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The Relation of Education and R&D to Productivity Growth in the Developing Countries of Africa

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Abstract

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This paper focuses on the returns to investment in human capital in the form of investment in primary and secondary education, and in technology transfer via higher education, in 30 of the poorest countries of Africa. It specifies a production function and controls over the 1970-1985 period for investment in physical capital, drought, oil price shocks, different labor utilization rates, Anglophone and Francophone differences, and differences in initial productivity levels.

The results find high 21.2% rates of return to investment in primary and secondary education, including 18 countries for which individual rate of return studies do not exist. Employed population growth alone lowers the growth of per capita output (by 35%). High 20.3% rates of return to investment in higher education are interpreted as capturing many of the benefits of technology transfer.

THE RELATION OF EDUCATION AND R&D TO PRODUCTIVITY GROWTH IN THE DEVELOPING COUNTRIES OF AFRICA

Walter W. McMahon

This paper focuses on the overall efficiency of investment in primary and secondary education, together with technology transfer via higher education, in 30 of the poorest countries in Africa. These countries have most of the problems that are common to all in the region. Data for all of the countries for which consistent data is available allows the process of per capita growth to be studied for recent years while controlling for physical capital investment and other influences on growth in a way that is not possible in studies confined to a single country. The way in which a particular fast-growing or a slow-growing country differs or is the same as others in the group will then be sorted out for separate analysis by use of a dummy variable technique.

Although education has long been recognized as a central element in economic development in Africa (e.g., Harbison and Meyers, 1964), it is only more recently that the economic criteria and the types of measurements needed as guides to achieving greater efficiency in human resource development for faster growth have begun to emerge (e.g., Psacharopoulos (1985), and McMahon (1986a, pp. 290-316)). The refinement and use of these techniques is particularly important to the very poorest countries. Human resources are often their most plentiful resource, but also they often are not developed very efficiently, while at the same time physical capital is scarce and relatively expensive.

But even though appropriate criteria for efficiency are coming into wider use, the necessary sample survey data covering costs, earnings and output do not always exist. This is true for many of these 30 sub-Saharan African countries.

To circumvent this problem, this paper employs data on investment in human an physical capital and on real per capita income growth that do exist within the context of a vintage human capital model. Investment also picks up some differences in quality of education that additional years of schooling do not, as has been developed recently by Heyneman and White (1986). The model is estimated by simultaneous equation methods extending earlier work by Wheeler (1980) to develop rates of return to investment flows in a way that recognizes the two way flow of causation as investment raises per capita growth, while this income growth in turn contributes to further investment in education.

I. Background of the Countries Studied and Their Economic Problems

The 14 Anglophone and 16 Francophone countries studied for which data exists on the key variables in the analysis from 1965 through 1985 are outlined more heavily on the map in Figure 1. These countries have the typical problems with which most are familiar. They include poverty, with the per capita income in ten of these countries at less than $200 per year. Low growth of real GDP per worker averages 68% for the 25 years from 1960 through 1985 taken as a whole compared to 170% for Asian countries over the same period as may be seen in Table 1. These African countries are also plagued by very

