NBER WORKING PAPER SERIES

EDUCATION AND NONMARKET OUTCOMES

Michael Grossman

Working Paper 11582
http://www.nber.org/papers/w11582

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
August 2005

Education and Nonmarket Outcomes
Michael Grossman
NBER Working Paper No. 11582
August 2005
JEL No. I10, I20

ABSTRACT

I explore the effects of education on nonmarket outcomes from both theoretical and empirical perspectives. Examples of outcomes considered include general consumption patterns at a moment in time, savings and the rate of growth of consumption over time, own (adult) health and inputs into the production of own health, fertility, and child quality or well-being reflected by their health and cognitive development. I pay a good deal of attention to the effects of education on health because they are the two most important sources of human capital: knowledge capital and health capital. There is a large literature addressing the nature of their complementarities. In the conceptual foundation section, I consider models in which education has productive efficiency and allocative efficiency effects. I then modify these frameworks to allow for the endogenous nature of schooling decisions, so that observed schooling effects can be traced in part to omitted "third variables" such as an orientation towards the future. An additional complication is that schooling may contribute to a future orientation. The empirical review provides a good deal of evidence for the proposition that the education effects are causal but is less conclusive with regard to the identification of specific mechanisms.

Michael Grossman
PhD Program in Economics
CUNY Graduate Center
365 Fifth Avenue, 5th Floor
New York, NY 10016-4309
and NBER
mgrossman@gc.cuny.edu

1. Introduction

Are more educated people healthier? Are they less likely to smoke cigarettes, more likely to quit smoking if they do smoke, and less likely to be obese? Are they more likely to have fewer children, healthier children, and better educated children? Do their consumption patterns differ from those of persons with less education? These are examples of the potential nonmarket outcomes of education that are considered in this chapter. I define these outcomes as those associated with the time that the consumer does not spend in the labor market, and I distinguish them from the labor market outcomes of education in terms of higher earnings and wage rates.

Until the early 1960s, treatments of the effects of education on nonmarket outcomes or behaviors were not explored by economists. The argument was that the impacts of variables other than real income or real wealth and relative prices must operate through tastes, and economists had little to say about the formation of tastes. Gary S. Becker changed all that, and this chapter is heavily influenced by his contributions [Becker (1960, 1965, 1991, 1996), Becker and Lewis (1973), Becker and Murphy (1988), Becker and Mulligan (1997)]. In his early work, Becker introduced the idea that consumers produce their fundamental objects of choice, called commodities, in the nonmarket sector using inputs of market goods and services and their own time. Education is quite likely to influence the efficiency of these production processes. Thus it may affect the absolute and relative marginal costs or shadow prices of home produced commodities and real income evaluated at shadow prices, with market prices of goods and money income held constant. In his later work, Becker stressed that the determinants and consequences of addictions, time preference, and other variables typically labeled as tastes can be approached by standard economic models of rational behavior, with important implications

for the role of schooling in decisions pertaining to, for example, the rate of growth in consumption with age, savings, investment in children, and consumption of harmfully addictive substances.

In the next section of this chapter, I outline several conceptual frameworks that generate effects of education on nonmarket outcomes. Empirical evidence with regard to these effects is summarized and critiqued in the sections that follow. The focus is on identifying causal effects of education and on mechanisms via which these effects operate. Before proceeding, a few comments on the scope of the chapter are in order.

First, the knowledge that a person has acquired through schooling is imbedded within himself and accompanies him wherever he goes: to the labor market where money earnings are produced, to the doctor where health is produced, to the bedroom where sexual satisfaction and perhaps children are produced, to plays and movies where entertainment is produced, and to the tennis court and the ski slope where exercise and recreation are produced. If knowledge and traits acquired through schooling influence decisions made at work, they are just as likely to influence decisions made with regard to cigarette smoking, the types of food to eat, the type of contraceptive technique to use, and the portion of income to save. While these examples suggest an infinite number of nonmarket outcomes that may be influenced by education, I keep the scope of this chapter manageable by considering a few. They include general consumption patterns at a moment in time, savings and the rate of growth of consumption over time, own (adult) health and inputs into the production of own health, fertility, and child quality or well-being reflected by their health and cognitive development.[1]

Second, I pay a good deal of attention to the effects of education on health for a variety of reasons. They are the two most important sources of human capital: knowledge capital and

health capital. They interact in their levels and in the ways they affect the cost and usefulness of the other. There is a large literature addressing the nature of their complementarities. While each affects the production and usefulness of the other, there are important dynamics of their interaction, seen in the age-structure of the net and gross production of the two. This sequencing also affects their optimal amounts.

Finally, my survey of the literature is meant to be selective rather than definitive. I highlight studies, mostly from the 1970s and early 1980s, that laid the foundations for empirical investigations of the impacts of schooling on nonmarket outcomes. I also highlight very recent research that focuses on mechanisms and causality. The reader can fill in the gaps by consulting the studies that I cite.

2. Conceptual foundations

2.1. Productive efficiency

Becker's (1965) model of the allocation of time serves as the point of departure for approaches that assume that increases in knowledge capital, in general, and education or years of formal schooling completed, in particular, (from now on these two terms are used as synonyms) raise efficiency in the nonmarket sector. Becker draws a sharp distinction between fundamental objects of choice--called commodities--that enter the utility function and market goods and services. Consumers produce these commodities using inputs of market goods and services and their own time.

In seminal contributions to the literature, Michael (1972b, 1973) develops theoretical tools to study the effects of variations in nonmarket efficiency. In the context of a static or one-period model, consumers maximize a utility function given by

$$U = U(Z_1, Z_2,\ldots,Z_n), \tag{1}$$

where each Z_i (i = 1, 2,…,n) is a commodity produced in the nonmarket or household sector. The set of household production functions is given by

$$Z_i = e^{\rho_i S} F_i(X_i, T_i), \tag{2}$$

where X_i is a market good or service input, T_i is an input of the own time of the consumer, S is a measure of the efficiency of the production process, and ρ_i is a positive parameter. Each production function is linear homogeneous in X_i and T_i. For simplicity, I assume that each production process uses a single unique good or service purchased in the market and a single unique own time input. Conceptually, X_i and T_i could be treated as vectors rather than scalars, and joint production (an increase in X_i raises Z_i and simultaneously raises or lowers other commodities) could be introduced. These modifications are useful when the commodities can be measured empirically, but are ruled out in Michael's empirical applications. I will return to these issues below.

The efficiency variable S in equation (2) coincides with the consumer's stock of knowledge or human capital, a theoretical concept, and operationalized by the number of years of formal schooling that he or she has completed. Of course, the stock of human capital depends on such additional factors as the quality of schooling, on-the-job training, and health capital, but the focus of this chapter is on the effects of schooling. Health is treated as one of the outputs of household production and is discussed in detail both theoretically and empirically later in the chapter. While the goods and time inputs are endogenous variables, schooling is predetermined. Complications due to the endogeneity of schooling are addressed after the basic model is developed.

Since each production function is linear homogeneous in the goods and time inputs, an

increase in S raises each commodity only if it raises the marginal products of the inputs on average. In fact, according to equation (2), an increase in S raises the marginal product of X_i and T_i by the same percentage (ρ_i). This is the Hicks- or factor-neutrality assumption applied to production in the nonmarket sector. As is the case with the other assumptions just made, Michael (1972, 1973b) requires it in his empirical work but not in the theoretical development of his model.

Michael makes empirical predictions about the impacts of schooling on the demand for commodities and market goods by considering variations in schooling, with money "full income" (the sum of property income and earnings when all available time is allocated to work in the market), the prices of market goods, and wage rates held constant. Because the more educated are more efficient, the marginal or average cost of each commodity is lower for them than for the less educated. Indeed, since a one unit increase in education raises the marginal products of X_i and T_i by ρ_i percent and since the Z_i production function is linear homogeneous in these two inputs, the marginal cost or average cost or "shadow price" of Z_i falls by ρ_i percent. Hence, with money full income evaluated at shadow prices held constant, real full income rises by ρ percent:

$$\rho = \sum_{i=1}^{n} k_i \rho_i , \tag{3}$$

where k_i is the share of Z_i in full income.[2] Since real income rises, an increase in education raises the demand for commodities with positive income elasticities. In addition, there may be substitution effects since relative commodity prices will change unless ρ_i is the same for each commodity.

Define the schooling parameter in the demand function for Z_i as $\tilde{Z}_i \equiv \partial \ln Z_i / \partial S$, and

keep in mind that this parameter summarizes an effect that holds money income, the prices of market goods, and the wage rate constant. This parameter is given by

$$\tilde{Z}_i = \eta_i \rho - k_i \sigma_{ii} \rho_i - \sum_{j \neq i=1}^{n} k_j \sigma_{ij} \rho_j, \tag{4}$$

where η_i is the income elasticity of demand for Z_i, $\sigma_{ii} < 0$ is the Allen own partial elasticity of substitution in consumption of Z_i, and σ_{ij} is the Allen cross partial elasticity of substitution in consumption between Z_i and Z_j. Given that Z_i is a superior commodity, the first term on the right-hand side of equation (4) is positive. The second term reflects an own substitution effect and also is positive. The third term reflects cross price effects and is negative since σ_{ij} is positive on average unless the prices of commodities that are strong complements to Z_i fall substantially (ρ_j is large when σ_{ij} is negative and large in absolute value).

Since most of the Z commodities cannot be measured empirically, assume that all cross partial elasticities of substitution in consumption are the same ($\sigma_{ij} = \sigma > 0$). Hence,[3]

$$\tilde{Z}_i = \eta_i \rho + \sigma(\rho_i - \rho). \tag{5}$$

According to equation (5), the quantity of Z_i demanded unambiguously rises as schooling rises provided more schooling raises marginal products in the Z_i production function by the same percentage as on average or by a greater percentage than on average ($\rho_i \geq \rho$). The sign of $\tilde{Z}_i$ is ambiguous if the reverse holds ($\rho_i < \rho$).

From equation (5), the schooling parameter in the demand function for the market good or service input in the production function of Z_i (X_i) is[4]

$$\tilde{X}_i = (\eta_i - 1)\rho + (\sigma - 1)(\rho_i - \rho). \tag{6}$$

Equation (6) highlights that changes in the quantity of X_i consumed as schooling rises close the gap between the percentage change in the quantity of Z_i demanded [$\eta_i \rho + \sigma(\rho_i - \rho)$] and the

percentage increase in the quantity of Z_i supplied by fixed amounts of the good and time inputs (ρ_i). Three pieces of information are required to predict the sign of $\tilde{X}_i$: (1) whether η_i is greater than, smaller than, or equal to one; (2) whether σ is greater than, equal to, or smaller than one; and (3) whether ρ_i is greater than, equal to, or smaller than ρ. Information on the third item would be available only if the full set of household production functions were estimated. If one could do this, one might not want to assume that all the partial elasticities of substitution in consumption are the same. But then one would need to estimate the full set of these elasticities.

Given the problems just mentioned, Michael (1972, 1973b) assumes that all ρ_i are the same and equal to ρ. He terms this assumption "commodity neutrality." It implies that relative prices remain the same and that no substitution effects accompany increases in education. Equation (6) becomes

$$\tilde{X}_i = (\eta_i - 1)\rho \gtrless 0 \text{ as } \eta_i \gtrless 1. \tag{7}$$

In words, an increase in schooling increases the demand for goods inputs associated with commodities that have income elasticities greater than one, reduces the demand for goods inputs associated with commodities that have income elasticities less than one, and has no impact on goods inputs associated with commodities that have income elasticities equal to one. This is the empirical test of the hypothesis that education has a productive efficiency effect devised by Michael. It can be implemented with detailed cross-sectional data on outlays on goods and services for items that exhaust total consumption. For each item, estimate an Engel curve that relates expenditures on that item to income and schooling. If the resulting income elasticity of demand for the item exceeds one, the schooling coefficient should be positive, while the schooling coefficient should be negative if the income elasticity is less than one. Schooling

effects should be zero for items with unitary income elasticities.[5] Put differently, with money income held constant, an increase in education should cause a reallocation of consumption expenditures towards luxuries and away from necessities. This same test could be applied to time budget surveys, although these surveys are less numerous and less detailed than consumer expenditure surveys.

2.1.1. Productive efficiency, total consumption, and hours of work

A modified version of Michael's (1972, 1973b) model can be employed to study the effect of an increase in schooling on total consumption and hours of work when schooling varies, with the wage rate and property income held constant.[6] Suppose that the utility function is

$$U = U(Z, X) = U(e^{\rho_Z S}T, X)$$

In this formulation, utility depends on a single good purchased in the market (X) and a commodity produced at home (Z) with a time input (T) alone. The marginal product of the time input $\left(e^{\rho_Z S}\right)$ rises as schooling rises. Obviously, since there is only one use of time in the nonmarket, T corresponds to leisure and is given by the difference between total available time and time allocated to work in the market. It can be measured as long as data on working time are available.

Consider demand functions for T and X that depend on the wage rate, property income, and schooling. The schooling parameters in these demand functions ($\tilde{T}$ and $\tilde{X}$, respectively) are

$$\tilde{T} = \{[k\eta_Z + (1-k)\sigma_{ZX} - 1]\}\rho_Z \qquad (9)$$

$$\tilde{X} = \left[\frac{k}{1-k}\right]\left[1 - k\eta_Z - (1-k)\sigma_{ZX}\right]\rho_Z. \qquad (10)$$

In these equations, k is the share of Z in full income, η_Z is the income elasticity of demand for Z or T and σ_{ZX} is the elasticity of substitution in consumption between Z or T and X. Note that $k\eta_Z + (1- k)\sigma_{ZX}$ defines absolute value of the uncompensated price elasticity of demand for Z (ε_Z). Hence, the quantity of leisure or nonmarket time is positively related to schooling and total consumption is negatively related to schooling if ε_Z is larger than one. The reverse holds if ε_Z is smaller than one. Empirically, this parameter can be retrieved from estimates of the elasticities of hours of leisure with respect to the wage rate and property income.[7]

The preceding model controls for market productivity effects of schooling because the wage rate is held constant. An alternative model is one in which a one-year increase in schooling raises market and nonmarket productivity by ρ_Z percent. In that model the schooling parameters become

$$\tilde{T} = \left[(1-s)\eta_Z - 1\right]\rho_Z \qquad (9a)$$

$$\tilde{X} = \left[(1-s)\left(\frac{1-k\eta_Z}{1-k}\right)\right]\rho_Z, \qquad (10a)$$

where s is the share of property income in full income. According to equation (9a), hours of leisure fall as schooling rises and hours of work rise unless η_Z is greater than 1/(1 - s). If s is relatively small, hours of work increase, remain constant, or fall as schooling rises according to whether η_Z is less than, equal to, or greater than one. This model suggests that only schooling and property income should be included in empirical estimates of demand functions for leisure and total consumption. Comparisons of the two models and the constraints they imply via goodness-of-fit tests allow one to distinguish between them.

2.1.2. Productive efficiency and health production

I [Grossman (1972a), (1972b), (2000)] explore the productive efficiency effect of schooling in the context of a model of the production of health and the demand for health. My model is somewhat complicated because it involves the selection of an optimal life cycle path of a durable stock of health capital and associated profiles of gross investment in that stock and inputs in the gross investment production function. My model also contains both investment and consumption motives for demanding health. As a consumption commodity, health is a direct source of utility. As an investment commodity, it determines the total amount of time in a period that can be allocated to work in the market and to the production of commodities in the nonmarket sector.

I simplify my model while retaining the aspects required to study the impacts of schooling on the demand for health and health inputs by employing a static version of my pure investment model in which health does not enter the utility function directly.[8] In the period at issue, say a year, the total amount of time that can be allocated to market and nonmarket production (h) is not fixed. Instead, it is a positive function of health (H) because increases in health lower the time lost from these activities due to illness and injury ($\partial h/\partial H \equiv G > 0$). Because the output of health has a finite upper limit of 8,760 hours or 365 days times 24 hours per day if the year is the relevant period, the marginal product of health falls as H rises ($\partial^2 h/\partial H^2 \equiv G_H < 0$). Health is produced with inputs of medical care (M) and the own time of the consumer (T):

$$H = e^{\rho_H S} F(M,T)$$

where F is linear homogeneous in M and T. An increase in schooling raises the marginal products of M and T by the same percentage (ρ_H).

The consumer maximizes $Wh - \pi_H H$, where W is the wage rate and π_H is the marginal or average cost of producing health. The first-order condition for optimal H is

$$WG = \pi_H. \tag{12}$$

Using this equation, one obtains formulas for the optimal percentage changes in the quantities of H and M caused by a one unit increase in schooling (S):

$$\tilde{H} = \varepsilon_H \rho_H \tag{13}$$

$$\tilde{M} = (\varepsilon_H - 1)\rho_H, \tag{14}$$

where

$$\varepsilon_H \equiv -\frac{G}{HG_H}.$$

The effects summarized by equations (13) and (14) hold the wage rate and the price of medical care constant.[9]

The parameter ε_H is the inverse of the absolute value of the elasticity of the marginal product of health (G) with respect to H. I [Grossman (1972a), (1972b), (2000)] show that ε_H is very likely to be smaller than one because the output of health has a finite upper limit. Given that this condition holds, an increase in schooling is predicted to increase the quantity of health demanded but to lower the quantity of medical care demanded.

2.2. Allocative efficiency

In the productive efficiency approach, an increase in knowledge capital or schooling raises the efficiency of the production process in the nonmarket or household sector, just as an increase in technology raises the efficiency of the production process in the market sector. Some persons object to this approach. In the specific context of the production of health, Deaton

(2002, p. 21) writes: "In many economic models of health, education is seen as enhancing a person's efficiency as a producer of health--a suggestive phrase, but not one that is very explicit about the mechanisms involved." In a study dealing with infant health production, Rosenzweig and Schultz (1982, p. 59) argue: "It is not clear…how education can actually alter marginal products of inputs…unless inputs are omitted from [the production function]. That is, it is doubtful that schooling can affect the production of…[health] without it being associated with some alteration in an input."

