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EDUCATIONAL CAPITAL IN A MODEL OF GROWTH AND DISTRIBUTION

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I. The "Residual" and the Technical Change Hypothesis

In the last ten years a substantial effort has been devoted to the analysis of the sources of economic growth. A frequent approach to this problem has entailed the use of an aggregate production function; the typical result has been that the traditional factors -- labor and capital -- can explain only a fraction of the observed changes in output. The major emphasis of more recent investigations has been on the nature and extent of the unexplained or "residual" growth.

Side by side, the pure theory of growth has undergone major development particularly with respect to the importance of the different assumptions about the elasticity of substitution in production and the way technical change comes into the productive process. Both elements are crucial to understand the process of economic growth and the nature of steady state equilibrium.

One approach to the problem posed by the residual is to attribute the latter to exogenous technical progress that is a function of time alone. In this case the real problem is to find the kind of technical progress that is most consistent with the behavior of the unexplained residual.

Under the assumption that technical change comes exogenously given as a function of time we can write the production function as:

(1) $$Y(t) = F[K(t), L(t), t].$$

We assume a one-sector model producing only one good -- national product. Because of that the price of output and of capital are one and the same. This permits us, in later manipulations, to represent capital in value units rather than physical units. L(t) are man-hours per year or the amount of hours in which the stock of labor is applied to the productive process in one year.

We can distinguish three cases of technical change, all of which are special cases of equation (1).

a) Hicks-neutral technical change:

(2) $$Y(t) = B(t)\ F[K(t),\ L(t)].$$

In this case B(t) is a shifting index of the production function and has the characteristic that leaves the ratio of marginal productivities constant at constant factor ratios.

b) Harrod-neutral technical change

This is defined as a shift in the production function in such a way that the marginal productivity of capital remains invariant at the same capital-output ratio.

It has been demonstrated by Uzawa[1/] that a sufficient condition to get a production function under those constraints is if technical change appears as an index correcting the labor input. In other words technical change appears as labor augmenting:

(3) $$Y(t) = F[K(t),\ A(t)\ L(t)].$$

1/ Hirofumi Uzawa, "Neutral Inventions and the Stability of Growth Equilibrium," Review of Economic Studies (February 1961).

c) Solow's embodiment equation:

(4) $$Y(t) = F[D(t), K(t), L(t)].$$

In this case technical change appears as capital augmenting and comes into the productive process embodied in gross investment.

II. The Introduction of Educational Capital

Any careful reader would agree that before attaching the residual to a particular sort of technical change (or to the one that explains best the data) one has to ascertain that all of the productive factors have been taken into account. Indeed, the central proposition of the human capital hypothesis is that improvement in the quality of the labor input represents an important source of economic growth; these improvements in quality take a variety of forms. In this paper we will concentrate upon education as one means of improving the labor input; more specifically, we will try to extend as precisely as possible this aspect of the human capital hypothesis within the aggregate production function approach to growth, and examine its relationship to the residual and to the technical change hypothesis.

The basis of our educational capital hypothesis is an empirical one arising from two observations: (a) there is a positive relation between the productivity of labor and the amount of education embodied in it, and (b) countries spend a big part of their resources (relatively to physical investment) on education.

TABLE 1

PUBLIC EXPENDITURE ON EDUCATION AS A PERCENTAGE OF NATIONAL INCOME[2/]

	1938	1950	1951	1952	1953	1954	1955	1956
Japan	2.9	4.8	4.8	5.3	5.7	6.1	---	---
Canada	3.6	3.0	2.9	3.0	3.2	3.5	---	---
Sweden	2.7	3.3	3.1	3.3	---	3.6	4.3	---
England	2.7	3.7	3.8	3.9	3.8	3.9	4.0	4.2
Netherlands	3.9	3.2	3.2	3.4	3.6	4.2	4.5	---
Germany	2.8	3.0	3.1	3.3	3.5	3.6	3.5	---
Denmark	2.8	2.9	2.9	3.2	3.4	3.6	3.9	---
United States	4.5	4.1	---	4.0	---	4.6	---	5.4

