Marcelo Selowsky

Nutrition, Health, and Education: The Economic Significance of Complementarities at Early Age

NUTRITION, HEALTH AND EDUCATION: THE ECONOMIC SIGNIFICANCE OF COMPLEMENTARITIES AT EARLY AGE*

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The paper derives orders of magnitudes for the economic value of increases in preschool children ability scores, i.e., the demand price for early abilities. This information is necessary to 'price' interventions that can increase ability scores of chronically deprived children. The analytical framework used is the semilog earnings function, relating earnings with schooling and early abilities. This function implies a complementarity between early abilities and schooling, namely, the marginal product of schooling increases with the level of these abilities. Hence, the benefits from preschool programs boosting early abilities stem from (a) the increase in earnings out of a given level of schooling, (b) the net benefits from additional schooling induced by a higher rate of return to schooling.

1. Introduction

This paper attempts to evaluate the economic significance of the following pieces of empirical evidence:

(1) An increasing number of studies show that preschool age children of the lower socioeconomic groups in developing countries perform substantially worse in tests of cognitive development than children from higher income groups.¹

(2) These studies also show that large part of this difference can be attributed to factors able to be influenced by public policy. Malnutrition, lack of sanitation, low levels of psychological stimulation and other environmental deficit surrounding children in poverty are some of these factors.²

(3) Earnings functions — relating earnings to levels of schooling and early ability scores, if available — show that early ability not only has an

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¹Evidence in Latin America is reported in: Monckeberg, Donoso, Valiente, Arteaga, Maccioni and Merchak (1967), Kardonsky et al. (1971) and Robles et al. (1959).

²See Berg (1973), Cravioto and De Licardie (1973) and McKay et al. (1978). In their survey Cravioto and De Licardie present studies showing the effect of malnutrition on specific abilities that are crucial
independent effect on future earnings. Most important, the functional forms that seem to fit the data best imply a complementarity between schooling and ability, the marginal product of additional schooling depending on the level of preschool abilities of the child.

(4) Future expansion in enrollment in primary schools in developing countries will mainly consist of additional enrollment of children from increasingly poorer segments of the population, i.e., those relatively excluded from the educational system in the present.

The above considerations imply that the productivity and effectiveness of future investments in schooling could be highly sensitive to present public policies to reach preschool age children in poverty. In addition, to the extent the demand for schooling by those families depends on the perceived benefits of education, these interventions could increase the incentives for additional schooling. In short, these actions, by increasing the level of early cognitive development of poor children could (a) increase the productivity of a given amount of schooling, (b) generate additional benefits to the extent it induces additional schooling.

By measuring these benefits the paper attempts to derive orders of magnitude for the economic value of increases in preschool ability scores, i.e., the demand price for early abilities. Such information is necessary to ‘price’ interventions that can increase ability scores of chronically deprived children. These interventions have become identified as a part of studies that researchers in the medical and psychological field have been undertaking on the determinants of the variability of these scores.

for further learning. This is particularly relevant to our hypothesis. These studies are summarized below:

Some studies on the effect of malnutrition on learning.8

<table>
<thead>
<tr>
<th>Authors</th>
<th>Deficit in performance</th>
<th>Probable effect on consequent learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cravioto and De Licardie (Mexico)</td>
<td>Auditory-visual integration</td>
<td>Reading ability</td>
</tr>
<tr>
<td>Cravioto et al. (Mexico)</td>
<td>Visual-kinesthetic integration</td>
<td>Writing and drawing abilities</td>
</tr>
<tr>
<td>Champakam et al. (India)</td>
<td>Visual identification</td>
<td>Reading abilities</td>
</tr>
<tr>
<td>Cravioto, et al. (Mexico, Guatemala); Guthrie et al. (Philippines)</td>
<td>Kinesthetic-visual, kinesthetic-haptic, haptic-visual, and auditory-visual integration</td>
<td>General learning abilities</td>
</tr>
</tbody>
</table>

8Source: Cravioto and De Licardie (1973).
The empirical results are highly tentative since a number of the parameter values required for the analysis are extremely scarce. Rather than to yield precise quantitative estimates, the main objective of the paper is to set out a framework within which the sensitivity of results to parameter values can be evaluated with the purpose of guiding future empirical research. Section 2 sets out such a framework. Section 3 presents some empirical estimates.

