

ECONOMICS OF MALNOURISHED CHILDREN:

A STUDY OF DISINVESTMENT IN

HUMAN CAPITAL.

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### Abstract

Medical evidence indicates that children who suffer from malnutrition and other environmental deprivations during infancy are likely to suffer rather severe mental retardation. Moreover, this may be "irreversible" insofar as mental capacities are formed early in life, with the possibility of large incremental changes in capacity diminishing sharply by age five or so. Since ability at this age affects both schooling performance and adult ability and earnings, one might expect that early malnutrition could significantly hinder adult economic performance. In this paper we try to quantify these effects, first in terms of a simple theoretical human capital model and then numerically with data on samples of Chilean malnourished infants and adult workers. Insofar as our cross-sample inferences are valid, the economic benefits to alleviating malnutrition are substantial--a long-term program could bring discounted returns equal to one percent of current Chilean GNP. On the basis of crude cost estimates for infant feeding programs, we also conclude that present discounted values of such programs are significantly positive.

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**The Economics of Malnourished Children:  
A Study of Disinvestment in Human Capital\***

**by Marcelo Selowsky and Lance Taylor  
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## 1--Introduction

Most Third World children suffer, many of them severely, from malnutrition.<sup>1/</sup> There are numerous socio-cultural reasons for this, some of them of recent origin (such as an increasing use of bottle feeding in unsanitary conditions) and some ancient (such as taboos against infants' eating protein foods). Each specialist no doubt can elaborate at great length on the importance and persistence of his preferred cause of infant malnutrition; certainly economists have little enough to say about most of them. As always, though, the costs and benefits are of some policy import, and thus the economic theory underlying them. This leads to our proposing here a somewhat modified version of the standard human capital model, to spell out in formal terms some of the microeconomic implications of infant deprivation. Naturally, the theory suggests ways to measure the private and social benefit of alleviating the problem, and much of this paper is devoted to making initial estimates of these benefits for lower class populations in Santiago, Chile. As the reader

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<sup>1/</sup> On the impacts of the so-called world food problem on the nutritional status of developing countries, see Frisch /4/ and /5/, and the President's Science Advisory Committee /11/. Many developing countries on the average have lower per capita consumption of animal protein than the usual norms. Poor people in developing countries often have protein intake far below adequate levels, at least according to existing case studies summarized by Woodruff /18/. Since adequate protein (along with vitamin A and, of course, caloric energy) appears to be necessary for full development of infants, these global findings in general substantiate our hypothesis that a large share of the world's young children are malnourished.

43

will see, we must resort to statistical sleight-of-hand to apply the theory to inadequate data, but we think that the results-- showing great benefits to amelioration of infant malnutrition-- are of sufficient interest to justify our methodological transgressions. A semi-starved infant is not a pleasant sight, and we hope that even a partial demonstration of the economic benefits from doing something about his condition may help induce policy makers to suppress their normal prudence in such matters, and act.

## 2--A Theoretical Model

After appropriate correction for region, race, sex, and class (all of which we magisterially exile to ceterus paribus), the empirical literature seems to show that adult earnings depend with some regularity on completed schooling and "ability" as measured by something like an IQ test,<sup>2/</sup>

$$Y = Y(S, A). \quad (1)$$

Both of these conditioning variables are the result of an accumulation process. Schooling, for example, can be said to be ac-

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<sup>2/</sup>The relative importance of these two factors varies greatly even in different studies in the U.S., and almost nothing is known of their differential impact on earnings in developing countries. (Absolutely nothing is known of the impact of psychological characteristics such as initiative, temperament, etc. on earnings, and yet these may be very important explanatory variables which also are strongly affected by early malnourishment.) For the record, we note that U.S.-based empirical studies usually show schooling to be a more important determinant of earnings than ability. This is less apparent for groups at the extreme low end of the earnings spectrum /6/ and the high end of the education spectrum /7/. In our results for Chile, ability is much more important than a modicum to schooling in explaining earnings of construction workers. See Section 3.

cumulated as a simple function of the time devoted to it,

$$ds/dt = \dot{s} = s \quad (2a)$$

with

$$0 \leq s \leq 1, \quad (3)$$

where  $s$  is the fraction of an individual's time that he spends being educated. Alternatively, a more abstract, quality-weighted education might depend on the pupil's ability. We scarcely lose generality by assuming that this type of schooling is accumulated according to the rule,

$$\dot{S} = sq(A), \quad (2b)$$

where  $q(A)$  presumably obeys the conditions  $dq/dA > 0$ ,  $d^2q/dA^2 < 0$ .

According to one school of psychological thought (Bloom /3/ is a major exponent), ability--perhaps best interpreted as one's relative position in the bell-shaped IQ distribution of his population cohort--is also an accumulated quantity, in the sense that a favorable environment can lead to ability increases, and the reverse for a poor environment. Bloom provides some empirical support for the simplest possible hypothesis about the evolution of ability, that it is a "random walk" with ability increments independent of ability levels and other historical influences:

$$\dot{A} = h(s, n; \text{many other current environmental factors}),$$

where  $n$  stands for the amount of "nutrition" the individual



receives.<sup>3/</sup> <sup>4/</sup> We immediately drop the other environmental factors as being too complicated for a simple model to deal with, but add the twist that the change in ability depends explicitly on time,

$$\dot{A} = h(\alpha(t)s, \beta(t)n). \quad (4)$$

Bloom's empirical results strongly suggest that the  $\alpha$  and  $\beta$  functions have the shape shown in Figure 1, i.e. ability change is much more influenced by the environment at an early age than a later one, with about half of the post-natal change coming before age four or five.

Besides "factor-reducing" technical progress, another important characteristic of a realistic ability change function is that it permits decumulation of ability, in the sense of reduction of a child's intelligence test scores relative to his population cohort. In other words, malnutrition and other environmental insults can cause "irreversible" ability loss, particularly

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<sup>3/</sup> "Nutrition" is, of course, a vector-valued quantity. Nutritionists point variously to protein, calories, and vitamin A as important limitational factors in the diets of Third World children. We ignore this, as we soon are to ignore the other environmental deprivations which assail children along with lack of food. As pointed out repeatedly in /13/, all these things are "synergistic" (which an economist would translate as complementary) in leading to ability loss. All this is lumped into our variable  $n$ . Keep in mind that it really is a rather long vector.

