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Investment Criteria and Financing Education for Economic Development

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ABSTRACT

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for Economic Development

There are economic criteria that are relevant to finding efficient and equitable human resource investment strategies, and to avoiding the perverse incentives that frequently generate major inefficiencies in education and wide variations in expenditure per pupil.

Sources of inefficiency and inequity include serious underinvestment in primary and secondary education many developing countries as reflected in high social rates of return relative to higher education and relative to physical capital. Inefficiencies in higher education include relatively high subsidies and prolonged degree programs, as well as high costs due to little use of RA's and TA's. Inequities include exclusion of children from poor families at all levels. Rates of return are presented based on micro economic data, and also on estimates from Cobb-Douglas and Nested CES production fractions.

It is concluded that improving the methods of financing could do a great deal to improve the incentives for efficiency, and to reduce inequity.

Investment Criteria and Financing Education for Economic Development

Walter W. McMahon

Both the level and the methods of financing human resource development are vital to economic development. It is important that the levels of financing be efficient--neither so high that diminishing returns set in, nor so low relative to other forms of investment or to consumption that development is retarded. But it is important also that the methods not contain perverse incentives so that efficiency within the schools and universities is low and funds are wasted. It is important also that the funds are not distributed so unequally among pupils that motivated and talented young people from poor families are denied access and denied reasonable equality of educational opportunity.

With so much at stake, it is unfortunate that the total resources that are available for economic development which are especially limited in the poor countries are used so inefficiently, and that the distribution of access to education is so unequal. The problems are particularly acute in Latin America, Africa, and South Asia where the needs are greatest in the sense that one of the best potentials for development there lies in their relatively large and seriously underdeveloped human resource base. Inequality in the income distribution there also tends to be greater. But inefficiency rooted largely in the levels and methods of financing education is not conducive to their rapid development, and the inequity in the financing mechanisms

perpetuates inequality in the distribution of income into future generations.

But there are problems in the U.S. as well, where there is concern about inefficiency in the secondary schools, slowing productivity growth, excessive variation in the expenditure per pupil depending on the wealth in each neighborhood, and about the loss of international competitiveness which depends on human capital intensive exports.

There are economic investment criteria which are useful for determining the inefficiency of the level and types of investment made, just as there are in the private sector, but they often are not applied. Furthermore, the methods of financing used often contain incentives that permit or encourage inefficiencies, some of which are beginning to be addressed by the World Bank, USAID, and some other donors. These include underinvestment in primary education, which is well-known to contribute dramatically to growth, relative to higher education which in many developing countries is inefficient and too costly. Other sources of inefficiency aggravated by the methods of financing include high drop-out rates in basic education, high repetition rates, low pupil achievement, and short time-on-task caused by short school days. In higher education in developing countries, inefficiencies include insufficient use of graduate students as teaching assistants and research assistants, which denies them the learning experience, makes higher education more costly, and limits the diffusion of the new technology to undergraduates and to outside employments, and 5, 6, or 7 years to finish 4 years degree programs.

The methods of financing are also perverse as they relate to equity. There are extremely wide variations in expenditure per pupil between urban and rural areas, and a noticeable lack of wealth neutrality as between pupils in high-income and low-income areas. This is particularly severe in Brazil, in many nations in Sub-Saharan Africa and in Pakistan and Nepal, for example. It is not conducive to economic development in the provinces and rural areas, and perpetuates inequality.

This paper will consider the level and the methods of financing human resource development in the developing countries with some comparisons to the United States and other industrial countries. It will draw for documentation on those aspects relating to finance in a series of recent background papers dealing with basic and higher education in Latin America (McMahon, 1989b), in the United States (McMahon, 1989c, 1989d, 1989e), in Africa (McMahon, 1988a, 1988b, 1989f), in Pakistan (McMahon, 1989g), in Nepal (McMahon, 1988c), in Indonesia (McMahon, 1986, 1989h), and in the O.E.C.D. countries (McMahon, 1984). Part II will go beyond the positive analysis with a normative analysis that defines and applies the efficiency criteria and equity criteria to the level and methods used in financing human resource development in a sample of these countries, and considers major policy options. Part III summarizes the conclusions about methods that are available for improving the decisions about financing in the effort to reduce the inefficiency and inequity that exists at present.

I. Methods of Financing Human Resource Development: A Brief Description

The financing of investment in education, and in health, is shared by parents, by their children, by government, and in the case of the developing countries, by the World Bank and various donors.