2. The demand price for early abilities

2.1. The semi-log earnings function

The studies described earlier in (2) can be summarized as attempts to estimate a function of the type

\[ A = f[N, H, E, G] = A(V, G), \]

where \( A \) represents a (vector) score of cognitive development at preschool age (before children enter primary schools); \( N, H, E \) represent nutrition, health status and the quality of home environment and \( G \) genetic endowment. Let us denote as \( V = (v_1, v_2, \ldots, v_n) \) the vector of explanatory variables to be manipulated by policy.

The value of the marginal contribution of manipulating a variable \( v_i \), i.e., the demand price for intervention \( i \), is equal to

\[ \Pi_i = \Pi \cdot \frac{\partial A}{\partial v_i}, \]

where \( \Pi \) is the demand price or shadow price of one unit of ability score before the child enters primary school.

To derive such a price, a functional form relating labor earnings to preschool ability scores is required. Following the literature we will adopt the semilog earnings function. This function has become accepted on theoretical and empirical grounds. Mincer, using a schooling investment model, provided a theoretical justification for this form.\(^3\) Heckman and Polachek empirically verified this hypothesis by using the Box and Cox transformation to test for the correct functional form.\(^4\) Working with several sets of data they concluded that, under the normality assumption, the semilog form was the most appropriate simple transformation to be used in the specification of the earnings function. Neither Mincer's theoretical argument nor Heckman and Polachek's empirical test explicitly dealt with the preschool ability variable. However, Griliches, using the Malmo data to regress earnings on schooling and preschool ability,

\(^3\)Mincer (1974).
\(^4\)Heckman and Polachek (1974), and Box and Cox (1964).
concluded that the semilog form fitted the data best on the 'standard error in comparable units criterion'.

The semilog earnings function can be written as

$$\log W = a + bS + cA + dt,$$

where $W$, $S$, $A$ and $t$ are wages, years of schooling, preschool ability scores and age. The most significant feature of this function is the complementarity it implies between early abilities and subsequent schooling, the marginal product of schooling depends on the level of early abilities. Hence increases in early abilities will not only increase the present value of earnings ($PV$) out of a given amount of schooling; it will also increase the rate of return to additional schooling and increase the incentives for demanding additional education. Consequently $\Pi$ can be written:

$$\Pi = \frac{dPV}{dA} = \left| \frac{\partial PV}{\partial A} \right|_{S=S_0} + \frac{\partial PV}{\partial S} \frac{dS}{dA},$$

where the first term are the benefits holding years of schooling constant and the second term shows the benefits generated by the induced additional schooling.

Behind expression (4) are some assumptions that can be explained better with fig. 1. We do assume (a) a diminishing rate of return, $\rho$, to additional schooling, (b) a behavior such that households always equate its opportunity cost of capital to the marginal rate of return to schooling.

When the level of $A$ increases, the rate of return to education schedule shifts upwards due to the complementarity described earlier. The household will adjust years of schooling so as to maintain the earlier rate of return $\rho_0$ determined by its cost of funds or discount rate. The area $A$ shows the increase in the marginal rate of return on all intramarginal units of schooling that give origin to the first component of $\Pi$, namely, $\left| \frac{\partial PV}{\partial A} \right|_{S=S_0}$. The area $(B+C)$ is the additional excess return over society's opportunity cost of capital on the additional induced years of schooling $dS$. It gives origin to the second component of $\Pi$. If $\rho_0=r$, the cost of capital to the household and to society are equal, benefits would be only $B$. The value of $C$ is an added benefit since $dA$ expands an activity where there might be a positive discrepancy between private and social cost, $\rho_0 > r$.


6The nature of the analysis and conclusion would not change under alternative specifications, as long as they imply a complementarity between $A$ and $S$. A linear function with an interaction term will also provide this complementarity.
2.2. Main definitions and properties

Let us define the present value of earning when schooling is equal to $S$ as

$$ PV = \int_{S}^{\infty} W_t(S, A) e^{-rt} dt - \int_{0}^{S} K_t e^{-rt} dt, \quad (5) $$

where $r$ is the social discount rate and $K_t$ are the direct costs of schooling in the $t$th year of schooling, $K_t = K_0 e^{\sigma t}$. Using the earnings function defined in (3), $PV$ can be written

$$ PV = \left[ \frac{W_0}{r - d} \right] e^{cA + (b+d-r)S} \left( \frac{K_0}{\phi - r} \right) [e^{(\phi - r)S} - 1], \quad (6) $$

where $W_0$ is the wage of an individual with no schooling and base preschool abilities when he enters the labor force instead of the first grade.