The statements by Deaton and by Rosenzweig and Schultz point to an allocative efficiency effect of education. Clearly, this is a very legitimate alternative to the productive efficiency hypothesis, but one can raise the same objection to the many treatments of exogenous technological change in the literature on production by firms and industries. In fact, the set of household production functions specified by equation (2) is very similar to a specification of the production of earnings in which the more educated get more of this output with the same amount of time allocated to the market than the less educated. Thus, it is important for the reader to keep in mind that the productive efficiency hypothesis has testable implications in comparing the two approaches.

Allocative efficiency pertains to situations in which the more educated pick a different mix of inputs to produce a certain commodity than the less educated. The mix selected by the more educated gives them more output of that commodity than the mix selected by the less educated. As the quotes by Deaton and Rosenzweig and Schultz cited above imply, education will have no impact on outputs unless it alters inputs, and education coefficients in production functions will be zero if all relevant inputs are included. Since data on outputs as well as inputs are required to test the allocative efficiency hypothesis and since health is one of few outputs of

household production that can be measured, most theoretical treatments of allocative efficiency are in the context of the production of health.

Theoretical underpinnings of the allocative efficiency approach are contained in Rosenzweig and Schultz (1982, 1989), Kenkel (1991, 2000), Rosenzweig (1995), Meara (1999, 2001), Goldman and Lakdawalla (2002) Goldman and Smith (2002), Lleras-Muney and Lichtenberg (2002), Glied and Lleras-Muney (2003), and de Walque (2004, 2005). These treatments correctly recognize the multivariate nature of the health production function and include a variety of market goods inputs, such as diet, cigarette smoking, and alcohol use, in addition to medical care. Some of these inputs have negative marginal products in the production of health. For example, cigarette smoking lowers health but raises utility at least for some consumers because it simultaneously produces the commodity "smoking pleasure" that is a positive source of utility. Hence, models of allocative efficiency incorporate joint production in the nonmarket sector.[10] Some of these models replace a generic time input with time allocated to such activities as exercise and weight control.

Typically, approaches to allocative efficiency assume that the more educated have more information about the true nature of the production function. For example, the more educated may have more knowledge about the harmful effects of smoking or about what constitutes an appropriate diet. In addition, they may respond to new knowledge more rapidly. These approaches also pay attention to the role of endowed or inherited health. Clearly, a favorable endowment raises current health. At the same time, the demand for inputs with positive marginal products falls while the demand for inputs with negative marginal products may rise.

To fully test the allocative efficiency hypothesis, one needs to estimate the health production function and show that the schooling coefficient is zero once all inputs are included.

Difficulties arise because the production function is a structural equation that relates an output of health to endogenous inputs. Biases that are encountered when it is estimated by ordinary least squares (OLS) are discussed in detail by Rosenzweig and Schultz (1982, 1983, 1991), Corman, Joyce, and Grossman (1987), Grossman and Joyce (1990), and Joyce (1994). There are two types. Adverse selection occurs when individuals with low levels of initial health obtain larger quantities of health inputs. Here the unobserved disturbance term in the production function reflects the health endowment and is negatively correlated with the inputs. In general OLS input coefficients are biased towards zero in this case. Favorable selection occurs when there is at least one unmeasured healthy behavior input (for example, appropriate diet or exercise or absence of stress) and when individuals who are risk averse obtain larger quantities of all health inputs, which have positive effects on health and less of the inputs with negative effects. Here the unobserved disturbance term in the production function reflects unmeasured healthy behavior inputs and is positively correlated with measured inputs. These considerations suggest that the production function should be obtained by such simultaneous equations methods as two-stage least squares. Since the productive efficiency hypothesis makes predictions about reduced form coefficients, simultaneous equations methods are not required to explore its implications unless one questions the exogeneity of schooling (see Section 2.5).

One could also test the productive efficiency model by fitting the production function by simultaneous equations methods. It predicts a positive schooling coefficient with all relevant inputs held constant. On the other hand, the allocative efficiency model predicts no direct schooling effect. These models need not be viewed as competitors. Aspects of both may be relevant, and both predict positive schooling coefficients in reduced form health equations.

Some treatments formally combine aspects of productive and allocative efficiency.

Typically, these treatments implicitly or explicitly assume costs of adjustment or interactions between past health status and the marginal products of health inputs. Thus, positive effects of past health on current health and negative effects of past health on current input use (positive effects of past measures of poor health on current input use) are incorporated.[11] For example, using a model developed by Nelson and Phelps (1966), Glied and Lleras-Muney (2003) postulate a lag between the introduction of a new medical technology for treating a certain illness and its adoption by a specific individual. In turn, the lag is negatively related to the person's education. In this framework, the health production function is

$$H = F[M_0 e^{\rho(t-u)}], \tag{15}$$

where M_o is the medical technology available at time 0, $M_0e^{\rho t}$ is the state-of-the-art technology at time t, $M_0e^{\rho(t-u)}$ is the technology actually employed by the individual or his physician at time t, and other inputs are suppressed. The variable u measures the adoption lag and is negatively related to the person's schooling. This model predicts that the marginal product of schooling in the production function is positively related to ρ, the rate of technological progress. Hence, the impact of schooling on disease-specific mortality, for example, should be larger in absolute value for diseases for which significant advances in treatment have occurred in the recent past.

Using a somewhat related framework, Goldman and Lakdawalla (2002) examine the properties of a model in which individuals with a given initial health problem employ medical care and their own time in a Cobb-Douglas technology to improve their health:

$$H = M^{\alpha}T^{\beta}. \tag{16}$$

In their model the output elasticity of medical care (α) is positively related to schooling for some diseases--especially those where progress in treatment has been rapid in the recent past. The output elasticity of the patient's own time input (β) also may be positively related to schooling,

especially treatment regimes that require significant amounts of this input. Innovations that diminish the importance of patient monitoring--for example, one that makes it less important for a patient with type 1 diabetes to monitor blood sugar--lower β and may also reduce the positive relationship between β and schooling.[12]

2.3. Schooling effects in the quantity-quality model of fertility

Parents' schooling plays an important role in the quantity-quality model of fertility developed by Becker (1960), Becker and Lewis (1973), Willis (1973), Becker (1991) and summarized in detail by Hotz, Klerman, and Willis (1997). Parents maximize a utility function that depends on the number of children (N), the quality or well-being of each child (Q, assumed to be the same for each child in a given family), and the parents' standard of living (Z). These three commodities are produced with inputs of market goods and services and the own time of the parents. The full income budget constraint is

$$R = \pi_Z Z + \pi NQ + \pi_N N + \pi_Q Q, \tag{17}$$

where π_Z is the price of Z, π is the price of one unit of NQ, π_N is the fixed cost of N, and π_Q is the fixed cost of Q.

According to Becker (1991), the cost component $\pi_N N$ reflects the time and expenditure spent on pregnancy and delivery and the costs of avoiding pregnancies. These outlays are independent of quality. The component $\pi_Q Q$ represents costs that do not depend on the number of children because of joint consumption by different children such as acquiring information and knowledge from the parents at the same time. On the other hand, the component πNQ reflects costs that depend on both N and Q. Hence, the marginal costs or shadow prices of N and Q are

$$P_N = \pi_N + \pi Q \tag{18}$$

$$P_Q = \pi_Q + \pi N. \quad (19)$$

The shadow price of N rises with Q because each additional child is more costly the higher is his quality. Along the same lines the shadow price of Q rises with N because an additional unit of quality is more costly the larger is the number of children in the family who will receive it.

Suppose that more educated parents face lower costs of contraception either because they are more likely to use the most effective birth control methods or are more efficient at using a given method. Note that a reduction in the cost of contraception raises π_N. The increase in the relative price of N induces a substitution effect away from N and towards Q. The expansion in the ratio of Q to N causes a further increase in the relative price of N and an additional substitution effect in favor of Q and away from N. The presence of both a direct substitution effect (π_N increases which increase the relative price of N) and a secondary substitution effect (Q/N rises which increases the relative price of N) suggests a sizable reduction in N and a sizable increase in Q even if these two commodities are not particularly good substitutes in consumption. Exactly the same analysis follows if π_Q falls as parents' education rises because more educated parents are more efficient producers of quality. Since the parents' time is spent in encouraging the child's curiosity and in training the child in how to learn and in what satisfaction comes from learning, it is highly likely that more educated parents will be more effective or successful in encouraging these traits in their children.

Clearly the quality or well-being of children is positively related to their health and cognitive development. In turn, the latter depends on such outcomes as school achievement test scores and years of formal schooling completed. Since mothers typically allocate more time to childcare than fathers, it is natural to obtain separate estimates of the effects of mother's schooling and father's schooling on these outcomes. Especially in the case of the former, one

wants to take account of increases in the wage or the value of time associated with schooling. Willis (1973) assumes that the production of child quality or well-being is more intensive in the wife's time than the production of the parents' standard of living. But child quality rises with the wage while family size falls because child well-being and parents' standard of living are complements in consumption. Becker and Lewis (1973) get the same result for a different reason. They assume that the fixed costs of number of children exceed the fixed costs of quality. They then show that an increase in the value of the wife's time lowers the price of quality relative to that of number of children, although it raises the price of quality relative to parents' standard of living. Thus, they predict a small negative or even a positive effect of an increase in the wage on child well-being. The point I wish to emphasize is that in both models wage or value of time effects are extremely unlikely to reverse efficiency effects and are very likely to reinforce these effects.

2.4. Biases, biases, biases

So far I have considered frameworks that generate causal effects of schooling on a variety of outcomes. For example, regardless of whether the mechanism is productive or allocative efficiency, an increase in an individual's own schooling is predicted to increase his or her own health. Similarly, an increase in parents' schooling is expected to increase the well-being of their children as measured by their health and cognitive development. These frameworks have been questioned, however, because schooling clearly is an endogenous variable. A variety of optimal schooling models, some of which are discussed and extended by Card (1999, 2001), raise the possibility that health, for example, may cause schooling or that omitted "third variables" may cause schooling and adult health or child well-being to vary in the same direction. I illustrate the

issues involved with respect to adult health and child well-being outcomes.

Causality from better health to more schooling results if healthier students are more efficient producers of additions to the stock of knowledge (or human capital) via formal schooling. In addition, they may miss fewer days of school due to illness and therefore learn more for that reason. Furthermore, this causal path may have long lasting effects if past health is an input into current health status. Thus, even for non-students, a positive relationship between health and schooling may reflect reverse causality in the absence of controls for past health. Evidence linking poor health in early childhood to unfavorable educational outcomes is contained in Edwards and Grossman (1979), Shakotko et al. (1983), Chaikind and Corman (1991), Currie (2000), Alderman et al. (2001), and Case et al. (2005). Health also may cause schooling because a reduction in mortality increases the number of periods over which the returns from investments in knowledge can be collected.

The third-variable hypothesis has received a good deal of attention in the literature because it is related to the hypothesis that the positive effect of schooling on earnings, explored in detail by Mincer (1974) and in hundreds of studies since his seminal work [see Card (1999, 2001) for reviews of these studies], is biased upward by the omission of ability. Fuchs (1982) identifies time preference as the third variable. He argues that persons who are more future oriented (who have a high degree of time preference for the future or discount it at a modest rate) attend school for longer periods of time and make larger investments in their own health and in the well-being of their children. Thus, the effects of schooling on these outcomes are biased if one fails to control for time preference. Behrman and Rosenzweig (2002) present an argument that is even more closely related to ability bias in the earnings-schooling literature. In their model, parents with favorable heritable

endowments obtain more schooling for themselves, are more likely to marry each other, and raise children with higher levels of well-being. In turn these endowments reflect ability in the market to convert hours of work into earnings and childrearing talents in the nonmarket or household sector.

The time preference hypothesis is worth considering in more detail because it is related to the recent and very rich theoretical models in which preferences are endogenous discussed in Section 2.5. Suppose that human capital investments and the inputs that produce these investments do not enter the utility function directly. Then differences in time preference among individuals will not generate differences in investments in human capital unless certain other conditions are met. One condition is that the ability to finance these investments by borrowing is limited, so that they must be funded to some extent by foregoing current consumption. Even if the capital market is perfect, the returns on an investment in schooling depend on hours of work if schooling raises market productivity by a larger percentage than it raises nonmarket productivity. Individuals who are more future oriented desire relatively more leisure at older ages. Therefore, they work more at younger ages and have a higher discounted marginal benefit on a given investment than persons who are more present oriented. If health enters the utility function, persons who discount the future less heavily will have higher health levels during most stages of the life cycle. Hence, a positive relationship between schooling and health does not necessarily imply causality.

de Walque (2004, 2005) constructs a specific model with some of the above aspects in which differences in time preference have causal impacts on schooling and health. In his model the capital market is perfect and nonmarket productivity effects are not relevant

since time is not an input in household production. Investments in schooling raise wage rates. Returns to these investments depend on health because healthier persons live longer and lose less time from work due to illness.[13] Health is endogenous because future health is negatively related to a good that enters the current period utility function such as cigarette smoking. Persons who discount the future heavily will consume more of this good and will have lower levels of health. This reduces the returns to investments in schooling and lowers the optimal level of schooling. Clearly, one can add a component to de Walque's model and related models in which parents who are more future oriented attend school for longer periods of time and make larger investments in the well-being of their children.

The preceding discussion suggests that the coefficient of own schooling in a regression in which own health is the dependent variable and the coefficient of parents' schooling in a regression in which child well-being is the dependent variable may be biased and inconsistent estimates of the true parameters. Several econometric procedures can be employed to correct for these biases. First, one can include past health measures in regressions that relate adult health to own schooling. Second, one can control for unmeasured third variables by examining differences in outcomes due to differences in schooling between siblings or twins. Third, one can employ the technique of instrumental variables. Here the idea is to employ variables that are correlated with schooling but not correlated with such omitted third variables such as ability, other inherited genetic traits, and time preference to obtain consistent estimates of schooling effects. In the context of two-stage least squares estimation and its variants, the instruments are used to predict

schooling in the first stage. Then predicted schooling replaces actual schooling in the adult health or child well-being equation.

The problem with the first procedure is that measures of past health may not be available or may be measured imprecisely. The second procedure, especially if it is based, on twins has several difficulties. Typically, it is based on small samples. In addition, differencing between twins exacerbates biases due to measurement error [Griliches (1979), Bound and Solon (1999), Neumark (1999)]. Finally, Bound and Solon (1999) stress that variations in schooling between identical twins may be systematic rather than random. Given the large literature that uses the technique of instrumental variables to investigate the causal impact of schooling on earnings [see Card (1999, 2001) for reviews], the third procedure appears to be the most promising. Of course, the difficulty here is that one must uncover instruments that plausibly are not correlated with third variables. The reader should keep these factors in mind in evaluating the studies discussed in Sections 4 and 5.

2.5. Schooling effects in models with endogenous tastes

Typically, economists have not emphasized the effects of variations in taste variables on the optimal consumption of goods and services at a moment in time or on changes in consumption over the life cycle because they have lacked theories about the formation of tastes. They have, however, devoted attention to the impacts of time preference and addiction or habit formation--two key components of tastes--in models that assume that tastes are exogenous. In most models of consumption over the life cycle [see Frederick, Lowenstein, and O'Donoghue (2002) for a recent review], consumers maximize a lifetime utility function (L) defined as the discounted sum or present value of utility at each age

$$L = \sum_{t=0}^{n} D^t U(C_t). \qquad (20)$$

Here $U(C_t)$ is the current period utility function at time or age t, C_t is consumption at age t, and D is the discount factor. In turn, $D = 1/(1 + g)$, where g is the rate of time preference for the present. Consumers who discount the future heavily (have small values of D or large values of g) will exhibit much slower rates of increase in consumption over their life cycles than consumers who discount the future at modest rates. Indeed, if g is large enough, consumption by the former group may actually fall with age.[14]

Pollak (1970) and others incorporate addiction or habit formation into the standard model of consumer behavior by assuming that past consumption of certain goods influences current period tastes or utility. Let A be a good that exhibits this property and C be a good that does not, so that A is the addictive good. Then the current period utility function is $U(C_t, A_t, A_{t-1})$. An increase in A_{t-1} lowers current period utility because there is a "necessary" component of consumption due to physiological or psychological factors. At the same time, an increase in past consumption is assumed to increase the marginal utility of current consumption in the case of addictive goods. This suggests that the current consumption of these goods is positively related to past consumption. It is natural to associate the reductions in current period utility caused by an increase in past consumption of addictive goods with the harmful health effects of cigarette smoking, excessive alcohol use, and the consumption of such illegal drugs as cocaine, heroin, marijuana, and opium. Moreover, experimental studies by psychologists of harmful addictions [for example, Peele (1985)] usually have identified reinforcement in the sense that greater past consumption of these goods raises their current consumption.

What do economic models that emphasize the effects of time preference and addiction add to conceptual frameworks for studying the relationship between schooling and adult health

or between parents' schooling and child well-being? The answer is very little if time preference and past consumption are exogenous variables. We have already seen that exogenous variations in time preference can cause schooling and health or well-being to vary in the same direction in Section 2.4. Clearly, one wants to take account of the relationship between current consumption and past consumption or between current and future consumption in estimating demand functions for addictive goods with harmful health effects. But if past consumption is exogenous, these effects were ignored by consumers when they selected the optimal value of A_{t-1}. Similarly, the harmful future effects of current consumption are ignored when the optimal amount of A_t is selected.

The story is very different if time preference is endogenous and future effects are incorporated into current decisionmaking. For example, proponents of the time preference hypothesis assume that a reduction in the rate of time preference for the present causes years of formal schooling to rise. On the other hand, Becker and Mulligan (1997) argue that causality may run in the opposite direction: namely, an increase in schooling may *cause* the rate of time preference for the present to fall (may *cause* the rate of time preference for the future to rise). They point out that the present value of utility in equation (20) is *higher* the smaller is the rate of time preference for the present. Hence, consumers have incentives to make investments that *lower* the rate of time preference for the present.

