned}
$$

where $U_{i}$ is the marginal utility of $C_{i}, \lambda$ is the marginal utility of wealth, and $z$ defines the present value of expenditures per child $\left[B(1+r)^{-1}+\right.$ $\mathrm{pM}+\mathrm{qX}^{\mathrm{X}}$.
inputs are chosen. 12 products of $M$ and $X$ fali as $M$ and $X$ increase, respectively, and that children's earnings (W) is produced subject to rising marginal cost. ${ }^{13}$ To summarize this model, children's wealth at the inception of independence has a future earnings component and a bequest component. Parents' investments aimed at increasing chilaren's earning power are subject to decreasing returns, while those that are in the form of a bequest are not. Cost minimization (or utility maximization) dictates that no matter how much wealth (Q) parents wisn to transfer to their children, the amount of earning power or human capital (W) they will provide is the same and is totally determined by the interest rate and the nature of the marginal cost schedule of $W$. Put differently, the least-cost exDansion path of $Q$ is one in which $M$ and $X$ and therefore $H, D$, and $W$ remain constant. If the optimal level of $W$ is greater than their desired $Q$, parents simply leave their children a negative bequest in the form of net debts.

12
An alternative interpretation of equation (8) for the optimal quantities of $M$ and $X$ is that $\left(Q_{M} / P\right)-1$ and $\left(Q_{X} / q\right)-1$ define the marginal rates of return on investments in health and development. In equilibrium these rates of return must equal the rate of return on a financial transfer (r).
${ }^{13}$ The relevant second-order conditions are

| $Q_{M M}$ | $<0$ |
| :--- | :--- |
| $Q_{X X}$ | $<0$ |
| $Q_{M M} Q_{X X}$ | $>Q_{M X}^{2}$. |

These conditions follow because the utility function is "weakly separable" in $B, M$, and $X$ and because the marginal product of $B$ in the $Q$ function is constant $\left(Q_{B B}=Q_{B M}=Q_{B X}=0\right)$.

These ideas are depicted graphically in Figure 1 , which shows the determination of the optimal amounts of $Q, W$, and $B$ for three different families. ${ }^{14}$ The curve labeled MC shows the relationship between $W$ and the marginal cost of $W$ for combinations of $M$ and $X$ that satisfy $\left(p / Q_{M}\right)=\left(q / Q_{X}\right) .^{15}$ The point at which the $M C$ curve intersects the horizontal axis, $W_{0}=W\left(H_{0}, D_{0}\right)$, is that level of lifetime earnings if no investments in health and development are made during the period of dependence. The curves labeled $d_{1}, d_{2}$, and $d_{3}$ depict the relationship between the marginal benefit of $Q\left(\alpha=U_{Q} / \lambda N\right.$, where $\lambda$ is the marginal utility of wealth) and 2 at three different wealth levels ( $S_{3}>S_{2}>S_{1}$ ). These functions may be interpreted as compensated (utility or real income constant) demand functions for quality. The optimal amount of $W$ always is given by $Q_{2}$, where $M C$ equals $(1+r)^{-1}$. The optimal amounts of

14
This diagram and our discussion of the determination of the optimal amounts of $Q, W$, and $B$ are closely related to Fisher's (1930) classic analysis of investment and interest.

15
The precise nature of the marginal cost curve depends upon the behavior of marginal products of inputs in the investment functions and marginal products of stocks in the earnings function. In the diagram we assume diminishing marginal productivity of inputs ( $I_{M M}<0$ and $\left.G_{X X}<0\right)$ and constant marginal productivity of stocks $\left(W_{H H}=W_{D D}=0\right)$. An alternative set of assumptions would be constant marginal productivity of inputs $\left(I_{M M}=G_{X X}=0\right.$ ) and diminishing marginal productivity of stocks $\left(W_{H H}<0\right.$ and $\left.W_{D D}<0\right)$. These alternative assumptions would not alter the sign of the slope of the MC function and therefore would not alter our basic analysis. It also should be noted that for simplicity of exposition the marginal cost curve is drawn as a straight line. In fact, it could take a variety of forms including a curve convex to the origin, a curve concave to the origin, or a straight line.


Figure 1
$Q\left(Q_{1}, Q_{2}\right.$, and $\left.Q_{3}\right)$ are determined by the intersections of the downward sloping demand functions and the supply curve of 0 --the horizontal line whose height equals $(1+r)^{-1}$.

For family 2, the intersection of its demand $\left(d_{2}\right)$ and supply curves is at $Q_{2}$. Since $Q_{2}$ is the optimal $W$ for all families, the financial transfer (B) equals zero for family 2. Family 3 makes a positive financial transfer equal to distance $Q_{2} Q_{3}$, while family 1 makes a negative financial transfer equal to distance $Q_{2} Q_{1}$. Thus, in this model, differences in human capital of chilaren are determined solely by differences in endowments and in marginal costs of producing this capital. Differences among families in their demand for children's quality have no bearing on differences in children's realized human capital.

So far we have assumed that the financial transfer can be positive, zero, or negative. In analyses of intergenerational transfers that are similar țo ours, Becker (1967); Friedman and Leibowitz (1975); Ishikawa (1975); Becker and Tomes (1976); and Tomes (1977) point out that it is reasonable to impose a solvency constraint, a constraint that parents cannot leave debts to their children, or that $B \geq 0$. In terms of Figure 1 , the imposition of a solvency constraint changes the supply curve of $Q$ as follows. The "constrained" supply curve coincides with the MC curve up to the point where $M C=(1+r)^{-1}$ and thereafter is horizontal at $(1+r)^{-1}$ (schedule $\left.W_{0} a b\right)$. The imposition of the solvency constraint does not affect the quantities of $Q$ and $W$ selected by families 2 and 3 , but it does alter the quantities selected by family 1. Family 1 chooses quality $Q_{l}^{\prime}$, where its demand function intersects the MC function. since $Q_{1}^{\prime}$ also gives the quantity of $W$ if $B$ equals zero $\left(Q_{1}^{\prime}=W_{1}^{\prime}\right)$, the parents in family $l$
choose a larger quantity of $Q$ in the constrained case (compare $Q_{1}$ and $Q_{1}^{\prime}$ ) but a smaller quantity of $W$ (compare $W_{1}^{\prime}=Q_{1}^{\prime}$ and $W_{1}=Q_{2}$ ).

We impose the solvency constraint in the rest of our analysis. ${ }^{16}$ As a consequence, households whose demand functions intersect the supply function in its upward sloping segment $\left(W_{O} a\right)$ will demand more $H, D, X$, and $M$ as their income rises. That is, we anticipate a positive effect of parents' income or wealth on child health or development at relatively low wealth levels, where $B$ equals zero, but not at relatively high wealth levels, where $B$ exceeds zero. 17
B. Demand Functions for Health and Development

The above framework suggests a two-regime specification of demand functions for children's earnings (W), children's health capital (H), children's development capital (D), and endogenous inputs in the production of health and development ( $M$ and $X$ ). Since we analyze only health and development empirically in this paper, hereafter we focus on the properties of their demand functions. ${ }^{18}$ parents who do not make financial transfers to their cinildren $(B=0)$ are members of Regime 1 anc have demand functions of the form
${ }^{16}$ Formally, if the constraint is binding, then the equilibrium condition for $B$ is replaced by the inequality $\left(U_{Q} / \lambda N\right)<(1+r)^{-1}$.
${ }^{17}$ For similar conclusions, see Becker (1967); Friedman and Leibowitz (1975); Ishikawa (1975); Becker and Tomes (1976); and Tomes (1977).

18
For an analysis of input demand functions, see Edwards and Grossman (1976).

$$
\begin{align*}
& H=\varnothing_{1}\left(S, p, q, F, F^{\prime}, H_{0}, D_{0}\right)  \tag{9}\\
& D=\Psi_{1}\left(S, p, q, F, F^{\prime}, H_{0}, D_{0}\right) \tag{10}
\end{align*}
$$

Parents who do make positive financial transfers to their children ( $B>0$ ) are members of Regime 2 and have demand functions of the form

$$
\begin{align*}
& H=\varnothing_{2}\left(r, p, q, F, F^{\prime}, H_{0}, D_{0}\right)  \tag{11}\\
& D=\Psi_{2}\left(r, p, q, F, F^{\prime}, H_{0}, D_{0}\right) \tag{12}
\end{align*}
$$

These demand functions are reduced form equations in the sense that the marginal cost of $W$ has been replaced by its determinants ( $\mathrm{P}, \mathrm{G}, \mathrm{F}, \mathrm{F}^{\prime}, \mathrm{H}_{0}$, and $D_{0}$.

We have already pointed out that parents' income or wealth (S) has a positive effect on $H$ or $D$ for members of Regime 1 , but not for members of Regime 2. With respect to the rate of interest (r), it is obvious from Figure 1 that an increase in $r$ raises children's quality (Q), lowers children's earnings ( $W$ ), and lowers $H$ and $D$ for members of Regime 2, but has no effect on these variables for members of Regime 1 .

The six remaining variables enter the demand functions for $H$ and $D$ in both regimes: two input prices ( $p$ and $q$ ), two efficiency measures ( $F$ and $F^{\prime}$ ), and two endowment measures ( $H_{0}$ and $D_{0}$ ). In general, the direction of the effect of any of these variables is the same in each regime, although the magnitude of the effect differs. For example, in the demand curve for $H$, the own innut price ( $p$ ) effect is negative, the own efficiency (F) effect is positive, and the own endowment ( $H_{0}$ ) effect is positive. The signs of the cross input price ( $\sigma$ ), cross efficiency $\left(F^{\prime}\right)$, and cross endowment $\left(D_{0}\right)$ effects are ambiguous. Similar statements can be made with regard to own and cross effects in each regime's demand curve for $D .^{19}$

As an illustration of how differences can arise in the manitude of effects of comon detemminants of $H$ or $D$ in the two regimes, consider the simole model depicted in Figure 2. The demand curve for 2 of a family in Regime 1 is given by $d_{1}$, while the corresponding demand curve of a family in. Regime 2 is given by $d_{2}$. Each family has the same marginal cost curve Woab. An increase in efficiency or a reduction in input prices would cause the upward sloping segment of the marginal cost curve to rotate to the right from $W_{0}$ a to $W_{0} a^{\prime}$. Family $l$ would increase its optimal amount of $Q$ or $W$ from $Q_{1}=W_{1}$ to $Q_{1}^{\prime}=W_{1}^{\prime}$. Family 2 would increase its optimal amount of $W$ from $W_{2}$ to $W_{2}^{\prime}$, but would not change its optimal amount of $\Omega$. Although both families would demand more $v$, the expansion would be greater

19
For a detailed analysis of own and cross effects, see Edwards and Grossman (1976).


Figure 2
5. Visual and hearing acuity, as defined above.