Table 1 shows the percentage that public expenditure on education represents on national income. In most of the European countries it is over 3 per cent and to get the total (economic) investment we have to add private expenditure and foregone income. Schultz's study for the U.S.[3/] shows that for 1940-1956 approximately 40 per cent of the total investment in education is foregone income. If we apply those figures for Western Europe it means that those countries have spent in the last 20 years at least 5 per cent of their national income on education. Japan's figure has doubled in 16 years and the data would suggest that Japan has invested in education in the last 10 years about 10 per cent of its national income.

[2/] Friederich Edding, "International Tendenzen in die Entwicklung der Ausgaben fur Schulen und Hochschulen," Kieler Studien, Kiel, 1958.

[3/] T. W. Schultz, "Capital Formation by Education," Journal of Political Economy (December, 1960).

For the U.S. we have the following figures of the total investment in education as a percentage of GNP:[4/]

1900:	2.14	1956:	6.84
1910:	2.29	1958:	8.02
1920:	2.74	1960:	8.35
1930:	5.50	1962:	8.91
1940:	6.35	1964:	9.65
1950:	5.96	1965:	9.72

On the other hand, also according to Schultz,[5/] the stock of educational capital rose by 200 per cent between 1930 and 1957 and in 1957 represented 1.2 times the GNP of this year.

After looking at these data we have to accept that any production function that does not take into account in some way the effect of the accumulation of educational capital on the efficiency of labor is not a complete specified model and would tend to cause the contribution of increased education to appear in the residual.

One way of including the effect of education on the productivity of the labor input is to adjust the conventionally measured figures of labor by a quality index.[6/] The possibility we explore here is to treat educational capital

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4/ From 1900 to 1956 we divide Schultz's estimates of investment by the GNP given by OBE. From 1958 on we use data from the office of Education (Long Term Economic Growth: U.S. Department of Commerce) and we apply the same ratio that direct expenditure to foregone income had in 1956.

5/ T. W. Schultz, "Reflections on Investment in Man," Journal of Political Economy (October, 1962), Supplement.

6/ The index usually used is an index of average years of schooling using as weights earnings by level of schooling. See Z. Griliches and D. Jorgenson, "The Explanation of Productivity Changes," Report 6715, Center for Mathematical Studies in Business and Economics, University of Chicago.

as an explicit input: the reason is twofold. First, we put education in a capital accumulation context emphasizing, therefore, that an increase in education does not come free but involves the use of real resources and, second, we can derive some propositions on the determinants of the productivity of those resources or the rate of return to education.

III. The Model

We think that adequately explaining past growth consists of explaining the residual on one hand, and explaining the behavior of relative returns to factors on the other. It seems that the human capital hypothesis, as we all know it, has been addressed to the first problem. The formal models of economic growth have been addressed to the second problem.

The model that is presented below attempts to incorporate the human capital hypothesis in such a way that not only the residual is explained but also the long-run behavior of distributive shares.

As it was implied earlier, the Harrod-neutral technical change models have the property that the rate of return to capital can remain roughly constant in the face of dramatic rises in the (physical) capital-labor ratio. This is true precisely because Harrod-neutral technical change is labor-augmenting, i.e., the force of the technical change is to cause the labor input to appear to grow more rapidly than do physical units (man-hours). I take it as evident that this is the thrust of the human capital hypothesis. On the other hand, it can be shown that Harrod's neutral technical progress (or labor-augmenting technical progress) is the only one consistent with equilibrium growth under any (constant) value

of the elasticity of substitution in production.[7/]

It can be shown that a model involving educational capital also has a labor-augmenting effect and, therefore, has the same properties as a model with Harrod's neutral technical change; furthermore, one cannot tell on a priori grounds if the correction factor A(t) of equation (3) is the result of technical change or the accumulation of educational capital embodied in the labor force.