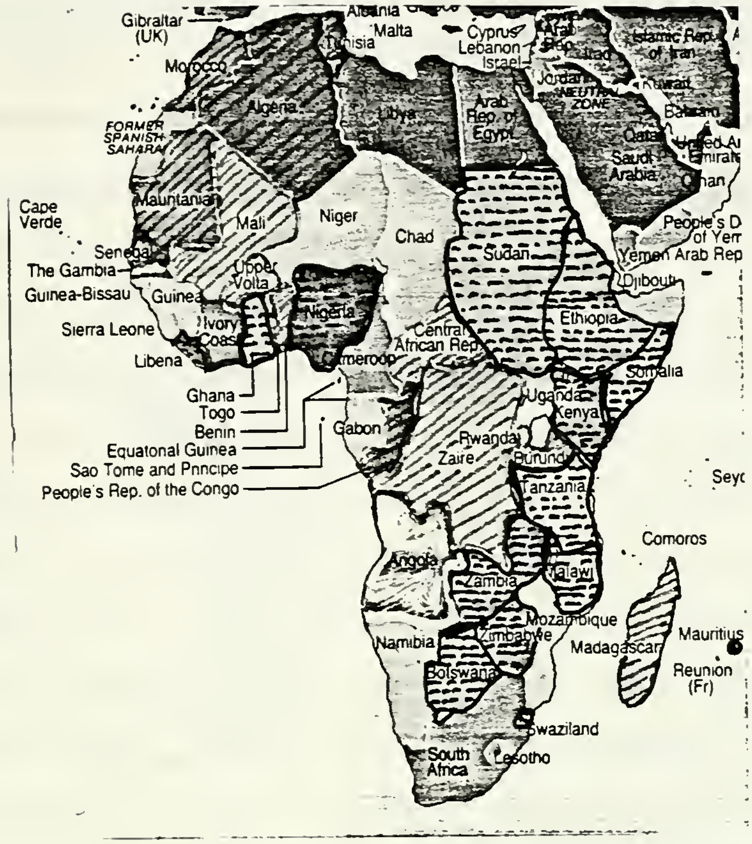

Figure 1

The Thirty African Countries in the Study of Sources of Productivity Growth

14 Anglophone

16 Francophone

Table 1

Growth Rates of Real Gross Domestic Product Per Worker for the 30 African Countries in this Study, 1960 through 1985

Country (Anglophone)	Percent Growth 1960-85	Country (Francophone)	Percent Growth 1960-85
Botswana	287.5	Algeria	90.0
Ethiopia	47.5	Benin	30.0
Ghana	5.0	Berundi	75.0
Kenya	90.0	Congo	145.0
Liberia	25.0	Central African Rep.	5.0
Malawi	97.5	Ivory Coast	112.5
Mauritius	47.5	Madagascar	10.0
Nigeria	92.5	Mali	30.0
Somalia	20.0	Mautania	95.0
Sudan	17.5	Morocco	67.5
Swaziland	170.0	Rwanda	72.5
Tanzania	80.0	Senegul	30.0
Zambia	10.0	Togo	97.5
Zimbawe	25.0	Tunisia	142.5
Average	72.5%	Upper Volta	37.5
		Zaire	-10.0
		Average	64.3%

Average, 30 Countries in Africa	68.17%
Average, Asian Countries	170.0%

high rates of population growth, and great inequality in the distribution of income (see World Bank, 1985, Annex Tables 19 and 27). Artificially depressed agricultural prices and overvalued currencies in foreign exchange markets impede productivity growth in agriculture. These problems are accompanied by a poor showing on most of the sources of medium term productivity growth that will be included in our analysis. These include high rates of unemployment and underemployment, low rates of investment in physical capital (and the related low median private saving rates, e.g., 10% compared to 20% in many industrialized countries), and low human capital investment. These lead to very low literacy rates and low life expectancy at birth. Finally almost all of these countries suffered from the adverse effects of oil shocks in the 70's and 80's and from drought.

The most striking single fact is the marked tendency of the poorest countries in Africa to grow more slowly than the others. According to a recent World Bank (1986) study, the 29 lowest income countries in sub-Saharan Africa that are eligible for help from the World Bank's International Development Association together now have a lower income and output per head than they did in 1960, and per capita income that is 20% lower than it was in 1970.

There are some bright spots however. Cheaper oil is now helping most of these countries since most are oil importers. This effect must be controlled for in the empirical analysis that follows. The economic recovery now occurring in the industrialized countries also helps, since northern industrial countries buy 80% of Africa's exports. Lower interest rates are helping to reduce debt service in these debtor countries, while also facilitating private domestic investment and making foreign loans more accessable. Finally, although real GDP per person fell in most of these countries over the last 15 years, there is the interesting case of Botswana where it rose at 7 1/4% per year.