Efficiency in the production of both types of children's human capital is measured by the parents' educational attainment (MEDUCAT and EEDUCAT). 16 Since mothers traditionally spend more time with children than do fathers, MEDUCAT should have a greater effect in the reduced form equations than FEDUCAT (as measures solely of inherited IO, they would be expected to have equal effects).

Information about the prices of the inputs in the health and development production functions is difficult to obtain for the Cycle II data set. There are no direct measures of relevant prices such as the price of medical care or the price of parents' time (or their wage rates). Moreover, since the precise locality of each observation cannot be identified, it is not possible to estimate these prices with local market data. Therefore, we use a set of crude proxy variables to control partiallv for these prices.

To control for price variation due to region and size of place of residence, we enter a set of three region dummy variables (denoted NEAST, MWEST, SOUTH) and four sizes of place variables (denoted URB1, URB2, URB3, NURE). Information about whether or not the child's vision has been corrected (SEEG, NSEEG) provides some indication of the price of medical care. To hold constant the cost of the mother's time (probably one of the most important inputs in both the health and development functions), we control for the primary activity of the mother (full-time work, part-time work, or no

[^1]To conclude, our model has an important implication for the estimation of demand curves for children's health and intellectual development. Besides suggesting the relevant explanatory variables, it calls attention to the need for allowing for interactions between parents' income, clearly an important determinant of the relevant regime, and determinants of the marginal cost schedule of children's earnings.

## II. Data and Estimation

Actual estimation of the relationsiips represented by equations (9) tirough (12) is conditioned by the nature of the data. In this section we describe our data set, specify which empirical measures will be used to represent the theoretical variables in (9) through (12), and outline the statistical techniques to be used for estimation.
A. Tine Data

Our data set is Cycle II of the U.S. Health Examination Survey (HES) conducted by the National Center for Health Statistics (NCHS). Cycle II is a nationally representative sample of 7,119 children aged six to eleven years examined over the $1963-65$ period. ${ }^{l}$ This sample is an exceptionally rich source of information about chilaren's health, their intellectual development, and the characteristics of their families. More specifically, the data comprise complete medical and developmental histories of each cinild provided by the parent, information on family socioeconomic characteristics, birth certificate information, and a school report with data on school performance and classroom behavior provided by teachers or other school officials. Most important, there are objective measures of health from detailed physical examinations and scores on psychological (including vocabulary and achievement) tests. The physical examinations and the psychological tests were administered by the Public Health Service.

Although the sample contains children of all races, for three reasons we restrict our analysis to white children only. First, this procedure
${ }^{1}$ For a full description of the sample, the sampling technique, and the data collection, see NCHS (1967a).
avoids the problem associated with alleged "cultural biases" in IQ and achievement tests. Second, in preliminary estimates of equations (9) through (12), it was found that the hypothesis of equality between sets of coefficients for whites and blacks was rejected. Therefore, these groups could not be pooled for purposes of estimation. Third, the black sample alone is too small to allow for reliable coefficient estimates. 2 Our sample is limited further by excluding children who do not live with both of their natural or adopted parents or for whom there were missing data. ${ }^{3}$ The resulting subsample reported on here contains 3,608 children. A caveat concerning the use of the model developed in Section $I$ for the analysis of children's health and intellectual development in Cycle II of the HES is the following: the model and its predictions apply to children's health and development at the age of independence rather than to children in mid-childhood. This discrepancy does not undermine the usefulness of our model as long as there are no systematic differences across families in the time paths of human capital formation. Given such an assumption, our basic predictions will hold eaually well for the six to eleven year-old cohort as for young adults at the onset of independence.
B. Variable Measures

The measurement (and even the definition) of the theoretical variables that we wish to study--children's health and intellectual development-is a formidable task. Indeed, the measurement of these variables has been the

[^2]subject of a large literature. Our actual choices of measures will be detemined primarily by the data available in CVcle II and will be guided by the existing literature.

## 1. Measures of Health

The issue of how to measure children's health is very much an unresolved one, even among professionals in the area of public health. ${ }^{4}$ Most recent studies of children's health have used data taken from one or more of the following categories: measures of disability, measures related to the incidence of abnormal conditions, and measures derived from parental assessments of children's health (for example, Wallace 1962; Mechanic 1964; Mindlin and Lobach 1971; Talbot, Kagan, and Eisenberg 1971; Kaplan, Lave, and Leinhardt 1972; Hu 1973; Schack and Starfield 1973; Kessner 1974; Haggerty, Roghmann and Pless 1975; Inman 1976). Although we plan to follow the precedent of these earlier studies, some of the above measures (disability and the incidence of certain physical conditions) are not entirely appropriate to our model because our health variable refers to the child's "permanent" state of health rather than short-run deviations from that "permanent" state. 5 Much childhood disability results from the natural sequence of childhood diseases and acute conditions which do not reflect on the child's "permanent" state of health. ${ }^{6}$ Sullivan (1966), Berg (1973), and Ware (1976) discuss the general issue of measuring health, and Starfield (1975) and Schack and starfield (1973) focus on the specific problem of measuring children's health.

5
By "permanent" state of health we mean the child's prospect for life preservation and normal functioning.

6 that a child with poor "permanent" health is more likely to contract acute conditions and to have them for a more extended time period. For example, Birch and Gussow (1970) discuss how nutrition (clearly a determinant of permanent health status) and disease are intimately related.

The ideal measure of "permanent" health from an empirical perspective is a single measure that appropriately sumarizes all available and relevant information. Health, however, is clearly a multidimensional concept. A single index is not feasible and would not be desirable from a medical point of view. In particular, even if it were clear what the components of such an index should be, there would be no agreement about the weights assigned to each component. In the case of children's health, the derivation of such weights would be especially complicated because some of the components would be development-related: a given observation might indicate low health capital at one stage of development but not at another stage of development. Finally, although a single health status index would be conceptually neat, it is possible that the various components of health will be differentially affected by the socioeconomic factors. Analysis of a set of components rather than a single index will allow us to detect such differential effects.

The set of measures we use are height, the peridontal index, the number of decayed teeth, and the parents' assessment of the child's health. 7 These are described below.
${ }^{7}$ We selected health measures from the HES based on the advice of John McNamara, M.D., Assistant Professor of Public Health and Pediatrics at Columbia University School of Public Health and Associate Commissioner in the New York City Department of Health; Roy Brown, M.D., Associate Professor of Community Medicine and Pediatrics at the Mount Sinai School of Medicine of the City University of New York; and Thomas Travers, D.D.S., Director of Ambulatory Care in the New York City Department of Health.

1. IHEIGHT, children's height standardized by the mean and standard deviation of neight for each age-sex group. ${ }^{8}$ Height is a standard indicator of children's nutritional status, and good nutrition is an obvious and natural vehicle for maintaining children's health (for example NCHS 1975b).
2. IPERI, the child's peridontal index, which is a good overall index of oral health as well as a positive correlate of nutrition (Russell 1956). Due to the significant age trend in this variable (NCHS 1972b), it is standardized by age in the same manner as IHEIGHT. Higher values of IPERI indicate poorer oral health.
3. IDECAY, the number of decayed primary and permanent teeth, adjusted for age and sex as is IHEIGHT. IDECAY is a supplemental measure of oral health and also reflects nutritional status. Higher values of IDECAY indicate poorer oral health.
4. PFHEALTH, a dichotomous variable that indicates the parents' assessment of the child's current state of health. PFHEALTH equals one when parents assess the child's health as poor or fair and equals zero if they assess it as good or very good.

## 2. Measures of Intellectual Development

Three measures of intellectual development are used to represent intellectual development capital (D): an IQ measure derived from two subtests from

[^3]the Wechsler Intelligence Scale for Children (denoted WISC), ${ }^{9}$ and reading and arithmetic test scores on the Wide Range Achievement (denoted RWRAT and AWRAT, respectively). ${ }^{10}$ Many persons have criticized these measures of intellectual development, but even more have used them to conduct empirical analyses (for example, the studies cited in Averch et al. 1972). We distinguish between reading and arithmetic achievement because of evidence that among various school achievement measures mathematical achievement is the most important determinant of earnings (Ashenfelter and Mooney 1968; Kenny 1977). Achievement rather than IQ would seem to be most appropriate for our purposes since we wish to measure intellectual development rather than innate ability. It is, however, intellectual development at the onset of independence that is desired, and since IQ has been found to be a good predictor of success at school (for example, Carroll 1973), we use WISC and current achievement (RWRAT and AWRAT) as alternative measures of $D$. All three measures are scaled to
${ }^{9}$ The Wechsler Intelligence Scale for Children is a common IQ test, similar to (and highly correlated with results from) the stanfordBinet IQ test. The full test consists of twelve subtests, but only two of these (vocabulary and block design) were administered in the HES. The possible difficulties in the estimation of full scale IQ from these two subtests is examined in NCHS (1972b). For a full discussion of all psychological tests administered in the HES, see NCHS (1966).
${ }^{10}$ The Nide Range Achievement Test is a single test that can be given to children of varying ages. In particular, the same test was given to all of the 7,119 children in the sample. (Only twelve-year olds, who are excluded from our basic sample, were given a different version of WRAT.) The two tests used here were found to ". . . have reasonably good construct validity as judged by their relationship to conventional achievement tests (NCHS 1967b)."
have means of 100 and standard deviations of 15 for each age-group (fourmonth cohorts are used for WISC and six-month cohorts are used for RNRAT and AWRAT).

## 3. Explanatory Variables

The explanatory variables in the reduced form equations are health and development endowments, prices of the composite health and development inputs, measures of efficiency in the production of health and development capital, family income, and the rate of return on financial investments. The rate of return on financial investments is assumed to be constant for all members of our sample. Measures of the other theoretical variables are described below and are defined precisely in Table 1. The table also contains definitions of the seven dependent variables described above.

The health endowment of the child is represented by the following measures: ${ }^{11}$

1. Birth weight, measured by the dichotomous variable IIGHT. A child is considered to have low birth weight if he or she weighs less than 2,500 grams at birth.
2. Mother's age at the time of birth, represented by three dummy variables (LMAG, HMAG35, and HMAG40). Mother's age at the time of birth is considered an endowment measure because relatively older mothers have been found to have a greater frequency of infants in poor health, while relatively young mothers are likely to have "unwanted" births and consequently receive poorer prenatal care.

11
As mentioned in Section $I$, a number of the health and development endowment measures which are treated here as exogenous would be considered endogenous in a more fully specified model.