There is some evidence that the U.S. data has been behaving according to the labor-augmenting model (3); the (physical) capital-output ratio and the rate of return to physical capital have remained (roughly) constant through time. Therefore, the residual -- that should appear as a labor-augmenting factor given the behavior of those variables -- could be explained as well by investment in education or by one exogenously given technical change of the Harrod type.

Because human capital is necessarily embodied in the labor input it seems obvious to treat that labor input as a composite input, one element of which is what might be referred to as "brute force" or "the original properties of labor," the other element of which consists of improvement in the human agent.

The best way to describe this composite is by an analogy to land. Ricardo and Malthus foresaw secular increases in the price of land because, in part, they failed to distinguish between the original properties of the soil and man-made improvements or substitutes for the soil. In the same way a

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7/ For a clear treatment of this point see Hahn and Matthews: "The Theory of Economic Growth: A Survey," in Surveys of Economic Theory (vol. II, pp. 47-54).

monolithic conception of the labor input has masked the contribution to output of improvements in the human agent and hidden a more or less simple explanation for a rough constancy of factors shares in the face of dramatic changes in "input" ratios.

This rough constancy is sometimes taken as evidence for Cobb-Douglas production functions. An alternative explanation <u>not requiring an elasticity of substitution in production equal to one</u> is simply that the ratio of capital to the composite labor input (L^*) has not changed dramatically over time. One might, therefore, specify the composite labor input in a general way as:

$$L^* = G[L,E] \tag{5}$$

where L is a measure of "brute force" and E for simplicity, will be restricted to educational capital.

The aggregate production function will be specified as:

$$Y(t) = F[K(t),L^*(t)]. \tag{6}$$

Taking F and G as homogeneous of first degree, equation (6) can be written:

$$Y(t) = F[K(t),\ L(t)\ \varphi[e(t)]] \tag{7}$$

where

$$\varphi[e(t)] = G[1,e(t)]$$

and

$$e(t) = E(t)/L(t).$$

e(t) is a measure of educational capital per member of the labor force. It is clear from equation (7) that the accumulation of educational capital per head is equivalent to labor-

augmenting technical change and hence the desirable steady-state characteristics of Harrod neutrality hold also for the educational capital hypothesis.

In other words, we cannot distinguish on a priori grounds between equation (7) and equation (3) because both are labor augmenting. The interesting point is that in (3) the factor A(t) is exogenously given and in (7) the factor of $\varphi[e(t)]$ is a function of a variable which can be affected by policy.

It is known that stability of Harrod-neutral steady state depends on constancy of the elasticity of substitution but not upon it being greater or less than unity. Therefore, the only restriction in the subsequent analysis will be the assumption of constant elasticities of substitution in production. In addition, we are going to treat L* as being "produced" by L and E subject also to a constant elasticity of substitution.

Therefore we will define the following model:[8/]

8/ With this presentation the analogy with Harrod-technical change can be demonstrated in the following way:

$$L^* = [(1-b)L^\rho + bE^\rho]^{1/\rho}$$

where e = E/L therefore:

$$L^* = [(1-b)L^\rho + be^\rho L^\rho]^{1/\rho}$$
$$L^* = [L^\rho[(1-b) + be^\rho]]^{1/\rho}$$
$$L^* = L[(1-b) + be^\rho]^{1/\rho}.$$

Calling $[(1-b) + be^\rho]^{1/\rho} = \varphi(e)$ and substituting in (6) we get $Y = F[K, L\varphi(e)]$ which has the same labor-augmenting properties as Harrod's technical change; in this explicit case the correction factor is a function of the distributive parameter b (which is an index of the intensity of E in producing L*) and of the elasticity of substitution between E and L.

(8) $$Y = [(1-a)k^{\eta} + aL^{*\eta}]^{\frac{1}{\eta}}$$

(9) $$L^* = [(1-b)L^{\rho} + bE^{\rho}]^{\frac{1}{\rho}}$$

where

$$\eta = \frac{\sigma_{KL^*}-1}{\sigma_{KL^*}} \quad \text{and} \quad \rho = \frac{\sigma_{EL}-1}{\sigma_{EL}}$$

where σ_{KL^*} is the elasticity of substitution between K and L* and σ_{EL} is the elasticity of substitution between E and L.