Becker and Mulligan then show that the marginal costs of investments that lower time preference fall and the marginal benefits rise as income or wealth rises. Marginal benefits also are greater when the length of life is greater. Hence, the equilibrium rate of time preference falls as the level of education rises because education raises income and life expectancy. Moreover, the more educated may be more efficient in making investments that lower the rate of time

preference for the present--a form of productive efficiency not associated with health production. To quote Becker and Mulligan: "Schooling also determines...[investments in time preference] partly through the study of history and other subjects, for schooling focuses students' attention on the future. Schooling can communicate images of the situations and difficulties of adult life, which are the future of childhood and adolescence. In addition, through repeated practice at problem solving, schooling helps children learn the art of scenario simulation. Thus, educated people should be more productive at reducing the remoteness of future pleasures (pp. 735-736)." This argument amounts to a third causal mechanism in addition to productive and allocative efficiency in health production via which schooling can cause health.

Becker and Mulligan's model appears to contain useful insights in considering intergenerational relationships between parents and children. For example, parents can raise their children's future health, including their adulthood health, by making them more future oriented. Note that years of formal schooling completed is a time-invariant variable beyond approximately age 30, while adult health is not time invariant. Thus, parents probably have a more important direct impact on the former than the latter. By making investments that raise their offspring's schooling, parents also induce them to make investments that lower their rate of time preference for the present and therefore raise their adult health.

There appear to be important interactions between Becker and Mulligan's theory of the endogenous determination of time preference and Becker and Murphy's (1988) theory of rational addiction. Unlike in the myopic models of addiction developed by Pollak (1970) and others, in the Becker-Murphy model, consumers are farsighted in the sense that they take account of the expected future consequences of their current decisions. That is, they realize that an increase in the consumption of a harmfully addictive good in the present period lowers future utility due to

adverse health effects at the same time as it increases current utility. According to Becker and Mulligan (1997, p. 744), "Since a decline in future utility reduces the benefits from a lower discount on future utilities, greater consumption of harmful substances would lead to higher rates of time preference by discouraging investments in lowering these rates..." This is the converse of Becker and Murphy's result that people who discount the future more heavily are more likely to become addicted because they give relatively little weight to future adverse health effects. Thus, "...harmful addictions induce even rational persons to discount the future more heavily, which in turn may lead them to become more addicted (Becker and Mulligan 1997, p. 744)."

An extreme version of the ideas contained in the endogenous time preference and rational addiction literature suggests the following econometric specification of the relationship between health and schooling:

$$H = \alpha D \tag{21}$$

$$D = \beta S \tag{22}$$

$$H = \alpha\beta S. \tag{23}$$

Intercepts, disturbance terms, and other determinants of health and time preference (D) are suppressed. Since D is a positive correlate of time preference for the future, α and β are positive. This specification assumes that there is no direct effect of adult schooling on adult health, with time preference held constant. It also assumes that schooling has an important indirect effect on these outcomes that operates through time preference. Hence, the reduced-form parameter of schooling ($\alpha\beta$) is positive. Clearly, this is the relevant parameter from a policy perspective.

Estimation of the model just specified would be challenging because time preference is difficult to measure and because the disturbance terms in equations (21) and (22) are likely to be correlated. Suppose that an instrument exists that affects D but not H, so that one can test the

hypothesis that the direct effect of schooling on H is zero in equation (21). Acceptance of that hypothesis *does not* imply the absence of a causal schooling effect if β is positive.

I realize that the Becker-Murphy (1988) and Becker-Mulligan (1997) models are controversial.[15] In the absence of direct and comprehensive measures of time preference, an important research strategy is to treat schooling as endogenous and employ instruments that are correlated with it but not correlated with time preference. The point I wish to emphasize is the existence of a conceptual framework in the literature in which causality runs from schooling to time preference. This framework suggests that it is not appropriate to include an exogenous measure of time preference in health outcome equations to investigate the causal nature of schooling effects unless one assumes or has evidence that there is no causality from schooling to time preference.

3. Empirical evidence: consumption patterns, total consumption, and consumption growth

3.1. Consumption patterns

Michael (1972, 1973b) uses the 1960-61 Bureau of Labor Statistics Consumer Expenditures Survey to test the predictions of a factor- and commodity-neutral model of productive efficiency. Recall that the model predicts that the schooling effect should be positive for luxuries, negative for necessities, and zero for items with unitary income elasticities. He employs total consumption as a measure of permanent income or wealth. He finds that, of 52 items that exhaust total consumption, 29 have the predicted schooling effect. These items account for 71 percent of total consumption. When the analysis is limited to nondurables, 26 of 35 items have the predicted schooling effect. These items account for 84 percent of total nondurable consumption. The findings for nondurables are particularly important because actual

consumption is much better measured for these items than for durables.

Given estimates of the income elasticities and schooling parameters in equation (7) [η_i and $(\eta_i - 1)\rho$, respectively], Michael attempts to estimate ρ, the percentage increase in nonmarket productivity caused by a one-year increase in schooling. His preferred procedure is to impose alternative values of ρ on the system of Engel curves and pick the one that minimizes the weighted (by expenditure shares) residual sum of squares. He compares this estimate to the impact of education on market productivity, measured by the percentage increase in consumption caused by a one-year increase in schooling. He finds that the ratio of the nonmarket productivity effect to the market productivity effect is approximately equal to 0.6.[16] Thus, although the market effect is larger, the nonmarket effect is substantial. This estimate is comparable in magnitude to one obtained by Gronau (1980) with data on wage rates of married women and the time that they allocate to housework.

The BLS has conducted consumer expenditure surveys like the one used by Michael on an annual basis since 1980. Given these surveys, it is very surprising that his research has not been replicated and extended. The availability of detailed price data for many items from the American Chamber of Commerce Researchers Association [ACCRA (various years)] would facilitate these efforts. The ACCRA surveys cover between 250 and 300 cities on a quarterly basis since 1968. In addition to specific prices, the surveys contain cost-of-living indexes for each city. These data could be used to adjust expenditures for price variation and to include real prices as explanatory variables. It might also be possible to take account of the impacts of variations in the price of time due to schooling by adding the city-specific real wage rate to the set of independent variables.[17] In addition, the new BLS American Time Use Survey offers the possibility of doing with the time input in household production the same analysis previously

done on the goods input. The time use survey, if used in combination with the consumer expenditure surveys, may be a vehicle for breaking out of the constraining data limitations faced by Michael and other researchers who have attempted to test the productive efficiency hypothesis.

3.2. Total consumption

In Section 2.1.1, I considered the impact of an increase in schooling on total consumption and hours of work when schooling varies, with the wage rate and property income held constant. The prediction is that consumption and hours of work will rise if the uncompensated price elasticity of demand for nonmarket time is less than one in absolute value. I also considered an alternative model in which the market and nonmarket productivity effects of schooling are the same. In that model hours of work rise if the income elasticity of demand for leisure is less than one. These specific hypotheses have never been tested. One reason is that the impact of schooling on consumption at a moment in time or in the cross section may reflect forces associated with its rate of growth over time or with age. Thus, the more educated may consume less from a given income because they desire a more rapid growth in consumption with age (see Section 3.3 for evidence in favor of this proposition). Another reason is that schooling, the wage rate, and property income may be highly correlated, although a number of studies of the determinants of health reviewed in Section 4 employ all three variables as regressors.

Morris (1976) estimates consumption functions derived from a variant of the static model presented in Section (2.1.1), but he assumes that the wage rate is strictly proportional to schooling, which is highly questionable. Moreover, his development requires one to include full income and the ratio of the wage rate to nonmarket productivity as regressors. A much more

flexible specification is one in which the wage rate, schooling, and property income are the regressors. In my view little should be made of his rejection of the hypothesis that education does not have a nonmarket productivity effect.

If the productive efficiency model is to be tested with aggregate consumption data in future research, supply curves of hours of work or demand functions for nonmarket time should be obtained at the same time. It also seems necessary to develop a strategy to control for the life cycle components of these behaviors. One approach might be to focus on cross-sectional variations at the age or ages at which consumption and hours of work peak and to allow the peak ages to depend on schooling.[18]

3.3. Consumption growth

The lifetime utility function given by equation (20) implies that the rate of growth of consumption with age is approximately equal to $\sigma(r - g)$, where σ is the intertemporal elasticity of substitution in consumption, r is the market rate of interest and g is the rate of time preference for the present. If σ and r do not vary among individuals, consumption growth is governed by time preference. Persons who discount the future heavily (have large values of g) exhibit much slower growth than those who are more future oriented (have small values of g).[19]

Carroll and Summers (1991) and Lawrence (1991) present evidence that consumption grows more rapidly over the life cycle for persons with more years of formal schooling. Using the 1960-61 BLS Consumer Expenditures Survey, Carroll and Summers (1991) find that consumption grows by 25 percent for college graduates between the ages of 27 and 32 but only by 10 percent for high school graduates who did not attend college. Between the ages of 27 and 47, the growth rates for the two schooling groups are 70 percent and 35 percent, respectively.[20]

Lawrence (1991) uses annual data from the Panel Survey of Income Dynamics for the years 1974 through 1982 to estimate regressions in which the rate of growth in consumption depends on income, age, race, the real after-tax interest rate, and a dichotomous indicator for households in which the head had a college education. Her results suggest that families with a college-educated head have a time preference rate that is about two percentage points lower than families whose head did not have a college education.

In discussing these results, especially those of Carroll and Summers, Becker and Mulligan (1997) point out that they have often been explained by liquidity constraints. Proponents of this hypothesis note that earnings grow rapidly at young ages and for the highly educated. These groups would like to borrow against their future earnings but cannot do so. Hence, their consumption is limited by their earnings. Becker and Mulligan proceed to argue that the liquidity constraint hypothesis does not explain why savings might be observed for young college graduates.

I acknowledge that the empirical evidence just discussed does not prove that schooling causes time preference. Clearly, it is consistent with the alternative hypothesis that time preference causes schooling. The point I wish to emphasize is that this evidence also does not prove that time preference causes schooling. Absent definitive tests that establish causality in one direction only, empirical evidence that time preference measures greatly reduce the effects of schooling on adult health or child well-being should be interpreted with caution. Such results do not necessarily imply absence of causality from schooling to these outcomes.

Another point worth noting is that Becker and Mulligan (1997) summarize evidence of positive relationships between parents' income and the rate of growth of consumption of their children when they become adults. They indicate that these results could be traced to exogenous

inherited traits that determine time preference. But they also indicate that these genetic correlations would have to be quite large--larger than those that have been estimated in the literature--to account for the sizable relationship between the outcomes at issue. Thus a scenario in which higher income parents make larger investments in the future orientation of their children is equally likely if not more likely.

4. Empirical evidence: health

Most of the empirical evidence discussed in this paper pertains to schooling and health outcomes. As pointed out in Section 1, this is a natural focus because the evidence pertains to complementary relationships between the two most important components of the stock of human capital. The very large literature in this area has been reviewed recently by Grossman and Kaestner (1997) and by Grossman (2000). My aim in this section is to give the reader a "flavor" for this literature rather than repeating all the material in the two papers just cited. I highlight research that laid the foundations for current studies and the results of these and ongoing studies. I consider adult health in Section 4.1 and child health (defined to include the health of infants, children, and adolescents) in Section 4.2. Within each topic, I begin with studies that employ the productive efficiency framework or that relate health to schooling and variables that are not endogenous inputs into the production of health. I then turn to research on allocative efficiency and to approaches that address the time preference and other third variables hypotheses, some of which do so by treating schooling as endogenous.

At the outset, I note that Grossman and Kaestner (1997) and Grossman (2000) conclude from their extensive reviews of the literature that years of formal schooling completed is the most important correlate of good health. This finding emerges whether health levels are

measured by mortality rates, morbidity rates, self-evaluation of health status, or physiological indicators of health, and whether the units of observation are individuals or groups. The studies reviewed also suggest that schooling is a more important correlate of health than occupation or income, the two other components of socioeconomic status. This is particularly true when one controls for reverse causality from poor health to low income. Of course, schooling is a causal determinant of occupation and income, so that the gross effect of schooling on health may reflect in part its impact on socioeconomic status. The studies reviewed, however, indicate that a significant portion of the gross schooling effect cannot be traced to the relationship between schooling and income or occupation. The main message of my review is that research completed since the Grossman-Kaestner and Grossman papers were published has not altered their basic conclusions.

4.1. Adult health

4.1.1. Productive efficiency and related frameworks

I [Grossman (1972b)] report positive effects of schooling on self-rated health[21] and negative effects of schooling on work-loss days due to illness and injury and on restricted activity days due to illness and injury in a nationally representative 1963 United States survey conducted by the Center for Health Administration Studies and the National Opinion Research Center of the University of Chicago. These findings control for the weekly wage rate, property income, age, and several other variables. In the demand function for medical care (measured by personal medical expenditures on doctors, dentists, hospital care, prescribed and nonprescribed drugs, nonmedical practitioners, and medical appliances), the schooling coefficient is positive but not statistically significant. This finding is not consistent with the version of my pure

investment model in which the inverse of the elasticity of the marginal product of health with respect to health is less than one in absolute value (see Section 2.1.2). But note that I was forced to use a very aggregate measure of medical care and had no information on health insurance. Since more generous health insurance coverage increases the quantity of care demanded and since coverage and schooling are positively related, my estimated schooling effect is biased away from zero.

Wagstaff (1986) and Erbsland et al. (1995) provide more definitive evidence in favor of the productive efficiency hypothesis. Wagstaff (1986) uses the 1976 Danish Welfare Survey to estimate a multiple indicator version of my demand for health model. He performs a principal components analysis of nineteen measures of non-chronic health problems to obtain four health indicators that reflect physical mobility, mental health, respiratory health, and presence of pain. He then uses these four variables as indicators of the unobserved stock of health. His estimation technique is the so-called MIMIC (multiple indicators-multiple causes) model developed by Jöreskog (1973) and Goldberger (1974) and employs the maximum likelihood procedure contained in Jöreskog and Sörbom (1981). His contribution is unique because it accounts for the multidimensional nature of good health both at the conceptual level and at the empirical level.

Wagstaff reports a positive and significant effect of schooling on his measure of good health and a negative and significant effect of schooling on the number of physician visits in the past eight months. The latter result differs from mine. One factor that may account for the discrepancy is that Wagstaff has a much better measure of medical care utilization than I had. Another factor is that Wagstaff is able to control for variations in the price of a physician visit. Since money cost of medical care is heavily subsidized in Denmark, this price is given by the time required by survey respondents to travel to their physicians.

Erbsland et al. (1995) provide another example of the application of the MIMIC procedure to the estimation of a demand for health model. Their database is the 1986 West German Socio-economic Panel. The degree of handicap, self-rated health, the duration of sick time, and the number of chronic conditions, all as reported by the individual, serve as four indicators of the unobserved stock of health. In the reduced form demand function for health, schooling has a positive and significant coefficient. In the reduced form demand function for visits to general practitioners, the schooling effect is negative and significant.

Gilleskie and Harrison (1998) perform a direct test of the productive efficiency hypothesis by estimating a self-rated health production function with four endogenous inputs: the number of preventive doctor visits in the past year, the number of curative doctor visits in the past year, and dichotomous indicators that identify persons who smoke cigarettes and who exercise regularly. They employ the 1987 National Medical Expenditure Survey and control for the past stock of health by including the number of chronic conditions and the body mass index (weight in kilograms divided by height in meters squared) as regressors. They use Mroz's (1999) discrete factor estimator to account for the endogeneity of the inputs.

Gilleskie and Harrison report positive and significant schooling coefficients for both males and females. This is direct evidence in support of a productive efficiency effect of schooling. Some caution is required in interpreting their results because the proxies for past health may be endogenous but are treated as exogenous. Moreover, they achieve identification in part with attitudinal variables (for example, whether a person says that he or she is more than an average risk taker) that may be caused by schooling and correlated with unmeasured health inputs.

The remaining studies to be discussed in this subsection contain equations that are best interpreted as reduced form health outcome equations. A number of them contain direct controls for potential third variables such as past health, physical and mental ability, and parents' schooling. They do not attempt to distinguish between the productive and allocative efficiency hypotheses.

I [Grossman (1975)] conclude that schooling has a significant positive impact on the current self-rated health of middle-aged white males in the NBER-Thorndike sample.[22] The estimated schooling effect in my study controls for health in high school, parents' schooling, scores on physical and mental tests taken by the men when they were in their early twenties, current hourly wage rates, property income, and job satisfaction. My finding is particularly notable because all the men graduated from high school. Hence it suggests that the favorable impact of schooling on health persists even at high levels of schooling.

My analysis of the mortality experience of the Thorndike sample between 1955 and 1969 confirms the important role of schooling in health outcomes. This analysis is restricted to men who reported positive full-time salaries in 1955. In the fitted logit functions, schooling has a positive and statistically significant effect on the probability of survival. Indeed, schooling is the only variable whose logit coefficient differs from zero in a statistical sense. The schooling effect is independent of the level of median salary in 1955 and suggests that, in the vicinity of the mean death rate, a one-year increase in schooling lowers the probability of death by 0.4 percentage points. These results must be interpreted with some caution because the men in the Thorndike sample were only in their thirties in 1955, and relatively few variables were available for that year.

The importance of schooling as a determinant of self-rated health status of persons in the preretirement years is reinforced in studies by Hartog and Oosterbeek (1998) for the Netherlands and Gerdtham and Johannesson (1999) for Sweden. Hartog and Oosterbeek study the health in 1993 of men and women who were sixth grade pupils in 1953 in the Dutch province of Noord-Brabant. The schooling coefficients in their study control for IQ in 1953 and parents' schooling among other variables. Gerdham and Johannesson fit a model of the demand for health to the 1991 Swedish level of Living Survey. The schooling coefficient in their study actually may be underestimated because they include a measure of obesity in their equation. Schooling has a well-established negative impact on this outcome [for example, Chou et al. (2004)].