By differentiating (6) with respect to $S$ we derive the present value of additional schooling:

$$ \frac{\partial PV}{\partial S} = \left( \frac{b + d - r}{r - d} \right) W_0 e^{cA + (b+d-r)S} - K_0 e^{(\phi - r)S}. \quad (7) $$
The value of \( r \) at which \( \partial PV/\partial S = 0 \), \( r = \rho \), or the internal rate of return to the \( S \)th year of schooling becomes

\[
\rho(S) = \frac{b}{1 + k(S)} + d, \quad k(S) = \frac{K_0}{W_0 e^{(\varphi - b - d)S - c^A}},
\]

where \( k(S) \) is the ratio of direct costs to foregone earnings costs for the \( S \)th year of schooling.\(^7\)

A diminishing rate of return to schooling will hold if

\[
\frac{\partial \rho}{\partial S} = -\frac{bk}{(1 + k)^2} (\varphi - b - d) < 0 \quad \text{that is if} \quad \varphi > (b + d).
\]

\( \rho \) will decline with additional schooling if the direct costs of schooling increase by a larger percentage \( (\varphi) \) than the increase in earnings \( (b + d) \).

The effect of \( A \) on the rate of return is equal to

\[
\frac{\partial \rho}{\partial A} = \frac{c}{(1 + k)^2} \frac{bk}{(1 + k)^2} > 0
\]

which is positive. This positive effect results from the complementarity between \( A \) and \( S \) implicit in the semi-log earnings function.\(^8\)

When \( A \) increases the new equilibrium implies a decline in \( \rho \) — due to the induced additional schooling — equal to the increase in \( \rho \) induced by the change in early abilities:

\[
-\frac{\partial \rho}{\partial S} dS = \frac{\partial \rho}{\partial A} dA.
\]

\(^7\)By replacing (8) into (7) we can rewrite \( \partial PV/\partial S \) in terms of the difference between the rate of return to the \( S \)th year of schooling and the discount rate:

\[
\frac{\partial PV}{\partial S} = \frac{b(\rho - r)}{(r - d)(\rho - d)} W_0 e^{A + (b + d - r)S}.
\]

\(^8\)Exactly the opposite result is obtained if we were to use an earnings function of the form \( W = g(S) + f(A) \), let us say \( W = a_1 + b_1 S + c_1 A \). In this case

\[
\rho = \Delta W/(K + W) = b_1/(K + W), \quad \frac{\partial \rho}{\partial A} = -b_1 W'(A)/((K + W)^2) < 0.
\]

Under this earnings function an extra unit of \( A \) increases wage earnings by the same absolute amount, independently of the initial level of schooling. Therefore, it does not change the extra benefits of additional schooling while it increases its cost via a higher foregone income. Although lifetime earnings increase, investment in schooling becomes less attractive. Increases in \( A \) act like a substitute of schooling.

\[\]
From (9) and (10) this condition yields
\[
\frac{dS}{dA} = \frac{c}{(\varphi - b - d)}.
\]

(12)

It is clear that the responsiveness of years of schooling to increases in early abilities is inversely proportional to the slope of the rate of return function.

2.3. The expression for the benefits or demand price of early abilities

With the above definitions we can now rewrite the expression for the demand price of early abilities as defined in (4). The first component of the benefits, the effect of additional abilities on lifetime earnings — holding schooling constant — can be derived by partial differentiation of (6) with respect to \(A\). The second component — the benefits from induced additional schooling — is the product of (7') and (12). Hence (4) can be written as

\[
\frac{dPV}{dA} = \frac{\partial PV}{\partial A} + \frac{\partial PV}{\partial S} \frac{dS}{dA} = W_0 e^{\varphi A + (b + d - r)S} \left[ \frac{c}{r - d} + \frac{b(\rho - r)}{(r - d)(\rho - d)(\varphi - b - d)} \right]
\]

\[
= W_0 \left( \frac{c}{r - d} \right) e^{\varphi A + (b + d - r)S} \left[ 1 + \frac{b(\rho - r)}{(\rho - d)(\varphi - b - d)} \right].
\]