We know $\sigma_{KL^*} > 0$ and $\sigma_{EL} > 0$

therefore $\eta < 1$ $\rho < 1$.

From equations (8) and (9) we get the following derivatives:[9/]

(10) $$f_K = (1-a)[(1-a) + a(L^*/K)^{\eta}]^{1-\eta/\eta}$$

(11) $$f_{L^*} = a[(1-a)(K/L^*)^{\eta} + a]^{1-\eta/\eta}$$

(12) $$g_E = b[(1-b)(L/E)^{\rho} + b]^{1-\rho/\rho}$$

(13) $$g_L = (1-b)[(1-b) + b(E/L)^{\rho}]^{1-\rho/\rho}.$$

9/ Redefining the input units in order to eliminate one of the parameters of distribution we get:

(10') $$f_K = [1 + \alpha(L^*/K)^{\eta}]^{1-\eta/\eta}$$

(11') $$f_{L^*} = \alpha[K/L^*)^{\eta} + \alpha]^{1-\eta/\eta}$$

(12') $$g_E = \beta[(L/E)^{\rho} + \beta]^{1-\rho/\rho}$$

(13') $$g_L = [1 + \beta(E/L)^{\rho}]^{1-\rho/\rho}$$

where $\alpha = \frac{a}{1-a}$ and $\beta = \frac{b}{1-b}$.

Differentiating the general equation (6) with respect to time we get:

(14) $$\dot{Y} = f_K \dot{K} + f_{L*} \dot{L}*$$

(15) $$\dot{Y} = f_K \dot{K} + f_{L*} [g_L \dot{L} + g_E \dot{E}]$$

where f_K is the rate of return to physical capital, $f_{L*} g_L$ the "brute force" wage rate and $f_{L*} g_E$ the rate of return to educational capital.

Dividing by Y and multiplying by $\frac{K}{K}$, $\frac{L}{L}$ and $\frac{E}{E}$ the first, second and third term we get (assuming competition) an expression of the growth rate in terms of factor shares:

(16) $$\frac{\dot{Y}}{Y} = f_K \frac{K}{Y} \frac{\dot{K}}{K} + f_{L*} [g_L \frac{L}{Y} \frac{\dot{L}}{L} + g_E \frac{E}{Y} \frac{\dot{E}}{E}]$$

(17) $$\frac{\dot{Y}}{Y} = \alpha_K \frac{\dot{K}}{K} + \alpha_L \frac{\dot{L}}{L} + \alpha_E \frac{\dot{E}}{E}$$

where α_K, α_L, and α_E are the shares of physical capital, brute force and educational capital respectively.

A more interesting presentation from the theoretical and empirical point of view is to work with labor with constant education per head and therefore to separate the contribution of the net investment in education, net in the sense that allows an increase in the average educational capital per labor input.

We know $\frac{\dot{E}}{E} = \frac{\dot{e}}{e} + \frac{\dot{L}}{L}$; substituting in (16) we get:

(18) $$\frac{\dot{Y}}{Y} = f_K \frac{K}{Y} \frac{\dot{K}}{K} + f_{L*} \left\{ [g_L \frac{L}{Y} + g_E \frac{E}{Y}] \frac{\dot{L}}{L} + g_E \frac{[\dot{E} - E/L \, \dot{L}]}{Y} \right\}$$

where:

(a) $f_K \frac{K}{Y}$ = share of physical capital,

(b) $f_{L*}[g_L \cdot \frac{L}{Y} + g_E \frac{E}{Y}] = (f_{L*}g_L)\frac{L}{Y} + (f_{L*}g_E)\frac{E}{Y} =$

share of labor or the payments to L* in terms of L and E. In other words, (b) is equal to the payments to brute force plus the payments to the educational capital embodied in L. Therefore, it shows the contribution to output of labor of a given educational capital per head.