<sup>4/</sup> Nutrition also directly influences current schooling performance of children and earnings of adults. To keep to our main interest--the impact of early nutritional improvements on later accumulation of ability and schooling--we leave these possibly very important effects out of the model.

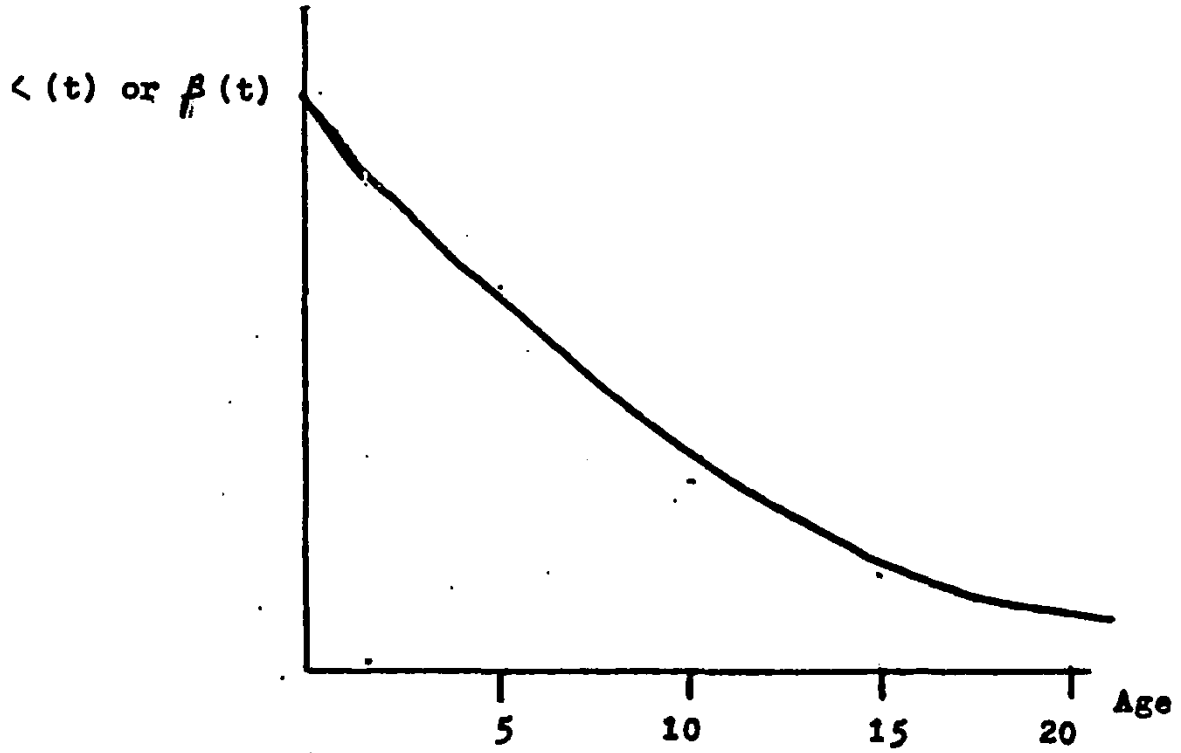


Figure 1: Impact of environmental variables on change in ability as a function of age.

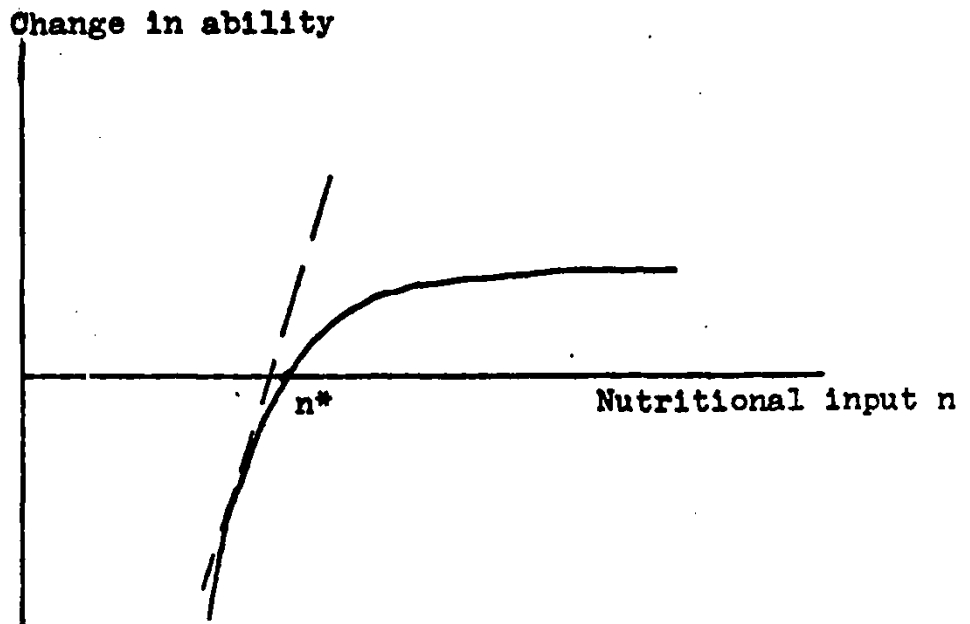


Figure 2: Impact of nutrition on ability change.

among young children.<sup>5/</sup> This is shown in Figure 2, where low levels of nutrition lead to drastic relative losses in ability, while levels not so far above the "norm"  $n^*$  cause essentially no marginal ability increases. Early ability losses are essentially irreversible insofar as our hypothesis about the declining impact with age of environmental variables on ability is correct.

Most of the human capital literature assumes a constraint set like (2) - (4), and in addition maintains the behavioral hypothesis that the individual and his guardians jointly maximize his discounted lifetime earnings, i.e. the functional

$$\int_0^T e^{-rt} [(1-s) Y(S,A) - cn] dt. \quad (5a)$$

In this formulation,  $r$  is the rate of discount in the perfect capital market which the individual is assumed to face,  $(1-s)Y$  is the part of his potential earnings not foregone via time spent in school (we assume his perceived direct costs of schooling are negligible),  $c$  is the cost-per-unit of the nutrition input, and  $T$  is the age at which the individual expects to die. Since people also derive satisfaction from being schooled

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<sup>5/</sup> There is a huge literature on this hypothesis, and some feel that it is yet to be established, particularly as regards irreversibility. A good survey of the evidence is contained in the proceedings of an M.I.T. 1967 conference /13/, and the reader can draw his own conclusions about the acceptability of our "reasonable" hypothesis from there.