Parents

From an economic point of view, the largest investment being made which includes the value of the time invested, usually measured by the earnings foregone while the child is in school, is made by the parents. This foregone earnings cost is borne entirely by the parents at the primary and secondary levels, and there are sometimes additional fees for books, uniforms, and teachers' supplements. So parents bear a much larger percentage of the total investment costs than is commonly realized out of their income. This foregone earnings cost is a major contributing factor to the high drop-out rates after about fifth grade in most developing countries, especially in the rural areas, and a major explanation of the high illiteracy rates in the labor force.

In higher education, these maintenance costs are much more heavily subsidized in developing countries than they are in the U.S. Resource recovery is very low in higher education in Bolivia, Brazil, Dominican Republic, Uruguay, Turkey, Pakistan, Indonesia, and all of the countries in Africa except Nigeria (for data see McMahon, 1988d and 1989b). In Africa even secondary school boarding costs are subsidized. These large higher education subsidies occur even though 60-83% of the students typically come from the highest income families. (See World Bank, 1986, p. 61.) This method of financing results in an enormous

cost per student in higher (and African secondary) education, and the loss of considerable potential for resource recovery from parents who are able to pay amounts that then would be available for further expansion of higher education. In Brazil, for example, higher education costs per student are 18 times what they are at the primary level, compared to 10 times primary in all of Latin America, 2 times primary in the U.S. and in the industrial countries, and 53 times primary in Sub-Saharan Africa. (See the World Bank, 1988.)

This over participation of parents in the financing of primary and junior secondary education where the social rates of return are higher and insufficient participation by those higher income parents who have the ability to support higher education encourages inefficiency. At the primary and secondary levels, the relatively high costs to the parents is associated with the high drop-out and repetition rates. In higher education, the subsidized maintenance and free tuition tends to lengthen the time it takes a typical student to graduate, which runs up the costs. It takes 6 1/2 years to finish a 4-year degree in Indonesia, for example, and longer than that in Greece and some countries in Africa. (See McMahon, Millot, and Eng, 1986, p. 196.)

Students

Students bear a portion of the costs in all of the industrialized countries and a few of the developing countries through student loans and work-study.

Student loans accounted for $10.4 billion of U.S. Federal student aid in 1987, compared to $1.5 billion subsidy plus earnings from work

study, and $4.2 billion in direct grants. The average loan was $2,478, average earnings from work study was $880, and the average Pell Grant was $1,312, with 31% of the 12.4 million students enrolled holding loans and 29% receiving Pell Grants. (Source: U.S. Bureau of the Census, 1988, p. 147.) Student loans are used extensively in Sweden, Canada, and Korea, and are available in Norway, Japan, Columbia, Venezuela, and Argentina. New student loan programs are now being underwritten by the World Bank in Jamaica and some other places.

Studies of the experience with student loan and grant programs generally conclude three things:

1. Tuition waivers and maintenance grants should all be targeted more adequately to the students from poor families who are the ones who need them by use of means tests.
2. The same is true of access to student loans, because loan programs are usually heavily subsidized, and because higher income families can use the funds for other purposes.
3. A combination of loans, tuition waivers, work-study, and grants is a more flexible system of student aid than is a student aid program that contains only one of these. (See Woodhall, 1987, p. 449.)

At the Masters' and Ph.D. levels, parents seldom support either tuition and fees or maintenance costs. Most graduate students in the U.S. finance these costs themselves by means of half-time teaching and research assistantships. This practice is less common in the European countries or in developing countries where usually full-time faculty and full-time research assistants are used. There is increasing

awareness that his latter practice limits access due to the higher costs, and limits diffusion of the technology since trained full-time research assistants do not interact with undergraduates or flow through into industry.

Government Financing

About 60% of the total investment in education, and 85% of the institutional expenditure is borne by the central government in most countries, and by state and local governments in the U.S. The remainder of the institutional costs are accounted for by the private sector, which accounts for only 10-20% of the primary and secondary students in each geographical region throughout the world, and by tuition and fees at public institutions (World Bank, 1988, p. 134). The private sector tends to grow more rapidly when public schools are underfinanced and do not meet the needs.