Estimates of dynamic demand for health models in panel data by Van Doorslaer (1987), Wagstaff (1993), Bolin et al. (2002), and Case et al. (2005) also confirm the importance of schooling as a determinant of health. These studies take account of reverse causality from health at early stages in the life cycle to the amount of formal schooling completed. They also relax the assumption that there are no costs of adjustment, so that lagged health becomes a relevant determinant of current health. Van Doorslaer (1987) employs the 1984 Netherlands Health Interview Survey. While this is a cross-sectional survey, respondents were asked to evaluate their health in 1979 as well as in 1984. Both measures are ten-point scales, where the lowest category is very poor health and the highest category is very good health. Van Doorslaer's main finding is that schooling has a positive and significant coefficient in the regression explaining health in 1984, with health in 1979 held constant.

Wagstaff (1993) uses the Danish Health Study, which followed respondents over a period of 12 months beginning in October 1982. As in his 1986 study, a MIMIC model is estimated. Three health measures are used as indicators of the unobserved stock of health capital in 1982

(past stock) and 1983 (current stock). These are a dichotomous indicator of the presence of a health limitation, physician-assessed health of the respondent as reported by the respondent, and self-assessed health. Both of the assessment variables have five-point scales. Wagstaff reports positive schooling effects for adults under the age of 41 and for adults greater than or equal to that age, although only the former effect is statistically significant.

Bolin et al. (2002) fit the exact version of the dynamic demand for health model that I developed [Grossman (2000, pp. 390-392)]. I show that a model with rising marginal cost of gross investment in health results in a second-order difference equation in which current health (health at age t) is positively related to past health (health at age t-1) and future health (health at age t + 1). Bolin et al. use the 1980/81, 1988/89, and 1996/97 waves of The Swedish Survey of Living Conditions to estimate this model. Current self-rated health is taken from the second wave, and past and future self-rated health are taken from the first and third waves, respectively. Based on order-probit specifications, schooling raises the probability of being in the highest health category and reduces the probabilities of being in the lowest and intermediate categories. Since these results hold past and future health constant and since past and future health are found to raise current health, long-run schooling effects are even larger.[23]

Case et al. (2005) employ a unique data set: the 1958 British National Child Development Study. All children born in England, Scotland, and Wales in the week of March 3, 1958 have been followed in this study from birth through age 42. Parents were interviewed at the time of the birth, and health and socioeconomic data have been collected on panel members at ages 7, 11, 16, 23, 33, and 42. Case et al. (2005) relate self-rated health of males at age 42 to corresponding measures at ages 23 and 33, birthweight, the number of physician-assessed chronic health conditions at ages 7 and 16, own schooling, earnings at age 42, and family income

age 16. The schooling coefficient is positive and significant even in models that include self-rated health at ages 23 and 33. Clearly, these two outcomes may depend on schooling.

The importance of schooling as a determinant of the self-rated health of older males and of the mortality experience of males of all ages is underscored in studies by Rosen and Taubman (1982), Taubman and Rosen (1982), and Sickles and Taubman (1986). The first study is based on the 1973 Exact Match Sample, which was obtained by matching persons in the March 1973 Current Population Survey with their Social Security and Internal Revenue Service records and then tracing their mortality experience through 1977. Rosen and Taubman estimate separate mortality regressions for white males aged 25 through 64 in 1973 and for white males aged 65 and over in that year. For both groups mortality is negatively related to education, with marital status, earnings in 1973, and health status in that year held constant. Rosen and Taubman conclude: "... the effect of education does not flow solely or primarily through income effects, does not reflect a combination of differential marriage patterns and the health benefits of having a wife, and ... those who are disabled or not working because of ill health are not found disproportionately in any one education group (p. 269)."

Taubman and Rosen (1982) use the 1969, 1971, and 1973 Retirement History Survey to study the self-rated health and survival experience of white males who were between the ages of 58 and 63 in the initial year of this panel survey. The dependent variable compares health with that of others the same age and has four categories: better, same, worse, or dead. With health in 1969, income, and marital status held constant, health levels in 1971 and 1973 and changes over time are strongly related to years of formal schooling completed. There also is evidence that own schooling is a more important predictor of health than wife's schooling for married men.

Sickles and Taubman (1986) add the 1975 and 1977 waves to the panel data employed by

Taubman and Rosen and include black males as well as white males in their analysis. They fit a model with two endogenous variables: health status and retirement status. The model is recursive (health status determines retirement status) and allows for correlated errors between the two equations and heterogeneity, which is treated as a random effect. Since the health equation is an ordered polytomous probit and the retirement equation is a binary probit, full information maximum likelihood estimation methods are employed. As in the Taubman-Rosen study, higher schooling levels are associated with better health. Taken together, the two studies suggest that the schooling effect is not sensitive to very different model specifications and estimation strategies.

Hurd and Kapteyn (2003) buttress findings reported by Rosen and Taubman and by Sickles and Taubman with regard to the effect of schooling on self-rated health in the Health and Retirement Survey--households with one member between the ages of 51 and 61 in 1992. They employ baseline data and follow-ups conducted in 1994, 1996, 1998, and 2000. Controlling for baseline health, current income, and wealth, they show that more educated persons are more likely to report maintaining their health in the highest category.

Deaton and Paxson (2001) confirm the importance of schooling in mortality outcomes of both men and women in two data sets. One consists of all-cause mortality for the United States for the years 1975-1995 merged by birth cohort and sex to the 1976-1996 Current Population Survey (cohort file). The second is the National Longitudinal Mortality Study (NLMS)--a survey of individuals originally sampled in the CPS around 1980 and in the 1980 Census of Population into which death certificates have been retrospectively merged.

In both data sets negative schooling effects on mortality are observed for persons under the age of 60 as well as for persons over that age. These estimates control for family income. In

the NLMS, the income effect becomes weaker as the length of time between 1980 and the year of death increases, while the schooling effect increases in absolute value for males. Deaton and Paxson argue that this is because moving forward in time reduces reverse causality from poor health to low income.

In the cohort file, the schooling coefficients are negative and significant while the income coefficients are either insignificant or positive and significant when both variables are included. Deaton and Paxson caution that the income and schooling measures are highly correlated, making it difficult to sort out the separate impacts of each variable. They mention but dismiss an argument by Fuchs (1974) and others that income can actually have harmful effects on health with schooling held constant because higher income people may consume larger quantities of items that are harmful to their health. Their dismissal is based on inconclusive evidence in the studies cited by Fuchs. They do not, however, refer to my study (Grossman 1972b) that reports a negative effect of family income on several health measures with schooling and the wage rate held constant. In any case their evidence is consistent with the mortality studies conducted in the 1980s.[24]

4.1.2. Allocative efficiency

Leigh (1983) employs data from the University of Michigan's Quality of Employment Surveys of 1973 and 1977 and considers persons 16 years of age and older who worked for pay for 20 or more hours per week in these two national surveys. He shows that most of the statistically significant positive effect of schooling on self-rated health can be explained by decisions with regard to cigarette smoking, exercise, and the choice of less hazardous occupations by the more educated. This finding provides support for the allocative efficiency

hypothesis. But it also supports the alternative hypotheses that schooling causes health because of its impacts on tastes, primarily its impact on time preference. Of course, the finding also is consistent with a third hypothesis that both schooling and the determinants of health are caused by time preference.

Kenkel (1991) explores the allocative efficiency hypothesis by examining the extent to which schooling helps people choose healthier life styles by improving their knowledge of the relationships between health behaviors and health outcomes. He uses direct measures of health knowledge to test this explanation. He does this by estimating the separate effects of schooling and health knowledge on cigarette smoking (the number of cigarettes smoked per day), excessive alcohol use (the number of days in the past year on which the respondent consumed five or more drinks of an alcoholic beverage), and exercise (the number of minutes of exercise in the past two weeks) using data from the Health Promotion/Disease Prevention Supplement to the 1985 National Health Interview Survey. Cigarette knowledge is measured by the number of correct responses to whether smoking causes each of seven illnesses. Drinking knowledge is measured by the number of correct responses to whether heavy drinking causes each of three illnesses. Exercise knowledge is given by correct responses for the amount of exercise required to strengthen the heart and lungs and the required change in heart rate and breathing.

With age, family income, race, marital status, employment status, and veteran status (for males only), held constant, an increase in schooling leads to a reduction in smoking and excessive alcohol use and to an increase in exercise. Moreover, knowledge of the health consequences of smoking decreases smoking, and similar relationships hold for excessive alcohol consumption and exercise. The results also show that part of the relationship between schooling and health behaviors is due to health knowledge, but the schooling coefficients are

significant with health knowledge held constant. Moreover the reductions in schooling coefficients due to the inclusion of health knowledge are relatively small; they range between 5 and 20 percent. The results are not altered when health knowledge is treated as an endogenous variable. Kenkel interprets this result as indicating that unobservables, such as individual rates of time preference, are important determinants of health behavior and schooling but acknowledges that other interpretations are possible.

Situations in which new information becomes available or in which new medical technologies are introduced provide the best setting to explore and test the allocative efficiency hypothesis. As pointed out in Section 2.2, most treatments of allocative efficiency assume that the more educated respond more rapidly to these new developments. Sander (1995a, 1995b) and de Walque (2004) present national data showing that cigarette smoking initiation and participation rates fell more rapidly and quit rates rose more rapidly as the level of education rose between the middle 1960s and the 1970s. These data suggest that those with more schooling were more responsive to new information about the harmful effects of smoking in the 1950s and early 1960s, which culminated in the issuance of the first Surgeon General's Report on Smoking and Health in 1964. These trends persisted, however, in the 1980s and 1990s. Since information concerning the health risks of smoking was widespread by the early 1980s, the more recent data are not consistent with the allocative efficiency hypothesis.

The spread of the HIV/AIDS epidemic since the early 1980s provides another setting to examine the allocative efficiency hypothesis. Glied and Lleras-Muney (2003) point out that by the late 1980s new AIDS cases among gay men (a group with high education) were significantly below predicted rates, while new cases among intravenous drug users (a group with lower levels of education) were at or above projected rates. This suggests that there had been little behavioral

change in the latter group. Goldman and Smith (2002) report that more educated HIV patients are more likely to adhere to therapy, reflected by highly active antiretroviral treatments (HAART), which became available in the mid 1990s. Their data source is the HIV Cost and Services Utilization Study, conducted in three waves between 1996 and 1998, and their findings control for initial health status and insurance status. In turn, adherence to therapy leads to improvements in self-rated health between the three waves of the survey. Schooling has no impact on improvements in health with adherence to therapy held constant. Hence, adherence to therapy by the more educated appears to be an important mechanism via which schooling can improve health among persons with a relatively new disease when a new treatment regime is introduced.

Goldman and Lakdawalla (2002) reinforce the results just discussed by considering self-reported CD4 T-lymphocyte cell counts as an outcome in the same survey used by Goldman and Smith (2002). A depletion in these cells correlates strongly with the worsening of HIV disease and raises the probability of developing AIDS. They find negative and significant schooling effects on this outcome in the second and third waves of the survey, but not in the baseline wave, with insurance status, self-reported baseline health, and the number of years since the individual had been diagnosed with HIV held constant.

de Walque (2005) reinforces Goldman and Smith's results in a very different setting. He finds that, after more than a decade of prevention campaigns about the dangers of the HIV/AIDS epidemic in Uganda, there has been a significant change in the HIV/education gradient. In 1990 no relationship existed, but by 2000 education lowers the risk of being HIV positive among young individuals. He also reports a positive relationship between schooling and condom use during the recent period, which may partially explain his findings. Not enough time in the AIDS

epidemic has elapsed to examine whether a permanent relationship between the prevalence and severity of the disease and schooling has emerged. The weakening of this relationship would provide further support for the allocative efficiency hypothesis, while its persistence would provide support for productive efficiency effects or for the role of third variables.

Lleras-Muney and Lichtenberg (2002) and Glied and Lleras-Muney (2003) present evidence of important interactions between education and new medical technologies in a variety of cases. Using the 1997 U.S. Medical Expenditure Panel Survey, Lleras-Muney and Lichtenberg (2002) find that the more educated are more likely to use drugs recently approved by the Federal Drug Administration. Their findings only pertain to individuals who repeatedly purchase drugs for a given condition, indicating that the more educated are better able to learn from experience.

Glied and Lleras-Muney (2003) focus on mortality from 55 diseases that account for mortality from all diseases and on cancer mortality from 81 different cancer sites. The former analysis employs the 1986-1990 Health Interview Surveys matched to the Mortality Cause of Death files for 1986-1995 and examines disease-specific mortality within five years. The latter employs the Surveillance Epidemiology and End Results Cancer Incidence Public Use Database, which contains information on every person diagnosed with cancer from 1973 through 1998 in six states and three cities in different states. The outcome is mortality within five years of diagnosis. In the disease-specific mortality analysis, technological progress is measured by the annual percentage change in the age-adjusted mortality rate for the period 1969-1999 for each of the 55 diseases. In the cancer analysis, it is based on the percentage change in the five-year survival rate conditional on diagnosis using diagnosis data for each of the 81 sites for the years 1973-1975 and 1991-1993. Alternatively, progress in treating cancer is given by the number of

drugs that existed in 1999 and the number of drugs approved between 1973 and 1999 by site.[25] Their principal result is that negative effects of schooling on mortality are largest for diseases and cancer sites in which progress has been the most rapid.

Goldman and Lakdawalla (2002) point out that not all new medical innovations require better self-management skills on the part of patients. They give as an example the introduction of new antihypertensive drugs, called beta-blockers, in the late 1960s and early 1970s. These new drugs serve as a substitute at least to some extent for the former treatment of diet, exercise, weight control, and the occasional use of diuretics. In terms of their model outlined in Section 2.2, the positive relationship between the output elasticity of the patient's own time and schooling falls when beta-blockers are introduced. Consistent with this prediction, they find that the negative effect of schooling on the presence of hypertensive cardiovascular disease as diagnosed by a physician in the Framingham Heart Study is reduced in absolute value in the post-beta-blocker period.

Goldman and Smith (2002) give an example in which the persistence of long-run schooling effects is not necessarily evidence against allocative efficiency. They study treatment regimes pursued by diabetics in the Health and Retirement Survey--households with one member between the ages of 51 and 61 in 1992. Using four waves of data and information on alternative treatment regimes (swallowed medication only, insulin shots only, medication and insulin shots an external pump, or nothing), Goldman and Smith classified treatment patterns as good or bad and report that the more educated are less likely to adhere to poor treatment regimes.[26] In turn, a poor regime is associated with a deterioration in self-rated health between the first and fourth regimes. Finally, the negative effect of schooling on a poor treatment regime is eliminated when

the Wechsler Adult Intelligence Score, a measure of higher-level reasoning, is included as a regressor. This suggests that the schooling effect measures cognitive ability.

4.1.3. Time preference, other omitted factors, and instrumental variables

Fuchs (1982) measures time preference in a telephone survey by asking respondents questions in which they choose between a sum of money now and a larger sum in the future. He includes an index of time preference in a multiple regression in which health status is the dependent variable and schooling is one of the independent variables. Fuchs is not able to demonstrate that the schooling effect is due to time preference. The latter variable has a negative regression coefficient, but it is not statistically significant. When time preference and schooling are entered simultaneously, the latter dominates the former. These results must be regarded as preliminary because they are based on one small sample of adults on Long Island and on exploratory measures of time preference.

Farrell and Fuchs (1982) explore the time preference hypothesis in the context of cigarette smoking using interviews conducted in 1979 by the Stanford Heart Disease Prevention Program in four small agricultural cities in California. They examine the smoking behavior of white non-Hispanics who were not students at the time of the survey, had completed 12 to 18 years of schooling, and were at least 24 years old. The presence of retrospective information on cigarette smoking at ages 17 and 24 allows them to relate smoking at these two ages to years of formal schooling completed by 1979 for cohorts who reached age 17 before and after the widespread diffusion of information concerning the harmful effects of cigarette smoking on health.

Farrell and Fuchs find that the negative relationship between schooling and smoking,

which rises in absolute value for cohorts born after 1953, does not increase between the ages of 17 and 24. Since the individuals were all in the same school grade at age 17, the additional schooling obtained between that age and age 24 cannot be the cause of differential smoking behavior at age 24, according to the authors. Based on these results, Farrell and Fuchs reject the hypothesis that schooling is a causal factor in smoking behavior in favor of the view that a third variable causes both. Since the strong negative relationship between schooling and smoking developed only after the spread of information concerning the harmful effects of smoking, they argue that the same mechanism may generate the schooling-health relationship.

A different interpretation of the Farrell and Fuchs finding emerges if one assumes that consumers are farsighted. The current consumption of cigarettes leads to more illness and less time for work in the future. The cost of this lost time is higher for persons with higher wage rates who have made larger investments in human capital. Thus, the costs of smoking in high school are greater for persons who plan to make larger investments in human capital.

Leigh (1985) presents evidence that supports Fuchs's (1982) finding that the positive relationship between schooling and health cannot be explained by time preference. Using the Panel Study of Income Dynamics, a nationally representative panel survey conducted by the University of Michigan's Survey Research Center annually since 1968, Leigh measures health inversely with a dichotomous variable that identifies persons who became disabled (developed conditions that limited the amount or kind of work they could do) in 1971 or 1972. The independent variables in logit equations that explain the probability of becoming disabled pertain to the year prior to the onset of the disability. Schooling has a negative and statistically significant logit coefficient. When a risk preference index, which is highly correlated with a time preference index [Leigh (1986)], is introduced into the equation, the schooling coefficient

declines by only 10 percent and remains statistically significant (personal communication with Leigh).