(particularly if their "ability" as measured by their educators' tests is high), we also consider the variant maximand,

$$\int_0^T e^{-rt} [U(S,A) + (1-s) Y(S,A) - cn] dt. \quad (tb)$$

where  $\partial^2 U / \partial S \partial A < 0$ . That is, an increment in schooling reduces the marginal satisfaction resulting from an increment in ability. (Presumably the opposite is true for income:  $\partial^2 Y / \partial A \partial S > 0$ .)

To describe in intuitive terms the solution to this problem, we observe that at any age  $t$ , the return to the individual from having a small amount of additional schooling is just

$$P_S(t) = \int_t^T e^{-r(\tau-t)} [(1-s)Y_S + U_S] d\tau, \quad (6)$$

i.e. the discounted marginal non-foregone income and satisfaction resulting from additional education. (The subscripts on  $Y$ ,  $U$ , and  $q$  indicate partial differentiation.) Similarly, the individual will value a small increment in ability according to the rule

$$P_A(t) = \int_t^T e^{-r(\tau-t)} [(1-s)Y_A + U_A + P_S s q_A] d\tau \quad (7)$$

which takes into account the direct effect of more ability on income and satisfaction, as well as the future value of its effect on the current quality of the individual's education.

Both  $P_A$  and  $P_S$  will normally decrease with time, as a shorter re-

maining lifetime reduces the expected benefits from one's accumulated schooling and ability.

The marginal cost of obtaining more schooling at age  $t$  is just  $Y(S(t), A(t))$ , i.e. the income the individual would have to forego while being schooled. The benefits are the discounted income and satisfaction which result from having more schooling,  $P_S q(A)$ , and more classroom-created ability,  $P_A \alpha(t) h_s$ . Therefore the individual will increase his time devoted to schooling until

$$Y(S, a) = P_S q + P_A \alpha(t) h_s \quad s < 1. \quad (8a)$$

If equality of benefits and costs of schooling is not attained with  $s < 1$  (which is likely in the early years of life), then this condition is modified to

$$Y(S, A) < P_S q + P_A \alpha(t) h_s \quad s = 1, \quad (8b)$$

i.e. devoting more than a full working day to schooling would be desirable for a child's future welfare, if only his time allowed. Moreover, since  $\alpha$ ,  $P_A$  and  $P_S$  decline with age while  $Y$  increases, then<sup>6/</sup>

Rule 1: The optimal time pattern of schooling will be an initial phase of full time education, followed by continuing education at a declining rate (normally) throughout one's lifetime.

Since the immediate cost of more nutrition is just  $c$ , then the rule for deciding how much to spend on that input is

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<sup>6/</sup> Of course, Ben-Porath already derived this rule in /2/, for a model with only one kind of accumulated human capital.

$$c = P_A \beta(t) h_n.$$

Rule 2: Nutrition input is increased until its marginal product in creating long term income and satisfaction through ability increases just equals its cost.

This rule means that it may be perfectly "optimal" in economic terms for parents to allow their children to become malnourished during infancy, even though this can lead to ability loss which cannot be made up later because of the decreased impact on ability change of environmental factors with increasing age. All that is required for this is a relatively high value of  $c/P_A \beta(t)$ , which can lead to an ability-reducing tangency with the  $h$ -function, as shown in Figure 2. In terms of the model, this is less likely to occur at any early age than a late one, since both  $P_A$  and  $\beta$  decline with time. Nonetheless, with high enough nutrition costs, rational parents might still disinvest in their child's future by not feeding him adequately, even in our make-believe world of perfect capital markets and certainty about the deleterious effects of early deprivation.<sup>7/</sup> We think

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<sup>7/</sup> Lest the reader think we exaggerate in stressing that food costs to the family are an important determinant of how well children in developing countries are fed, we cite--almost at random--a study made in a lower class district of Cali, Colombia /10/. Median per capita income per month of the people studied was 124 pesos, or about seven U.S. dollars. To feed a five-year old Cali child an adequate diet according to FAO standards (including animal protein) would cost the same 124 pesos per month. Since rent, clothing, fuel, etc. are also costly, it is clear enough that deciding whether or not to provide adequate food for an infant (who is, by the way, less able to protest inadequate feeding than older family members) would be a serious economic decision in a family at this level of income. And Cali is a relatively prosperous city within Colombia; Colombia, a relatively prosperous country.

that this is an excellent argument for government intervention, even though no apparent "distortion" exists.

Suppose that the government does intervene, with (quite possibly) costly programs to avoid infant deprivation. If it counts the individual's benefits as its own, then increasing the child's nutritional intake at age  $t$  will bring a long run return of

$$\int_t^T P_A \Delta A \, d\tau = \beta(t) h_n \Delta n \int_t^T P_A \, d\tau \quad (10)$$

where  $\Delta n$  is the additional amount of nutritional input provided by the government,  $\Delta A = \beta h_n \Delta n$  is the resultant ability increase, and  $P_A$  and  $h_n$  take values from the individual's optimizing program, without government help. Naturally, given the time shapes of  $P_A$  and  $\beta$ ,

Rule 3: Government help in the form of programs increasing nutrition will be more productive for the individual the earlier in life they are undertaken, under our assumptions regarding the impact of nutrition on ability change.