(13)

where \(W_0\) is the numeraire. The value of \(\Pi\) is directly proportional to \(c\), the coefficient of early abilities in the semi-log earnings function. It is important to notice that in this formulation the induced additional schooling does not generate benefits if there is no discrepancy between the rate of return (or the cost of capital) to those households and the social opportunity cost of capital, \(\rho = r\). In this case, due to the continuous nature of the analysis, the area \(B\) of fig. 1 always tends to be zero.

3. Empirical evaluation

3.1. Parameter values

By now a considerable data on wage differentials and rate of returns to schooling has been reported for developing countries. Psacharopoulos provides a comprehensive survey of these data.\(^9\) These are, however, difficult to compare since usually they differ in the type of sample used (i.e., modern sector workers or

\(^9\)Psacharopoulos (1973).
representative samples of all sectors); also, the assumptions used in calculating the rates of return (i.e., age at which the student enters the schooling system) differ. What is important for our purposes is some minimum consistency among the parameters. These can be achieved since there is a clear relationship between \( \rho, k, d \) and \( b \).

The mean rate of return to primary schooling for developing countries reported by Psacharopoulos is 19.4 percent (with a standard deviation of 8.3 percent). The reported ratio of earnings of workers with primary education over workers with none yields an implicit value of \( b \) equal to 0.18. Values of \( k \) range from 0.44 to 1.59. Econometric estimates of \( d \) from several sources yield values ranging between 0.04 to 0.07.\(^9\) For our purposes we will use \( b = 0.20, d = 0.06 \) and \( k_1 = 1 \) (for the first year of primary schooling) which, by using eq. (8), yields a rate of return of 16 percent for the first year of primary education.\(^11\) For \( \phi \) we will use 0.30, namely the direct costs of schooling increase by 30 percent for each consecutive year of primary education.

The evidence on \( c \) comes from studies using different tests and different scaling. Therefore, it is convenient to express their results in terms of the effect on log \( W \) of changes in \( A \) measured in terms of standard deviations. Comparability of results assumes that the effect on log \( W \) depends on the relative performance of an individual, independently of what particular abilities the test is measuring.

Table 1 shows a summary of results from these studies. The last column shows the effect on d log \( W \) of one standard deviation change in the IQ or ability score.

\begin{table}[h]
\centering
\begin{tabular}{lccc}
\hline
Sample & Age of & Earnings & Coefficient \\
       & measurement &  & \\
\hline
I NBER–Thorndike\(^a\) & 18–22 & 44–48 & 0.03–0.04 \\
II Rogers sample\(^b\) & 14 & 44 & 0.08 \\
III Husen sample (Sweden) & 10 & 35 & 0.03–0.07 \\
   \quad Hause\(^c\) & & & 0.05 \\
   \quad Griliches\(^d\) & & & \\
IV Chilean workers\(^e\) & 30 & 30 & 0.15 \\
\hline
\end{tabular}
\caption{Effect on d log \( W \) of one standard deviation of within sample measured IQ scores.}
\end{table}

\(^a\)Hause (1972). We report here the significant coefficients.
\(^b\)Griliches (1970).
\(^c\)Selowsky and Taylor (1973). The mean age of measurement of both was approximately 30 with a standard deviation of 2.6 and 5.4 for the two sets of workers sampled.
\(^d\)Birdsall (1979), Chiswick (1978).
\(^e\)The difference between this figure and the higher figure of 19.4\% reported earlier could be explained by the fact that the effect of age on d log \( W \) increases with schooling, i.e., an interactive term \( tS \) ought to be included in the earnings function.
Except for the Husen sample, all measures of IQ are measures of ‘late’ not ‘early’ abilities. Late abilities are probably a function of early abilities plus the effect of schooling and other socioeconomic variables. Most of them were included in the multiple regressions for earnings; this solves the problem of isolating the net effect of subsequent schooling acquired after that late ability measure, i.e., the value added of that schooling. However, it still provides an upward bias estimate of the effect of early abilities, the bias being more important the later the measure.¹²

One could also argue that these regression coefficients underestimate the ones one would find by working in the range of ability scores characterizing disadvantaged children in developing countries. For the purpose of our analysis we will use a value of c, expressed in terms of standard deviations of the ability score, equal to 0.05. It corresponds to the Husen sample estimate and it is still below the ‘adjusted’ value derived from the Chilean workers’ sample (see last footnote).