Ross and Mirowsky (1999) find that the impacts of schooling on self-rated health and on a continuous positive correlate of physical functioning are significantly reduced when a measure of sense of control is included as a regressor in the 1995 Aging, Status, and the Sense of Control Survey. This is a nationally representative U.S. sample of persons aged 18 and over, with an oversampling of the elderly. Sense of control pertains to the belief that one can and does master, control, and shape his own life. Studies by psychologists summarized by Ross and Mirowsky (1999) and by Hammond (2003) indicated that sense of control is positively related to self-efficacy and to a future orientation.

Ross and Mirowsky note that lack of personal control makes efforts to change health by quitting smoking, exercising, or limiting alcohol consumption appear to be useless. They argue: "Human capital acquired in school increases a person's real and perceived control of life. Education develops the habits and skills of communication….Because education develops one's ability to gather and interpret information and to solve problems on many levels, it increases one's control over events and outcomes in life (p. 446)." Although Ross and Mirowsky are sociologists, their argument is very similar to the one proposed by Becker and Mulligan (1997) regarding why education makes a person more future oriented. The point we wish to make is that Ross and Mirowsky treat sense of control as a mechanism via which schooling can affect health rather than as a third variable that must be held constant is assessing whether more schooling causes better health.

A counterpoint to the point made by Ross and Mirowsky is contained in a study by Coleman and DeLeire (2003). Using the National Education Longitudinal Study, they show that

sense of control measured in the eighth grade is a positive predictor of high school completion and college attendance. This suggests that sense of control may be an exogenous influence on schooling rather than a mechanism via which schooling affects health. They also report, however, that increases in personal control between the eighth and twelfth grades are positively related to increases in cognitive test scores between those two grades. This finding implies that sense of control has an endogenous component.

Ippolito (2003) takes a somewhat different approach to controlling for time preference in his study of the determinants of health in the Health and Retirement Survey used by Goldman and Smith (2002). He employs three measures of health from the 1992 baseline data: dichotomous indicators that identify respondents in poor health and respondents who have difficulty walking stairs and the number of reported ailments. He also employs death within six years of the 1992 survey from the National Death Index as a fourth health outcome. With income and several other variables held constant, schooling has a negative and significant impact on each outcome. The schooling coefficients are greatly reduced and in the case of ailments and mortality become insignificant when proxies for time preference are included as regressors. These proxies include the amount of formal schooling obtained by the oldest child in the household, whether there is an Individual Retirement Account (IRA) in the household, whether the respondent has a pension in the present job or had one in the past job, and willingness to sacrifice some lifetime consumption in favor of leaving a bequest to children or grandchildren (a five-point scale, with five indicating that the respondent definitely plans to leave a bequest).

Ippolito indicates that his results are subject to several interpretations. One is that they provide evidence in favor of the time preference hypothesis. An alternative interpretation is that the time preference variables are determined by schooling and are mechanisms via which an

individual's own schooling affects his or her own health. That interpretation is the one implied by the Becker-Mulligan model and the one stressed by Ross and Mirowsky (1999). An interpretation of the findings with respect to pensions and IRAs not mentioned by Ippolito is that they reflect reverse causality from longevity to savings. Hurd (1987, 1989) points out that individuals (or couples) with a longer life expectancy have more reason to save.

Definitive estimates of the partial effects of schooling and time preference on health would treat both as endogenous in a system of equations that allows for causality between schooling and time preference in both directions. Given difficulties in measuring time preference and in identifying this system, no attempts have been made to estimate it. There is, however, an extremely promising line of research that treats schooling as endogenous and estimates the causal effect of schooling on health by the method of instrumental variables. This line of research does not attempt to distinguish between the direct effect of schooling on health and the indirect effect that operates through time preference. The latter variable is treated as the disturbance term in the health equation and is assumed to be correlated with schooling. The idea is to find instruments that are correlated with schooling but not correlated with time preference. These variables serve as instruments for schooling in estimation of health equations by two-stage least squares and its variants.[27]

The earliest studies to apply the instrumental variables (IV) methodology to the relationship between health and schooling are by Berger and Leigh (1989), Sander (1995a, 1995b), and Leigh and Dhir (1997). Berger and Leigh apply the methodology to two data sets: the first National Health and Nutrition Examination Survey (NHANES I) and the National Longitudinal Survey of Young Men (NLS). In NHANES I, health is measured by blood pressure, and separate equations are obtained for persons aged 20 through 40 and over age 40 in

the period 1971 through 1975. The schooling equation is identified by ancestry and by average real per capita income and average real per capita expenditures on education in the state in which an individual resided from the year of birth to age 6. These variables enter the schooling equation but are excluded from the health equation. In the NLS, health is measured by a dichotomous variable that identifies men who in 1976 reported that health limited or prevented them from working and alternatively by a dichotomous variable that identifies the presence of a functional health limitation. The men in the sample were between the ages of 24 and 34 in 1976, had left school by that year, and reported no health limitations in 1966 (the first year of the survey). The schooling equation is identified by IQ, Knowledge of Work test scores, and parents' schooling.

Results from the NLS show that the schooling coefficient rises in absolute value when predicted schooling replaces actual schooling, and when health is measured by work limitation. When health is measured by functional limitation, the two-stage least squares schooling coefficient is approximately equal to the ordinary least squares coefficient, although the latter is estimated with more precision. For persons aged 20 through 40 in NHANES I, schooling has a larger impact on blood pressure in absolute value in the two-stage regressions. For persons over age 40, however, the predicted value of schooling has a positive and insignificant regression coefficient. Except for the last finding, these results are inconsistent with the time preference hypothesis and consistent with the hypothesis that schooling causes health.

In another application of the same methodology, Leigh and Dhir (1997) focus on the relationship between schooling and health among persons ages 65 and over in the 1986 wave of the Panel Survey of Income Dynamics (PSID). Health is measured by a disability index comprised of answers to six activities of daily living and by a measure of exercise frequency.

Instruments for schooling include parents' schooling, parents' income, and state of residence in childhood. The schooling variable is associated with better health and more exercise whether it is treated as exogenous or endogenous.

Sander (1995a, 1995b) applies the methodology to the relationship between schooling and cigarette smoking studied by Farrell and Fuchs (1982). His data consist of the 1986-1991 waves of the National Opinion Research Center's General Social Survey. In the first paper the outcome is the probability of quitting smoking, while in the second the outcome is the probability of smoking. Separate probit equations are obtained for men and women ages 25 and older. Instruments for schooling include father's schooling, mother's schooling, rural residence at age 16, region of residence at age 16, and number of siblings.

In general schooling has a negative effect on smoking participation and a positive effect on the probability of quitting smoking. These results are not sensitive to the use of predicted as opposed to actual schooling in the probit regressions. Moreover, the application of the Wu-Hausman endogeneity test [Wu (1973), Hausman (1978)] in the quit equation suggests that schooling is exogenous in this equation. Thus, Sander's results, like Berger and Leigh's and Leigh and Dhir's results, are inconsistent with the time preference hypothesis.

The aforementioned conclusion rests on the assumption that the instruments used to predict schooling in the first stage are uncorrelated with time preference. The validity of this assumption is most plausible in the case of measures such as real per capita income and real per capita outlays on education in the state in which an individual resided from birth to age 6 (used by Berger and Leigh in NHANES I), state of residence in childhood (used by Leigh and Dhir in the PSID), rural residence at age 16, and region of residence at that age (used by Sander). The validity of the assumption is less plausible in the case of measures such as parents' schooling

(used by Sander and by Berger and Leigh in the NLS and by Leigh and Dhir in the PSID) and parents' income (used by Leigh and Dhir in the PSID).

Very recent work by Lleras-Muney (2005), Adams (2002), Arendt (2005), Spasojevic (2003), Arkes (2004), and de Walque (2004) address the schooling-health controversy by using compulsory education laws, unemployment rates during a person's teenage years, or the risk of draft induction during the Vietnam war era to obtain consistent estimates of the effect of schooling on health or on cigarette smoking--a key determinant of many adverse health outcomes. These variables, some of which result from quasi-natural experiments, are assumed to be correlated with schooling but uncorrelated with time preference. Hence, they serve as instruments for schooling in the estimation of health equations by two-stage least squares and its variants.

Lleras-Muney (2005) employs compulsory education laws in effect from 1915 to 1939 to obtain consistent estimates of the effect of education on mortality in synthetic cohorts of successive U.S. Censuses of Population for 1960, 1970, and 1980. This instrument is highly unlikely to be correlated with unobserved determinants of health, especially because she controls for state of birth and other state characteristics at age 14. Her ordinary least squares estimates suggest that an additional year of schooling lowers the probability of dying in the next ten years by 1.3 percentage points. Her IV estimate is much larger: 3.6 percentage points.

Adams (2002) uses the same instrument as Lleras-Muney in the first wave of the Health and Retirement survey, conducted in 1992. He restricts his analysis to individuals between the ages of 51 and 61 and measures health by functional ability and self-rated health. He finds positive and significant effects of education on these positive correlates of good health and larger IV coefficients than the corresponding OLS coefficients.

Arendt (2005) capitalizes on compulsory school reform in Denmark in 1958 and 1975 to study the impact of schooling on self-rated health in the 1990 and 1995 waves of the Danish National Work Environment Cohort Study. Respondents were between the ages of 18 and 59 in 1990. His results are similar to those of Adams.

Spasojevic (2003) focuses on a unique social experiment, the 1950 Swedish comprehensive school reform. Between 1949 and 1962, the school system created by the 1950 act was implemented randomly and in stages by municipalities in Sweden. Because of that, persons born between 1945 and 1955 went through two different school systems, one of which implied at least one additional year of compulsory schooling. This serves as the instrument for schooling in estimates of health equations for males born between 1945 and 1955 in the 1981 and 1991 waves of the Swedish Level of Living Survey. Health is measured by an index constructed from information on the presence of fifty different health conditions (illnesses and ailments). Results suggest that the negative IV effects of schooling on the index of poor health are at least as large in absolute value as the corresponding OLS effects.

Arkes (2004) focuses on white males aged 47 to 56 in the 1990 Census of Population. His instrument for schooling is the state unemployment rate during a person's teenage years. With state per capita income held constant, he argues that a higher unemployment rate should lead to greater educational attainment because it reduces the opportunity cost of attending school. From two-stage least squares probit models, he finds that an additional year of formal schooling lowers the probability of having a work-limiting condition by 2.6 percentage points and reduces the probability of requiring personal care by 0.7 percentage points. Both estimates exceed those that emerge from probit models that treat schooling as exogenous.

de Walque (2004) examines the effect of schooling on the probability that males born

between 1937 and 1956 are current cigarette smokers in the 1983, 1985, 1987, 1988, 1990, 1991, 1992, 1994, and 1995 U.S. National Health Interview Survey. These men were of draft age during the Vietnam war era, and some of them enrolled in college to avoid the draft. Thus de Walque uses the risk of induction, defined as the average yearly number of inductions in Vietnam during the years in which a particular birth cohort was aged 19-22 divided by the size of the cohort, as an instrument for college education. In some specification, the induction risk is multiplied by the risk of being killed in Vietnam (the ratio of the number of soldiers killed in action in a year and the number of troops engaged in Vietnam in that year) to obtain the risk of being inducted and killed in action. The IV estimates of the effect of education on the probability of smoking are negative and significant. In some cases, they are at least as large in absolute value as the corresponding OLS coefficients.

The results of the six very recent studies just reviewed suggest causality from more schooling to better health. The finding that the IV estimates exceed the OLS estimates may arise because the instruments are based on policy interventions that affect the educational choices of persons with low levels of education (Card 2001). If different individuals face different health returns to education, IV estimates reflect the marginal rate of return of the group affected by the policies (Angrist, Imbens, and Rubin 1996). Card (2001) points out: "For policy evaluation purposes…the average marginal return to schooling in the population may be less relevant than the average return for the group that will be impacted by a proposed reform. In such cases, the best available evidence may be IV estimates of the return to schooling based on similar earlier reforms (p. 1157)."

A second explanation of the larger IV than OLS estimates is that the schooling variable contains random measurement error, which leads to a downward bias in the OLS estimates. As

long as the instruments for schooling are not correlated with this error, the IV procedure eliminates this bias (Card 1999, 2001). A third explanation is that there may be spillover effects in the sense that the health outcome of an individual depends on the average schooling of individuals in his area as well as on his own schooling or that of his parents (Acemoglu 1996; Acemoglu and Angrist 2000). Currie and Moretti (2003) show that IV estimates of this combined effect based on area-level instruments are consistent, while OLS estimates understate it.

In summary, the six very recent studies that I have discussed in detail underscore the utility of employing IV techniques with area-level instruments to obtain consistent estimates of the effects of schooling on health and other measures of well-being. This methodology controls for time preference and other unmeasured variables that potentially are correlated with health and schooling.

4.2. Child health

4.2.1. Productive efficiency and related mechanisms

Evidence that parents' schooling causes children's health is contained in research by my colleagues and me on the determinants of child and adolescent health [Edwards and Grossman (1981), (1982), (1983), Shakotko et al. (1981)]. We study child and adolescent health in the context of the nature-nurture controversy. Our research uses data primarily on whites from Cycle II of the U.S. Health Examination Survey (children aged 6 through 11 years in the period 1963 through 1965), Cycle III of the Health Examination Survey (adolescents aged 12 through 17 years in the period 1966 through 1970), and the panel of individuals (one third of the full Cycle III sample) who were examined in both cycles.

We find that the home environment in general and mother's schooling in particular play an extremely important role in the determination of child and adolescent health. It is not surprising to find that children's home environment has a positive impact on their health with no other variables held constant. Moreover, it is difficult to sort out the effect of nature from that of nurture because it is difficult to measure a child's genetic endowment and because genetic differences may induce environmental changes. Nevertheless, we have accumulated a number of suggestive pieces of evidence on the true importance of the home environment. With birthweight, mother's age at birth, congenital abnormalities, other proxies for genetic endowment, and family income held constant, parents' schooling has positive and statistically significant effects on many measures of health in childhood and adolescence. For example, children and teenagers of more educated mothers have better oral health, are less likely to be obese, and less likely to have anemia than children of less educated mothers. Father's schooling plays a much less important role in the determination of oral health, obesity, and anemia than mother's schooling. The latter findings are important because equal effects would be expected if the schooling variables were simply proxies for unmeasured genetic endowments. On the other hand, if the effect of schooling is primarily environmental, one would expect the impact of mother's schooling to be larger because she was the family member most involved with children's health care in the late 1960s and early 1970s.

Several additional pieces of evidence underscore the robustness of the above finding. When oral health is examined in a longitudinal context, mother's schooling dominates father's schooling in the determination of the periodontal index in adolescence, with the periodontal index in childhood held constant. Similar comments apply to the effect of mother's schooling on school absence due to illness in adolescence (with school absence due to illness in childhood

held constant) and to the effect of mother's schooling on obesity in adolescence (with obesity in childhood held constant).

Edwards and Grossman (1979) document a variety of positive associations between good health and cognitive development, measured by IQ and school achievement, in Cycle II of the Health Examination Survey. As part of the longitudinal study just described, Shakotko et al. (1981) investigate the direction of causation implied by these associations. They apply the notion of causality introduced by Granger (1969) by estimating two multivariate equations. One relates adolescent health to childhood health, childhood cognitive development, and family background measures. The second relates adolescent cognitive development to childhood cognitive development, childhood health, and family background. They find feedback both from good health to cognitive development and from cognitive development to good health, but the latter of these relationships is stronger. Since an individual's cognitive development is an important determinant of the number of years of formal schooling that he or she ultimately receives, this finding may be viewed as the early forerunner of the positive impact of schooling on good health for adults that we discussed above.

The study by Shakotko et al. (1981) is unique in several respects. First, it exploits time-varying measures of health and school achievement in panel data to investigate the causal priorness of these measures. We assume that the processes governing these outcomes are Markov and can be estimated by a simple first-order autoregressive model. We show that, if the genetic impact on these outcomes is restricted to the determination of initial conditions, then the estimates of the time paths will be free of genetic bias and will reflect the true environmental effects of family background, childhood health, and childhood cognitive development variables. Second, indicators of education generally are fixed over time in panel studies of adult health, but

these indicators are not fixed in our panel. Finally, most of the studies summarized in this paper measure education by years of formal schooling completed and ignore the quality of schooling. The school achievement variable that we employ reflects in part school quality.

Research by Wilcox-Gök (1983) calls into question some of the findings in the studies just described. She studies the determinants of child health in a sample of natural and adopted sibling pairs. The children in her sample were between the ages of 5 and 14 in 1978 and were all members of the Medical Care Group of Washington University (a prepaid, comprehensive medical care plan) in St. Louis, Missouri. Health is measured by the number of days a child had missed from usual activities due to illness or injury in a five month period as reported by parents. The results for natural siblings reveal that the proportion of the variation in health explained by unmeasured sources of common family background is much greater than the proportion explained by measured variables. Moreover, the correlation between natural siblings' health is significantly higher than for sibling pairs in which one child was adopted (was not the natural child of at least one parent). These results point to the importance of genetic endowment.

Clearly, Wilcox-Gök's findings are not generalizable to the population of the United States. Not only are they specific to the residents of one city, but the families in the sample had a higher mean income and a larger number of children (the prepaid group practice offered special family membership rates) than the typical U.S. family. In addition, one parental reported health indicator is employed in contrast to the variety of measures, many of which come from physical examinations, used by Shakotko et al. (1981).

Corman and Grossman (1985) document the importance of mother's schooling as a determinant of neonatal mortality rates (deaths of infants within the first 27 days of life per thousand live births) in the United States. They use large counties of the United States (counties

with a population of at least 50,000 persons in 1970) as the units of observation and a three-year average of the neonatal mortality rate centered on 1977 as the dependent variable. Separate regressions are obtained for whites and blacks. To examine the relative contributions of schooling, poverty, and public program measures to the recent U.S. neonatal mortality experience, Corman and Grossman apply the estimated regression coefficients to trends in the exogenous variables between 1964 and 1977, a period during which the neonatal mortality rate declined rapidly.