The government help will naturally lead the individual to modify his human capital accumulation program to some extent. In particular, he will arrive at the age  $t^*$  at which he would have ceased full time schooling with somewhat higher stocks of ability and schooling and (although this is a second order effect) values of  $P_A$  and  $P_S$  which will have changed slightly to take into

account his greater stocks.<sup>8/</sup> The effects of these changes on the amount of schooling he desires just after  $t^*$  can be calculated by totally differentiating (8a) and (9) and solving for  $ds$ , the change in the amount of time the individual desires to devote to schooling. The analytical expression (dropping  $\alpha$  and  $\beta$  for convenience) is

$$ds = \frac{h_{nn}}{P_A^2 (h_{ss} h_{nn} - h_{sn}^2)} [Y_S ds + (Y_A - P_S q_A) dA - q dP_S - h_s dP_A]. \quad (11)$$

The term outside the brackets will be negative as long as the function  $h$  shows decreasing returns. This means that

$$\frac{ds}{ds} < 0$$

$$\frac{ds}{dA} \text{ ambiguous}$$

$$\frac{ds}{dP_S} > 0 \quad \frac{ds}{dP_A} > 0.$$

The impact of the government's intervention will be in the direction of reducing the individual's time allocated to schooling at age  $t^*$  (and effectively reducing the school-leaving age) through its effects on  $S$  and  $P_S$ . The effect of the

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<sup>8/</sup>The changes in the shadow prices  $P_A$  and  $P_S$  are likely to be empirically insignificant, at least judging<sup>S</sup> from numerical solutions to similar models /16/. Analytically, it is extremely difficult to say anything about their magnitudes, although  $P_S$  should fall and  $P_A$  may rise or fall depending on the relative importance of a change in ability in adding to earnings and reducing utility for a given increment of schooling.



positive change in ability is ambiguous: school-leaving age will tend to decrease because of the increased opportunity cost of higher income from higher ability (this is also why  $ds/dS < 0$ ), and tend to increase because of the effect of increased ability on reducing satisfaction with the existing level of schooling ( $dP_A$  has an ambiguous sign) and on the marginal productivity of school-time in creating quality-weighted schooling ( $P_S q_A > 0$ ).

Rule 4: The effect of the government's increasing a child's nutritional intake at an early age on the age at which he ceases full-time schooling is ambiguous, due to the trade-off between foregone earnings and additional benefits from additional schooling.

Since we implicitly assume that the government bears all direct schooling cost, the effect of its nutrition programs on the length of the child's schooling should obviously enter into its social benefit-cost calculus. The theory cannot tell us the magnitude and direction of this effect. We discuss it empirically in the following section.<sup>9/</sup>

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<sup>9/</sup> In fact, American evidence shows that the impact of higher ability on schooling is positive (see Hause /7/ for discussion of these findings). As (11) shows, this would not be consistent with traditional human capital models, which have the individual maximizing only discounted income, as in (5a). The satisfaction-from-schooling and quality-corrected schooling additions modify the theory to save the phenomenon. At our present level of phenomenological groping, this is a perfectly reasonable intervention.

### 3--Empirical Tests for Chile

Strictly speaking, the foregoing dynamic theory should be tested dynamically, with a carefully followed, statistically controlled group of malnourished children. Several of the longitudinal studies necessary for this type of analysis are underway, but if we wish to make estimates now of the effects on adult earnings of improved infant nutrition we must specify a more static model, and try to infer its parameters from a variety of sources. This is the approach adopted here.

We begin our empirical specification by noting that the theory of ability change in equation (4) implies an equation of the following form for pre-school ability  $A_0$ ,

$$A_0 = a_1 + b_1(w/\bar{w}) + c_1x_1, \quad (12)$$

where  $(w/\bar{w})$  is an average over infancy of the child's weight  $w$  relative to his "normal" weight-for-age  $\bar{w}$ , and  $x_1$  is a collection of "background" variables such as parental schooling and ability, the family's socioeconomic status, etc. The relative weight variable is an index of malnutrition, the significance of which is discussed below.

Similarly, the idea that ability does change over time leads as to an equation of the form

$$A_t = a_2 + b_2A_0 + c_2S + d_2x_2 \quad (13)$$

for ability at some mature age,  $A_t$ . Besides depending on pre-school ability ( $A_0$ ),  $A_t$  also depends on accumulated schooling

(S), and another package of background variables ( $x_2$ ).

Besides the effect of schooling on increasing ability, there is also the reverse possibility that more ability leads to more schooling. We saw in equation (11) that it is by no means theoretically certain that this effect exists, given the trade-off between foregone earnings and the increased personal satisfaction from more schooling. Nonetheless, we can test for it with an equation like

$$S = a_3 + b_3 A_0 + c_3 x_3. \quad (14)$$

This states that the amount of schooling an individual chooses depends on his initial ability and background variables (which would be sufficient to determine his choice if he were actually following a maximizing plan, as supposed above).

Finally, we expect an equation of the form

$$Y = f(A_t, S, x_4) \quad (15)$$

to hold for the individual's post-school earnings. We describe our specific functional form below.

Our strategy in estimating these relationships is to use a sample of malnourished children (and well-nourished controls) to estimate (12), and a sample of adult Chileans to estimate (15). We use other people's results in conjunction with our own to "estimate" equations (13) and (14), bridging infancy and adulthood.

We discuss the details of all this in what follows:

A. Effects of Early Malnutrition on Adult Intelligence

We begin by noting that in principle, equation (12) should be of distributed lag form, since a child's ability at age three or four will depend on his history of malnutrition, and not just on the average of his weight to the norm over some period, but our data did not permit this kind of estimation. Also, relative weight is not a completely satisfactory physical index of malnutrition, but in our sample it gave ability predictions similar to those from more scattered data on height and cranial circumference, the other commonly used measures of child development.<sup>10/</sup>

To estimate equation (12) for a group of Chilean children, we used data gathered, and very kindly provided us, by Drs. Kardonsky, Undurraga, Alvarado, Seguir, and Manterola /9/. As we will see, statistical analysis of this sample indicates not only that severely malnourished children have lower measured IQ's than well-nourished controls (the usual finding) but also that even within the handicapped group there is negative correlation between malnutrition and IQ. This intra-group relationship is very important, because it gives evidence for the malnutrition-IQ relationship independent of controls, whose selection is

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<sup>10/</sup> The use of weight-for-age  $\bar{w}$  as a normalizing factor in (12) corresponds to usual diagnostic practice, i.e. a child malnourished in the third (worst) degree reaches sixty percent or less of normal weight. We used the "Iowa" weight norms /8/ which describe well the development of well-nourished Chilean children, but the significance of our regression results would not be altered by use of other norms.

extremely difficult in this type of study.

The thirty-three malnourished children came from a very low income neighborhood in Santiago. They all experienced grade three protein-calorie malnutrition in their first year of life,

were then hospitalized, and followed in a longitudinal study (with monthly weight measurement). They received adequate nutrition and medical care after their initial hospitalization. The distribution of their birth weight was normal, and they were apparently free of birth abnormalities and disease other than malnutrition.