TABLE 1
Definition of Variables

| Variable <br> Name | Definition | Source ${ }^{\text {a }}$ | ```Predicted Direction of Effectb,c (where relevant)``` |
| :---: | :---: | :---: | :---: |
| IHEIGHT | Height, standardized by the mean and standard deviation of one-year age-sex cohorts | 3 |  |
| IPERI | Peridontal index, standardized by the mean and standard deviation of one-year age cohorts | 3 |  |
| IDECAY | Number of decayed primary and permanent teeth, standardized by the mean and standard deviation of one-year age-sex cohorts | 3 |  |
| PFHEALTH | Dummy variable that equals one if parental assessment of child's health is poor or fair and zero if assessment is good or very good | 1 |  |
| WISC | Child's IO as measured by vocabulary and block design subtests of the Wechsler Intelligence Scale for Children, standardized by the mean and standard deviation of four-month age cohorts | 4 |  |
| PWRAT | Child's reading achievement as measured by the Wide Range Achievement Test, standardized bv the mean and standard deviation of six-month age conorts | 4 |  |
| AWRAT | Child's arithmetic achievement as measured by the Wide Range Achievement Test, standardized by the mean and standard deviation of sixmonth age cohorts | 4 |  |
| LIGHT | Dumun variable that equals one if child's birth weight is under 2,500 grams | 2 | + |
| LMAG | Dunry variable that equals one if the mother was less than 20 years old at birth of child | 1 | - |


| Variable <br> Name | Definition | Source ${ }^{\text {a }}$ | Predicted Direction of Effect $b, c$ (where relevant) |
| :---: | :---: | :---: | :---: |
| HMAG35 | Dummy variable that equals one if the mother was more than 35 years old at birth of child | 1 | $\pm$ |
| HMAG40 | Dummy variable that equals one if the mother was 40 years old or more at birth of child | 1 | - |
| FYPH | Dumy variable that equals one if child's health at one year was noor or fair, and zero if it was good | 1 | - |
| MBEED | Dumn variable that equals one if the child was breast-fed | 1 | + |
| IHEAR | Dumny variable that equals one if hearing is abnormal and zero otherwise | 3 | - |
| ABN | Dummy variable that equals one if the physician finds a "significant abnormality" in examining the child (other than an abnormality resulting from an accident or injury) | 3 | - |
| SEEG | Dumy variable that equals one if binocular distance vision is abnormal and child usually wears glasses | 3 | $\pm$ |
| NSEEG | Durumy variable that equals one if binocular vision is normal and child usually wears glasses | 3 | $\pm$ |
| SEENG | Dumy variable that equals one if binocular vision is abnormal and the child does not wear glasses | 3 | - |
| YEDUCAT | Years of formal schooling completed by mother | 1 | $\pm{ }^{\text {d }}$ |
| FEDUCAT | Years of formal schooling completed by father | 1 | $\pm{ }^{\text {d }}$ |
| FLANG | Dumpy variable that equals one when a foreign language is spoken in the home | 1 | $\pm$ |

## TABLE 1 (continued)

| Variable <br> Name | Definition | Source ${ }^{\text {a }}$ | Predicted <br> Direction <br> of Effect <br> (where <br> relevant) |
| :---: | :---: | :---: | :---: |
| FIRST | _ Dummy variable that equals one if child is the first born in the family | 1 | + |
| TWIN | Dummy variable that equals one if child is a twin | 1 | - |
|  | Dummy variables that equal one if child lives in Northeast, Midwest, or South, respectively | 1 | $\pm$ |
| URB1 <br> URB2 <br> URB3 <br> NURB | Durny variables that equal one if child lives in an urban area with a nopulation of 3 million or more (URBl); in an urban area with a population between 1 million and 3 million (URB2); in an urban area with a ponulation less than 1 million (URB3); or in a nonrural and non-urbanized area (NURB); omitted class is residence in a rural area | 1 | $\pm$ |
| MWORKPT MFORKFT | Dumny variables that equal one if the mother works part-time or full-time, respectively | 1 | - |
| KIND | Dumny variable that equals one if child attended kindergarten or nursery school | 1 | $\pm$ |


| Variable Name | Definition | Source ${ }^{\text {a }}$ | Predicted Direction of Effect (where relevant) |
| :---: | :---: | :---: | :---: |
| FINC | Continuous family income computed by assigning midpoints to the following closed income intervals, $\$ 250$ to the lowest interval, and $\$ 20,000$ to the highest interval. The closed income classes are: | 1 | See text |
|  | $\begin{array}{r} \$ 500-\quad \$ 999 \\ \$ 1,000-\quad \$ 1,999 \\ \$ 2,000-\quad \$ 2,999 \\ \$ 3,000-\$ 3,999 \\ \$ 4,000-\quad \$ 4,999 \\ \$ 5,000-\$ 6,999 \\ \$ 7,000- \\ \$ 10,999 \\ \$ 10,000-\$ 14,999 \end{array}$ |  |  |
| MALE | Dumn variable that equals one if child is male | 1 | $\pm$ |
| LESS20 | Number of persons in the household 20 years of age or less | 1 | - |

## Footnotes to TABLE 1

$\mathrm{a}_{\text {The }}$ sources are $1=$ medical history form completed by parent, $2=$ birth certificate, 3 = physical examination, $4=$ psychological examination, $5=$ school form.
$b_{A}$
positive sign means that the variable is expected to have a positive effect on a positive correlate of child health or intellectual development; a negative sign means a corresponding predicted negative effect.
${ }^{c}$ predictions about the directions of efficiency, and input prices. One conin a health endowment, for example, might so, investment in the production function of investment in health. If increase most of theman constant, or decrease. A second consideration is that most of the proxies are correlated with both health and development endowments, health and development efficiency, or health and development input prices. Given that cross endowment, cross efficiency, and cross input price effects cannot be signed a priori, the effects of these proxy measures also cannot be predicted a priori. The signs in the table are based on two assumptions: (1) the own endowment effect is positive, and (2) the cross effect does not outweigh the own effect if the two go in opposite directions.
${ }^{d}$
Subject to the modifications in note $c$, the effect of MEDUCAT or FEDUCAT would be positive if the price of time were held constant and ambiguous if it were not.
3. The child's health $a t$ one year, measured $b y$ a dumy variable indicating the parents' assessment of the child's health at one year (denoted FYPH).
4. Whether or not the child was breast-fed (denoted MBFED).
5. Hearing acuity, measured by a dicnotomous variabie that indicates whether or not the child has normal nearing in his best ear (denoted IHEAR). 12
6. Overall diagnostic impressions of the physician concerning whether or not the child had any "significant abnormalities." Our variable (ABN) is a dummy variable that takes the yalue one when such abnormalities are present. ${ }^{13}$
7. Visual acuity, measured by a set of dummy variables indicating whether or not the cnild has poor vision ${ }^{14}$ and if

12
A child is defined here to have "normal" hearing if the average threshold decibel reading of the child in his best ear over the range of 500 , 1,000 , and 2,000 cycles per second (c.0.s.) is 15 or lower. 500, 1,000, and 2,000 c.p.s. are the frequencies that occur most frequently in normal speech. A threshold of less than 15 decibels above audiometric zero at these frequencies is classified as corresnonding to "no significant difficulty with faint speech" by the Comittee on Conservation of Hearing of the Americar Academy of Ophthalmology and Otolaryngology (NCHS 1970a).
${ }^{13}$ In defining $A B N$, we exclude abnormalities resulting from accidents or injuries because these cannot be treated as endowments. The remaining abnormalities are classified as heart disease (congenital or acquired); neurological, muscular, or joint conditions; other ongenital abnormalities; and otner major diseases.
${ }^{14}$ In Cycle II the children were examined without glasses. A child is defined here to have "normal" binocular vision if his or her binocular distance acuity is $20 / 30$ or better (NCHS 1972a).
it has been corrected (SEEG, NSEEG, SEENG). Although, strictly speaking, information about the correction of visual defects cannot be included in an endowment variable, such information does provide some evidence about the price of medical care, one of our other explanatory variables.

The development endowment is represented by the following variables:

1. Mother's and father's educational attainment (denoted MEDUCAT and FEDUCAT, respectively). Parents' educational attainment is a crude proxy measure of the child's inherited intelligence.
2. A dumny variable indicating whether or not a foreign language is spoken in the home (denoted FLANG). This factor could contribute either positively or negatively to the child's intellectual endowment.
3. Two dumny variables measuring aspects of birth order-one indicating whether the child is the first born in the family (denoted FIRST) and one indicating if the child is a twin (denoted TWIN). Everything else equal, more parental time is available to first born children and non-twins than to later children or twins.
4. Birth weight as defined above. Since birth weight is partially determined by maternal health and nutrition during pregnancy, it is frequently used as a crude index of overall fetal development (including brain development). 15

15
See Birch and Gussow (1970). Another aspect of educational endowment is publicly-supplied school quality. In future work we hope to supplement the data with measures of school quality.
5. Visual and hearing acuity, as defined above.

Efficiency in the production of both types of children's human capital is measured by the parents' educational attainment (MEDUCAT and FEDUCAT). ${ }^{16}$ Since mothers traditionally spend more time with children than do fathers, MEDUCAT should have a greater effect in the reduced form equations than FEDUCAP (as measures solely of inherited IO, they would be expected to have equal effects).

Information about the prices of the inputs in the health and development production functions is difficult to obtain for the Cycle II data set. There are no direct measures of relevant prices such as the price of medical care or the price of parents' time (or their wage rates). Moreover, since the precise locality of each observation cannot be identified, it is not possible to estimate these prices with local market data. Therefore, we use a set of crude proxy variables to control partially for these prices.

To control for price variation due to region and size of place of residence, we enter a set of three region dummy variables (denoted NEAST, MWEST, SOUTH) and four sizes of place variables (denoted URB1, URB2, URB3, NURB). Information about whether or not the child's vision has been corrected (SEEG, NSEEG) provides some indication of the orice of medical care. To hold constant the cost of the mother's time (probably one of the most important inputs in both the health and development functions), we control for the primary activity of the mother (full-time work, part-time work, or no
${ }^{16}$ The literature on household production functions commonly treats parental education as an efficiency variable.
work, denoted by the dummy variables MWORKFT and MWORKPT). Everything else equal, mothers with higher ooportunity costs are more likely to work in the iabor market (and to work longer hours). ${ }^{17}$ The cost of time, both of mothers who work and those who do not, might also be related to their schooling (MEDUCAT). 18 A similar comment applies with respect to the correlation betweeen the father's price of time and his schooling (FEDUCAT). The final input price proxy is a dumny variable that indicates whether the child attended kindergarten or nursery school (denoted KIND). We assume that the iikelihood of kindergarten attendance is negatively related to the price of this type of schooling and positively related to the value of the mother's time.