In the period at issue the white neonatal mortality rate fell by 7.5 deaths per thousand live births, from 16.2 to 8.7. The black neonatal mortality rate fell by 11.5 deaths per thousand live births, from 27.6 to 16.1. The statistical analysis "explains" approximately 28 percent of the white decline on average and 33 percent of the black decline on average. The increase in white female schooling makes the largest contribution to the decline in white neonatal mortality. The reduction due to schooling amounts to approximately 0.5 deaths per thousand live births. The increase in black female schooling ranks second to the increase in abortion availability as a contributing factor to the reduction in black neonatal mortality. The estimated abortion effect amounts to a decline of about 1 death per thousand live births, while the schooling trend produces a decline of about 0.7 death per thousand live births.

While Corman and Grossman (1985) fit reduced form infant health outcome equations, Grossman and Joyce (1990) obtain a direct estimate of productive efficiency by fitting birthweight production functions for blacks in New York City in 1984. They do not employ two-stage least squares estimation. Instead, they control for a variety of unobservables governing pregnancy resolutions and birthweight by pooling data on births and abortions. They then estimate a three-equation model. The first equation is a probit for the probability of giving birth,

given that a woman is pregnant. With this as the criterion equation, they test for self-selection (correlations between unobserved variables and observed outcomes) in the birthweight production function and in the prenatal care demand function using Heckman's (1979) methodology.[28] They report that black women who completed at least one year of college gave birth to infants who weighed 69 grams more than the infants of women who completed at least 8 but no more than 11 years of schooling. This amounts to a 2 percent increase relative to a mean of 3,132 grams for the latter group.

Recent studies by Case et al. (2002) and by Currie and Stabile (2003) confirm the importance of parents' schooling on child health outcomes at a variety of different ages. Case and her colleagues employ data from the 1988 U.S. National Health Interview Survey. They find positive effects of mother's and father's schooling on parental rating of child health, with family income held constant. The favorable effect of family income on this outcome is larger for older children, but this pattern is not observed for the schooling effects. The authors conclude: "It appears that income (and what it buys a child) has a different effect on a child's health from the skills that accompany parental education (p. 1314)." Currie and Stabile (2003) report cross-sectional results that mirror those of Case and her colleagues in the Canadian National Longitudinal Survey of Children and Youth--children ages 0-11 in 1994, with follow-ups in 1996 and 1998. Moreover, mother's schooling has a positive effect on her rating of the child's health in 1998, with health status in 1994 (measured by the presence of a chronic condition in 1994, the presence of asthma in 1994, or by hospitalization in 1994) held constant.

A number of the studies summarized in this subsection bear on the somewhat controversial but highly influential work by Barker (1995) and the less controversial studies by Da Stavola et al. (2000) because they report effects of parents' schooling on children's current

health status, with past health status held constant. Barker (1995) suggests that in-utero growth and adolescent growth affect heart disease at age 75. Da Stavola et al. (2000) report that estrogen in utero affects birth size, and large female babies with elevated estrogen have a much higher incidence of pre-menopausal breast cancer. In their study with the 1958 British National Child Development Survey described in Section 4.1.1, Case et al. (2005) find that men who experienced poor health in utero and at ages 7, 16, 23, and 33 have lower health at age 42, with parents' schooling and socioeconomic status held constant. But self-rated health at age 42 is positively related to parents' schooling, unless own schooling is included in the regression analysis.

The reader is cautioned about the difference between my emphasis on findings and that of Case et al. (2005). I stress the significant effects of parent's schooling and own schooling on current health, with past health held constant. They stress the significant effects of past health on current health, with the schooling variables held constant. In general, their results and those in other studies summarized in this subsection suggest a long term association between parents' attributes and children's attributes including health. Schooling is part of this relationship, but uncoupling the causal links associated with genetic and behavioral factors is very difficult. Clearly, breaking into this complicated bundle is a challenge for future research.

4.2.2. Allocative efficiency

Thomas et al. (1991) and Glewwe (1999) explore the allocative efficiency hypothesis in the context of the determinants of child health in developing countries. Both studies consider the anthropometric outcome of height standardized for age and gender, which is closely related to nutritional intakes in these countries. Low values signal stunting due to nutritional deficiencies.

In a study based on approximately 1,300 children age 5 or less in the 1986 Brazilian Demographic and Health Survey, Thomas et al. (1991) find that practically all of the positive effect of mother's schooling on child height is due to information as measured by whether the woman reads newspapers, watches television, and listens to the radio. These three variables are treated as endogenous. The instruments are the existence of a local newspaper in the mother's municipio (similar to a county in the U.S.) of residence, dichotomous indicators of the number of television channels in the municipio of residence, and mother's age.

Glewwe (1999) employs a sample of approximately 1,500 children ages 5 or younger in Morocco in 1990-91 obtained as part of the World Bank's Living Standards Measurement Study. This sample contains a direct measure of the mother's general health knowledge obtained as the number of correct responses to five questions. Unlike Thomas et al. (1991), he is able to control directly for the child's health endowment by employing mother's and father's height as regressors. He finds that all of the favorable impact of mother's schooling on child height operates through health knowledge. He treats knowledge as endogenous and instruments it with the number of married sisters of the mother and her husband, education of the mother's parents, number of radios and televisions in the household, and the availability of local newspapers.

Clearly, Thomas et al. (1991) and Glewwe (1999) find much more support for the allocative efficiency hypothesis than Kenkel (1991), whose study was described in Section 4.1.2. This may be traced to the more general and "less noisy" information variables that they employ. Of course, their studies pertain to developing countries. Thomas et al. do, however, conduct separate analyses for children who reside in rural and urban areas. Despite the larger values of schooling and information in the urban areas, they report the same results for both areas. One caution is that issues can be raised with regard to the validity of the instruments used in the two

studies. Thomas et al. do not perform overidentification tests. Glewwe does perform these tests and accepts the hypothesis that the variables employed as instruments do not belong in the health outcome equation. Yet one can still question the validity of using the education of the mother's parents as an instrument if time preference is an important omitted variable.

In another application to child health and allocative efficiency in developing countries, Jalan and Ravallion (2003) consider interactions between access to piped water and mother's schooling in determining the prevalence and duration of diarrhea in rural India. They point out that this disease causes approximately four million children under the age of five in developing countries to die each year and that unsafe water is the major cause. They use a sample of 33,000 rural households in 16 states of India conducted in 1993-94. Approximately 25 percent of the households had access to piped water. Based on propensity score matching methods, they find that the incidence and duration of diarrhea among children is significantly lower on average for families with piped water. They also report, however, no effects if the mother is poorly educated and effects that rise in absolute value as the mother's education rises. These patterns continue to be observed when household income per capita is held constant.

Meara (1999, 2001) explores the allocative efficiency hypothesis in the context of birth outcomes in the U.S. National Maternal and Infant Health Survey, conducted in 1988. Her outcome is the probability of a low-birthweight (less than 2,500 grams) birth. Low birthweight is the most important proximate cause of infant death. She obtains separate production functions of this outcome for white and black mothers.[29] She finds that the negative and significant effects of mother's schooling on the probability of a low-birthweight birth are greatly reduced in absolute value when five health inputs are held constant. For blacks, schooling is not significant in models with the inputs. The inputs are dichotomous indicators for smoking cigarettes during

pregnancy, drinking more than five drinks of alcohol during pregnancy, using cocaine during pregnancy, beginning prenatal medical care during the first trimester, and taking vitamins during pregnancy. The smoking indicator has the most important impact by far on the schooling coefficients.

Taken at face value, the results just described provide support for the allocative efficiency hypothesis, although the inputs are treated as exogenous. As pointed out in Section 2.2, health production functions that ignore the endogeneity of inputs are subject to biases due to adverse and favorable selection. Meara puts these considerations aside and proceeds to show that knowledge of the harmful effects of smoking cannot explain why more educated women of childbearing age are less likely to smoke. This analysis employs the 1985 and 1990 Health Promotion and Disease Prevention Supplements to the U.S. National Health Interview Survey. These results are similar to Kenkel's 1991 study, except that he includes men and women of all ages. Based on this evidence, Meara rejects the allocative efficiency hypothesis in favor of one emphasizing the role of third variables.

To buttress the importance of omitted factors, Meara (1999) examines the probabilities that adolescent girls between the ages of 14 and 20 smoked cigarettes regularly and used an illegal drug besides marijuana in the 1994-95 Longitudinal Adolescent Health Survey. She finds that the negative effects of mother's schooling on these two probabilities are greatly reduced in absolute value when proxies for discount rates, self-control, and measures of symptoms of depression are included in the probit functions that she estimates. Like Kenkel (1991), Meara is careful to conclude that her results are subject to more than one interpretation. She does tend to emphasize the third variable hypothesis stressed by Fuchs (1982), although she points out that

more educated mothers could influence health and human capital investment decisions made by their daughters in a causal sense.

I would add that her results are not inconsistent with the Becker-Mulligan (1997) story in which more educated parents make investments in their children to make them more future oriented. These investments and the amount of formal schooling acquired by the prospective mother determine her rate of time preference for the present. Hence, a finding that differences in knowledge about the harmful effects of smoking cannot explain why more educated pregnant women are less likely to smoke is not inconsistent with a causal effect of education on smoking. The mechanism here is that education causes time preference which in turn causes smoking.

4.2.3. Time preference, other omitted factors, and instrumental variables

Currie and Moretti (2003) examine the relationship between maternal education and birthweight among U.S. white women with data from individual birth certificates from the Vital Statistics Natality files for 1970 to 2000. They use information on college openings between 1940 and 1990 to construct an availability measure of college in a woman's 17th year as an instrument for schooling. They find that the positive effect of maternal schooling on birthweight increases when it is estimated by instrumental variables. They also find that the negative IV coefficient of maternal schooling in an equation for the probability of smoking during pregnancy exceeds the corresponding OLS coefficient in absolute value. Since prenatal smoking is the most important modifiable risk factor for poor pregnancy outcomes in the United States (U.S. Department of Health and Human Services 1990), they identify a very plausible mechanism via which more schooling causes better birth outcomes. Finally, parity falls and the probability of being married rises as maternal education rises. The OLS coefficients are somewhat larger than

the IV coefficients, although both sets are significant. These results suggest other mechanisms via which more schooling leads to better infant health outcomes.

Breierova and Duflo (2004) capitalize on a primary school construction program in Indonesia between 1973 and 1978. In that period 61,000 primary schools were constructed. Program intensity, measured by the number of new schools constructed per primary-school age child in 1971, varied considerably across the country's 281 districts. In a study of the effects of schooling on earnings, Duflo (2001) shows that average educational attainment rose more rapidly in districts where program intensity was greater. She also argues that the program had a bigger effect for children who entered school later in the 1970s and no effect for children who entered school before 1974. Therefore, she uses the interaction between year of birth and program intensity as an instrument for schooling for male wage earners in the 1995 intercensal survey of Indonesia who were between the ages of 2 and 24 in 1974. This instrument turns out to be an excellent predictor of schooling.

Breierova and Duflo (2004) use the instrument just described to estimate the effects of mother's and father's education on child mortality in the same survey employed by Duflo. They employ fertility and infant mortality histories of approximately 120,000 women between the ages of 23 and 50 in 1995. They find that mother's and father's schooling have about the same negative effects on infant mortality. Some, but not all, of the IV coefficients exceed the corresponding OLS coefficients. The authors treat their results as very preliminary.

5. Empirical evidence: other outcomes

Numerous studies report that more educated parents have fewer children in developed and developing countries [for example, De Tray (1973), Michael (1973a), Willis (1973), Becker

(1991), Schultz (1993), Hotz, Klerman, and Willis (1997), Lam and Duryea (1999)]. Indeed, Schultz (1993) terms this relationship "one of the most important discoveries in research on nonmarket returns to women's education (p. 74)." A majority of the studies indicate larger effects for mother's schooling than for father's schooling. This finding is consistent with a division of labor within the household in which the mother is the family member most involved with child care.

Theoretical bases for the negative impacts of mother's schooling on fertility were discussed in Section 2.3. I leave the reader to evaluate the detailed empirical evidence and the suggested mechanisms in the studies just mentioned and in the ones that they cite. I do, however, want to call attention to two potential mechanisms that are directly related to allocative and productive efficiency. One is the effect of education on contraceptive efficiency. Michael (1973a) studies the relationship between wife's schooling and the contraceptive technique employed by women in specific birth intervals in the 1965 National Fertility Survey. He employs published data on the monthly birth probability of each technique (a measure of contraceptive failure) and uses this as the dependent variable in a regression in which schooling, actual or desired level of fertility, age, birth interval, race, and religion (Catholic/non-Catholic) are the independent variables. The control for intended family size eliminates the differential incentive to contracept by level of schooling, which is related to different levels of desired fertility. He finds that more educated women have significantly lower risks of conception. Since these results hold constant desired fertility, they cannot be attributed to the impacts of income and the value of time. Instead, since the data pertain to a period of rapid diffusion of new and effective methods of birth control--the oral contraceptive (pill) and IUD--Michael's results suggests an interaction between schooling and the adoption of new technology. Similar

interactions in the health area were found in a number of the adult health studies discussed in Section 4.1.2.

Using more recent data for the 1970s and a more complicated econometric framework in which fertility is endogenous, Rosenzweig and Schultz (1989) extend Michael's (1973a) results by showing that more educated couples have a wider knowledge of contraceptive methods in cases in which such knowledge is not widely disseminated. To be specific, the more educated had more information about such ineffective methods as withdrawal and the rhythm calendar method. This does not carry over to methods that are immune to misuse such as the condom, diaphragm, foam, IUD, and the pill. They also find that the use-effectiveness of ineffective methods increases in absolute value with wife's schooling. This result comes from the longitudinal sample of women from the 1970 National Fertility survey who were reinterviewed in 1975. The dependent variable, which measures fertility, is the number of conceptions between 1970 and 1975, divided by the number of months of exposure to the risk of conception. The fertility control variables as well as the monthly frequency of intercourse are treated as endogenous.

Finally, Rosenzweig and Schultz explore interactions between an estimate of fecundity and schooling in determining the proportion of unplanned births and between that outcome and schooling in determining the effectiveness of the method of contraception selected. An increase in fecundity has a smaller impact on unplanned pregnancies for more educated women, and an increase in previous unplanned pregnancies has a larger impact on the selection of more effective methods of contraception for women with higher levels of education. The magnitude of the latter effect is dramatic. Contraceptive use effectiveness rises by almost 93 percent for more educated women in response to an unplanned pregnancy, with birth intentions held constant.

The second mechanism that I wish to call attention to is the increased schooling levels of children of more educated parents. This relationship is analogous to the one between parents' schooling and the health of their children discussed in Section 4.2. As I indicated in Section 2.5, higher levels of child quality, measured in part by the number of years of formal schooling they acquire, are likely to be accompanied by lower optimal levels of numbers of children.[30]

Many studies summarized by Haveman and Wolfe (1995) find that the children of more educated parents obtain more schooling. Consistent with the fertility literature, the effect of mother's schooling typically exceeds that of father's schooling. Behrman and Rosenzweig (2002) examine the extent to which these results are due to omitted third variables by examining differences in years of formal schooling completed by the offspring of 424 female and 244 male identical (monozygotic) twins in the Minnesota Twin Registry. While mother's schooling has a positive and significant effect on children's schooling in the cross section, the within-twin estimate either is insignificant or negative and marginally significant. On the other hand, the coefficient of father's schooling is positive and significant in both cases. Behrman and Rosenzweig argue that the cross-sectional mother's schooling coefficient reflects the combined effect of nature (children of more educated mother's have a more favorable genetic endowment) and nurture or the home environment (more educated mothers make larger investments in the human capital of their children). Only the latter component is present in the within-twin estimates. They also argue that their findings may be attributed to the increased amount of time that educated women spend in the labor market and consequently the reduced amount of time that they spend with their children.

While the study by Behrman and Rosenzweig is novel and provocative, several

considerations suggest that their findings should not be viewed as definitive. First, it is based on a small sample. Second, differencing between twins exacerbates biases due to measurement error in schooling (Griliches 1979; Bound and Solon 1999; Neumark 1999), although Behrman and Rosenzweig do attempt to adjust for these biases. Third, since more educated women have fewer children, their increased time in the labor market does not necessarily mean that they spend less time with their offspring than less educated women. Finally, Bound and Solon (1999) stress that variation in schooling between identical twins may be systematic rather than random.

Sacerdote (2000, 2002) presents evidence on the relative importance of nature and nurture in child schooling outcomes that conflicts with that reported by Behrman and Rosenzweig. He does this by considering parental schooling effects in samples of adopted children and comparing them to parental schooling effects in samples of children raised by their biological parents. In the latter case both nature and nurture are at work, while in the former case only nurture is at work. If the nature and nurture components are additive, the ratio of the adopted parent's schooling coefficient to the biological parent's schooling coefficient shows the percentage contribution of nurture to the intergenerational transfer of educational attainment. Using completed schooling of children of women in NLSY79 as the outcome, he finds that the ratio just defined is approximately 64 percent in the case of mother's schooling and approximately 57 percent in the case of father's schooling. Moreover, the adopted mother's education effect is 40 percent larger than the adopted father's education effect.[31] One caution in interpreting these results is that schooling levels of biological parents are not available for adopted children. This biases the adopted parent schooling effect unless schooling levels of biological and adopted parents are uncorrelated.

In my discussion of the empirical literature dealing with adult and child health, I

highlighted studies that employ instrumental variables for schooling to establish its causal impact on these outcomes. Lochner and Moretti (2004) and Dee (2004) employ IV procedures to very different outcomes: crime in the former study and voter participation in the latter study, support for free speech, and civic knowledge (reflected by the frequency of newspaper readership) in the latter case. Lochner and Moretti (2004) treat incarceration from the Census of Population and arrests from the FBI Uniform Crime Reports. Changes in state compulsory schooling laws serve as instruments for schooling. This is the same instrument that was employed by Lleras-Muney (2005) in her study of adult mortality discussed in Section 4.1.3. The negative and significant effects of schooling on the crime outcomes are at least as large in absolute value when they are obtained by IV as when they are obtained by OLS.