Eleven "normal" children from the same neighborhood were selected as controls. However, we were able to trace the exact weight history for only seven of them. Between ages three and three and a half all of these children were given a Terman-Merril Intelligence Test. Data on the mothers' IQ (Wechsler Test) and years of schooling are available for the normal children but only for twenty-eight of the malnourished children. Four sample groups can therefore be distinguished according to the availability of data:

Group I (n=33) - group of malnourished children

Group II (n=40) - total sample (malnourished + normal children)

Group III (n=28) - malnourished children with family background data

Group IV (n=35) - total number of children with family background data

Table 1  
Means and Standard Deviations (in parenthesis)  
of the Variables Used

	<u>malnourished</u> <u>children</u>	<u>normal</u> <u>children</u>
Terman-Merril Children Test	72.8(11.4)	97.1(9.9)
S <sub>1</sub> = average (relative) monthly weight first semester	62.0(7.1)	104.6(15.8)
S <sub>2</sub> = average (relative) monthly weight second semester	58.8(10.5)	104.1(15.8)
S <sub>3</sub> = average (relative) monthly weight third semester	73.9(10.5)	102.2(11.0)
W <sub>18</sub> = average (relative) monthly weight first 18 months	65.0(6.8)	102.6(13.2)
W <sub>30</sub> = average (relative) monthly weight first 30 months	72.6(7.3)	103.9(13.5)
mothers' years of schooling	3.7(2.3)	3.8(2.1)
mothers' Intelligence Test	70.9(14.7)	70.7(13.4)

Note: The weight is relative to the Iowa standard and expressed as a percentage.

Table 1 summarizes the means and standard deviations of the main variables used. The control group appears to be normal according to weight and IQ; however, mothers' IQ and schooling are almost the same for both groups.

Table 2 shows the results of regressing the children's Terman-Merrill scores on different weight variables. These are aggregated over various time periods, since multiple regressions with lagged quarterly weight data gave unstable and insignificant coefficients. However, in most of these regressions the coefficient corresponding to weight in the third semester (half-year) of life was stable and significant, as shown in regressions 1 and 2 of Table 2. (The  $S_i$  are average weight relative to the norm in the  $i$ -th semester.) When average relative weight for the first eighteen ( $W_{18}$ ) or thirty ( $W_{30}$ ) months of life was used as the explanatory variable, similar results were obtained. All coefficients were insensitive to changes in the sample used.

The fact that the weight coefficients have magnitudes ranging between 0.50 and 0.65 means that a gain of ten percentage points in the corresponding relative weight variable would generate an increase in IQ of five to 6.5 points. The stability of these coefficients across samples suggests that this impact may be similar for all levels of relative weight loss, although this should be investigated more thoroughly.

Table 2  
Dependent Variable - Terman-Merril Childrens' Test

No.	Indep. Regr. Variab.	Group I n=33 mal-nourished children	Group II n=40 pool	Group III n=28 mal-nourished children	Group IV n=35 pool
	intercept	41.32(1.99)	28.79(2.75)	43.65(1.75)	28.92(2.38)
	S <sub>1</sub>	-0.14(-0.56)	-0.02(-0.14)	-0.14(-0.51)	-0.03(-0.18)
1	S <sub>2</sub>	0.05(0.23)	0.14(0.76)	0.06(0.23)	0.14(0.71)
	S <sub>3</sub>	0.51(2.45)	0.51(2.37)	0.46(1.65)	0.49(1.73)
		R <sup>2</sup> = 0.25	R <sup>2</sup> = 0.48	R <sup>2</sup> = 0.17	R <sup>2</sup> = 0.48
	intercept	33.36(2.63)	25.13(2.76)	35.18(2.18)	23.83(2.44)
2	S <sub>3</sub>	0.53(3.14)	0.66(5.81)	0.50(2.26)	0.67(5.50)
		R <sup>2</sup> = 0.24	R <sup>2</sup> = 0.47	R <sup>2</sup> = 0.16	R <sup>2</sup> = 0.47
	intercept	35.11(1.91)	37.43(4.78)	42.13(1.92)	36.53(4.47)
3	W <sub>18</sub>	0.58(2.06)	0.55(5.19)	0.56(1.33)	0.55(5.03)
		R <sup>2</sup> = 0.12	R <sup>2</sup> = 0.41	R <sup>2</sup> = 0.08	R <sup>2</sup> = 0.43
	intercept	25.35(1.34)	26.13(2.61)	32.98(1.43)	25.94(2.47)
4	W <sub>30</sub>	0.65(2.53)	0.65(5.18)	0.54(1.69)	0.65(4.90)
		R <sup>2</sup> = 0.17	R <sup>2</sup> = 0.41	R <sup>2</sup> = 0.10	R <sup>2</sup> = 0.42
	intercept			9.33(0.45)	
5	S <sub>3</sub>			0.49(2.32)	
	SI			0.46(1.94)	
				R <sup>2</sup> = 0.27	
	intercept			1.03(0.03)	
	W <sub>18</sub>			0.59(1.83)	
6	SI			0.56(2.24)	
				R <sup>2</sup> = 0.22	



Table 2 (Cont.)

No.	Indep. Repr. Variab.	Group I n=33 mal-nourished children	Group II n=40 pool	Group III n=28 mal-nourished children	Group IV n=35 pool
	intercept			-6.13(-0.22)	
7	W <sub>30</sub>			0.64(2.14)	
	SI			0.56(2.27)	
				R <sup>2</sup> = 0.25	

Note: Figures in parentheses represent the t ratio of the coefficient.

If heredity has a role in explaining childrens' IQ scores, mothers' IQ could be used as a proxy for the ability endowment at birth. It also could be used, together with mothers' years of schooling, as a proxy for family environment affecting mental growth. However, we found these two variables to be insignificant in the explanation of IQ. What did turn out to be significant was a composite socio-economic index (SI) provided to us by Dr. Kardonsky and her collaborators from the Institute of Psychology, University of Chile.<sup>11/</sup> The index may be a better proxy for the long-run overall environment than one of its components, family income.

Regressions (5) - (7) show that relative weight and the index explain between 22% and 27% of the variance in childrens' IQ. Since the coefficient of weight is not sensitive to the introduction of SI, we conclude that the impact of nutrition on IQ is relatively independent of easily measured socioeconomic factors.