3.2. Orders of magnitude

What probable values of A could be expected as a result of preschool intervention benefiting low income children? Table 2 shows results from probably the most comprehensive study on the effect of such interventions in a developing country. It has been conducted by McKay and Sinisterra and other

<table>
<thead>
<tr>
<th>Group</th>
<th>43</th>
<th>49</th>
<th>63</th>
<th>77</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Low SES</td>
<td>1.47</td>
<td>-0.16</td>
<td>0.41</td>
<td>0.72</td>
</tr>
<tr>
<td>2 Low SES</td>
<td>1.38</td>
<td>-0.26</td>
<td>0.55</td>
<td>0.96</td>
</tr>
<tr>
<td>3 Low SES</td>
<td>1.57</td>
<td>-0.61</td>
<td>1.69</td>
<td>1.31</td>
</tr>
<tr>
<td>4 Low SES</td>
<td>1.48</td>
<td>1.30</td>
<td>1.66</td>
<td>1.74</td>
</tr>
</tbody>
</table>

*Arrows show periods under treatment.
Source: McKay et al. (1978).

¹²Assume the true theoretical model is equal to log \( W = a + bS + cA + v \). However, we estimate the following: log \( W = a + bS + c_2A + c + v \). If there is a theoretical model relating \( A_s \) and \( A \), of the form \( A_s = x + \beta S + \gamma A + Z \) the true estimate of \( c \) becomes \( \hat{c} = c_2 \). Research by John Conlisk [reported in Bowles (1970)] by regressing IQ at age 18 with IQ between ages 1–5 and with schooling, yields

\[
IQ_{18} = 4.77 + 0.49IQ_{1-5} + 1.51S, \quad R^2 = 0.45,
\]

by using 0.5 as an estimate of \( \gamma \) and applying it to the estimate of \( c_2 \) derived for the Chilean workers (0.15) we obtain a value of \( c \) equal to 0.075.
collaborators in the city of Cali, Colombia. What is of interest is that the low SES (socioeconomic status) children selected for nutritional and environmental treatment were rather typical of children in poverty. They are not children under extreme undernutrition (many times already hospitalized) which have been selected in medical studies attempting to trace the effect of severe malnutrition on mental development. The children in the Colombian study had height and weight, as a percentage of normal for age, equal to 90 and 79. Years of schooling of their parents were 3.65 years and their per capita income was 5 percent the one of the high SES group (where parents had some college education). They probably represent the typical children of the poorest quintile of the population, although their parents' education is substantially above the mean for that quintile.\textsuperscript{13} At 43 months these children had ability scores 1.5 standard deviations below the high SES group. Programs providing nutritional supplementation, health care and preschool educational treatment closed the gap by approximately one standard deviation. (See table 2.)

Stronger effects can probably be achieved in the case of children under extreme deprivation. Extremely malnourished Chilean infants (with weight for age 70 percent of the norm) had Terman-Merrill test scores almost 2.5 standard deviations below controls of similar socioeconomic groups measured at age 3\frac{1}{2}. Multiple regression results based on the sample of undernourished children yielded coefficient showing that elimination of the early weight deficit would increase test scores by two standard deviations.\textsuperscript{14}

For the purpose of deriving orders of magnitudes we will use two values of $\Delta A$, equal to one and two standard deviations, respectively.\textsuperscript{15} Table 3 presents the

<table>
<thead>
<tr>
<th>Years of schooling</th>
<th>Initial values</th>
<th>With increases in $A$ equal to</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>One standard deviation</td>
</tr>
<tr>
<td>1</td>
<td>16.00</td>
<td>16.25</td>
</tr>
<tr>
<td>2</td>
<td>15.80</td>
<td>16.05</td>
</tr>
<tr>
<td>3</td>
<td>15.60</td>
<td>15.85</td>
</tr>
<tr>
<td>4</td>
<td>15.40</td>
<td>15.65</td>
</tr>
<tr>
<td>5</td>
<td>15.20</td>
<td>15.45</td>
</tr>
<tr>
<td>6</td>
<td>15.00</td>
<td>15.25</td>
</tr>
</tbody>
</table>

\textsuperscript{13}In Colombia the mean per capita income of the poorest quintile of the population (according to household per capita income) is approximately 6 percent of the one of the richest decile. Mean years of schooling of head of households in that quintile are 2.3 years. Selowsky (1979).