Family income is represented by FINC, a continuous income variable computed by assigning miapoints to the income classes reported in Cycle II. 19

Finally, two additional variables are included. The first, a dummy variable indicating whether or not the child is male (denoted MAIE), holds
${ }^{17}$ We overlook problems with selectivity bias, which are discussed in detail by Gronau (1974). We have information on the primary activity of the mother at the time of the survey, but do not know how many years she has worked. The latter factor might be related in part to the mother's age at the birth of the child.
${ }^{18}$ See Heckman (1974) for evidence that the mother's potential market wage rate and the "shadow value" of her time are positively related to her schooling.
${ }^{19}$ Since this family income measure does not hold constant the mother's labor force status and the father's experience, we experimented with an income measure that held these two factors constant. The adjusted income variable was very highly correlated with FINC (the correlation coefficient was greater than .99) and the regression results were not altered when adjusted income was used in place of FINC. Therefore, we report results based only on the use of FINC in this paper.


#### Abstract

constant possible sex differences in parents' desired child quality ${ }^{20}$ and is included when estimates are reported for both sexes combined. The second is a measure of family size (denoted LESS20). 21 Although our model does not call for the latter variable in the reduced form (it is simultaneously determined with child quality), it is among our explanatory variables for the following reason. Family size is not determined with perfect certainty. The resulting random variations in the actual number of children will generate adjustments in final child quality. For example, when a family has more than the desired number of children, this increases the relative price of child quality and leads to a downward adjustment in desired child quality. ${ }^{22}$ Thus, we expect children in large families to have lower $H$ and $D$.

Tha above variable definitions are summarized in Table l, along with predicted variable effects in the reduced form. Means and standard deviations of the variables are shown in Table 2.

\section*{C. Estimation Method}

The relationship summarized by equations (9) and (11) or (10) and (12) can be written as:


${ }^{20}$ See Ben-Porath and Welch (1976) for a discussion of this possibility.
${ }^{21}$ LESS20 does not measure completed family size, but rather the number of persons in the household younger than 20 years at the time of the Cycle II interview. Therefore, LESS 20 may overstate or understate completed family size. The mean value of LESS20 in our sample (3.6) may seem high, but it must be remembered that this figure is computed from a sample of children, not from a sample of families. In general the mean computed from a sample of children will be larger than that computed from a sample of families for two reasons. First, families with no children do not appear in a sample of children, but they do appear in a sample of families. Second, among families with children, the probability of any family being represented in a sample of children is greater the more children in the family, whereas the probability of any family being represented in a sample of families is independent of the number of children in that family.

[^4]TABLE 2
Means and Standard Deviations of Dependent and Independent Variables, Whites, Ages 6-11, Mother and Father Present ( $\mathrm{N}=3608$ )

| Variable | Mean | Standard Deviation |
| :---: | :---: | :---: |
| IHEIGHT | . 0456 | . 9680 |
| IPERI | -. 0394 | . 9831 |
| IDECAY | -. 0651 | . 9677 |
| PFHEALTE | . 0424 | . 2015 |
| WISC | 103.1951 | 13.9566 |
| RWRAT | 103.0055 | 13.7343 |
| AWRAT | 102.8672 | 13.1335 |
| LIGHT | . 0538 | . 2256 |
| LMAG | . 0696 | . 2545 |
| HMAG35 | . 1045 | . 3059 |
| HMAG40 | . 0310 | . 1735 |
| FYPH | . 0840 | . 2774 |
| MBFED | . 3007 | .4586 |
| IHEAR | . 0058 | .0761 |
| ABN | . 0030 | . 0550 |
| SEEG | . 0710 | .2568 |
| NSEEG | . 0432 | . 2034 |
| SEENG | . 0482 | . 2143 |

$$
I I-19
$$

TABLE 2 (concluaied)

| Variable | Mean | Standard Deviation |
| :---: | :---: | :---: |
| : AEDUCAT | 11.2406 | 2.7510 |
| FEDUCAT | 11.2650 | 3.4470 |
| ELANG | . 1020 | . 3027 |
| FIRST | . 2894 | .4535 |
| TWIN | . 0233 | .1508 |
| NEAST | . 2384 | . 4261 |
| MWEST | . 3276 | . 4694 |
| SOUTH | . 1768 | . 3816 |
| URB1 | .1971 | . 3978 |
| URB2 | .1256 | . 3314 |
| URB3 | .1815 | . 3855 |
| NURB | . 1502 | . 3573 |
| :MWORKPT | . 1375 | . 3444 |
| \MWORKFT | .1375 | . 3444 |
| KIND | .7306 | . 4437 |
| FINC ${ }^{\text {a }}$ | 7.8277 | 4.4149 |
| MALE | . 5116 | . 4999 |
| LESS20 | 3.6159 | 1.6371 |

[^5]\[

$$
\begin{array}{ll}
y_{j}=\alpha_{1}+\beta_{1} X_{j}+u_{1 j}, & j \text { a member of Regime } 1 \\
y_{j}=\alpha_{2}+\beta_{2} X_{j}+u_{2 j}, & j \text { a member of Regime } 2, \tag{13}
\end{array}
$$
\]

where $j$ ranges from 1 to $n$. In (13), $y_{j}$ represents the $j$ th observation on either of the dependent variables, $X_{j}$ represents the $j^{\text {th }}$ vector of observations on the independent variables, $\alpha_{1}$ and $\alpha_{2}$ are constant terms, $\beta_{1}$ and $\beta_{2}$ are vectors of coefficients, and $u_{1 j}$ and $u_{2 j}$ are independent, normally distributed error terms with zero means and identical variances. ${ }^{23}$ The two regimes are defined by the solvency constraint on the financial bequest: Regime 1 denotes the set of observations for which the constraint is effective $\left(B_{j}=0\right)$ and Regime 2 denotes those observations for which the constraint is ineffective ( $B_{j}>0$ ). In this context, the major predictions of Section $I$ are restated as follows: $\alpha_{1}$ and $\beta_{1}$ are different from $\alpha_{2}$ and $\beta_{2}$; and the element of $\beta_{1}$ that is the coefficient of income will be positive while the corresponding element of $B_{2}$ will be zero. 24

## 23

We overlook the dichotomous nature of one of the dependent variables (PFHEALTH). In principle an appropriate transformation, such as a logit transformation, should be introduced here, but we have not done so in the results reported in Section III.

24
With respect to coefficients of variables other than income, our model predicts differences between regimes but does not identify the regime in which the effect will be larger. Even if we had enough additional information to make predictions about relative magnitudes (see Section $I$, note 21), these predictions might be altered by the possibility that our measures of health and intellectual development are nonlinear transformations of the theoretical variables, $H$ and $D$. Note, however, that this measurement problem does not alter the prediction concerning the effects of income in the two regimes. For a more complete discussion of this point, see Edwards and Grossman (1976).

Estimation of equation (13) would be straightforward if we could identify which observations belong in each of the two regimes. ${ }^{25}$ In our data, however, there is no direct way to do so. An alternative procedure would be to estimate B (which from Figure 1 can be seen to depend on those factors which determine the location of the demand and marginal cost curves of children's quality) and use the estimated value of $B$ to classify observations. But again, this procedure requires information about the value of $B$, at least for a subset of observations. Another tactic is to note that among the determinants of $B$, it seems likely that variations in income will cause the greatest amount of variation in $B$. This suggests the simple, though admittedly crude, procedure of classifying observations by family income. 26

We estimate the relations in equation (13) using this simple classification scheme. The two subsamples are children whose families have an annual income of under $\$ 7,000$ and those whose families have an annual income of $\$ 7,000$ or more. Although $\$ 7,000$ is not the most obvious cutoff point to use to identify the regimes, ${ }^{27}$ we use it for

25
Even in this case, however, there is the possibility that in each of the two regimes the error term would be correlated with some of the independent variables, leading to biased coefficient estimates. For a similar point in the context of the estimation of separate fertility demand functions for women who work and women who do not work, see willis (1973).

26
The appropriate estimation procedure for this type of two-regime model in the absence of direct information for classifying observations into regimes is the "switching of regimes" model described in Goldfeld and Quandt (1973). The application of this statistical model to our estimation problem is discussed in Edwards and Grossman (1976). We do not use this technique here because it is very expensive.

27
Lansing and Sonquist (1969) find that about 30 percent of families receive an inheritance. If this same percentage were applied to our sample this would imply an income cutoff somewnere in the $\$ 7,000$ to $\$ 10,000$ interval (47 percent of our sample has family income of $\$ 7,000$ or more and 22 percent has family income of $\$ 10,000$ or more). Such a cutoff would be infeasible with our data set.
several reasons. First, this cutoff point separates our data into two roughly equal subsamples, so that standard errors of coefficient estimates in each regime will not differ due to differences in samole sizes. Second, since our observations consist of families with young children, the current income of these families is likely to understate their lifetime wealth (relative to the population at large). If one takes account of this understatement, the top 50 percent of our sample may correspond to the top, say, 40 percent of the population at large. Third, preliminary estimates of equation (13) using, alternately, observations with annual income greater than or equal to $\$ 7,000$ and those with annual incomes greater than or equal to $\$ 10,000$ showed that the coefficient estimates for these two subsamples do not greatly differ (although, of course, their standard errors are larger for the higher income class). Finally, many persons are interested in the behavior of low income groups, and public policy often is aimed at these groups. Hence, we choose a $\$ 7,000$ cutoff point because estimates derived from the resulting pair of income classes will be more useful for policy-makers in the fields of children's health and intellectual development than those derived from a $\$ 10,000$ cutoff point.

Means and standard deviations of all variables in each of the two subsamples are shown in Table 3. A cursory examination of this table reveals that there are indeed important differences between these two groups with respect to both the dependent and independent variables.