#### B. Increments in Early IQ vs. Later IQ and Schooling

As mentioned above, to "estimate" equations (13) and (14) linking our malnourished children and present day Chilean adults,

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<sup>11/</sup> The index is a weighted average of indices of the following ten characteristics of the children's homes: type of housing, toilet facilities, bathing facilities, cooking facilities, location of cooking facilities, ownership or rental arrangement of the house, elimination facilities, water source, lighting system, per capita income. For more details on the construction of SI, see Selowsky /15/.

we have to rely on hypothetical bridges between these two groups. As a start toward building these, we asked psychologists to provide us with an adult IQ test able to measure "as closely as possible" the same kind of capabilities that the Children's Terman Merrill Test was measuring at age three and one-half. They decided that a particular subset of the Wechsler-Bellevue Test for adults would be appropriate.<sup>12/</sup>

Groups of thirty-one employed construction workers and sixty unemployed workers were given the Wechsler-Bellevue Test, on the premise that construction work and temporary unemployment might well be representative future occupations for lower class Chilean children--even those not severely handicapped by infant malnutrition.<sup>13/</sup> Table 3 summarizes the information we obtained for the two groups. It can be seen that there are some differences between them; however, as far as we could tell members of both groups grew up in similar environments. Parents' years of schooling are almost the same for the two groups, as are rough indices of income of their childhood families (age at which they began working, number of siblings).

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<sup>12/</sup> The subtests used were general comprehension, similarities, picture completion, picture arrangement, object assembly and block design.

<sup>13/</sup> We wish to thank Mrs. Marilu Figueroa and Mrs. M. Eugenia Pulido for their assistance in obtaining and processing the sample data.

The data summarized in Table 3 would permit us to estimate equations (13) and (14) if we knew the covariances of the relevant variables with some measure of the workers' childhood ability. Furthermore, we could use the regression results to infer future intelligence levels of the malnourished children, if we felt that the workers in some sense represent the probable future of the children.

In an illustrative way, we will make this inference in the next section, since we lack any other means of forecasting the children's future development. But to do so, we have to "estimate" (13) and (14) on the basis of covariance information not contained in the workers' sample. Fortunately, the problem of relating youthful and adult IQ scores has long concerned psychologists, who have obtained fairly consistent results from a variety of samples. (See again Bloom /3/.) An important example is the Berkeley growth study, which analyzed intelligence test performance of sixty-one children from high income homes from birth to eighteen years /1/. For these children, intelligence measured at age two had a correlation of 0.41 with intelligence measured at age seventeen. By age four, the correlation with the measurement at age seventeen increased to 0.71, and by age eleven, to 0.92.

In the spirit of sensitivity analysis, let us assume that the correlation between the workers' adult and juvenile IQ (at

Table 3  
Means and Standard Deviations (in parentheses) of Workers Data

	<u>construction workers (n=31)</u>	<u>unemployed workers (n=60)</u>
I (1) age	31.9(2.6)	28.2(5.4)
(2) years of schooling	4.6(2.4)	5.2(1.0)
(3) mother's years of schooling	2.8(2.6)	3.0(2.2)
(4) father's years of schooling (n=20)	3.7	(n=40) 3.8
(5) no. siblings	5.4	5.1
(6) fraction of those who spend their childhood in the rural sector	.52	.57
(7) age they began earning any income	13.7(2.7)	13.6(2.4)
(8) months of unemployment be- tween jobs	1.1(1.0)	2.3(2.1)
(9) monthly earnings last job (Chilean Escudos of 1970)	1320(440)	819(378)
(10) Standardized IQ test	87.3(14.9)	77.6(17.8)

about age four) was either 0.75 (close to Bayley's estimate) or 0.5. We also assume that the youthful distribution had the same mean and variance as the adult distribution. For schooling, we note that the simple correlation  $r_{S',A_0}$  between years completed and early ability will be given by

$$r_{S,A_0} = \beta_{S,A_t} r_{A_t,A_0} + \text{other terms}$$

where  $\beta_{S,A_t}$  is the standardized regression coefficient of schooling on adult IQ. In the univariate case,  $\beta_{S,A_t}$  will just equal  $r_{S,A_t}$ , so we can approximate  $r_{S,A_0}$  by the product  $(r_{S,A_t})(r_{A_t,A_0})$ .

Together with the means, variances and covariances of schooling and IQ in the workers' sample, this gives us enough information to "estimate" (13) and (14). The results appear in Table 4. Although it is impossible to attach statistical significance to the regression coefficients, they do indicate that a ten-point increase in the workers' early IQ might have led to later-life IQ increments ranging between five and seven points and schooling increments of a month or two.

These figures, of course, refer to the hypothetical childhoods of the workers. But we are going to use them to infer something about the hypothetical adult earning potential of the malnourished children, had they not been so malnourished. Before conjuring this next castle into the air, it is perhaps worthwhile to note what Chilean psychologists thought about the future development of the thirty-three malnourished children. According to them, the absolute level of retardation of many of the

**Table 4**  
**Regressions for Adult Ability and Schooling of the**  
**Ninety-one Chilean Workers (t-ratios in parentheses)**

Dpt. Variable	Coefficient w.r.t.		Inter- cept	R <sup>2</sup>
	Schooling (S)	Early ability (A <sub>0</sub> )		
$r_{A_t, A_0} = .75$				
A <sub>t</sub>	0.6256(0.94)	0.7419(10.45)	17.823	0.5660
S		0.0196(1.78)	3.434	0.0126
$r_{A_t, A_0} = 0.50$				
A <sub>t</sub>	1.0632(1.23)	0.4915(5.34)	35.969	0.2627
S		0.0080(0.73)	4.372	0.0056

Total Effects of a Ten-point Increase of A<sub>0</sub> on

	S	A <sub>t</sub>
$r_{A_t, A_0} = 0.75$	0.196	7.54
$r_{A_t, A_0} = 0.50$	0.080	5.00

children requires only one remedy--special schooling. In ordinary schools, their condition would only deteriorate further. Hence raising the mean IQ of the group from around seventy to over eighty (the mean IQ of the workers) would enable the more severely handicapped children to acquire some schooling and enter the labor force, even if half their incremental IQ was lost by adulthood (as the more pessimistic hypothesis above would indicate). This is a benefit we do not consider in the following analysis of the effects of IQ on earnings.