(c) $(f_{L*}g_E)\frac{(\dot{E}-E/L\,\dot{L})}{Y}$ = contribution to the growth rate of the per head accumulation of educational capital.

Substituting the simplified equations (10') to (13') into equation (18) we get our explicit model for the growth rate of output:

$$(19)\ \frac{\dot{Y}}{Y} = \left[1+\alpha\left[\left(\frac{L}{K}\right)^{\rho}+\beta\left(\frac{E}{K}\right)^{\rho}\right]^{\eta/\rho}\right]^{\frac{1-\eta}{\eta}}\frac{K}{Y}\frac{\dot{K}}{K} + a\left[\left[\left(\frac{L}{K}\right)^{\rho}+\beta\left(\frac{E}{K}\right)^{\rho}\right]^{-\frac{\eta}{\rho}}+a\right]^{\frac{1-\eta}{\eta}}\left\{\left[\left[1+\beta\left(\frac{E}{L}\right)^{\rho}\right]^{\frac{1-\rho}{\rho}}\frac{L}{Y}+\beta\left[\left(\frac{L}{E}\right)^{\rho}+\beta\right]^{\frac{1-\rho}{\rho}}\frac{E}{Y}\right]\frac{\dot{L}}{L}+\beta\left[\left(\frac{L}{E}\right)^{\rho}+\beta\right]^{\frac{1-\rho}{\rho}}\left(\frac{\dot{E}-\frac{E}{L}\dot{L}}{Y}\right)\right\}$$

Some Comments on the Elasticities of Substitution

The model developed earlier is the most general one that can be developed in an explicit form for the three-factor case; the only restrictions we have imposed are the constancy of σ_{L*K} and σ_{LE}. What kind of constraints are we implicitly imposing on the partial elasticities of substitution, σ_{LK} and σ_{EK}? Before answering this question we have to realize that under the three-factor case we do not have a unique definition of the elasticity of substitution between any two pairs of inputs; the definition depends on what we assumed constant about the third factor. If we hold his price constant we get Allen's definition; if we hold the quantity constant we get what MacFadden has called "the direct" elasticity of

substitution.[10/]

We think that for macroeconomic purposes -- we are interested in the behavior of relative shares -- this last definition is more relevant. The interesting point is that this model does not impose any restrictions on the "direct" partial elasticities, σ_{LK} and σ_{EK}, except to be functions of σ_{LE} and σ_{L*K}. It has been demonstrated by K. Sato[11/] that any production function which is a C.E.S. function of a subset of factors and in which any subset is itself a C.E.S. function of the factors in it has the property that the elasticities of substitution of any pair of factors in different subsets -- in this case σ_{LK} and σ_{EK} -- is a weighted harmonic mean of the within group (σ_{LE}) and between group (σ_{L*K}) elasticities. In the expression of the harmonic mean the relative expenditure shares appear and therefore those partial elasticities are not necessarily equal nor constant.[12/]

10/ D. McFadden, "Constant Elasticity of Substitution Production Functions," Review of Economic Studies, June 1963.

11/ K. Sato, "A Two Level Constant Elasticity of Substitution Production Function," Review of Economic Studies, April 1967.

12/ Let us define S_{L*} and S_K as the shares of L* and K in total output; also let us define s_L and s_E as the shares of L and E in the product. We can write the expressions for the partial elasticities as:

$$\sigma_{LK} = \frac{s_L + 1}{\frac{1}{\sigma_{LE}}\left(1 - \frac{s_L}{S_{L*}}\right) + \frac{s_L}{\sigma_{L*K}}\left(\frac{1}{S_K} + \frac{1}{S_{L*}}\right)}$$

$$\sigma_{EK} = \frac{s_E + 1}{\frac{1}{\sigma_{LE}}\left(1 - \frac{s_E}{S_{L*}}\right) + \frac{s_E}{\sigma_{L*K}}\left(\frac{1}{S_K} + \frac{1}{S_{L*}}\right)}$$

A desirable alternative is a function with no grouping of factors (of type $Y = F[K,L,E]$) and with constant but different partial elasticities of substitution; in other words, a C.E.S. for three factors but with different partial elasticities. Unfortunately, such a function is impossible to generate explicitly and therefore in choosing one grouping we thought the most convincing one -- from the theoretical and empirical point of view -- was L and E generating therefore L*. At the same time, as we saw earlier, this grouping is consistent with long-run equilibrium growth because the production function generated behaves equal to a one with Harrod-neutral technical progress.