TABLE 3
Means and Standard Deviations of Dependent and Independent Variables, Whites, Ages 6-11, Mother and Father Present

| Variable | Income $<\$ 7,000^{\text {a }}$ |  | Income $\geq \$ 7.000^{\text {b }}$ |  |
| :---: | :---: | :---: | :---: | :---: |
|  | Mean | Standard Deviation | Mean | Standard Deviation |
| IHEIGHT | -. 0869 | . 9687 | . 1896 | . 9468 |
| IPERI | . 0790 | 1.1126 | -. 1681 | .8002 |
| IDECAY | . 1226 | 1.0750 | -. 2691 | . 7866 |
| PFHEALTH | . 0580 | .2338 | . 0254 | .1575 |
| WISC | 99.3097 | 13.0889 | 107.4176 | 13.6436 |
| RWRAT | 99.6754 | 13.7437 | 106.6246 | 12.7786 |
| ANRAT | 100.1884 | 13.6789 | 105.7785 | 11.8497 |
| LIGHT | . 0596 | . 2368 | . 0474 | . 2126 |
| IMAG | . 0963 | . 2951 | . 0405 | .1972 |
| HMAG 35 | .1043 | . 3057 | . 1074 | . 3062 |
| LULAG40 | . 0362 | .1868 | . 0254 | . 1575 |
| FYPH | .0963 | . 2951 | . 0706 | . 2562 |
| MBFED | . 3092 | . 4623 | . 2915 | . 4546 |
| IHEAR | . 0075 | . 0860 | . 0040 | . 0635 |
| ABN | . 0043 | . 0651 | . 0017 | . 0416 |
| SEEG | . 0553 | . 2287 | . 0879 | . 2832 |
| NSEEG | . 0431 | . 2030 | . 0434 | . 2038 |
| SEENG | . 0442 | . 2055 | . 0526 | .2234 |

TABLE 3 (concluded)

| Variable | Income < $\$ 7,000^{\text {a }}$ |  | Income $\geq \$ 7.000^{\mathrm{b}}$ |  |
| :---: | :---: | :---: | :---: | :---: |
|  | Mean | Standard Deviation | Mean | Standard Deviation |
| MEDUCAT | 10.1985 | 2.7935 | 12.3730 | 2.2027 |
| FEDUCAT | 9.7286 | 3.2953 | 12.9346 | 2.7647 |
| FLANG | . 1251 | . 3309 | . 0769 | . 2665 |
| FIRST | .2869 | . 4524 | . 2921 | . 4548 |
| TWIN | . 0165 | . 1274 | .0307 | . 1724 |
| NEAST | .1937 | . 3953 | . 2869 | . 4524 |
| HWEST | . 3225 | . 4676 | . 3331 | . 4715 |
| SOUTH | . 2342 | .4236 | . 1145 | . 3185 |
| URB1 | .1346 | . 3414 | . 2649 | . 4414 |
| URB2 | . 0793 | .2703 | . 1758 | . 3808 |
| URB3 | .1703 | . 3760 | . 1938 | . 3954 |
| NURB | .1799 | . 3842 | . 1180 | . 3227 |
| MWORKPT | .1426 | .3498 | . 1319 | .3384 |
| :TNORKFT | . 1213 | . 3266 | . 1550 | . 3620 |
| KIND | . 6275 | .4836 | . 8427 | . 3642 |
| FINC ${ }^{\text {c }}$ | 4.6281 | 1.6811 | 11. 3048 | 3.7928 |
| MALE | . 4944 | . 5001 | . 5304 | . 4992 |
| LESS20 | 3.8302 | 1.7639 | 3.3829 | 1.4523 |
| ${ }^{\text {a }} 1879$ observations. |  |  |  |  |
| $\mathrm{b}_{1} 729$ observations. |  |  |  |  |
| $\mathrm{c}_{\text {Thousands }}$ |  |  |  |  |

Ordinary least squares estimates of the reduced form equations for the dependent variables WISC, RWRAT, AWRAT, IHEIGHT, IPERI, IDECAY, and PFHEALTH for each income class annear in Tables $A-1$ through $A-7$ in the Appendix. In discussing these results we focus first on the basic hypotheses generated by the theoretical model and second on specific fincings concerning the effects of the explanatory variables and how these effects differ for the two income classes. Kll of our equations zre estimated for males and females senarately as well as for both sexes pooled. Only the pooled results are discussed in detail, however, because coefficient estimates were not found to differ significantly by sex. ${ }^{1}$
A. Basic Hypotheses

There are two orimary predictions qenerated by the model: the sets of coefficients in the two reqimes will differ; and the family income variable will have a positive effect in Regime 1 and no effect in Reqime 2. There is also the more fundamental prediction that the set of explanatory variables suggested by the model do succeed in explaining a significant portion of the variance in tine health and development variables. The latter nrediction is clearly supoorted by our results. Adjusted $\mathrm{R}^{2}$ 's range from a high of .238 (for WISC in the lower income class) to a low of . 025 (for IHEIGHT in the unper income class). Even

[^6]the lowest of these $R^{2}$ 's is statistically significant at the 1 percent level of significance. Thus, even though the explanatory variables are in some cases imperfect proxies for the desired theoretical variables, taken as a set they do have a significant impact on our health and development measures.

The prediction of two distinct regimes or two different relationships between each of our health and development variables and the set of explanatory variables is also generally supported by our results (see Table 4). 2 Statistically significant differences in the sets of cofficients for the two income classes are reported for RWRAT, AWRAT, IHEIGHT, IDECAY, and PFHEALTH. Only for IPERI and WISC are the differences in coefficients not significant. Although these results cannot be characterized as "unanimous" support for the basic structure of our model, they do constitute stronger verification than may be initially apparent. The two income classes used here are unlikely to coincide completely with the two regimes specified by the model. The resulting misclassification of observations will tend to bias the coefficient in the two income classes towards equality, making it more difficult to obtain significantly different coefficients in the two income classes even though such differences do exist in the two regimes. We observe

2The "F" tests presented here cannot prove the validity of our model because there are alternative explanations for finding significant differences between coefficients in the two regimes. For example, the true relationship between $H$ (or D) and the set of explanatory variables could be identical in the two regimes, but different estimates still could be generated if our proxy measures of $H$ (or D) are nonlinear transformations of its true value.

TABLE 4
"F" Statistics from Testina Hypothesis of No the Two Income Subsamoles ${ }^{\text {a }}$

Dependent
Variable
$F_{30,3548}$

WISC
1.31

RWRAT
1.62

ATRRAT
2.02

IHEIGHT
1.54

IPERI
1.33

IDECAY
2.00

PFHEALTH
2,10
${ }^{\text {a Critical value for }} \mathrm{F}_{30,1000}$ is 1.47 at the 5 percent level of significance.
significant differences in coefficients for five of our seven variables despite this bias towards finding no such difference.

The final prediction of our model--that income will have a positive effect on health or development for families in Regime 1 (our lower income class) and no effect in Regime 2 (our upper income class)--does not receive strong support in our results. Even though the income coefficients are uniformly lower in the upper income class than in the lower income class, only for the two achievement measures (AWRAT and RWRAT) do we observe the predicted pattern of income coefficients (see Table 5). For both of these dependent variables, income has a positive, significant impact for lower income families and a nonsignificant impact for upper income families. For the other dependent variables, family income is either statistically significant in both income classes (WISC, IPERI, and IDECAY) or in neither income class (IHEIGHT and PFHEALTH).

One likely explanation for the significant coefficients in the upper income class is the previously mentioned bias resulting from the misclassification of observations. In particular, it is likely that members of Regime 1 are erroneously included in the over $\$ 7,000$ income class, causing an upward bias in the coefficient of FINC for that class. The plausibility of this explanation is confirmed by an additional test. In the upper income class we replace the continuous income variable FINC with two dummy variables indicating whether the family had income of $\$ 10,000$ and over, or of $\$ 15,000$ and over. These dummy variables allow for a nonlinear income effect in the upper income class. In no case was income found to have a significant marginal effect when it exceeded

TABLE 5

$$
\text { Regression Coefficients of Family Income }{ }^{a}
$$

| Denendent | Income < \$7,000 | Income $\geq$ \$7,000 |
| :---: | :---: | :---: |
| Variable | FINC | FINC |
| WISC | $\begin{array}{r} .762 \\ (15.94) \end{array}$ | $\begin{aligned} & .245 \\ & (8.01) \end{aligned}$ |
| RWRAT | $\begin{array}{r} .712 \\ (11.61) \end{array}$ | $\begin{array}{r} .035 \\ (0.18) \end{array}$ |
| AWRAT | $\begin{array}{r} 1.018 \\ (22.99) \end{array}$ | $\begin{array}{r} .087 \\ (1.25) \end{array}$ |
| IHEIGHT | $\begin{array}{r} .017 \\ (1.18) \end{array}$ | $\begin{array}{r} .004 \\ (0.43) \end{array}$ |
| IPERI | $\begin{aligned} & -.033 \\ & (3.45) \end{aligned}$ | $(4.53)$ |
| IDECAY | $\begin{array}{r} -.067 \\ (16.44) \end{array}$ | $\begin{array}{r} -.019 \\ (12.94) \end{array}$ |
| PFHEALTH | $\begin{gathered} -.006 \\ (2.47) \end{gathered}$ | $\begin{aligned} & -.0002 \\ & (0.03) \end{aligned}$ |

${ }^{\text {a }}$ Source: Appendix, Tables Al - A7. F statistics in parentheses. The critical $F$ value at the 5 percent level of significance is 2.69 on a one-tailed test.
$\$ 15,000$; and only for WISC and IDECAY did income have a significant marginal effect when it exceeded $\$ 10,000$. Thus, for those observations in the upper income class which have higher incomes--the very observations most likely to actually belong in Regime 2--income does not have a significant marginal impact on health and developnent.

## B. Effects of Other Variables

In discussing effects of variables other than income on intellectual development and health, we deal with narents' schooling, mother's work status, number of children in the family, health endowments measured in infancy, and health endowments measured currently. ${ }^{3}$ To focus the discussion, note that among our health variables height would be viewed as the best health measure by persons concerned with the relationshin between health output and proper nutrition (for example, National Center for Health Statistics 1970b, 1975; Seoane and Latham 1971; Owen 1973). The peridontal index and the number of decayed primary and permanent teeth are good overall indexes of oral health and supplementary measures of nutrition. It is plausible that the peridontal index, which reflects status of the gums, is less sensitive to appropriate dental care than the number of decaved teeth. This proposition is supported by the higher adjusted $R^{2}{ }^{2} s$ in the decay regressions than in the peridontal regressions. Parental assessment of the child's current state of health is employed as a dependent variable to
${ }^{3}$ The reader is left to insoect the effects of the following variables: twin status of child, sex of child, foreign lanquage spoken in the home, first born child, and kindergarten or nursery school attendance.
show how results differ when health is measured subiectivelv by parents as odoosed to objectively bv physicians.

Table 6 contains reqression coefficients of motiner's schooling and father's schooling. These two variables have positive and statisticallv significant effects on all measures of intellectual develonment in both the high income sample and the low income sample. When health is defined in a positive manner, ${ }^{4}$ fifteen of the sixteen schoolinc coefficients are positive, but only ten achieve statistical significance at conventional levels of confidence. These ten appear primarily in the low income sample. It is noteworthy that neight, which nutritionists would view as the most important health measure in Table 6, is practically independent of schooling in the high income sample but dependent unon schooling in the low income sample. We reach the tentative conclusion that schooling effects are more important for low income families in the case of health but not in the case of intellectual develoment.