This dominance of the public sector is the prevailing pattern because there is market failure, with the private market failing to provide education in sufficient quantities. There are three basic reasons for this. A major one is that families cannot borrow sufficient sums to finance human resource development, even though the rates of return on educational investment are higher, a capital market failure due to the uncertainty of future earnings and insufficient collateral. (See Ritzen, 1989, and McMahon, 1989a and 1989c, for analytic proofs and empirical research results.) A second reason for public sector financing is that there are externalities, or spillover benefits to the society that the parents who otherwise would have to

do all of the financing are unable to perceive or to recoup. A third reason is that the poor would remain uneducated, or insufficiently educated, as the private sector "skims" the market, unless there is public financing.

Once government does intervene, its financing induces further saving and investing of foregone earnings and fees by parents. The government's financing role in determining the total level and types of investment in education therefore is the major determining one and is crucial (see McMahon, 1989c, for the two relevant models and empirical tests).

The result is that the government can apply appropriate economic investment criteria in the form of cost/benefit and rate of return analysis to ensure that the total level of investment (financed by parents, students, and taxes) and the investment made at primary, secondary, and higher education levels is economically efficient.

However, it is also the responsibility of the government, since investment in human beings is involved (in contrast to private investment in machines which can be driven only by efficiency considerations) to see that the investment is equitable. Education cannot be provided only to the children of the wealthy, who can pay for private schools or be an influential pressure group distorting expenditure per child upward in wealthy suburbs and downward in rural areas and urban ghettoes. This might be viewed as instance of "public sector failure," as pressure groups distort education expenditure to their own ends. The result is a breakdown of "wealth neutrality," which is a frequent subject of litigation in U.S. courts (see Cohn, 1979, pp. 270-86).

It also involves a lack of horizontal equity, a widely accepted principle in public finance, in this case as among children at the same level in different schools, and leads to inequality of educational opportunity.

It is fortunate that in financing human resource development the directions indicated by efficiency criteria and by equity criteria in many important situations are not in conflict. For example, if there is diminishing returns to expenditure per pupil, a certain amount of equalization increases the total returns. In another important dimension, rates of return to primary education tend to be higher than they are to higher education, and primary education benefits the poorest segment of the population as well. For example, rates of return to primary education in Latin America are 26-27%, compared to higher education, and 51-59% of the benefits of public primary education go to the poorest 40% of the population. (Sources shown in McMahon, 1988d, Table 4, and World Bank, 1986, p. 61.) So this is a case where an improvement in efficiency by increasing financing faster for primary education where the rates of return are higher simultaneously increases equity.

International Donors

In the developing countries, the World Bank, Asian and Latin American Development Banks, and national donors have made large sector loans and grants to governments to assist with the financing of human resource development. These transfers have usually stressed those areas where there is a comparative advantage to assistance from the

industrialized countries, such as higher education and graduate study abroad where there is an additional advantage to be gained from the transfer of technology. Sometimes they have supported activities where the cost effectiveness is known to be relatively lower (e.g., excessive expansion of vocational education in Latin America and South Asia, or too much emphasis on buildings in relation to texts and teaching materials which are known to be more cost effective). (See Fuller, 1988, for a good survey of cost effectiveness as it relates to pupil achievement.) This leaves the government in the developing country with the task of "topping up" the education budget from its own tax sources so that the efficiency and equity of the entire budget is not distorted by this action by donors. Unfortunately this is a task that often has not been performed.

More recently, a great deal more emphasis is being placed by major donors on achieving greater efficiency and equity in human resource investments. Large education sector loans have been made by the World Bank to expand primary education in Pakistan, African nations, and elsewhere. Policy reform requiring more resource recovery in higher education and means tested student loans and grants have also been imposed as a condition of higher education loans in Indonesia, Jamaica, Morocco, and elsewhere (see Jiminez, 1989). A large USAID grant to Pakistan, and one in preparation to Bangladesh, finances investment in primary education, as will the forthcoming USAID project ABLE worldwide.

II. Investment Criteria in Financing Education

The types of taxes used in support of the government's contribution are largely irrelevant to the operation of the system of financing education. Some taxes may be preferred to others, however, for various reasons. Also, the relevance of various kinds of resource recovery from families in the financing of higher education has already been discussed.

The major tax sources in use used to support education all have some degree of income elasticity. An exception is the very regressive "house-tax" that is a poll tax not based on the value of the house or land used in Nepal and in Africa. Real expenditure per capita on education rises when income rises, either because the revenue base is income elastic or if it is not, as is the case with sales taxes or property taxes in the U.S., the rates are changed. (For regressions that establish this, see McMahon, 1971.) The income elasticity of government investment in education is 1.0 in the U.S. in the long run, and 1.4 to 1.6 in a cross section of 89 low, middle, and higher-income countries (McMahon, 1989c, and T. Paul Schultz, 1988).