Implications

1. Constancy of factor shares and changing input ratios are consistent with technical change in the context of Cobb-Douglas production functions. In the context of constant elasticity of substitution production functions it is consistent with Harrod-neutral technical change.

Our model implies that the behavior of those variables, which has been the long-run characteristics of the U.S. economy, can be consistent without restricting the production function to a Cobb-Douglas case or to a one implying Harrod-neutral technical change. The only element we need is an appropriate increase in our third factor: educational capital.

This formulation allows constancy of shares because it permits, through the accumulation of educational capital, constancy of L^*/K in spite of a strong trend in the K/L ratio. It also allows the shares to be constant independently of the movements in the ratio E/L; this ratio would, under those

circumstances, only affect the distribution of the share of labor between "brute force" and the payments to the educational capital embodied in the labor force.

Another way of looking at the effect of E is to realize that f_K, the rate of return to physical capital, is a positive function of the ratios L/K and E/K. The long-run constancy of the rate of return to physical capital in the U.S. could therefore be explained by the opposite movements that those ratios have experienced in the long run. Table 2, columns (1) and (9), shows the behavior of E/K and K/L for the period 1900-1957.

2. From equation (15) we know that the rate of return to educational capital is equal to $f_{L*}g_E$. Looking at equation (19) we can realize that the variables that enter into f_{L*} are the same ones that enter into f_K so we could write the rate of return to education as:

$$f_{L*}g_E = \Psi(f_K)\beta[(L/E)^{\rho} + \beta]^{1-\rho/\rho}$$

where f_{L*} is a function ψ of the rate of return to physical capital. In other words, we can write the rate of return to educational capital as a function of the rate of return to physical capital, the amount of educational capital per head and the elasticity of substitution between brute force and educational capital.

Given that for the U.S. f_K has remained roughly constant, the movement of the rate of return to education could be explained by the movement of the ratio $\frac{L}{E}$ only.

This ratio as we can see in Table 2, fell in 1957 to less than one third of the 1900 value. On the other hand, according

TABLE 2

INTERNATIONAL COMPARISONS OF FACTOR ENDOWMENT

	Educational Capital Per Worker (dollars of 1956)				Ratio of Educational Capital (in the labor force) to Reproducible Physical capital				Reproducible Physical Capital Per Worker (dollars of 1956)			
	U.S.A. (1)	Chile (2)	Mexico (3)	India (4)	U.S.A. (5)	Chile (6)	Mexico (7)	India (8)	U.S.A. (9)	Chile (10)	Mexico (11)	India (12)
1900	2,246				.22				10,190			
1910	2,626				.23				11,415			
1920	3,068				.24				12,781			
1930	3,696				.24				15,397			
1940	4,697	581	378		.33	.13	.12		14,091	4,467	3,149	
1945		572	353			.13	.12			4,399	2,940	
1950	5,973	575	353	42	.37	.14	.11	.13(.08)	16,145	4,106	3,208	323 (525)
1955		604	374			.15	.11			4,022	3,400	
1957	7,556				.42				17,983			
1960		653	410	48		.17	.10	.13(.08)		3,840	4,100	369 (600)
1964		712	466			.18				3,952		

a) Columns (1) and (5): T. W. Schultz: "Education and Economic Growth" in Social Forces Influencing American Education, ed. N. Henry (Chicago, National Society for the Study of Education, 1961).

b) Rest of the figures: Marcelo Selowsky, "Education and Economic Growth," unpublished Ph.D. Dissertation, Department of Economics, University of Chicago, (Table 27).

c) Columns (8) and (12): Value in parenthesis is obtained when land is included in our concept of physical capital.

to Becker the rate of return to education[13/] has not experienced radical changes in the same period.[14/] This would imply that the elasticity of substitution between "brute force" and educational capital is relatively very high.