Presumably, schooling of both parents is positively correlated with the endowment, efficiency, and the value of time. Subject to the modification in Table 1 (note $c$ ), an increase in the endowment or in efficiency raises health or development, while an increase in the value of time lowers it. Since we are not able to control fully for the value of time as schooling varies, our results imply that the efficiency or endowment effect outweighs the value of time effect.

[^7]TABLE 6

Regression Coefficients of Mother's Schooling and Father's Schooling ${ }^{\text {a }}$

| Dependent Variable | Income < \$7,000 |  | Income $\geq$ \$7,000 |  |
| :---: | :---: | :---: | :---: | :---: |
|  | MEDUCAT | FEDUCAT | MEDUCAT | FEDUCAT |
| WISC | $\begin{array}{r} .909 \\ (49.05) \end{array}$ | $\begin{array}{r} .706 \\ (41.83) \end{array}$ | $\begin{array}{r} .944 \\ (29.91) \end{array}$ | $\begin{array}{r} .574 \\ (16.94) \end{array}$ |
| RWRAT | $\begin{array}{r} .817 \\ (33.13) \end{array}$ | $\begin{array}{r} .665 \\ (30.97) \end{array}$ | $\begin{array}{r} .717 \\ (18.97) \end{array}$ | $\begin{array}{r} .616 \\ (21.52) \end{array}$ |
| AWRAT | $\begin{array}{r} .565 \\ (15.33) \end{array}$ | $\begin{array}{r} .720 \\ (35.11) \end{array}$ | $\begin{array}{r} .684 \\ (19.28) \end{array}$ | $\begin{array}{r} .354 \\ (7.95) \end{array}$ |
| IHEIGHT | $\begin{array}{r} .025 \\ (5.66) \end{array}$ | $\begin{array}{r} .018 \\ (4.16) \end{array}$ | $\begin{gathered} .012 \\ (0.87) \end{gathered}$ | $\begin{array}{r} .004 \\ (0.16) \end{array}$ |
| IPERI | $\begin{aligned} & -.023 \\ & (3.54) \end{aligned}$ | $\begin{array}{r} -.032 \\ (10.07) \end{array}$ | $\begin{gathered} -.005 \\ (0.25) \end{gathered}$ | $\begin{array}{r} -.017 \\ (4.06) \end{array}$ |
| IDECAY | $\begin{array}{r} -.036 \\ (10.37) \end{array}$ | $\begin{array}{r} -.025 \\ (6.94) \end{array}$ | $\begin{array}{r} -.034 \\ (10.74) \end{array}$ | $\begin{aligned} & -.020 \\ & (5.66) \end{aligned}$ |
| PFHEALTH | $\begin{array}{r} .001 \\ (.33) \end{array}$ | $\begin{aligned} & -.006 \\ & (8.44) \end{aligned}$ | $\begin{aligned} & -.003 \\ & (1.46) \end{aligned}$ | $\begin{aligned} & -.002 \\ & (1.78) \end{aligned}$ |

${ }^{\text {a }}$ Source: Appendix, Tables Al-A7. F statistics in parentheses. The critical $F$ values at the 5 percent level of significance are 2.69 on a one-tailed test and 3.84 on a two-tailed test.

There is some evidence in Table 6 that mother's schooling has a larger impact on cognitive development than father's schooling. Five of the six mother's schooling coefficients exceed the corresponding father's schooling coefficients. This is consistent with the notion that mother's schooling is a more important determinant of efficiency in development production than father's schooling. A related and interesting finding emerges when separate development functions are estimated for boys and girls (see Tables $A-8$ through $A-10$ ). In almost all instances, mother's schooling has a larger effect on the intellectual development of girls than of boys. On the other hand, father's schooling has a larger effect on the intellectual development of boys than of girls. We do not know whether this reflects basic properties of the development production function or whether it reflects psychological forces in early childrearing such as the child's attachment to the parent of the same sex.

Table 7 contains regression coefficients of the two variables for mother's work status in the labor force. The signs of twenty-three of the twenty-eight coefficients in the table indicate that children whose mothers work full-time or part-time have lower levels of health and development than children whose mothers do not work. In the development functions only one of six work status effects is significant for the low income sample, while three of six are negative and significant for the high income sample. 5 In the health functions

[^8]TABLE 7
Regression Coefficients of Mother's Work Status ${ }^{\text {a }}$

| Dependent Variable | Income < \$7,000 |  | Income $\geq$ \$7,000 |  |
| :---: | :---: | :---: | :---: | :---: |
|  | MWORKFT | MWORKPT | MWORKFT | MWORKPT |
| WISC | -1.764 | . 566 | -2.388 | . 190 |
|  | (4.46) | (0.53) | (7.55) | (0.04) |
| RWRAT | -. 645 | -. 793 | -2.234 | 2. 383 |
|  | (0.50) | (0.87) | (7.27) | (7.51) |
| AWRAT | -. 495 | -. 338 | -1.760 | . 085 |
|  | (0.28) | (0.15) | (5.04) | (0.01) |
| IHEIGHT | -. 110 | -. 227 | -. 072 | -. 095 |
|  | (2.61) | (12.83) | (1.23) | (1.91) |
| IPERI | . 080 | -. 004 | . 106 | . 080 |
|  | (1.80) | (0.003) | (3.90) | (2.03) |
| IDECAY | . 230 | . 068 | . 188 | . 007 |
|  | (10.23) | (1.04) | (13.07) | (0.02) |
| PFHEALTH | . 011 | . 007 | . 005 | . 025 |
|  | (0.49) | (0.25) | (0.25) | (5.00) |

${ }^{\text {a }}$ Source: Appendix, Tables Al-A7. $F$ statistics in parentheses. The critical $F$ values at the 5 percent level of significance are 2.69 on a one-tailed test and 3.84 on a two-tailed test.
about the same number of effects are significant in each sample. While no overall pattern of effects is apparent for the health measures, our results suggest that mother's participation in the labor market has a greater detrimental effect on the children in high income families than on those in low income families. Interpretation of this finding is subject to the caution that unlike other parental characteristics, mother's labor force status changes over the child's early life cycle. Our work status variables provide information only on the primary activity of the mother at the time of the Health Examination Survey. Before firm conclusions can be reached with respect to the role of mother's labor force status in the determination of children's health and development, the effects of length of participation and of the life cycle pattern of participation would also have to be examined.

Regression coefficients of the number of persons in the household 20 years of age or less are presented in Table 8. This variable serves as a proxy for completed family size. It has negative and statistically significant effects on the three measures of intellectual development. The effects of number of children in the family on health are more erratic. When health is defined in a positive manner, six of the eight regression coefficients are negative, but only four are statistically significant. A striking finding is the importance of family size in the determination of the height of children from low income families and its unimportance in the determination of the height of children from high income families.

When health is measured by height, a consistent pattern of results emerges from Tables 6, 7, and 8. Parents' schooling, mother's work

TABLE 8

Regression Coefficients of Number of Persons in Household 20 Years of Age or Less ${ }^{\text {a }}$

|  | Income < \$7,000 | Income > \$7,000 |
| :---: | :---: | :---: |
| Dependent |  |  |
| Variable | LESS20 | LESS20 |
| WISC | -. 620 | -. 720 |
|  | (13.44) | (10.03) |
| RWRAT | -. 808 | -. 745 |
|  | (19.03) | (11.82) |
| AWRAT | -. 354 | -. 468 |
|  | (3.54) | (5.21) |
| IHEIGHT | -. 060 | -. 022 |
|  | (18.92) | (1.63) |
| IPERI | . 013 | -. 00001 |
|  | (0.72) | (0.00) |
| IDECAY | . 027 | . 048 |
|  | (3.39) | (12.73) |
| PFHEALTH | . 006 | -. 001 |
|  | (3.49) | (0.28) |
|  |  |  |

${ }^{\mathrm{a}}$ Source: Appendix, Tables Al-A7. F statistics in parentheses. The critical $F$ values at the 5 percent level of significance are 2.69 on a one-tailed test and 3.84 on a two-tailed test.
status, and family size are significant predictor variables of height in the low income sample but not in the high income sample. On the other hand, these three variables tend to be as important (or more important) predictors of development in the hign income sample as in the low income sample. A possible explanation of this pattern is that investments in certain kinds of health are subject to more sharply diminishing returns than investments in intellectual development. If so, determinants of the marginal cost of investment in health would have relatively small effects in the reduced form demand curve at relatively high levels of health and investment.

Table 9 contains regression coefficients of health endowments measured in infancy. In discussing this set of variables, we focus on the effects of birth weight and breast-feeding on intellectual development. The dummy variable for birth weight under 2,500 grams or 5 pounds (LIGHT) has significant, negative effects on all measures of development in both high and low income samples. Somewhat surprisingly, absolute effects are larger in the high income sample than in the low income sample. Intuitively, one might expect high income parents to compensate more for the effects of low birth weight than low income parents by making relatively larger investments in the health and intéliectual development of the poorly endowed child. Subject to some modifications spelled out in Section $I$, our finding is consistent with a model in which birth weight is a positive correlate of efficiency in production and a positive correlate of the endowment.
TABLE 9
$e^{\text {nouefui ut yaxnseon squəumopug प7teon } \ddagger 0 \text { squototafoon uorssexbay }}$