Dee (2004) studies voter participation in High School and Beyond (HSB), a longitudinal study of high school sophomores in 1980 conducted by the U.S. Department of Labor, with follow-ups in 1984 and 1992. He adds support for free speech and frequency of newspaper readership to the voting outcome by pooling 1972-2000 cross sections of the General Social Surveys (GSS). The availability of junior and community colleges is the instrument for schooling in HSS, while the compulsory schooling laws employed by Lochner and Moretti (2004) are the instruments in GSS. Dee's findings mirror those of Lochner and Moretti: the positive and significant OLS schooling effects on the outcomes he considers become larger when they are estimated by IV.

6. Conclusions

This paper has been written with a particular point of view: namely, theory and existing empirical evidence support the proposition that education causes a variety of nonmarket

outcomes. In reaching this conclusion, I do not deny the importance of future research on the mechanisms via which schooling affects these outcomes and on the causal nature of the outcomes at issue. In my view one of the most important empirical developments in the past two decades has been the application of instrumental variables techniques to the relationship between schooling and earnings. There are many fewer examples of the application of this technique to the relationship between schooling and nonmarket outcomes. Such research deserves high priority on an agenda for future research, especially as developing countries increase the amount of compulsory schooling and invest more resources in the educational sector.

New research on mechanisms also is important, both in understanding the sources of the schooling effects and in formulating public policy. These efforts should keep in mind, however, that potential mechanisms are unlikely to be exogenous. They also should keep in mind that a finding that schooling has no impact on the outcome at issue when mechanisms are held constant does not mean that schooling has no causal impact on the outcome. All too often researchers have followed a strategy of controlling for a few mechanisms (sometimes without taking account of their endogeneity), finding that schooling still is a significant determinant of the outcome, and concluding that the observed effect must be due to a hard-to-measure variable such as time preference.

To the extent that the beneficial effects of schooling on nonmarket outcomes summarized in this paper are causal, the rate of return to investments in schooling are underestimated if the benefits of these investments are simply measured in terms of the higher wage rates or annual earnings enjoyed by the more educated. I have already called attention to Michael's (1972, 1973b) estimate that education raises nonmarket productivity by three-fifths as much as it raises market productivity. de Walque (2005) combines his estimates of the reduced risk of being HIV

positive among young residents of Uganda with secondary education compared to those with primary education with mortality rates from HIV/AIDS to obtain a rate of return to secondary education that includes the value of additional longevity. He finds that the rate of return rises from 10.2 percent when additional longevity is ignored to a range between 11.5 and 13.7 percent.

Clearly, the estimates made by Michael and de Walque are suggestive and preliminary because they do not encompass all the nonmarket benefits of education. Future research should investigate this issue in more detail and should address the difficult task of how to put a dollar value on some of these benefits. Of course, even if the total rate of return (the rate inclusive of nonmarket benefits) is significantly larger than the market rate of return, it does not follow that the amount of government intervention with the education decisions of its citizens should increase. Government intervention is justified only to correct for externalities and capital market imperfections. Moreover, some of the nonmarket effects of education may take the form of external costs. For example, the more educated have fewer children, yet Lee and Miller (1990) report that the net positive externality to childbearing in the United States was approximately $100,000 in 1985 dollars. The main contributors to this figure were public goods, intergenerational transfers supporting health, education, and pension programs, and the sharing of government debt. Grossman and Kaestner (1997) consider the rationale for government policies that use schooling as a tool to correct for health externalities, and I will not repeat that discussion here. I do think that it is appropriate to conclude by considering the value of identifying time preference as a mechanism via which schooling affects health in the context of the formulation of public policy.

Becker and Mulligan (1997) suggest a more definitive and concrete way to measure time preference and incorporate it into estimates of health demand functions than those that have been

attempted to date. They point out that the natural logarithm of the ratio of consumption between consecutive time periods (N) is approximately equal to $\sigma(r - g)$, where σ is the intertemporal elasticity of substitution in consumption, r is the market rate of interest, and g is the rate of time preference for the present. If σ and r do not vary among individuals, variations in N capture variations in time preference. With panel data, N can be included as a regressor in the health demand function. Since Becker and Mulligan stress the endogeneity of time preference and its dependence on schooling, simultaneous equations techniques appear to be required. Identification of this model will not be easy, but success in this area has the potential to greatly inform public policy.

To illustrate the last point, suppose that most of the effect of schooling on health operates through time preference. Then school-based programs to promote health knowledge in areas characterized by low levels of income and education may have much smaller payoffs than programs that encourage the investments in time preference made by the more educated. Indeed, in an ever-changing world in which new information constantly becomes available, general interventions that encourage future-oriented behavior may have much larger rates of return in the long run than specific interventions designed, for example, to discourage cigarette smoking, alcohol abuse, or the use of illegal drugs.

It is well known that cigarette smoking and excessive alcohol abuse begin early in life [for example, Grossman et al. (1993)]. Moreover, bandwagon or peer effects are much more important in the case of youth smoking or alcohol consumption than in the case of adult smoking or alcohol consumption. The two-way causality between addiction and time preference and the importance of peer pressure explain why parents who care about the welfare of their children have large incentives to make investments that make their children more future oriented. These

forces may also account for the relatively large impact of schooling on health with health knowledge held constant reported by Kenkel (1991).

Some parents may ignore or be unaware of the benefits of investments in time preference. Given society's concern with the welfare of its children, subsidies to school-based programs that make children more future oriented may be warranted. But much more research dealing with the determinants of time preference and its relationship with schooling and health is required before these programs can be formulated and implemented in a cost-effective manner.

References

Acemoglu, D. (1996), "A microfoundation for social increasing returns in human capital accumulation", Quarterly Journal of Economics 111:779-804.

Acemoglu, D., and J. Angrist (2000), "How large are human-capital externalities? Evidence from compulsory schooling laws", in: B. S. Bernanke and K. Rogoff, eds., NBER Macroeconomics Annual Vol. 15 (MIT Press, Cambridge, Massachusetts) 9-59.

Adams, S. J. (2002), "Educational attainment and health: evidence from a sample of older adults", Education Economics 10: 97-109.

Alderman H., J.R. Behrman, V. Lavy, and R. Menon (2001), "Child health and school enrollment: a longitudinal analysis", Journal of Human Resources 36: 185-205.

American Chamber of Commerce Researchers Association (various years), ACCRA Cost of Living Index (ACCRA, Arlington, VA).

Angrist, J.D., G.W. Imbens, and D.B. Rubin (1996), "Identification of causal effects using instrumental variables", Journal of the American Statistical Association 91: 444-472.

Arendt, J.N. (2005), "Does education cause better health? A panel data analysis using school reform for identification", Economics of Education Review 24:149-160.

Arkes, J. (2004), "Does schooling improve health?" Working paper (RAND Corporation, Santa Monica, CA).

Barker, D.J.P. (1995), "Fetal origins of coronary heart disease", British Medical Journal 311:171-174.

Becker, G.S. (1960), "An economic analysis of fertility", in: Demographic and Economic Change in Developed Countries (Princeton University Press for the National Bureau of Economic Research, Princeton, NJ) 209-231.

Becker, G.S. (1965), "A theory of the allocation of time", Economic Journal 75:493-517.

Becker, G. S. (1991), A Treatise on the Family, second edition (Harvard University Press, Cambridge, MA).

Becker, G.S. (1996), Accounting for Tastes (Harvard University Press, Cambridge, MA).

Becker, G. S. and H. G. Lewis (1973), "On the interaction between the quantity and quality of children", Journal of Political Economy 81:S279-S288.

Becker, G.S. and C.B. Mulligan (1997), "The endogenous determination of time preference", Quarterly Journal of Economics 112:729-758.

Becker, G.S. and K.M. Murphy (1988), "A theory of rational addiction", Journal of Political Economy 96:675-700.

Behrman, J. R. and M. R. Rosenzweig (2002), "Does increasing women's schooling raise the schooling of the next generation?" American Economic Review 92: 323-334.

Berger, M.C. and J. P. Leigh (1989), "Schooling, self-selection, and health", Journal of Human Resources 24:433-455.

Bolin, K., L. Jacobson, and B. Lindgren (2002), "The demand for health and health investments in Sweden", in: B. Lindgren, ed., Individual Decisions for Health (Routledge, London) 93-112.

Bound, J. and G. Solon (1999), "Double trouble: on the value of twins-based estimation of the return to schooling", Economics of Education Review 18:169-182.

Breierova, L. and E. Duflo (2004), "The impact of education on fertility and child mortality: do fathers really matter less than mothers? Working paper no. 10513 (National Bureau of Economic Research, Cambridge, MA).

Card, D. (1999), "The causal effect of education on earnings", in: O. Ashenfelter and D. Card, eds. Handbook of Labor Economics, vol. 3 (Elsevier, Amsterdam) 1801-1863.

Card, D. (2001), "Estimating the return to schooling: progress on some persistent econometric problems", Econometrica 69:127-1160.

Carroll, C.D. and L.H. Summers (1991), "Consumption growth parallels income growth", in: B.D. Bernheim and J.B. Shoven, eds., National Saving and Economic Performance (University of Chicago Press, Chicago) 305-343.

Case, A., A. Fertig, and C. Paxson (2005), "The lasting impact of childhood health and circumstances", Journal of Health Economics 24:365-389.

Case, A., D. Lubotsky, and C. Paxson (2002), "Economic status and health in childhood: the origins of the gradient", American Economic Review 92:1308-1334.

Chaikind, S. and H. Corman (1991), "The impact of low birthweight on special education costs", Journal of Health Economics 10:291-311.

Chou, S.-Y., M. Grossman, and H. Saffer (2004), "An economic analysis of adult obesity: results from the behavioral risk factor surveillance system", Journal of Health Economics 23:565-587.

Coleman, M. and T. DeLeire (2003), "An economic model of locus of control and the human capital investment decision", Journal of Human Resources 38:701-721.

Corman, H. and M. Grossman (1985), "Determinants of neonatal mortality rates in the United States: a reduced form model," Journal of Health Economics 4: 213-236.

Corman, H., T.J. Joyce, and M. Grossman (1987), "Birth outcome production functions in the United States", Journal of Human Resources 22:339-360.

Currie, J. (2000), "Child health", in: A.J. Culyer and J.P. Newhouse, eds., Handbook of Health Economics, vol. 1B (Elsevier, Amsterdam) 1053-1090.

Currie, J. and E. Moretti (2003), "Mother's education and the intergenerational transmission of human capital: evidence from college openings", Quarterly Journal of Economics: 118:1495-

1532.

Currie, J. and M. Stabile (2003), "Socioeconomic status and health: why is the relationship stronger for older children?" American Economic Review 93:1813-1823.

Deaton, A. (2002), "Policy implications of the gradient of health and wealth", Health Affairs 21:13-30.

Deaton, A. and C. Paxson (2001), "Mortality, education, income, and inequality among American cohorts", in: D.A. Wise, ed., Themes in the Economics of Aging (University of Chicago Press, Chicago) 129-165.

Dee, T.S. (2004), "Are there civic returns to education?" Journal of Public Economics 88:1697-1720.

De Stavola, B.L., R. Hardy, D. Huh, I. dos Santos Silva, M. Wadsworth, and A.J. Swerdlow (2000), "Birthweight, childhood growth, and risk of breast cancer in a British cohort", British Journal of Cancer 83:964-968.

De Tray, D.N. (1973), "Child quality and the demand for children", Journal of Political Economy 81:S70-S95.

de Walque, D. (2004), "Education, information, and smoking decisions: Evidence from smoking histories, 1940-2000", Working paper no. 3362 (World Bank, Washington, DC).

de Walque, D. (2005), "How does the impact of an HIV/AIDS information campaign vary with educational attainment? Evidence from rural Uganda", Working paper no. 3289 (World Bank, Washington, DC).

Duflo, E. (2001), "Schooling and labor market consequences of school construction in Indonesia: evidence from an unusual policy experiment", American Economic Review 91:795-813.

Edwards, L.N. and M. Grossman (1979), "The Relationship between children's health and

intellectual development", in: S.J. Mushkin and D.D. Dunlop, eds., Health: What Is It Worth (Pergamon Press, Elmsford, NY) 273-314.

Edwards, L.N. and M. Grossman (1981), "Children's health and the family", in: R.M. Scheffler, ed., Advances in Health In Health Economics and Health Services Research Vol. II (JAI Press, Greenwich, CT) 35-84.

Edwards, L.N. and M Grossman (1982), "Income and race differences in children's health in the mid-1960's", Medical Care 20: 915-930.

Edwards, L.N. and M. Grossman (1983), "Adolescent health, family background, and preventive medical care", in: D.S. Salkever, I. Sirageldin, and A. Sorkin, eds., Research in Human Capital and Development Vol. III (JAI Press, Greenwich, CT:) 77-109.

Erbsland, M., W. Ried and V. Ulrich (1995), "Health, health care, and the environment. Econometric evidence from German micro data", Health Economics 4:169-182.

Farrell, P. and V.R. Fuchs (1982), "Schooling and health: the cigarette connection", Journal of Health Economics 1:217-230.

Frederick, S., G. Lowenstein, and T. O'Donoghue (2002), "Time discounting and time preference: a critical review", Journal of Economic Literature 40:351-401.

Fuchs, V.R. (1974), Who Shall Live? Health, Economics, and Social Choice (Basic Books, New York).

Fuchs, V.R. (1982), "Time preference and health: an exploratory study", in: V.R. Fuchs, ed., Economic Aspects of Health (University of Chicago Press, Chicago) 93-120.

Gerdtham, U.G. and M. Johannesson (1999), "New estimates of the demand for health: results based on a categorical health measure and Swedish micro data", Social Science & Medicine 49:1325-1332.

Ghez, G.R. and G.S. Becker (1975), The Allocation of Time and Goods Over the Life Cycle (Columbia University Press for the National Bureau of Economic Research, New York).

Gilleskie, D.B. and A.L. Harrison (1998), "The effect of endogenous health inputs on the relationship between health and education", Economics of Education Review 17: 279-297.

Glewwe, P. (1999), "Why does mother's schooling raise child health in developing countries?", Journal of Human Resources 34:124-159.

Glied, S. and A. Lleras-Muney (2003), "Health inequality, education and medical innovation", Working paper no. 9738 (National Bureau of Economic Research, Cambridge, MA).

Goldberger, A.S. (1974), "Unobservable variables in econometrics", in: P. Zarembreka, ed., Frontiers in Econometrics (Academic Press, New York) 193-213.

Goldman, D. and D. Lakdawalla (2002), "Health disparities and medical technology", Working paper (RAND Corporation, Santa Monica, CA).

Goldman, D.P. and J.P. Smith (2002), "Can patient self-management help explain the SES health gradient?" Proceedings of the National Academy of Sciences of the United States 99:10929-10934.

Granger, C.W.J. (1969), "Investigating causal relations by econometric models and cross-spectral methods," Econometrica 37:424-438.

Griliches, Z. (1979), "Sibling models and data in economics: beginnings of a survey", Journal of Political Economy 87:S37-S64.

Gronau, R. (1980), "Home production--a forgotten industry", Review of Economics and Statistics 62:408-416.

Grossman, M. (1972a), "On the concept of health capital and the demand for health", Journal of Political Economy 80:223-255.

Grossman, M. (1972b), The Demand for Health: A Theoretical and Empirical Investigation (Columbia University Press for the National Bureau of Economic Research, New York).

Grossman, M. (1975), "The correlation between health and schooling", in: N.E. Terleckyj, ed., Household Production and Consumption (Columbia University Press for the National Bureau of Economic Research, New York) 147-211.

Grossman, M. (2000), "The human capital model", in: A.J. Culyer and J.P. Newhouse, eds., Handbook of Health Economics, vol. 1A (Elsevier, Amsterdam) 347-408.

Grossman, M. and T. J. Joyce (1990), "Unobservables, pregnancy resolutions, and birth weight production functions in New York City", Journal of Political Economy 98:983-1007.

Grossman, M. and R. Kaestner (1997), "Effects of education on health", in: J.R. Behrman and N. Stacey, eds., The Social Benefits of Education (University of Michigan Press, Ann Arbor, Michigan) 69-123.

Grossman, M., J.L. Sindelar, J. Mullahy and R. Anderson (1993), "Policy watch: alcohol and cigarette taxes", Journal of Economic Perspectives 7:211-222.

Gruber, J. and B. Köszegi (2001), "Is addiction 'rational'? Theory and evidence," Quarterly Journal of Economics 116:1261-1303

Hammond, C. (2003), "How education makes us healthy", London Review of Education 1:61-78.

Hartog, J. and H. Oosterbeek (1998), "Health, wealth and happiness: why pursue a higher education?" Economics of Education Review 17:245-256.

Hausman, J.A. (1978), "Specification tests in econometrics", Econometrica 46:1251-1271.

Haveman, R. H. and B. L. Wolfe (1995), "The determinants of children's attainments: a review of methods and findings", Journal of Economic Literature 33:1829-1878.

Heckman, J.J. (1979), "Sample selection bias as a specification error", Econometrica 47:153-161.

Hotz, V.J., J.A. Klerman, and R.J. Willis (1997), "The economics of fertility in developed countries", in: M.R. Rosenzweig and O. Stark, eds., Handbook of Population and Family Economics, vol. 1A (Elsevier, Amsterdam) 275-347.

Hurd, M. (1987), "Saving of the elderly and desired bequests", American Economic Review 77:289-312.

Hurd, M. (1989), "Mortality risks and bequests", Econometrica 57:779-813.

Hurd, M. and A. Kapteyn (2003), "Health, wealth, and the role of institutions", Journal of Human Resources 38:387-415.