With respect to investment in education as a means of achieving faster growth, Table 2 summarizes the results of the previous rate of return studies that have been done in 12 of these 30 countries to date. If anything, studies of rates of return in these countries will tend to under-estimate the true returns since most of these governments have intervened to keep farm prices artificially low and since over 80% of the population is employed in agriculture. Nevertheless, the social rates of return are fairly high, averaging 27.2% for investment in primary education and 16.2% for investment in secondary education, rates which are also high in relation to the rates of return for most investment in physical capital.

The private rates of return to higher education are high in relation to the social rates in all of these countries. This is due to the extraordinary extent to which most of these governments subsidize room and board as well as tuition, often for young adults from the most well to do families. This pattern is even more pronounced in the Francophone countries, see Mingat and Psacharopoulos (1985) and Jimenez (1986). The contribution to production to using resources in this way is one of the effects that will be tested in the empirical analysis later.

Table 2

The Social and Private Rates of Return to Investment in Education

Country: (A = Anglophone B = Francophone)	Year	Primary	Secondary	Higher	Primary	Secondary	Higher
Botswana (A)	1983	42.0	41.0	15.0	99.0	76.0	38.0
Ethopia (A)	1972	20.3	18.7	9.7	35.0	22.8	27.4
Ghana (A)	1967	18.0	13.0	16.5	24.5	17.0	37.0
Kenya (A)	1971	21.7	19.2	8.8	28.0	33.0	31.0
Liberia (A)	1983	41.0	17.0	8.0	99.0	30.5	17.0
Malawi (A)	1982	14.7	15.2	11.5	15.7	16.8	46.6
Morocco (F)	1970	50.5	10.0	13.0			
Nigeria (A)	1966	23.0	12.8	17.0	30.0	14.0	34.0
Somalia (A)	1983	20.6	10.4	19.9	59.9	13.0	33.2
Sudan (A)	1974		8.0	4.0		13.0	15.0
Tanzania (A)	1982		5.0				
Upper Volta (F)	1982	20.1	14.9	22.3			
Average, These Countries		27.2	15.4	13.2	48.9	26.2	31.0

Source: The results of many studies as summarized by Psacharopoulos (1985).

II. The Model

Economic theory suggests a joint determination of growth of potential output from the supply side and growth of effective demand together determining growth of real output per capita. In either a neo-classical or a neo-classical-Keysesian synthesis model, physical capital, human capital, raw labor, and knowledge capital deepening can be introduced, while allowing for variable proportions, and these then together contribute to growing output from the supply side. This paper will concentrate on these "total" capital deepening effects. But there is also the growth of effective demand, especially investment demand, that contributes to higher employment rates that are also necessary to the growth of actual GDP. Demand growth and externally imposed shocks therefore must be controlled for, hopefully in ways more sophisticated than mere statistical smoothing in order to measure the net effects from total capital deepening.

Total Capital Deepening

Physical, human, and knowledge capital deepening effects are derived from the production function in equation (1) below. But first, this capital deepening typical of a growing economy is viewed as a process typical of the medium term. Focusing on the medium term recognizes that shorter term dynamic models are concerned primarily with 6 to 18 month demand-induced fluctuations. They deal with periods that are two short for the effects from capital deepening on the supply side to be readily apparent. Similarly, long run steady state growth solutions normally apply when capital deepening is no longer continuing to occur, a situation these African economies have not yet achieved. The medium term is shorter than this very long run, and also short enough to be relevant to most economic policy, including the human, physical, and knowledge capital investment policies typical of most five year plans.