| Dependent Variable | Income < \$7,000 |  |  |  |  |  | Income $\geq$ \$7,000 |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | FYPH | IMMAG | IMMAG35 | II:1AG40 | MIBPED | I/IGHT | FYPH | LMAG | HMAG35 | HMAG40 | MBFED | LIGHT |
| WISC | $\begin{array}{r} .119 \\ (0.02) \end{array}$ | $\begin{aligned} & -2.213 \\ & (5.20) \end{aligned}$ | $\begin{array}{r} 2.634 \\ (6.13) \end{array}$ | $\begin{aligned} & -1.730 \\ & (1.00) \end{aligned}$ | $\begin{array}{r} 1.931 \\ (1.0 .56) \end{array}$ | $\begin{gathered} -2.343 \\ (4.03) \end{gathered}$ | $\begin{aligned} & -2.523 \\ & (4.42) \end{aligned}$ | $\begin{gathered} -1.201 \\ (0.55) \end{gathered}$ | $\begin{array}{r} .887 \\ (0.62) \end{array}$ | $\begin{array}{r} -.190 \\ (0.01) \end{array}$ | $\begin{array}{r} 2.231 \\ (10.21) \end{array}$ | $\begin{gathered} -5.584 \\ (14.15) \end{gathered}$ |
| RWRAT | $\begin{gathered} -1.284 \\ (1.63) \end{gathered}$ | $\begin{gathered} -.668 \\ (0.40) \end{gathered}$ | $\begin{array}{r} 1.966 \\ (2.85) \end{array}$ | $\begin{gathered} -.038 \\ (0.00) \end{gathered}$ | $\begin{array}{r} 1.785 \\ (7.53) \end{array}$ | $\begin{aligned} & -2.411 \\ & (3.56) \end{aligned}$ | $\begin{array}{r} -1.615 \\ (1.99) \end{array}$ | $\begin{gathered} -1.173 \\ (0.58) \end{gathered}$ | $\begin{aligned} & -.100 \\ & (0.01) \end{aligned}$ | $\begin{array}{r} .164 \\ (0.01) \end{array}$ | $\begin{array}{r} 2.072 \\ (9.69) \end{array}$ | $\begin{gathered} -5.139 \\ (13.19) \end{gathered}$ |
| AWRAT | $\begin{aligned} & -.505 \\ & (0.25) \end{aligned}$ | $\begin{array}{r} -.645 \\ (0.36) \end{array}$ | $\begin{array}{r} .991 \\ (0.70) \end{array}$ | $\begin{gathered} -.431 \\ (0.05) \end{gathered}$ | $\begin{array}{r} 2.258 \\ (11.67) \end{array}$ | $\begin{array}{r} -4.619 \\ (12.64) \end{array}$ | $\begin{aligned} & -1.551 \\ & (2.05) \end{aligned}$ | $\begin{array}{r} -.925 \\ (0.40) \end{array}$ | $\begin{aligned} & -.296 \\ & (0.08) \end{aligned}$ | $\begin{array}{r} -1.823 \\ (0.86) \end{array}$ | $\begin{array}{r} .903 \\ (2.05) \end{array}$ | $\begin{array}{r} -4.767 \\ (12.67) \end{array}$ |
| IHEJGHT | $\begin{gathered} -.074 \\ (0.97) \end{gathered}$ | $\begin{aligned} & -.145 \\ & (3.36) \end{aligned}$ | $\begin{gathered} .190 \\ (4.80) \end{gathered}$ | $\begin{gathered} -.094 \\ (0.44) \end{gathered}$ | $\begin{array}{r} .098 \\ (4.08) \end{array}$ | $\begin{array}{r} -.363 \\ (14.50) \end{array}$ | $\begin{gathered} -.233 \\ (6.75) \end{gathered}$ | $\begin{gathered} -.274 \\ (5.14) \end{gathered}$ | $\begin{array}{r} .155 \\ (3.37) \end{array}$ | $\begin{gathered} -.203 \\ (1.54) \end{gathered}$ | $\begin{array}{r} .017 \\ (0.10) \end{array}$ | $\begin{array}{r} -.404 \\ (13.17) \end{array}$ |
| IPERI | $\begin{array}{r} .083 \\ (0.96) \end{array}$ | $\begin{array}{r} .207 \\ (5.32) \end{array}$ | $\begin{array}{r} .018 \\ (0.03) \end{array}$ | $\begin{aligned} & -.130 \\ & (0.66) \end{aligned}$ | $\begin{array}{r} .017 \\ (0.09) \end{array}$ | $\begin{array}{r} .032 \\ (0.09) \end{array}$ | $\begin{array}{r} .184 \\ (6.20) \end{array}$ | $\begin{array}{r} .115 \\ (1.33) \end{array}$ | $\begin{array}{r} .068 \\ (0.95) \end{array}$ | $\begin{array}{r} -.119 \\ (0.79) \end{array}$ | $\begin{gathered} -.013 \\ (0.09) \end{gathered}$ | $\begin{array}{r} .063 \\ (0.47) \end{array}$ |
| IDECAY | $\begin{array}{r} .157 \\ (3.98) \end{array}$ | $\begin{array}{r} .182 \\ (4.77) \end{array}$ | $\begin{array}{r} .032 \\ (0.13) \end{array}$ | $\begin{array}{r} .095 \\ (0.41) \end{array}$ | $\begin{array}{r} -.032 \\ (0.39) \end{array}$ | $\begin{array}{r} .024 \\ (0.06) \end{array}$ | $\begin{array}{r} .252 \\ (12.38) \end{array}$ | $\begin{gathered} .024 \\ (0.06) \end{gathered}$ | $\begin{array}{r} .116 \\ (2.95) \end{array}$ | $\begin{aligned} & .136 \\ & (1.10) \end{aligned}$ | $\begin{aligned} & -.026 \\ & (0.38) \end{aligned}$ | $\begin{array}{r} -.156 \\ (3.10) \end{array}$ |
| PFHEALTH | $\begin{array}{r} .197 \\ (124.41) \end{array}$ | $\begin{gathered} -.011 \\ (0.33) \end{gathered}$ | $\begin{array}{r} .001 \\ (0.01) \end{array}$ | $(0.38)$ | $\begin{array}{r} .002 \\ (0.03) \end{array}$ | $\begin{aligned} & -.006 \\ & (0.07) \end{aligned}$ | $\begin{array}{r} .142 \\ (93.04) \end{array}$ | $\begin{gathered} -.043 \\ (4.70) \end{gathered}$ | $\begin{array}{r} .021 \\ (2.38) \end{array}$ | $\begin{gathered} -.046 \\ (2.94) \end{gathered}$ | $\begin{array}{r} -.007 \\ (0.59) \end{array}$ | $\begin{gathered} -.018 \\ (0.99) \end{gathered}$ |

The coefficient of the dummy variable for breast-feeding (MBFED) indicates substantial returns to this activity in terms of cognitive development. While each discipline may offer its own interpretation of this result, a plausible explanation is that MBFED serves as an auxiliary measure of both the amount of time mothers spend with their children and families' tastes for children.

Regression coefficients of health endowments measured currently are presented in Table 10. All of these are based on the physical examinations administered in the Health Examination Survey. Once again we focus on endowment effects in the development functions. All six coefficients of abnormal hearing (IHEAR) are negative, and five of the six are statistically significant. It is not surprising that the impact of poor hearing is larger in the case of school achievement than in the case of IQ. The importance of poor hearing in the determination of school achievement is revealed by the following comparison. In the high income sample, with all other factors held constant, children with poor hearing have a RWRAT score that is approximately 14 points lower than children with normal hearing. This difference is twice as large as the 7 point difference in the mean RWRAT score in the high income sample as compared to the low income sample. The presence of significant abnormalities (ABN) also is detrimental to achievement and $I Q$, although the effects are insignificant in the high income sample. To a large extent, the last result is due to the very low prevalence of abnormalities (. 17 percent) in the high income sample.

Strictly speaking the vision variables in Table 10 (SEEG, NSEEG, SEENG) cannot be interpreted as endowments because they combine
table 10


| Dependent <br> Variable | Income < \$7,000 |  |  |  |  | Income $\geq$ \$ 7,000 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | IHEAR | SEEG | NSEEG | SEENG | ABN | IHEAR | SEEG | nseEg | SEENG | ABN |
| WISC | $\begin{gathered} -3.181 \\ (1.06) \end{gathered}$ | $\begin{gathered} 1.860 \\ (2.55) \end{gathered}$ | $\begin{gathered} -1.555 \\ (1.40) \end{gathered}$ | $\begin{array}{r} 1.483 \\ (1.32) \end{array}$ | $\begin{array}{r} -12.709 \\ (9.68) \end{array}$ | $\begin{aligned} & -8.209 \\ & (2.99) \end{aligned}$ | $\begin{array}{r} 2.208 \\ (4.24) \end{array}$ | $\begin{aligned} & -1.543 \\ & (1.06) \end{aligned}$ | $\begin{array}{r} .604 \\ (0.20) \end{array}$ | $\begin{aligned} & -6.508 \\ & (0.80) \end{aligned}$ |
| RWRAT | $\begin{aligned} & -8.099 \\ & (5.72) \end{aligned}$ | $\begin{array}{r} .527 \\ (0.17) \end{array}$ | $\begin{gathered} -1.217 \\ (0.72) \end{gathered}$ | $\begin{array}{r} 2.293 \\ (2.62) \end{array}$ | $\begin{aligned} & -5.424 \\ & (1.47) \end{aligned}$ | $\begin{gathered} -14.497 \\ (10.26) \end{gathered}$ | $\begin{array}{r} 2.536 \\ (6.16) \end{array}$ | $\begin{array}{r} -.430 \\ (0.09) \end{array}$ | $\begin{array}{r} .423 \\ (0.11) \end{array}$ | $\begin{gathered} -2.922 \\ (0.18) \end{gathered}$ |
| AWRAT | $\begin{aligned} & -8.735 \\ & (6.45) \end{aligned}$ | $\begin{gathered} -.134 \\ (0.01) \end{gathered}$ | $\begin{gathered} -1.034 \\ (0.50) \end{gathered}$ | $\begin{array}{r} .361 \\ (0.06) \end{array}$ | $\begin{array}{r} -10.574 \\ (5.42) \end{array}$ | $\begin{array}{r} -10.986 \\ (6.58) \end{array}$ | $\begin{array}{r} 2.523 \\ (6.81) \end{array}$ | $\begin{array}{r} 1.600 \\ (1.40) \end{array}$ | $\begin{aligned} & 1.760 \\ & (2.06) \end{aligned}$ | $\begin{gathered} -6.573 \\ (1.00) \end{gathered}$ |
| IHEIGHT | $\begin{array}{r} -.251 \\ (0.98) \end{array}$ | $\begin{array}{r} .193 \\ (4.12) \end{array}$ | $\begin{array}{r} .228 \\ (4.51) \end{array}$ | $\begin{array}{r} .107 \\ (1.03) \end{array}$ | $\begin{gathered} -.146 \\ (0.19) \end{gathered}$ | $\begin{array}{r} -.139 \\ (0.15) \end{array}$ | $\begin{array}{r} .057 \\ (0.50) \end{array}$ | $\begin{array}{r} -.020 \\ (0.03) \end{array}$ | $\begin{array}{r} .051 \\ (0.25) \end{array}$ | $\begin{gathered} -1.380 \\ (6.39) \end{gathered}$ |
| IPERI | $\begin{array}{r} .320 \\ (1.25) \end{array}$ | $\begin{array}{r} .164 \\ (2.32) \end{array}$ | $\begin{array}{r} .305 \\ (6.26) \end{array}$ | $\begin{array}{r} .010 \\ (0.01) \end{array}$ | $\begin{array}{r} -.002 \\ (0.00) \end{array}$ | $\begin{array}{r} .167 \\ (0.33) \end{array}$ | $\begin{array}{r} .002 \\ (0.001) \end{array}$ | $\begin{gathered} -.033 \\ (0.13) \end{gathered}$ | $\begin{array}{r} .175 \\ (4.37) \end{array}$ | $\begin{array}{r} .582 \\ (1.68) \end{array}$ |
| IDECAY | $\begin{gathered} -.014 \\ (0.00) \end{gathered}$ | $\begin{array}{r} -.182 \\ (3.32) \end{array}$ | $\begin{array}{r} -.127 \\ (1.27) \end{array}$ | $\begin{aligned} & -.163 \\ & (2.16) \end{aligned}$ | $\begin{array}{r} .529 \\ (2.27) \end{array}$ | $\begin{array}{r} -.296 \\ (1.09) \end{array}$ | $\begin{array}{r} .008 \\ (0.01) \end{array}$ | $\begin{gathered} -.120 \\ (1.80) \end{gathered}$ | $\stackrel{-.082}{(1.01)}$ | $\begin{array}{r} 1.025 \\ (5.55) \end{array}$ |
| PFHEALTH | $\begin{array}{r} .235 \\ (15.58) \end{array}$ | $\begin{array}{r} -.009 \\ (0.17) \end{array}$ | $\begin{array}{r} -.040 \\ (2.55) \end{array}$ | $\begin{aligned} & -.036 \\ & (2.08) \end{aligned}$ | $\begin{array}{r} .175 \\ (4.94) \end{array}$ | $\begin{array}{r} -.010 \\ (0.03) \end{array}$ | $\begin{array}{r} .012 \\ (0.89) \end{array}$ | $\begin{gathered} -.004 \\ (0.05) \end{gathered}$ | $\begin{array}{r} .005 \\ (0.08) \end{array}$ | $\begin{array}{r} -.057 \\ (0.40) \end{array}$ |