What is important on efficiency grounds to the financing of education is the percent of the government budget allocated to education. This influences the amounts invested by families, and thereby determines the total percent of GNP invested in human resource development.

What is also important on both efficiency and equity grounds is the method by which the funds are distributed to the schools. Both of these steps inherently contain a set of incentives; the former to

families to save and invest in education, and the latter to the method of operation of the schools.

Efficient Levels of Investment in Education

Are countries investing too much or too little in education, or are they balancing it with the rate of investment in physical capital and thereby employing an overall efficient investment strategy for growth?

Table 1 shows that investment strategies are not very efficient--differences in rates of return that persist over long periods of time and in many countries. There is clearly underinvestment in primary education in Latin America, Africa, and Asia where real rates of return average 16-44%, compared to about a 13% rate of return to investment in physical capital. The social rates of return to investment in higher education are less advantageous, but still substantial.

Comparing recent estimates in Indonesia and Pakistan, there are high 33% rates of return available to financing primary education there, whereas the returns are highest in Indonesia at 22% for the junior secondary level (from McMahon, 1989g and 1989h). This is not surprising when one considers the 74% illiteracy in the labor force in Pakistan, suggesting a relative shortage of workers with even primary school basic skills. In contrast, as shown in Figure 1 in Indonesia, 60% of the labor force has completed primary. With only 6% having completed junior secondary, this corresponds to the higher 22% rate of return available there. It is fortunate that both the World Bank and USAID have each made very large $250-500 million commitments each