C. Determinants of Earnings in the Sample of Workers

Recall from footnote 2 that most empirical results (for the U.S. at least) show that schooling (S) is more important than ability ( $A_t$ ) in determining earnings (Y) in a relationship like (15)--in the sense of adding to  $R^2$  or even in size of standardized coefficients. Moreover, in studies of Chile where ability was not used as an explanatory variable, additional schooling has been shown to raise earnings substantially /14/.

In light of this evidence, it is surprising that Table 3 shows that the construction workers had both higher earnings and a higher mean IQ than the unemployed workers, without much difference in schooling. One is tempted to attribute the earnings difference to IQ.<sup>14/</sup> To check out this possibility, we

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<sup>14/</sup> The construction workers had higher scores on all subtests of the Wechsler-Bellevue, not just the aggregate IQ measure. We also used subtest scores as explanatory variables in the regression equations of Table 5, with similar results. See /15/.



Table 5  
 Regressions from Workers Data  
 dependent variable = log earnings

reg. no.	indep. variable	construction workers	unemployed workers	pool
1	intercept	4.12(4.82)	3.08(3.55)	2.65(3.86)
	log age	0.87(3.52)	1.06(4.06)	1.23(6.03)
		$R^2 = 0.30$	$R^2 = 0.22$	$R^2 = 0.29$
2	intercept	3.23(2.28)	2.82(2.78)	1.92(2.16)
	log IQ	0.87(2.75)	0.87(3.74)	1.11(5.49)
		$R^2 = 0.21$	$R^2 = 0.19$	$R^2 = 0.25$
3	intercept	1.68(1.25)	1.36(1.26)	0.34(0.38)
	log age	0.74(3.08)	0.79(2.92)	0.92(4.48)
	log IQ	0.65(2.26)	0.60(2.52)	0.76(3.83)
		$R^2 = 0.41$	$R^2 = 0.30$	$R^2 = 0.39$

Note: Figures in parentheses show the t ratio of the coefficient.

ran several regressions (in logarithmic form) on the two samples, pooled and separated. Table 5 gives the most interesting results.

As can be seen, the estimated elasticities of earnings with respect to age and IQ are significant and stable, and the values of  $R^2$  are respectable for this kind of study. The results suggest that a ten percent change in IQ, as measured by our test, is associated with a six or seven percent increase in earnings. Parents' and workers' years of schooling were not significant in these regressions; this may be explained by both the low level and low variance in the workers' schooling variable.<sup>15/</sup>

#### 4--Benefits of Improving Infant Nutrition in Chile

The next task is to integrate the empirical results to say something about the effects of early malnutrition on future earnings. In principle, improving early nutrition can increase adult earnings in several ways. To trace these we begin by noting that equation (12) suggests that improved nutrition increases early ability,

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<sup>15/</sup> We note in passing that someone in the U.S. with about five years of schooling (the mean for the workers) is considered a functional illiterate. Perhaps this judgment would be unduly harsh for Chile, but there is still reason to expect that at very low levels of formal schooling, "native intelligence" (in the sense of, for example, being able to learn to read fairly well on one's own) might be a more important determinant of earnings than in highly educated rich countries.

$$dA_0 = (\partial A_0 / \partial n) dn,$$

which has impacts both on schooling (equation (14)),

$$dS = (\partial S / \partial A_0) dA_0$$

and directly and indirectly on later ability (equation (13)),

$$dA_t = (\partial A_t / \partial A_0) dA_0 + (\partial A_t / \partial S) dS.$$

Hence the total effect of early nutrition on earnings is given by

$$dY = \left\{ \frac{\partial Y}{\partial A_t} \left[ \frac{\partial A_t}{\partial A_0} + \frac{\partial A_t}{\partial S} \frac{\partial S}{\partial A_0} \right] + \frac{\partial Y}{\partial S} \frac{\partial S}{\partial A_0} \right\} \frac{\partial A_0}{\partial n} dn,$$

using (15). In our data, all these effects except the nutrition-early ability-adult ability-earnings linkage were small, so we ignore them. In other studies, however, they could prove to be important.

To evaluate this ability-mediated linkage, we begin by recalling that the mean IQ of the malnourished children would probably deteriorate without special schooling (which they are not likely to receive). Hence, we are being conservative in taking their current mean IQ as a base figure, and analyzing "what would have happened" if they had received adequate nourishment. The regression results of Table 2 indicate that if their initial weight deficit of 25 to 35 percent had not occurred, their early IQ would have been higher by about 0.6 times the deficit, with a mean somewhere between 90 and 95 instead of 72.8. Notice that this figure is still lower than the mean of 97.1 of the control children.

However, the results of the hypothetical regressions of Table 4 indicate that this higher IQ level could not be expected to persist, schooling and other environmental factors being similar to those which affected the construction workers. To account for this, we have assumed that the adult IQ of the children would not have been somewhat over 90, but instead the mean value for the employed construction workers, 87.3.