\textsuperscript{14}Selowsky and Taylor (1973).

\textsuperscript{15}The detailed formulae for deriving these results appear in the appendix.
Table 4

Present value of life time earnings ($PV$) by levels of schooling and levels of preschool ability, $A$ (values expressed in terms of the yearly wage of a worker with zero schooling).

<p>| Years of Initial | With increase in $A$ equal to |</p>
<table>
<thead>
<tr>
<th>schooling</th>
<th>$PV$</th>
<th>One standard deviation</th>
<th>Two standard deviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.26</td>
<td>12.91</td>
<td>13.58</td>
</tr>
<tr>
<td>2</td>
<td>14.02</td>
<td>14.78</td>
<td>15.76</td>
</tr>
<tr>
<td>3</td>
<td>16.06</td>
<td>16.95</td>
<td>17.89</td>
</tr>
<tr>
<td>4</td>
<td>18.44</td>
<td>19.48</td>
<td>20.58</td>
</tr>
<tr>
<td>5</td>
<td>21.19</td>
<td>22.41</td>
<td>23.70</td>
</tr>
<tr>
<td>6</td>
<td>24.38</td>
<td>25.82</td>
<td>27.34</td>
</tr>
</tbody>
</table>

$^{a}$Evaluated at an initial score of $A$ such that, given $K_1$, it generates a value of $k=K_1/W_0(A)=1$.

rates of return to marginal years of schooling; table 4 shows figures on the present value added of the total (not marginal) years of schooling completed, discounted at the year the child enters school. An opportunity cost of capital of 10 percent is used as the discount rate. These figures are expressed in terms of the yearly wage of a worker without schooling, which represents the numeraire.16

The economic benefits of $DA$ is the difference between the $PV$ achieved with the new level of $A$ and the $PV$ previously achieved, after allowing for adjustments in the years of schooling. After one standard deviation increase in $A$, equalization of the new to the old rate of return takes place with slightly more than one additional year of schooling (table 3, columns 1 and 2). After two standard deviations it takes place at a rate of return which is the mid-point of two and three additional years of schooling (i.e., 16.00 percent is the mid-point of the marginal rate of return to the 3rd and 4th year of schooling when $DA=2$ standard deviations$^{17}$ (columns 1 and 3). In order to bias downward the benefits we will use $\Delta S=1$ and $\Delta S=2$ as the induced effect.

Table 5 shows the resulting benefits. If a child previously attended only one year of schooling, the benefits of $DA$ equal to one s.d. is 2.52 times the wage of an illiterate worker. If $DA$ is equal to two s.d. the benefits are 5.63 times that wage. As a result of the complementarity between schooling and early abilities, the benefits are larger the higher the initial level of schooling achieved by the child.

It is clear from table 5 that the results are dominated by the benefits out of the induced additional schooling, i.e., column (2). As shown before, this depends fundamentally on $1/(\varphi - b - d)$ or the inverse of the slope of the rate of return with respect to years of schooling. A smaller induced effect could be derived by a more

16More precisely it is the wage of worker without schooling at age 20. See appendix.

17Recall that $dS=(c/(\varphi - b - d))dA=1.25dA$; therefore $dS=1.25$ when $dA=1$, $dS=2.5$ when $dA=2$. 

Values of $\Pi$: Changes in life time earnings induced by changes in preschool ability scores (values expressed in terms of the zero schooling yearly wage).