information on uncorrected vision with information on whether the child wears glasses. Nevertheless, these variables convey useful information concerning the impact of investment in vision on intellectual development. ${ }^{6}$ In particular, the difference between the coefficient of SEEG and the coefficient of SEENG compares children with abnormal uncorrected vision who wear glasses to children with abnormal uncorrected vision who do not wear glasses. These differences are shown in Table 11. In general investment in improved vision has a positive payoff in terms of intellectual development in the high income sample but not in the low income sample. Kessner (1974) reports that 40 percent of children in a low income sample who were tested with their glasses failed a visual acuity test. It is plausible that this percentage would be much smaller in a high income sample due to the receipt of higher quality optometric services by children in such a sample. If so, this provides an explanation of the results in Table 11 and evidence that the returns to appropriate vision correction might be substantial. 7
${ }^{6}$ A similar coment can be made with regard to hearing since children with endowed (uncorrected) abnormal hearing might have had their hearing corrected by investment. Such children cannot be identified in the sample. In the case of vision, since children who wear eyeglasses were examined without them, only endowed (uncorrect) abnormal vision can be identified precisely. Information on the use of eyeglasses was added to the regressions to make the results more comparable to those for poor hearing. Moreover, this procedure controls in part for reverse causality from intellectual development to poor vision due to excessive use of the eyes.
${ }^{7}$ The positive and significant coefficients of SEEG in the high income sample indicate that children with abnormal uncorrected vision who wear glasses have higher intellectual development scores than children with normal uncorrected vision who do not wear glasses. This might reflect a negative correlation between SEEG and the price of medical care, or it might reflect reverse causality from development to SEEG.

## TABLE 11 <br> Difference Between Coefficients of SEEG and SEENG in Intellectual Develonment Rearessions

| Devendent <br> Variable | Income $<\$ 7,000$ <br> Difference | Income $\geq \$ 7,000$ <br> WISC |
| :--- | :---: | :---: |
| DWRAT | .377 | 1.604 |
| AWRAT | -1.766 | 2.113 |
|  | -.495 | .763 |

C. Summary

A stated goal of public policy in the United States is to improve the economic and social well-being of certain groups of children by improving their cognitive develomment and health. To allocate scarce resources among competing programs with respect to children, policymakers require information about the dollar costs and benefits of these programs. Clearly, our results cannot supply policy-makers with all of this information. We have no measures of the costs of raising health or develomment via alternative programs such as those aimed at reducing the incidence of low birtin weight or lowering completed family size. Nor do we have measures of the dollar values of the benefits of such programs. Nevertheless, our results do contain policy relevant insights about potential benefits in terms of "physical" (health or cognitive development) units. Policy-makers are then free to assign whatever set of weights they choose to these "physical" units and can thereby translate increments in health or development into monetary magnitudes.

Further, our results are useful whether or not the mechanism by which a given variable alters health or development is fully understood. In the case where the mechanism is known, our results can be used to identify the appropriate kinds of government intervention. A case in point is the theoretical and empirical role of family income. Here we feel confident that the basic force at work is command over real resources provided by income. Alternatively, when effects of certain variables are large but mechanisms are not well understood, our findings
suggest the nature of additional research that is required to formulate public policy, rather than the appropriate policies per se. Consider for example, our result that parents' schooling is an important determinant of the height of children from low income families. This result has a very definite policy implication if the mechanism at work is a positive correlation between schooling and nutritional intakes or between schooling and knowledge of what constitutes an appropriate diet. The policy implication is much less clearcut if the mechanism at work is a positive relationship between parents' schooling and genetic inheritance.

Our major findings are:

1. The prediction of two distinct regimes or two different relationships between each of our health and development variables and the set of explanatory variables is generally supported by our results. Statistically significant differences in the sets of coefficients for the two income classes are reported for five of seven dependent variables. Although these results cannot be characterized as "unanimous" support for the basic structure of our model, they do constitute stronger verification than may be initially apparent. The two income classes used here are unlikely to coincide completely with the two regimes specified by the model. The resulting misclassification of observations will tend to bias the coefficient in the two income classes towards equality, making it more difficult to obtain significantly different coefficients in the two income classes even though such differences do exist in the two regimes. We observe significant differences in coefficients for five of our seven variables despite this bias towards finding no such difference.
2. The prediction that income will have a positive effect on health or development for families in Regime 1 and no effect in Regime 2 receives weaker support in our results. For the two achievement measures, income has a positive, significant impact for lower income families and a nonsignificant impact for upper income families. For the other dependent variables, family income is either statistically significant in both income classes or in neither income class. One likely explanation for the significant coefficients in the upper income class is the previously mentioned bias resulting from the misclassification of observations. In particular, it is likely that members of Regime 1 are erroneously included in the over $\$ 7,000$ income class, causing an upward bias in the coefficient of income for that class.
3. When health is measured by height, parents' schooling, mother's work status, and family size are significant predictor variables in the low income sample but not in the high income sample. On the other hand, these three variables tend to be as important (or more important) predictors of intellectual development in the high income sample as in the low income sample.
4. Health endowment and investment measures have significant, positive effects on cognitive development. In particular, cognitive development scores are higher when children weighed more than five pounds at birth, when they were breast-fed, when their current hearing is normal, and when abnormal uncorrected vision is corrected by the use of eyeglasses. These findings suggest that prenatal and pediatric care programs that could identify high risk mothers and children at modest cost would have relatively high expected benefits.

Finally, our findings highlight at least two fruitful areas for future research. One is an investigation of the extent to which endogenous current health measures affect intellectual development. The second is an investigation of health and development relationships at later stages in the child's life cycle. Both of these will contribute further to our understanding of how health and development interact and will provide more refined measures of benefits from investments in children's health.

TABLE AI
Ordinary Least squares Regressions of WISC
Regressions include 3 region and 4 residence dummy variables


TABLE $A Q$
Ordinary Least Squares Regressions of RWRAT
Regressions include 3 region and 4 residence dummy variables


TABLE AB
Ordinary least squares Regressions of AWRAT
Regressions include 3 region and 4 residence dummy variables


TABLE A 4
Ordinary Least squares Regressions of I HEIGHT Regressions include 3 region and 4 residence dummy variables


TABLE AS
Ordinary Least Squares. Regressions of IPERI
Regressions include 3 region and 4 residence dummy variables


TABLE AG
Ordinary Least squares Regressions of IDECAY Regressions include 3 region and 4 residence dummy variables


TABLE AT.
Ordinary Least squares Regressions of PFHEALTH
Regressions include 3 region and 4 residence dummy variables.


TABLE A 8
Ordinary Least Squares Regressions of WISC Regressions include 3 region and 4 residence dummy variables


TABLE Aq
Ordinary Least squares Regressions of RWRAT Regressions include 3 region and 4 residence dummy variables


TABLE A IO
Ordinary Least Squares Regressions of AWRAT Regressions include 3 region and 4 residence dummy variables


TABLE All
Ordinary Least Squares Regressions of IHEIGHT Regressions include 3 region and 4 residence dummy variables


TABLE AIR
Ordinary Least squares Regressions of IPERI Regressions include 3 region and 4 residence dummy variables


TABLE AI 3
Ordinary Least Squares Regressions of IDECAY Regressions include 3 region and 4 residence dummy variables


TABLE A! 4
Ordinary Least Squares Regressions of PFHEALTH: Regressions include 3 region and 4 residence dummy variables


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[^0]:    1
    For a partial survey of the literature on relationships among earnings, schooling, health, and intelligence of adults and children, see Grossman (1975).

[^1]:    16
    The literature on household production functions commonly treats parental education as an efficiency variable.

[^2]:    ${ }^{2}$ The full Cycle II sample contains 6,100 whites, 987 blacks, and 32 "others."
    ${ }^{3}$ Natural parents cannot be distinguished from adopted parents. Our procedure eliminates children who live with foster parents, stepparents, guarcians, or single, widowed, or divorced parents. It is designed to control for the effects of marital instability. We also exclude the 72 children who turned twelve by the time they had been examined.

[^3]:    ${ }^{8}$ It is well-known (for example, Bloom 1964) that physical growth rates differ by age and sex. For any observation IHEIGHT is the difference between the child's actual height and the mean height for his or her agesex group divided by the standard deviation of height for that age-sex group. If the actual height of each age-sex group is normally distributed, this standardized measure could be directly translated into the child's height percentile.

[^4]:    22
    See Becker and Lewis (1973).

[^5]:    a Thousands of dollars.

[^6]:    ${ }^{1}$ Estimates by sex are shown in Tables A-B through A-14.

[^7]:    4 Recall that IPERI, IDECAY, and PFHEALTH are neqative correlates of children's health.

[^8]:    ${ }^{5}$ The coefficient of MWORKPT on RWRAT in the high income sample is positive and significant.