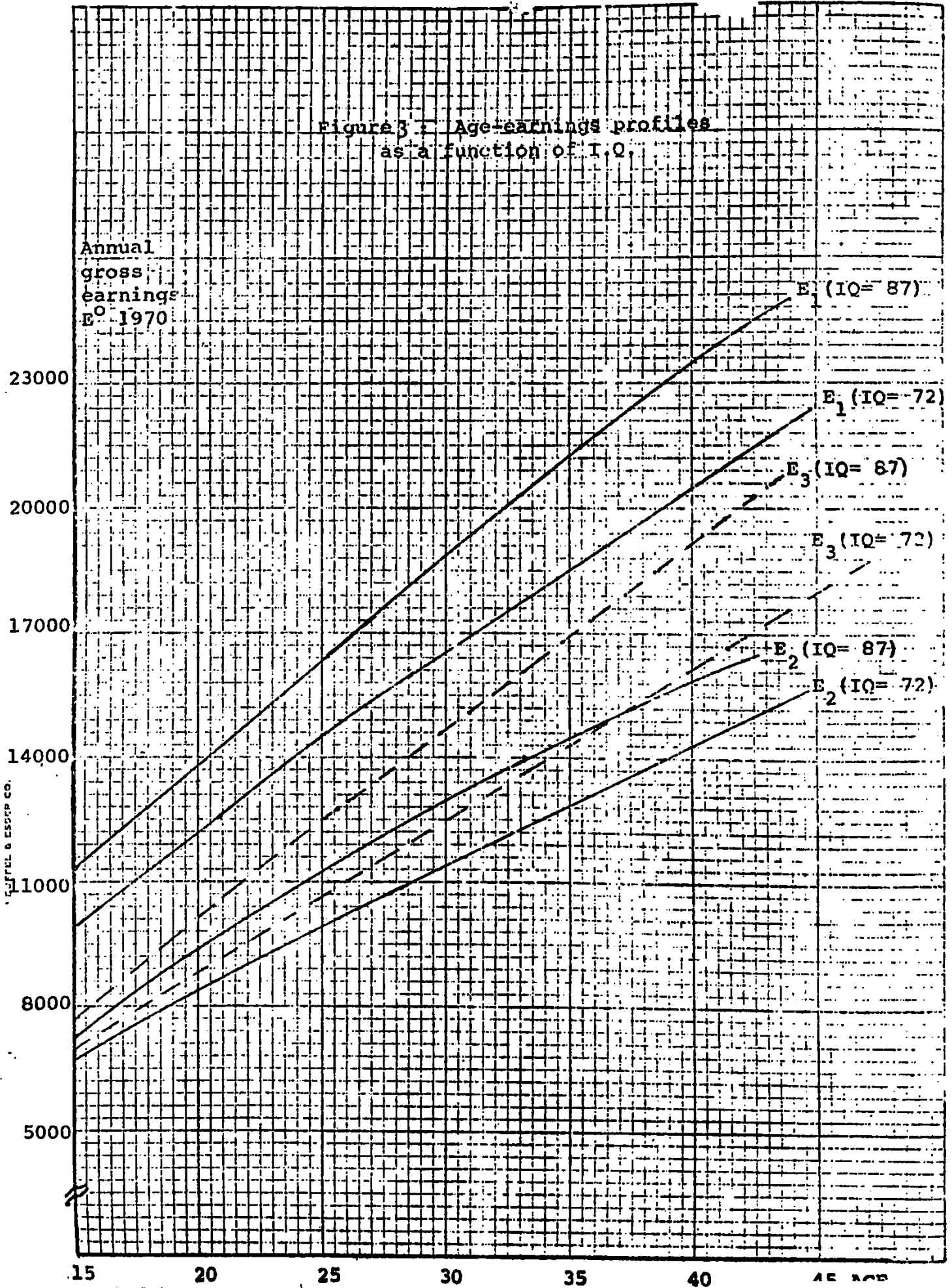
Figure 3 shows the annual earnings profile of individuals with IQs equal to 72 and 87 evaluated with the three earnings equations of Table 5, where  $E_1$ ,  $E_2$  and  $E_3$  are the earnings equations of the construction workers, unemployed workers and the pool of them, respectively. They include employer's contribution to the social security system, part of the marginal productivity of labor, which amounts to 30% of the net wage. If the children were to enter the labor force at age fifteen and the relevant discount rate is 10%, the present value of gains in gross earnings at age two would be <sup>16/17/</sup>

<u>Earnings equation</u>	<u>Chilean Escudos of 1970</u>	<u>U.S. Dollars</u>
$E_1$	6080	405
$E_2$	3842	256
$E_3$	5396	360.

<sup>16/</sup> We have used an exchange rate of E<sup>0</sup>15 per dollar for 1970. See Taylor and Bacha /17/.

<sup>17/</sup> By not adjusting the earnings profiles by the differential probability of being unemployed through time we are understating the benefits of a higher IQ.

Figure 3: Age-earnings profiles  
as a function of I.Q.



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If we think that these gains in earnings could be generated by a supplementary nutrition program during the first two years of life, the above figures would be estimates of the program's shadow price. Even highly discounted, the gains are about one-half of a worker's income (compare Table 3). Moreover, if 25,000 children are malnourished each year in Chile (a not improbable figure) and each one were to gain 4000 Escudos in discounted earnings, the total yearly return would be 100 million Escudos. If this stream of benefits is treated as an annuity, its present value is one billion Escudos, or more than one percent of GDP. Even if our estimates are off by a factor of two or more, this is a very large absolute return to a single program.

#### 5--Additional Benefits and an Estimate of Costs

We note that we are underestimating benefits of alleviating infant malnutrition because

(i) We omit the increase of schooling which would result from higher initial ability, and the effect of schooling on earnings. These effects were not important in our particular sample of construction workers, but other evidence indicates that they would be elsewhere.

(ii) There is evidence indicating that infectious disease is less severe and less frequent in well-nourished individuals /12/.

Malnutrition both adversely affects the defense mechanisms of the individual (leading to higher incidence of disease) and favors secondary infections (lengthening the convalescence period). To the extent that medical resources are used to combat disease induced by malnutrition, savings in these resources should be attributed to nutrition programs. A fortiori, the same is true with respect to resources lost through premature death.

(iii) Since programs to aid the malnourished, particularly infants, involve an equalization of the income distribution as well as productivity increases, there is implicit an equity improvement which we do not consider here. Depending on one's tolerance for extreme poverty, this benefit may be substantial.

On the cost side, we note that in calculations reported elsewhere /15/, we found that giving enough milk to an infant during his first two years to avoid severe malnutrition would yield a rate of return of twenty percent or more, just counting the benefits calculated above. Direct milk costs are not all that one must expend in a nutrition program (although we did probably overestimate their amount) but they are a major component. And twenty percent is a handsome rate of return for a program whose first benefits are perceived 15 years after the initial investment.

#### 6--Final Comments

If infant nutrition has an effect on the individual's fu-

ture economic productivity, it represents one of the ways in which human capital formation affects the income distribution-- at least within limits imposed by race, class and other strictures. However, infant nutrition has characteristics which sharply differentiate it from other types of investment in human capital, i.e. formal schooling, on the job training, etc.

First, infant malnutrition can hardly be compensated by later investment in human capital. On the job training is a much better substitute for a deficit in years of schooling than a deficit in preschool IQ.

Second, investments in human capital made later in life can, as a policy matter, be encouraged by improvements in capital markets (e.g. loans for high school or college education). This is not true for earlier investments in human capital, which are mainly determined by the family's income level. The most practical remedy for infant malnutrition is a redistribution of income toward the infant and his family; the cost of not undertaking this redistribution now is massive disinvestment in early human capital formation, and perhaps greatly increased distributional problems with a low income, low productivity segment of the population in the future.



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