<table>
<thead>
<tr>
<th>Initial level of schooling, S</th>
<th>$\Delta S = 0$</th>
<th>$\Delta S = 1$</th>
<th>$\Delta S = 2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Effect, (\Pi)</td>
<td>Effect, (\Pi)</td>
<td>Effect, (\Pi)</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>1</td>
<td>0.65</td>
<td>1.87</td>
<td>2.52</td>
</tr>
<tr>
<td>2</td>
<td>0.76</td>
<td>2.17</td>
<td>2.93</td>
</tr>
<tr>
<td>3</td>
<td>0.89</td>
<td>2.53</td>
<td>3.42</td>
</tr>
<tr>
<td>4</td>
<td>1.04</td>
<td>2.93</td>
<td>3.97</td>
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<tr>
<td>5</td>
<td>1.22</td>
<td>3.41</td>
<td>4.63</td>
</tr>
<tr>
<td>6</td>
<td>1.44</td>
<td>3.99</td>
<td>5.63</td>
</tr>
</tbody>
</table>

*From table 3: The induced increase in the years of schooling at which the rate of return to education is 'maintained' constant. Since both values $\Delta S = 1 \text{ and } \Delta S = 2$ are an underestimate of the induced schooling effect, the figures in column (2) are also an underestimate.*

The figures in table 5 show the 'demand' price for specific values of $\Delta A$ at the point in time when a typical child enters the schooling system at age 6. Any series of investments carried earlier to induce that $\Delta A$ will have a positive present value as long as, accumulated at that date, yields a value below $\Pi$. The maximum yearly investment during the first five years of those children that can be 'justified' on the basis of $\Pi$ is shown in table 6. *Yearly investments* per child in programs that can induce $\Delta A$ equal to one s.d. can be justified if they cost between 0.37 and 0.51 the yearly wage of an illiterate worker. If they can induce two s.d., values between 0.84 and 1.14 can be justified.

In order to derive magnitudes in relation to the per capita income of a country we need the ratio between the unskilled or illiterate wage and country per capita income, $W^0/\bar{Y}$. As expected, the ratio is quite sensitive to the precise definition of the reference worker (i.e., urban or rural, working in the formal or informal sector,
Table 6
Maximum investment in inducing $\Delta A$ justified by the increase in the value added of schooling. Yearly investment per child during ages 1-5.\(^a\)
(Expressed in terms of the zero schooling yearly wage.)

<table>
<thead>
<tr>
<th>Initial level of schooling</th>
<th>$\Delta A$ equal to</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One standard deviation</td>
</tr>
<tr>
<td>1</td>
<td>0.37</td>
</tr>
<tr>
<td>2</td>
<td>0.44</td>
</tr>
<tr>
<td>3</td>
<td>0.51</td>
</tr>
</tbody>
</table>

\(^a\)The yearly investment is computed as

$$I = \Pi \left[ \frac{1 + r}{r} \right] \left[ (1 + r)^{\Delta A} - 1 \right] = 0.149 \Pi,$$

where $\Pi$ is obtained from table 5. A value of $r = 0.1$ is used.

Table 7
Maximum investment in inducing $\Delta A$ justified by the increase in the value added of schooling. Yearly investment per child during ages 1-5 (values in dollars).\(^a\)

<table>
<thead>
<tr>
<th>Country per capita income (dollars per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta A$</td>
</tr>
<tr>
<td>One standard deviation</td>
</tr>
<tr>
<td>0.8</td>
</tr>
<tr>
<td>1.0</td>
</tr>
<tr>
<td>1.25</td>
</tr>
<tr>
<td>Two standard deviations</td>
</tr>
<tr>
<td>0.8</td>
</tr>
<tr>
<td>1.0</td>
</tr>
<tr>
<td>1.25</td>
</tr>
</tbody>
</table>

\(^a\)Children receiving $\Delta A = 2$ s.d. 'type programs' are assumed to have otherwise attended one year of schooling (from column two and row one of table 6). Those receiving $\Delta A = 1$ s.d. 'type program' are assumed to have otherwise attended two years (column one, row two, of table 6).

\(^b\)Ratio of wage of illiterate workers to the country, annual per capita income: ($W_o/Y$),

- **Brazil** (1977) 0.53
- **Colombia** (1966) 0.40
- **Philippines** (1971-73) 0.62
- **Korea** (1976) 0.61

**Colombia**: Wage of urban workers with no schooling. Selowsky (1968).
**Philippines**: Based on the daily wage of agricultural laborers: ILO Yearbook of Labor Statistics.
**Korea**: Equal to the income of landless agricultural workers estimated by Bhalla (1979).
**India** (1972): Based on daily wages of agricultural workers. 250 days worked per year is assumed. Jose (1974).
etc.). We, however, found that such ratio is inversely related to the per capita income of the country.