The capital deepening process is conceived of in Equation (1) as embodying scientific, social scientific, and technical knowledge in human capital $\overline{H}$, and similar technologies in physical capital, $\overline{K}$. Symbolically $\overline{H} = A_H H$ and $\overline{K} = A_K K$ where the A_H and A_K represent new technical and managerial knowledge embodied and the overbar symbolizes capital in efficiency units. Human capital is formed and the new knowledge embodied through the process of investment in the education of each new generation (I_H). Physical capital is formed with the new technology embodied in the newest vintages of physical capital again through the process of investment (I_K).

This emodiment of the new technology is assumed to take place through gross investment (I_H, and I_K), that is, not only through net new but also through replacement investment.[1] Replacement is a major part of human capital investment as people retire, and the most recent generation is taught the most recent skills. Similarly, replacement investment in physical capital is also an important means of embodying the new technology as machines and structures deteriorate. Capital embodying the new knowledge can also be imported from abroad. In the case of human capital, investment in higher education of graduate students studying abroad can become an important means of embodiment that transfers technology and innovative skills as these graduate students return home from the industrialized countries and, if they have the training and capacities to adapt their skills to local conditions, are productively employed. Gross Investment in higher education (I_{HE}) will therefore include investment by donors in the education of graduate students abroad.

The stock of knowledge capital, A, is disembodied technology that is also increased by acts of investment, in this case, in research and development. For these African countries, much of the basic investment in R&D however is done in the industrialized countries. This fact, plus the lack of consistent data on investment in R&D in African countries, and considerable exploration revealing the weakness of the direct immediate impacts of R&D on productivity growth in the industrialized nations, see McMahon (1954), all commend the assumption that most new science and technology is "embodied" first before transfer. Investment in R&D in the African countries that adapts research done elsewhere to local soil, climate, crop, and labor availability conditions is very important. But it will be assumed here that this residual domestic R&D, which may be relatively small, also is brought to bear on production only after investment that embodies it in physical or human capital, making human and physical capital investment more effective. Investment in R&D thereby increases the contribution of other forms of investment to productivity growth.

The production function accommodating these capital deepening effects is:

(1) $Y = Y(U, (\frac{Y}{N})_0 t, \overline{N}, \overline{K}, \overline{H}, \overline{HE}, E)$

where Y = Real output,

U = Utilization rate, measured as employment divided by the total population,

$(\frac{Y}{N})_0$ = Initial level of output per person employed,

N = Employment,

$\overline{K}$ = Physical capital, with science and technical change embodied, e.g., $\overline{K} = A_K K$, where $\overline{K}$ and other terms with overbars are conceived of as measured in efficiency units.

$\overline{H}$ = Human capital found by primary and secondary education, e.g., $\overline{H} = A_H H$ with $\overline{H}$ in efficiency units that embody the skills or attitudes that facilitate the dissemination of technology,

$\overline{HE}$ = Human capital formed by higher education, with science, social science, and other knowledge embodied in part by graduate study abroad, e.g., $\overline{HE} = A_{HE} HE$, and

E = Energy and drought shocks.

Before differentiating this with respect to time to focus on rates of growth, a brief explanation of two of the influences in addition to total capital deepening that are included above and that must be controlled for in the empirical analysis is needed.

<u>A higher labor utilization rate</u>, U, reflects lower unemployment and part-time underemployment, but is also correlated with less idle capital capacity in more capital intensive economies. Higher utilization is hypothesized to be associated with larger output, (Hyp: $\frac{\partial Y}{\partial U} > 0$), as is the pattern in industrialized countries. Since aggregate demand levels in each of these countries are not specified directly in the model, utilization rates serve as a proxy and control

for influences on output due to changes in demand or insufficiency of demand.

Higher initial productivity levels, $(\frac{Y}{N})_0$, after other effects are taken into account, are expected to be related to slower additional growth, (Hyp: $\frac{\partial Y}{\partial (\frac{Y}{N})_0} < 0$). This term controls for the difference in the intercepts of the equation explaining productivity growth as it is applied to data for the different African countries in the sample. This hypothesis is not inconsistent with the fact that the poorest countries are growing more slowly since there is less capital deepening in these countries to embody the technology and bring it to bear on production. This Rosenberg (1976) effect from higher failure rates for new innovations that is a cost borne by the leader should show up as a negative effect on growth but only when there are controls for the other influences.