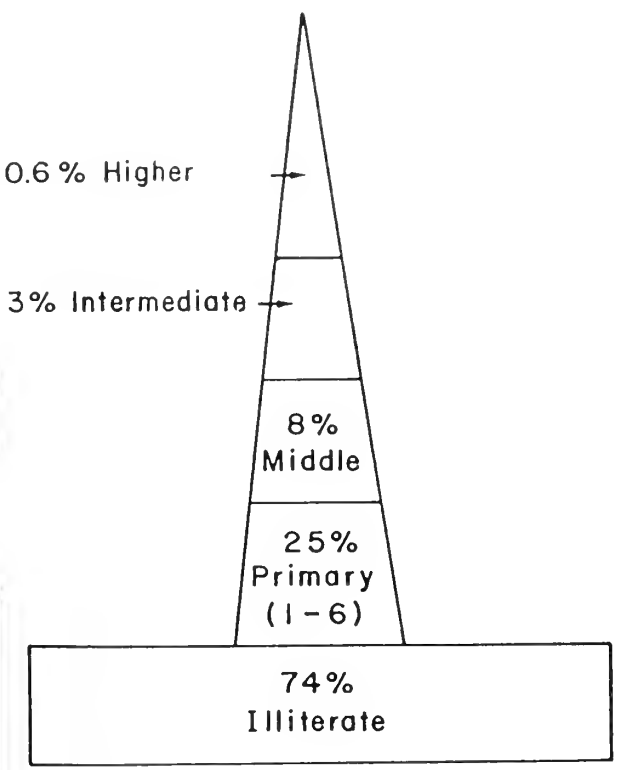
Table 1

Evidence on Rates of Return to Human and Physical Capital

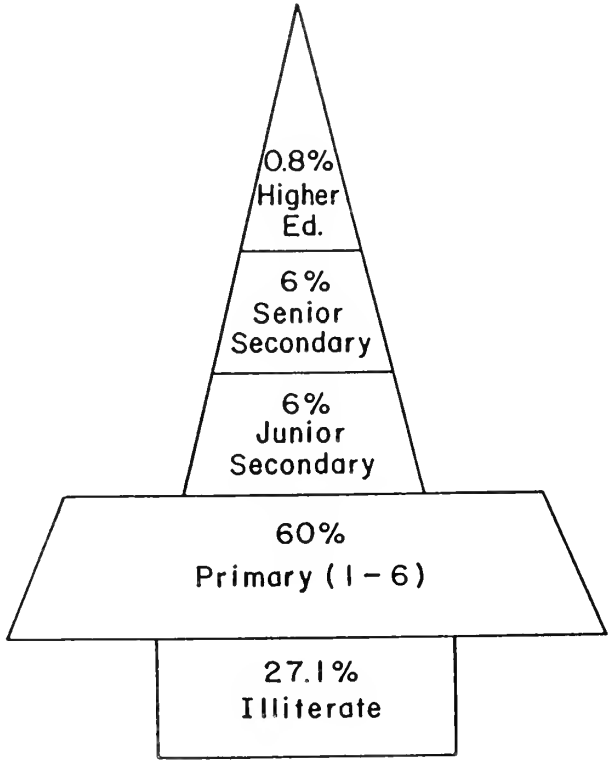
	Education[a]			Physical Capital	
	Primary	Secondary	Higher	Overall[g]	
Latin America	44%	17%	18%	13	
Africa	29	17	12	13	
Asia	16	12	11	13	
Indonesia[b]	14	22	9		
Pakistan[c]	33	3	10		
Industrial		10	9	Industry	Housing
United States[d]		12	12	15%[e]	5%[e]
Canada		11.7	14	9.9[f]	
Japan		4.6	6.4	13.6[f]	
Sweden		10.5	9.2	5.5[f]	
United Kingdom		3.6	8.2	5.9[f]	
Netherlands		5.2	5.5	28.3[f]	

	Education	Physical Capital
Developing[g]	15	13
Industrial[g]	9	11

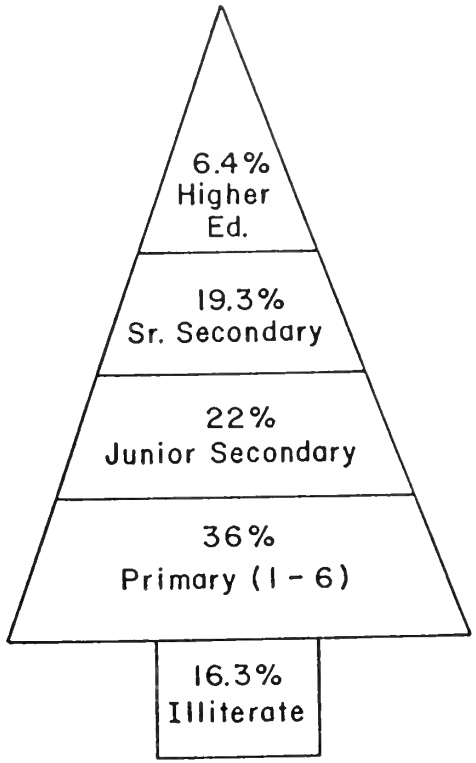
Sources:
a. Social rates of return from Psacharopoulos (1981, pp. 328-29).
b. McMahon (1989h, Table 7) (for 1986).
c. McMahon (1989g).
d. McMahon (1989d, Table 1).
e. E. Mills (1988).
f. T. P. Hill (1979, p. 23). This is the trend level for 1976 for industry including transport, i.e., adjusted to remove cyclical effects.
g. Psacharopoulos (1985, p. 591).



PAKISTAN 1985-8



INDONESIA 1982



SOUTH KOREA 1975

Figure 1

to expanding primary education in Pakistan, and that Indonesia has made the attainment of universal junior secondary education by 1993 the major human resource investment goal of its new five-year plan. Both would appear to be economically efficient investment strategies.

It should be stressed that the rates of return to investment in rural education at the primary level are very high, working out to about 27% on the average in studies covering 35 countries. Since a very large percentage of the low-income population is in the rural areas, this means that expansion of primary education in the rural areas is not only an efficient strategy, but it also improves equity. (For a survey of the studies of the effect of education on agricultural productivity, see M. E. Lockheed, 1987, pp. 110-115.)

The purely economic returns to the education of women tend to be as high or higher than to the education of men. Psacharopoulos (1985, p. 589) estimates 15% returns to the education of women, and 11% to men, with the largest advantage to women at the secondary level. But there is an additional effect, very important in the low-income countries where population growth rates are very high, averaging 2.8% per year in the developing countries compared to .6% in the industrial countries (Source: McMahon, 1989c, Table 1). It is the effect of education of women to the ninth grade level and beyond in enabling them to enter the labor force as teachers, for example, as this in turn lowers fertility rates and the size of completed families (see McMahon, 1989g, for a survey of the studies as they relate to Pakistan). This is another instance where efficiency in financing and equity are not in conflict.