3. As we saw earlier, the rate of return to physical capital, f_k, is a positive function of both ratios, L/K and E/K. This is consistent with the following observations:

a) In many underdeveloped countries the marginal productivity of physical capital is low in relation to more advanced countries even though one would expect the contrary, given the sharp differences in the ratio of physical capital to labor (K/L).

This phenomenon is rationalized by introducing the ratio E/K; one could justify relatively low rates of return on physical capital for countries of large endowment of labor to physical capital if they have a relatively small endowment of educational capital to physical capital.

Table 2 shows international differences in those ratios for the U.S., Chile, Mexico and India. We can see that the differences in the K/L ratio (columns 9 to 12) are also accompanied by quite substantial differences in the E/K ratio and for some cases those differences are roughly similar.

b) The capacity of absorbing additional physical capital in some underdeveloped countries has been relatively low (an

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13/ We refer to high school and college education.

14/ G. Becker, Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education, 1964 (pp. 131-135).

important part of the literature on foreign aid) in the sense that additional physical capital reduces sharply the rate of return on that capital.

One could expect that massive foreign aid to an underdeveloped country in the form of physical capital could reduce sharply f_K even though the K/L ratio approaches values no larger than in developed countries. The reason is the fall of the E/K ratio to values far smaller than those existing in the more developed countries.

With the same argument we could also rationalize why Western Europe could receive such a massive foreign aid after the war (Marshall Plan) without reducing substantially the rate of return to physical capital. The reason was the relatively high endowment of educational capital embodied in the labor force which avoided therefore a relatively big decline in the E/K ratio.[15/]

4. Intercountry comparisons of the rate of return to education and the amount of education per head suggest again a substantially high elasticity of substitution between brute force and educational capital.

Table 3 shows the internal rate of return to education for the four countries mentioned above. Table 2, columns (1) to (4), shows the amount of educational capital per head for each of those countries. We can appreciate that the variations in the rate of return are relatively much smaller than the variations in the amount of educational capital per head, suggesting therefore a substantially high elasticity of substitution between E and L.

15/ For a similar analysis see T. W. Shultz, "Reflection on Investment in Man," Journal of Political Economy, October 1962 (Supplement), specifically p. 3.

5. Table 2 shows that the biggest differences in factor endowments across countries is the amount of educational capital per worker, substantially bigger than the differences between physical capital per worker. This would suggest that the differential amount of educational capital per head between countries should be able to explain cross-country differences in per capita income and also the pattern of the world's international trade.

TABLE 2

TOTAL INTERNAL RATES OF RETURN TO EDUCATION[16/]

Years of Schooling	Mexico (1963)	Chile (1964)	India (1961)	U.S. (1959)
4	17.8	13.4		
5			21.2	
6	24.3	17.2		
8		16.0		12.0
10-11	22.5		18.9[a]	13.7[d]
12		15.2		13.6
15 or more	21.4		16.2[b]	12.1[e]
17			16.0[c]	

16/ By total internal rate of return we mean the return of achieving certain level of school from a position of no schooling.

a. corresponds to 11 years of schooling
b. corresponds to 15 years of schooling
c. corresponds to 17 years or more
d. Corresponds to 10 years of schooling
e. corresponds to 16 years of schooling

Sources: Mexico: Martin Carnoy "The Cost and Return to Schooling in Mexico" (unpublished Ph.D. Dissertation, University of Chicago, 1962).

Chile and India: Marcelo Selowsky, op. cit.

United States: Lee Hansen, "Total and Private Rates of Return to Investment in Schooling," Journal of Political Economy, April 1963.