Growth and Productivity Growth

Totally differentiating the production function given by Eq. (1) with respect to time gives:

$$(2) \qquad \frac{\partial Y}{\partial t} = \frac{\partial Y}{\partial U}\frac{\partial U}{\partial t} + \frac{\partial Y}{\partial (\frac{Y}{N})_0}(\frac{Y}{N_0}) + \frac{\partial Y}{\partial N}\frac{\partial N}{\partial t} + \frac{\partial Y}{\partial \overline{K}}\frac{\partial \overline{K}}{\partial t} + \frac{\partial Y}{\partial \overline{H}}\frac{\partial \overline{H}}{\partial t} + \frac{\partial Y}{\partial \overline{HE}}\frac{\partial \overline{HE}}{\partial t}$$

$$\frac{\partial Y}{\partial E}\frac{\partial E}{\partial t}$$

Dividing through by real output, Y, converts the growth rate on the left to a percentage rate of change over time. It also leads to investment expenditure terms on the right such as $(\frac{\partial \overline{K}}{\partial t})(\frac{1}{Y}) = \frac{I_{\overline{K}}}{Y}$ that are independent of national currencies.

$$(3) \qquad \frac{\partial Y}{\partial t}\frac{1}{Y} = \frac{\partial Y}{\partial U}\frac{\partial U}{\partial t}\frac{1}{Y} + \frac{\partial Y}{\partial (\frac{Y}{N})_0}(\frac{Y}{N})_0\frac{1}{Y} + \frac{\partial Y}{\partial N}\frac{\partial N}{\partial t}\frac{N}{N}\frac{1}{Y} + \frac{\partial Y}{\partial \overline{K}}\frac{\partial \overline{K}}{\partial t}\frac{1}{Y}$$

$$+ \frac{\partial Y}{\partial \overline{H}}\frac{\partial \overline{H}}{\partial t}\frac{1}{Y} + \frac{\partial Y}{\partial \overline{HE}}\frac{\partial \overline{HE}}{\partial t}\frac{1}{Y} + \frac{\partial Y}{\partial E}\frac{\partial E}{\partial t}\frac{1}{Y}$$

This can be simplified by using lower case letters to represent percentage rates of change over time (e.g., $y = \frac{\partial Y}{\partial t}\frac{1}{Y}$, $n = \frac{\partial N}{\partial t}\frac{1}{N}$), as well as by using parameters to represent coefficients (e.g., $\alpha_3 = \frac{\partial Y}{\partial U}$). Then notice that under the assumptions discussed below, the partial derivatives of output with respect to the inputs are the marginal physical products of each input (e.g., $\frac{\partial Y}{\partial \overline{K}} = MPP_{\overline{K}}$), and that the partial derivatives of each capital input with respect to time is merely investment. With these simplifications, Eq. (3) becomes:

$$(4) \qquad y = (\frac{MPP_N \cdot N}{Y})\, n + MPP_{\overline{K}}\frac{I_{\overline{K}}}{Y} + MPP_{\overline{H}}\frac{I_{\overline{H}}}{Y} + MPP_{\overline{HE}}\frac{I_{\overline{HE}}}{Y}$$

$$+ \alpha_2 \frac{Y/N_0}{Y} + \alpha_3 \frac{u}{Y} + \alpha_4 \frac{\partial E/\partial t}{Y}$$

This says that after controlling for changes in utilization rates, u, initial productivity levels $(Y/N)_0$, and energy and drought shocks, $\partial E/\partial t$, the growth of real output, y, is explainable in terms of the contribution made by the growth in employment of unimproved labor weighted by its marginal product, plus the rate of investment in physical, human, and knowledge capital weighted by their respective marginal products.