Education and Growth

Rates of return can be derived directly from a production function and then estimated directly with increments to output or to real gross national product on the left. This circumvents arguments about whether or not average earnings are a reasonably good measure of worker productivity, and arguments about self-selection and screening.

When this was done for the U.S., using a Cobb-Douglas production function, the real marginal productivities of each type of investment interpreted as real rates of return that were obtained are as follows:

$$(1) \qquad y_p = \underset{(.44)}{.35}\,\frac{NS}{Y} + \underset{(12.2)}{.13}\,\frac{I_K}{Y} + \underset{(3.8)}{.27}\,\frac{I_{H-5}}{Y} + \underset{(3.1)}{.30}\,\frac{I_{A-7}}{Y} - \underset{(3.4)}{.29}\,\frac{I_{HE-5}}{Y} - \underset{(1.6)}{.002}D, \qquad R^2 = .98$$

where y_p = rate of growth of real potential GNP,

NS = labor supply,

I_K = investment in physical capital,

I_H = investment in primary and secondary education,

I_A = investment in research and development,

I_{HE} = investment in higher education,

D = dummy variable for oil shocks, 1 after 1979,

Y = real gross national product.

Investment in education and in R&D was lagged 5 and 7 years respectively to allow for delayed effects, and the production function was estimated for 1947-1988 as part of a simultaneous 35 equation model to

allow for feedback effects as income grows on all of the four different forms of investment. t statistics are shown in parentheses.

These estimates suggest a 13% real rate of return to investment in physical capital, not far from the 15% for non-housing capital and 5% for housing capital obtained by Ed Mills (1988) as an average over the 1947-1984 period shown in Table 1. The regression estimates also suggest about a 27% rate of return to investment improving the quality and access to primary and secondary education. The coefficients of .30 for I_A and -.29 for I_{HE} are interdependent with one another, with I_{HE} sometimes becoming positive and I_A negative, so it was not possible to separately identify these two effects. In earlier work, using a similar production function with data for 39 African countries, a negative coefficient for higher education also was obtained. But its net effect became positive after I_{HE} was introduced with a longer 10 year lag (McMahon, 1987, p. 189, which also shows the derivation of rates of return from a Cobb-Douglas function).

There is evidence that physical capital substitutes for and displaces raw labor, but that education embodied in human capital and physical capital are complementary with one another. This difference in elasticities of substitution can be accommodated in a Nested Constant Elasticity of Substitution (CES) production function, and the rates of return then derived. The nested CES shown as equation (2) below was estimated for the U.S. using the same data, although it is highly non-linear and could not be estimated as part of the simultaneous macrodynamic model. The results were as follows:

$$(2)\qquad Y_P = \left[\underset{(120.3)}{.97}\, Z^{(8.4)} + \underset{(120.3)}{.03}\, (e^{at}NS)^{(8.4)} \right]^{-1.31}{}^{(8.4)} \quad -1/1.31$$

$$Z = \left[\underset{(29.1)}{.91}\, K^{(6.71)} + \underset{(2.67)}{.09}\, H^{(6.71)} + \underset{(2.67)}{.01}\, HE^{(6.71)} \right]^{-3.46}{}^{(6.71)} \quad -1/3.46$$

$$R^2 = .998; \quad DW = 1.92, \quad Rho = \underset{(3.59)}{.57}$$

where: Y_P = real potential GNP,

Z = the combined factor,

K = physical capital,

H = human capital (primary and secondary),

HE = human capital (higher education)

NS = labor supply, the number of workers, and

a = rate of growth of the R&D stock.

Technical change is regarded here as embodied as the result of past investment in both physical (K) and human capital (H and HE), but also containing a disembodied component that is raw-labor-augmenting via $e^{at}NS$.

The elasticity of substitution calculated from the estimates above is higher (s = .43) for the substitution of total capital (Z) for raw labor (NS) than it is for substitution among the different forms of human and physical capital (s = .22). This is as expected.

The rates of return derived as shown in Appendix A and calculated from the estimates of Eq. (2) are:

$$r_K^* = .11, \quad r_H^* = .14, \quad r_{HE}^* = .09$$

This 11% rate of return for physical capital, 1974-88, is remarkably close to the average of the 15% and 5% for Non-Housing and Housing capital that as mentioned earlier was obtained by Ed Mills (1988) and shown in Table 1. The 14% for primary and secondary and 9% for higher education is close to the 12% reported for secondary education alone in Table 1 and the 10.5 to 10.9% reported for the earlier 1949-1969 period for higher education by Psacharopoulos (1981). These latter estimates are based on microeconomic earnings data, which therefore are strengthened by these aggregate production function estimates.