Idler, E.L. and S.V. Kasl (1995), "Self ratings of health: do they also predict change in functional ability?", Journal of Gerontology: Social Sciences 508:S344-S353.

Ippolito, R. (2003), "Health, education, and investment behavior in the family", Working paper (George Mason University School of Law, Fairfax, VA).

Jalan, J. and M. Ravallion (2003), "Does piped water reduce diarrhea for children in rural India?" Journal of Econometrics 112:153-173.

Jöreskog, K.G. (1973), "A general method for estimating a linear structural equations system", in: A.S. Goldberger and O.D. Duncan, eds., Structural Equations Models in the Social Sciences (Seminar Press, New York) 85-112.

Jöreskog, K.G. and D. Sörbom (1981), LISREL: Analysis of Linear Structural Relationships by the Method of Maximum Likelihood (International Educational Services, Chicago).

Joyce, T. (1994), "Self selection, prenatal care, and birthweight among blacks, whites, and Hispanics in New York City", Journal of Human Resources 29:762-794.

Kenkel, D.S. (1991), "Health behavior, health knowledge, and schooling", Journal of Political Economy 99:287-305.

Kenkel, D.S. (2000), "Prevention", in: A.J. Culyer and J.P. Newhouse, eds., Handbook of Health Economics, vol. 1B (Elsevier, Amsterdam) 1675-1720.

Lam, D. and S. Duryea (1999), "Effects of schooling on fertility, labor supply, and investments in children, with evidence from Brazil", Journal of Human Resources 34:161-192.

Lawrence, E.C. (1991), "Poverty and the rate of time preference: evidence from panel data", Journal of Political Economy 99:54-77.

Lee, R. and T. Miller (1990), "Population policy and externalities to childbearing", Annals of the American Academy of Political and Social Sciences 510:17-43.

Leigh, J.P. (1983), "Direct and indirect effects of education on health", Social Science and Medicine 17:227-234.

Leigh, J.P. (1985)," An empirical analysis of self-reported, work-limiting disability", Medical Care 23:310-319.

Leigh, J.P. (1986), "Accounting for tastes: correlates of risk and time preferences", Journal of Post Keynesian Economics 9:17-31.

Leigh, J.P. and R. Dhir (1997), "Schooling and frailty among seniors", Economics of Education Review 16:45-57.

Lleras-Muney, A. (2005), "The relationship between education and adult mortality in the United States", Review of Economic Studies 72:189-221.

Lleras-Muney, A. and F.R. Lichtenberg (2002), "The effect of education on medical technology adoption: are the more educated more likely to use new drugs?" Working paper no. 9185 (National Bureau of Economic Research, Cambridge, MA).

Lochner, L. and E. Moretti (2004), "The effect of education on crime: evidence from prison inmates, arrests, and self-reports", American Economic Review 94:155-189.

Meara, E. (1999), "Why is health related to socioeconomic status?" Ph.D. Dissertation (Harvard University, Cambridge, MA).

Meara E. (2001), "Why is health related to socioeconomic status? the case of pregnancy and low birth weight", Working paper no. 8231 (National Bureau of Economic Research, Cambridge, MA).

Michael, R.T. (1972), The Effect of Education on Efficiency in Consumption (Columbia University Press for the National Bureau of Economic Research, New York).

Michael, R.T. (1973a), "Education and the derived demand for children", Journal of Political Economy 81:S128-S164

Michael, R.T. (1973b), "Education in nonmarket production", Journal of Political Economy 81:306-327.

Michael R.T. (1982), "Measuring non-monetary benefits of education: a survey", in: W.W. McMahon and T.G. Geske, eds., Financing Education: Overcoming Inefficiency and Inequity (University of Illinois Press, Urbana, IL) 119-149.

Michael, R.T., and R.J. Willis (1975), "Contraception and fertility: household production under uncertainty", in: N.E. Terleckyj, ed., Household Production and Consumption (Columbia University Press for the National Bureau of Economic Research, New York) 27-93.

Mincer, J. (1974), Schooling, Experience, and Earnings (Columbia University Press for the National Bureau of Economic Research, New York).

Morris, J. (1976), "Some simple tests of the direct effect of education on preferences and on nonmarket productivity", Review of Economics and Statistics 58:112-117.

Mroz, T. (1999), “Discrete factor approximation in simultaneous equations models: estimating the impact of a dummy endogenous variable on a continuous outcome”, Journal of Econometrics 92:233-274

Nelson, R.R. and E.S. Phelps (1966), “Investments in humans, technological diffusion, and economic growth”, American Economic Review 56:69-75.

Neumark, D. (1999), “Biases in twin estimates of the return to schooling”, Economics of Education Review 18:143-148.

Peele, S. (1985), The Meaning of Addiction: Compulsive Experience and Its Interpretation (Lexington Books, Lexington, MA).

Pollak, R.A. (1970), “Habit formation and dynamic demand functions”, Journal of Political Economy 78:745-763.

Rosen, S. and P. Taubman (1982), “Some socioeconomic determinants of mortality”, in: J. van der Gaag, W.B. Neenan, and T. Tsukahara, Jr., eds., Economics of Health Care (Praeger Publishers, New York) 255-271.

Rosenzweig, M.R. (1995), “Why are there returns to schooling?” American Economic Review 85:153-158.

Rosenzweig, M.R. and T.P. Schultz (1982), “The behavior of mothers as inputs to child health: the determinants of birth weight, gestation, and rate of fetal growth”, in: V.R. Fuchs, ed., Economic Aspects of Health (University of Chicago Press for the National Bureau of Economic Research, Chicago) 53-92.

Rosenzweig, M.R. and T.P. Schultz (1983), “Estimating a household production function: heterogeneity, the demand for health inputs, and their effects on birth weight”, Journal of Political Economy 91:723-746.

Rosenzweig, M.R. and T.P. Schultz (1989), "Schooling, information and nonmarket productivity: contraceptive use and its effectiveness", International Economic Review 30:457-477.

Rosenzweig, M.R. and T.P. Schultz (1991), "Who receives medical care? Income, implicit prices, and the distribution of medical services among pregnant women in the United States", Journal of Human Resources 26:473-508.

Ross, C.E. and J. Mirowsky (1999), "Refining the association between education and health: the effects of quantity, credential, and selectivity", Demography 36:445-460.

Sacerdote, B. (2000), The nature and nurture of economic outcomes", Working paper no. 7949 (National Bureau of Economic Research, Cambridge, MA).

Sacerdote, B. (2002), "The nature and nurture of economic outcomes", American Economic Review 92:344-348.

Sander, W. (1995a), "Schooling and quitting smoking", Review of Economics and Statistics 77:191-199.

Sander, W. (1995b), "Schooling and smoking", Economics of Education Review 14:23-33.

Schultz, T.P. (1993), "Returns to women's education", in: E.M. King and M.A. Hill, eds., Women's Education in Developing Countries: Barriers, Benefits, and Policies (Johns Hopkins University Press, Baltimore, MD) 51-99.

Shakotko, R.A., L.N. Edwards, and M. Grossman (1981), "An exploration of the dynamic relationship between health and cognitive development in adolescence", in J.van der Gaag and M. Perlman, eds., Contributions to Economic Analysis: Health, Economics, and Health Economics (North-Holland Publishing Company, Amsterdam) 305-325.

Sickles, R.C. and P. Taubman (1986), "An analysis of the health and retirement status of the elderly", Econometrica 54:1339-1356.

Spasojevic, J. (2003), "Effects of education on adult health in Sweden: results from a natural experiment", Ph.D. Dissertation (City University of New York Graduate Center, New York).

Taubman, P. and S. Rosen (1982), "Healthiness, education, and marital status", in: V.R. Fuchs, ed., Economic Aspects of Health (University of Chicago Press for the National Bureau of Economic Research, Chicago) 121-140.

Thomas, D., J. Strauss, and M.-H. Henriques (1991), "How does mother's education affect child height?", Journal of Human Resources 26:83-211.

U.S. Department of Health and Human Services (1990), The Health Benefits of Smoking Cessation: A Report of the Surgeon General (Public Health Service, U.S. Department of Health and Human Services, Rockville, MD).

Van Doorslaer, E.K.A. (1987), Health, Knowledge and the Demand for Medical Care (Assen, Maastricht, the Netherlands).

Wagstaff, A. (1986), "The demand for health: some new empirical evidence", Journal of Health Economics 5:195-233.

Wagstaff, A. (1993), "The demand for health: an empirical reformulation of the Grossman model", Health Economics 2:189-198.

Wilcox-Gök, V.L. (1983), "The determination of child health: an application of sibling and adoption data", The Review of Economics and Statistics 65:266-273.

Willis, R.J. (1973), "A new approach to the economic theory of fertility behavior", Journal of Political Economy 81:S14-S64.

Wu, D.-M. (1973), "Alternative tests of independence between stochastic regressors and

disturbances", Econometrica 41:733-750.

Footnotes

This paper was prepared for the Handbook of the Economics of Education, edited by Eric Hanushek and Finis Welch. Amsterdam: North-Holland, an imprint of Elsevier Science. I am deeply indebted to Robert T. Michael for his thorough reading of an earlier version of this paper and for his penetrating comments on that version. I also am indebted to Victor R. Fuchs and the participants at a conference on the economics of education held at the George Bush School of Public Policy of Texas A&M University, March 20-22, 2003 for helpful comments and suggestions. I wish to thank Inas Rashad and Jennifer Tennant for research assistance.

[1]For an earlier survey that considers additional nonmarket effects of education, see Michael (1982).

[2]The marginal cost or average cost or shadow price of Z_i is

$$\pi_i = \frac{P_i}{e^{\rho_i S}\partial F_i / \partial X_i} = \frac{W}{e^{\rho_i S}\partial F_i / \partial T_i} = \frac{P_i X_i + W T_i}{e^{\rho_i S} F_i},$$

where P_i is the price of X_i, W is the wage rate, and the last equality follows from linear homogeneity. The full income constraint for utility maximization is

$$W\Omega + V = \sum_{i=1}^{n} \pi_i Z_i = \sum_{i=1}^{n} (P_i X_i + W T_i),$$

where Ω is the constant amount of time available in the period (the sum of time allocated to the market and time allocated to the nonmarket), and V is property or nonearnings income. Real full income evaluated at shadow prices is $(W\Omega + V)/\Pi$, where Π is a Laspeyres geometric price level:

$$\Pi = \pi_1^{k_1}\pi_2^{k_2}...\pi_n^{k_n}$$

$$k_i = \frac{\pi_i Z_i}{\sum_{i=1}^{n}\pi_i Z_i}.$$

[3]To obtain equation (5), note

$$-k_i\sigma_{ii} = \sum_{j\neq i=1}^{n} k_j\sigma_{ij}.$$

Since $\sigma_{ij} = \sigma$, $-k_i\sigma_{ii} = (1 - k_i)\sigma$.

[4]Since the production function is linear homogeneous and input prices are held constant,

$$\tilde{X}_i = \tilde{T}_i = \tilde{Z}_i - \rho_i + \rho - \rho.$$

Replace $\tilde{Z}_i$ with the right-hand side of equation (5) to obtain equation (6).

[5]Since all production functions are homogeneous of degree one in the goods and time inputs and since input prices are held constant, a one percent change in Z_i due to a given percentage change in money income is accompanied by a 1 percent change in X_i. Hence, the income elasticities of Z_i and X_i are the same.

[6]The model developed in this subsection is based to some extent on Morris (1976). I depart from his analysis, however, because I focus on a case where schooling varies, with the wage rate held constant.

[7]Based on the definition of full income in note 2, the elasticity of Z or T with respect to property income is $s\eta_Z$, where s is the ratio of property income to full income and η_Z is the elasticity of Z with respect to full income. The elasticity of T or Z with respect to the wage rate is $[(1 - s - k)\eta_Z - (1 - k)\sigma_{ZX}]$. This elasticity holds schooling constant.

[8]I emphasize the pure investment model because it generates powerful predictions from simple analysis.

[9]Note that $G_H \equiv \partial G/\partial H$. Note also that the marginal product of medical care in the production of healthy time is GH_M. An increase in schooling raises H_M. With M constant, however, an increase in S lowers GH_M if $\varepsilon_H < 1$.

[10]For a detailed discussion of joint production, see Grossman (1972b, pp. 74-83).

[11]For the development of a demand for health model with costs of adjustment, see Grossman (2000, pp. 390-392).

[12]Goldman and Lakdawalla (2002) do not constraint the sum of α and β to equal one because they want to examine the effect of a change in one of these output elasticities, with the other one held constant. I have simplified their model in the discussion in the text. They emphasize that the health demand function has a multiplicative form in my model and in more complicated versions of it. Hence, any variable that raises the quantity of health demanded also will increase the marginal effect of schooling or the wage rate on health. In my view, the points that I emphasize in the text are consistent with and provide a simple explanation of their empirical evidence to be discussed in Section 4.

[13]de Walque only considers the mortality aspects of health, but his model can easily be extended to the morbidity aspects.

[14]Consumption rises with age if the market rate of interest exceeds g and falls with age if the converse holds.

[15]For critiques and alternative approaches, see, for example, Gruber and Köszegi (2001) and Frederick, Lowenstein, and O'Donoghue (2002).

[16]Michael employs the logarithm of schooling rather than schooling as a regressor. Hence he obtains an estimate of ρ/S. Obviously this does not affect the comparison of the relative magnitudes of market and nonmarket productivity effects

[17]An increase in the wage rate generates a substitution in production towards goods inputs and a substitution in consumption towards goods-intensive commodities (commodities in which the share of the time input in total cost is smaller than on average) and towards the inputs used to produce these commodities. The substitution in consumption effect lowers the demand for goods used to produce time-intensive commodities. Hence, with real income and schooling held constant, the impact of a change in the wage on the demand for a particular market good or service is ambiguous.

[18]Ghez and Becker (1975) show that the age at which consumption peaks may differ from the age at which hours of work peak.

[19]I assume in the text that r exceeds g. If the converse holds for people with large values of g, consumption falls over their life cycles.

[20]The above summary is based on Becker and Mulligan's (1997) analysis of data presented but not discussed in detail by Carroll and Summers (1991).

[21]Many of the studies discussed in Sections 4.1 and 4.2 employ self-rated health or parental rating of child health as an outcome. Thus, it is important to emphasize that these measures have been shown to be strongly predictive of mortality and other objective health outcomes. See Idler and Kasl (1995) for an extensive review of this literature.

[22]In 1955, Robert L. Thorndike and Elizabeth Hagan collected information on earnings, schooling, and occupation for a sample of 9,700 men drawn from a population of 75,000 white males who volunteered for, and were accepted as, candidates for Aviation Cadet status in the Army Air Force in the last half of 1943. Candidates were given 17 specific tests that measured 5 basic types of ability: general intelligence, numerical ability, visual perception, psychomotor

control, and mechanical ability. In 1969 and again in 1971, the National Bureau of Economic Research mailed questionnaires to the members of the Thorndike-Hagan 1955 sample.

[23]Long-run effects are obtained by setting past current and future health equal to each other. Bolin et al. (2002) cannot compute these effects because they treat past and future health as continuous variables in an ordered probit specification of current health. Some caution should be exercised in interpreting their findings because past and future health are endogenous variables in the dynamic model formulated by Grossman (2000), while Bolin et al. (2002) treat these variables as exogenous.

[24]For summaries and critiques of several studies that do not find negative effects of schooling on mortality, see Grossman and Kaestner (1997).

[25]Glied and Lleras-Muney (2003) cannot employ survival conditional on diagnosis in the NHIS data because there is no information on diagnosis. They argue that a drug measure is not accurate in the case of disease-specific mortality since drugs are used for conditions that can lead to death from multiple causes.

[26]For example, the same regime in each wave was considered good as was a progression from medication to insulin. Bad regimes included taking medication or insulin in one wave but not in a subsequent one or switching from one treatment to another and then back to the initial treatment.

[27]Let H be health, S be schooling, and D be the time discount factor (a positive correlate of future orientation). Consider the following model

$$H = \alpha_1 S + \alpha_2 D + u$$

$$D = \beta_1 S + v$$

$$S = \gamma_1 D + \gamma_2 X + w.$$

Here u, v, and w are disturbance terms, and X is an observed determinant of schooling that is not correlated with these disturbance terms. Substitute the second equation into the first:

$$H = (\alpha_1 + \beta_1\alpha_2)S + \alpha_2 v + u.$$

Solve the second and third equations for S to obtain the reduced form schooling equation

$$S = \left(\frac{\gamma_2}{1-\gamma_1\beta_1}\right)X + \left(\frac{\gamma_1}{1-\gamma_1\beta_1}\right)v + \left(\frac{1}{1-\gamma_1\beta_1}\right)w.$$

The next to last equation cannot be estimated by ordinary least squares because S is correlated with v. Since X is not correlated with v and has no impact on H with S held constant, it serves as an instrument for S in an estimation of the health equation by two-stage least squares.

[28]Based on Wu-Hausman tests [Wu (1973), Hausman (1978)] , Grossman and Joyce (1990) accept the consistency of birthweight production functions obtained by ordinary least squares once these functions are corrected for self-selection.

[29]Technically Meara estimates a mixture of a production function and a demand function because she includes income, health insurance, distance to the prenatal care provider, and other demand determinants in the birthweight equations.

[30]Refer to equations (18) and (19). Suppose that π_Q, the fixed cost of child quality, is negatively correlated with mother's schooling. Then an increase in mother's schooling causes a direct substitution effect in favor of Q and away from N since the relative price of Q falls. There also is a secondary substitution effect because an increase in Q/N lowers the relative price of Q. If one holds fixed costs constant, assumes that the fixed cost of numbers exceeds that of quality, and assumes that an increase in schooling lowers π, the price of one unit of NQ, the same result follows. That is because a reduction in π lowers the relative price of Q.

[31] Sacerdote does not include schooling of each parent in the same regression. Hence the mother's schooling effect and its estimated environmental component, for example, do not control for father's schooling.