Table 7 derives dollar figures for the yearly investment per child for a range of country per capita income levels. The demand price figures for one s.d. program assumes the children would otherwise have attended two years of schooling. For two s.d. it is assumed those children, given their initial disadvantaged situation, would have attended only one year. Even under this assumption it becomes clear that countries should spend almost twice for an extremely disadvantaged child where programs could induce a two s.d. change in \( A \).

If wages increase with the per capita income of the country it follows that richer countries should (in absolute values) spend more per child for the same type of program (defined by its induced \( \Delta A \)). A country like Brazil or Mexico with over $1,000 per capita income should spend two to three times more per child than Pakistan with a $200 per capita income.

If programs that can induce one s.d. change in \( \Delta A \) are typically applicable to preschool children in the poorest quintile of the population, we can derive a figure for the percentage of GNP to be devoted to such programs. This is shown in table 8. In countries with annual per capita incomes below 400 dollars, between 1.4 and 2.2 percent of GNP should be devoted to such programs. For higher per capita incomes it ranges between 0.6 and 1.8 percent of GNP.

Table 8

<table>
<thead>
<tr>
<th>Investment per child over per capita income (dollars per year)</th>
<th>Country per capita income</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>200</td>
</tr>
<tr>
<td>0.55</td>
<td>2.2</td>
</tr>
<tr>
<td>0.45</td>
<td>1.8</td>
</tr>
<tr>
<td>0.35</td>
<td>1.4</td>
</tr>
<tr>
<td>0.25</td>
<td>—</td>
</tr>
<tr>
<td>0.15</td>
<td>—</td>
</tr>
</tbody>
</table>

\( a \)

This share is equal to \( 0.2(C/Y) \), where \( C/Y \) is the investment per child over the country's per capita income and \( R \) the fraction of children ages 1-5 in the poorest quintile. A value of 0.2 is used for \( R \).

Appendix

For the purpose of computing the rate of return to each additional year of primary education we define

\[
\rho(S, A + \Delta A) = \frac{b}{1 + k_1 e^{(a - b - d)(S - 1) - c\Delta A}} + d,
\] (A.1)
where \( p(S, A + \Delta A) \) is the return to the \( S \)th year of schooling for an individual with a level of preschool ability equal to \( A + \Delta A \).

\[
k_1 = K_1/W_0(A) = 1.
\]  

(\( A.2 \))

\( k_1 \) is the ratio of the direct costs of the first year of schooling to the foregone income of that investment, namely the wage the individual would have perceived otherwise during that year. That wage is evaluated at the initial level of preschool abilities equal to \( A \).

The present value of earnings of somebody with \( S \) years of schooling and a level of preschool ability equal to \( A + \Delta A \) can be written:

\[
PV(S, A + \Delta A) = W_0(A)\left\{\frac{e^{\phi S + (b + d - r)S}}{(r - d)} - \frac{k_0}{(\phi - r)}(e^{(\phi - r)S} - 1)\right\}.
\]  

(\( A.3 \))

Since \( k_1 = k_0 e^{qs} = 1 \) when \( S = 1 \), we will define \( k_0 = 0.74 \).

The numeraire of (3) is \( W_0(A) \), the wage of a youngster with no schooling that enters the labor force instead of first grade. A more convenient numeraire is \( W_0^{20}(A) \), the wage of an individual with no schooling at age 20. If children enter the first grade at age 6 then

\[
W_0(A) = e^{-1 + 4d}W_0^{20}(A) = 0.43 W_0^{20}.
\]  

(\( A.4 \))

By substituting (4) into (3) as well as substituting the parameter values \( (b = 0.2, d = 0.06, r = 0.1, \phi = 0.3, c = 0.05) \) we obtain

\[
PV(S, A + \Delta A) = W_0^{20}0.43\left\{\frac{e^{0.05\Delta A + 0.16S}}{0.04} - \frac{0.74}{0.20}(e^{0.2S} - 1)\right\}.
\]  

(\( A.5 \))

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