This suggests that there is a degree of inefficiency in the sense that there is underinvestment in primary and secondary education (and overinvestment in housing) in the U.S. It also suggests that there is not overinvestment in human capital in the U.S.

Fast Growth

As shown in Table 2, the six fastest growing countries in the world who all had real growth rates that were sustained at 4.7 to 7.8% since 1965 are all investing between 18-21% of their total government budgets in education. (In Japan, provincial governments raise some money for education that is not included in Table 2.) But they also are saving and investing in physical capital at a high 29% average rate. Their investment financing strategy that takes into account the complementarity between human and physical capital and invests at relatively high rates in each does seem to work. The inequality in the distribution of income in these fastest growing countries is relatively low compared to most developing countries. This is probably

Table 2

What Works and What Doesn't

Fastest Growing Countries in the World	Real Per Capita Growth Rate 1965-85	I_K/Y	I_H/G	Income Received by Lowest 40%
Singapore	7.8%	47%	21.6%	NA
South Korea	6.6%	29%	20.5%	16.9%
Hong Kong	6.2%	24%	20%	16.2%
Botswana	6.2%	21%	19.4%	NA
Taiwan	4.9%	28%	18.0%	22.3%
Japan	4.7%	28%	12.0%	21.9%
Three Slow Growing Countries				
Pakistan	2.4%	17%	3.1%	NA
Philippines	2.6%	18%	25.6%	NA
Nepal	.2%	10%	7.2%	NA

Source: Data from World Bank (1988, Statistical Appendices).

partly because high rates of investment in primary and secondary education have made basic education universal in all of these countries except Botswana and thereby spread earnings more widely in the population.

In addition, the Philippines had very high rates of investment in education (25.6%) and Pakistan and Nepal had very low rates of investment in education (3.1% and 7.2%). Per capita growth was higher in the Philippines than in Pakistan or Nepal, but was basically much lower in all three of these countries than in the faster growing countries shown at the top of Table 2. There are of course other factors that affect growth (wars, the degree of political commitment to achieve efficient growth, an export-oriented growth strategy, etc.). But perhaps this is sufficient to illustrate that investment in education is not a sufficient condition for growth, but it does appear to be a necessary condition.

III. Conclusions

There are many sources of inefficiency, as well as inequity, in education that then transpose themselves into the pattern of economic development. Many of these are rooted in the methods of financing human resource development.

It is suggested that there are economic criteria that are relevant to finding efficient and equitable human resource investment strategies. The social rates of return to investment in education, especially in primary and secondary education, tend to be significantly higher than the rates of return to investment in physical capital in

the developing countries, and over twice the real rates of return to investment in housing in the U.S. Assuming that the externality benefits of education exceed the cost spillovers, and that the contribution made by investment in primary and secondary education to reducing inequality in the distribution of income in the future is non-negative, there are significant efficiency and equity gains to be made especially in the developing countries by improving investment strategies. Beyond this, improving the objectivity and equity with which funds are distributed by the Central Government to the schools, and increasing resource recovery in higher education while improving the targeting of financial aids through better means testing, are two specific additional ways the financing of human resource development could be refined. (See McMahon, 1989b for the specifics.) All of these steps would increase efficiency and equity in education, and thereby contribute significantly to economic development.

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Appendix A

Derivation of the Rates of Return from a Nested CES Production Function

Without the error terms, a nested CES production function is specified by the following two equations:

$$YP = [\alpha_1 Z^{-\rho} + \alpha_2 N^{-\rho}]^{-\frac{1}{\rho}}, \quad \alpha_1 + \alpha_2 = 1 \tag{1}$$

$$Z = e^{a}[\beta_1 K^{-\rho_2} + \beta_2 H^{-\rho_2} + \beta_3 HE^{-\rho_2}]^{-\frac{1}{\rho_2}}, \quad \beta_1 + \beta_2 + \beta_3 = 1 \tag{2}$$

Substituting (2) into (1), we have

$$YP = [\alpha_1 e^{-a\rho}\{\beta_1 K^{-\rho_2} + \beta_2 H^{-\rho_2} + \beta_3 HE^{-\rho_2}\}^{\frac{\rho}{\rho_2}} + \alpha_2 N^{-\rho}]^{-\frac{1}{\rho}} \tag{3}$$