Labor productivity growth, as distinguished from total factor productivity growth can be obtained at least to a very close approximation by merely subtracting n from both sides of equation (4), so that growth in output per person employed (y-n) appears on the left as in equation (5) below. It would be possible to conceive of this as growth in output per hour if one wished to measure N as the number of hours employed rather than the number of persons employed. On the right in equation (5) below, α_1, the coefficient of the employment growth term is raw labor's share of national output if there is some degree of competition, less one. α_1 therefore can be expected to be negative. If raw labor's distributive share is 60% for example, after subtracting n from both sides to explain productivity growth, the labor growth term that remains on the right is $\alpha_1 n = (\frac{MPP_N \cdot N}{Y} - 1)n = (.6-1)n = -.4n$. This illustrates that growth in unimproved raw labor due in part to population growth, without other forms of capital deepening, reasonably can be expected to be associated with falling, and not with rising, output per capita, and explains why $\partial(y-n)/\partial n$ is hypothesized to be negative.

Rates of Return, Simultaneity, and the Model to be Estimated

In the two final steps to derive the model to be estimated containing the hypotheses to be tested, if it is assumed that raw labor, physical, human, and knowledge capital are all paid amounts that are approximately equal to their respective marginal products, then in an investment-theoretic framework, their marginal products are also their respective rates of return. Using the symbol r* for each rate of return, equation (5) below therefore follows from equation (4) above. This is the first equation that is part of the jointly dependent system that will be estimated by simultaneous equation methods.

Second, the growth in per capita output generates income that feeds back into higher purchasing power and hence higher investment demand for physical, human, and knowledge capital as specified in equations (6)-(8) as shown:

$$(5)\qquad (y-n) = \alpha_1 n + r^*_{\overline{K}} \frac{I_{\overline{K}}}{Y} + r^*_{\overline{H}} \frac{I_{\overline{H}}}{Y} + r^*_{\overline{HE}} \frac{I_{\overline{HE}}}{Y} + \alpha_2 \frac{(Y/N)_0}{Y} + \alpha_3 \frac{u}{Y} + \alpha_4 D_3 + \alpha_4 D_5 + \alpha_4 D_6 + \alpha_0$$

$$(6)\qquad I_{\overline{K}}/Y = \beta_1 (y-n) + \beta_2 D_3 + \beta_2 D_4 + \beta_4 D + \beta_0$$

$$(7)\qquad I_{\overline{H}}/Y = \gamma_1 (y-n) + \gamma_2 D_3 + \gamma_3 D_4 + \gamma_4 D_5 + \gamma_0$$

$$(8)\qquad I_{\overline{HE}}/Y = \delta_1 (y-n) + \delta_2 D_3 + \delta_3 D_4 + \delta_4 D_5 + \delta_0$$

With the addition of the relevant shocks as measured by dummy variables, the system is identified. The remaining explanatory variables are:

r = rate of interest in each country in each period,

D_3 = 1 = Anglophone; 2 = Francophone country,

D_4 = drought shock to agricultural output, 1965-79 = 0; 1980-85 = 1,

D_5 = energy shock, 1965-74 = 0; 1975-85 = 1,

D_6 = geographical energy shock, where 0 = oil importing country; 1 = oil exporter.

III. Empirical Tests: The Data and the Results

In this section the data will first be described briefly. Then the model jointly determining medium term productivity growth and levels of investment in physical and human capital that is shown in equations (5)-(8) above is estimated by two stage least squares simultaneous equation methods with the results as shown in Table 3 below. The effects of using a more reasonable lag structure results in a recursive model that then can be estimated by ordinary least squares single equation methods with results for both the productivity growth equation and for growth not expressed in per capita terms then is shown in Table 4.