Let

$$\mathbf{P} = \alpha_1 e^{-a\rho}\{\beta_1 K^{-\rho_2} + \beta_2 H^{-\rho_2} + \beta_3 HE^{-\rho_2}\}^{\frac{\rho}{\rho_2}} + \alpha_2 N^{-\rho} = YP^{-\rho}$$

and

$$\mathbf{Q} = \{\beta_1 K^{-\rho_2} + \beta_2 H^{-\rho_2} + \beta_3 HE^{-\rho_2}\} = \left(\frac{Z}{e^{a}}\right)^{-\rho_2}.$$

Then, taking the total derivative of (3) with respect to time t, we have

$$\frac{dYP}{dt} = \frac{\partial YP}{\partial K}\frac{\partial K}{\partial t} + \frac{\partial YP}{\partial H}\frac{\partial H}{\partial t} + \frac{\partial YP}{\partial HE}\frac{\partial HE}{\partial t} + \frac{\partial YP}{\partial N}\frac{\partial N}{\partial t}$$

$$= \mathbf{P}^{-\frac{1+\rho}{\rho}}\left[\alpha_1 e^{-a\rho}\mathbf{Q}^{\frac{\rho-\rho_2}{\rho_2}}\beta_1 K^{-(\rho_2+1)}\frac{\partial K}{\partial t} + \alpha_1 e^{-a\rho}\mathbf{Q}^{\frac{\rho-\rho_2}{\rho_2}}\beta_2 H^{-(\rho_2+1)}\frac{\partial H}{\partial t}\right.$$

$$+ \left.\alpha_1 e^{-a\rho}\mathbf{Q}^{\frac{\rho-\rho_2}{\rho_2}}\beta_3 HE^{-(\rho_2+1)}\frac{\partial HE}{\partial t} + \alpha_2 N^{-(\rho+1)}\frac{\partial N}{\partial t}\right]$$

Appendix A (continued)

$$= YP^{\rho+1}\left[\alpha_1\beta_1 e^{-a\rho_z}Z^{\rho_z-\rho}K^{-(\rho_z+1)}\frac{\partial K}{\partial t} + \alpha_1\beta_2 e^{-a\rho_z}Z^{\rho_z-\rho}H^{-(\rho_z+1)}\frac{\partial H}{\partial t}\right.$$

$$\left. + \alpha_1\beta_3 e^{-a\rho_z}Z^{\rho_z-\rho}HE^{-(\rho_z+1)}\frac{\partial HE}{\partial t} + \alpha_2 N^{-(\rho+1)}\frac{\partial N}{\partial t}\right] \tag{4}$$

Since

$$Z^{\rho_z-\rho} = \frac{Z^{\rho_z+1}}{Z^{\rho+1}},$$

(4) becomes

$$\frac{dYP}{dt} = \alpha_1\beta_1 e^{-a\rho_z}\left(\frac{YP}{Z}\right)^{\rho+1}\left(\frac{Z}{K}\right)^{\rho_z+1}\frac{\partial K}{\partial t} + \alpha_1\beta_2 e^{-a\rho_z}\left(\frac{YP}{Z}\right)^{\rho+1}\left(\frac{Z}{H}\right)^{\rho_z+1}\frac{\partial H}{\partial t}$$

$$+ \alpha_1\beta_3 e^{-a\rho_z}\left(\frac{YP}{Z}\right)^{\rho+1}\left(\frac{Z}{HE}\right)^{\rho_z+1}\frac{\partial HE}{\partial t} + \alpha_2\left(\frac{YP}{N}\right)^{\rho+1}\frac{\partial N}{\partial t} \tag{5}$$

Therfore, the rate of return to physical capital,

$$r_K = \alpha_1\beta_1 e^{-a\rho_z}\left(\frac{YP}{Z}\right)^{\rho+1}\left(\frac{Z}{K}\right)^{\rho_z+1} \quad ;$$

the rate of return to basic education,

$$r_H = \alpha_1\beta_2 e^{-a\rho_z}\left(\frac{YP}{Z}\right)^{\rho+1}\left(\frac{Z}{H}\right)^{\rho_z+1} \quad ;$$

the rate of return to higher education,

$$r_{HE} = \alpha_1\beta_3 e^{-a\rho_z}\left(\frac{YP}{Z}\right)^{\rho+1}\left(\frac{Z}{HE}\right)^{\rho_z+1}.$$