<u>The Data</u>

The data on growth and on productivity growth all refer to total increments for the five year time periods of 1965-70, 1970-75, 1975-80, and 1980-85 for each of the 27 Sub-Saharan African Countries plus the northern countries of Morocco, Algeria, and Tunisia. The twenty year period should be long enough to clearly reveal the net effects of capital deepening on productivity growth.

The five year growth increments of real Gross Domestic Product, employment, and population, (the latter used to compute labor utilization rates), are from the National Income and Product Accounts published in the UNESCO (1983) <u>Statistical Yearbook</u>, updated with data supplied directly on request from the World Bank. The deflators are from the <u>World Tables</u>, published by the World Bank (1983) and updated by data from the Bank. Real investment and real GDP as shown on the right in equations (5) and on the left in equations (6)-(8) are from the same UNESCO and World Bank sources. These are measured in local currencies converted to constant prices since investment appears as a ratio to GDP eliminating the need for using exchange rates.

Table 3

Sources of Productivity Growth: 30 African Countries: Simultaneous Equation Estimates
1965-70, 1970-75, and 1975-80, (90 observations; t statistics in parentheses)

Per Capita Growth	Raw Labor's Share $(\frac{MPP_N \cdot N}{Y} - 1)$	Five Years Rates of Return (No Lags) r^*_K	r^*_H	r^*_{HE}	Controlling For: Initial Level	Change in Employment Rate	Anglophone or Francophone	Drought	Constant Terms	DW
(9) (y-n) =	-.82n	$2.09(\frac{I_{\overline{K}}}{Y})$	$+.80(\frac{I_{\overline{H}}}{Y})$	$+2.38(\frac{I_{\overline{HE}}}{Y})$	$-.227 \frac{(Y/N)_{70}}{Y}$	+8.36 u/Y	+.33D3	-.13D4	-.126	1.86
	(-.64)	(1.94)	(.29)	(-.57)	(-.68)	(.19)	(+.397)	(-.50)	(-.209)	

Feed-Back Effects as Per Capita Income Growth Facilitates Increased Total Investment

	Income Growth	Interest Rate (r), or Anglophone (D76)	Oil Exporting Nation (1)	Oil Price Shock	Constant	DW
(10) $I_{\overline{K}}/Y$ =	.521(y-n)	-.0081r	+.021D6	-.043D5	+.104	1.85
	(2.30)	(-1.54)	(.426)	(-1.29)	(3.28)	
(11) $I_{\overline{H}}/Y$ =	.137(y-n)	+.289D3	+.007D6	-.009D5	+.176	1.85
	(2.06)	(.375)	(.474)	(-1.04)	(1.71)	
(12) $I_{\overline{HE}}/Y$ =	.137(y-n)	-.0031D3	-.004D6	-.0042D5	+.897	1.86
	(1.14)	(-2.21)	(1.56)	(-2.55)	(4.79)	

Table 4

Sources of Productivity Growth: 30 African Countries: Recursive Model
1965-70, 1970-75, 1975-80, and 1980-85, (120 observations initially with 1965-70 dependent variable lost due to lag structure; t statistics in parentheses)

Growth Measure	Raw Labor's Share $(\frac{MPP_N \cdot N}{Y} - 1)$ or for y, $(MPP_N \cdot N)/Y$	Five Years Rates of Return to Investment: r^*_K	r^*_H	r^*_{HE}	Controlling For: Initial Productivity Level	Change in Employment Rate	Oil Exporters	75-80 Oil Shock	Anglophone or Francophone	Drought Years	Further Lagged Effects	Constant Term
(13) (y-n) =	$-.35n_{-1}$	$+.65(\frac{I_{\overline{K}}}{Y})_{-1}$	$+1.62(\frac{I_{\overline{H}}}{Y})_{-1}$	$+1.52(\frac{I_{\overline{HE}}}{Y})_{-1}$	$-.040 \frac{(Y/N)_{70}}{Y}$	+4.31 u/Y	+.01D6	-.06D5	+.0003D3	-.10D4	$+.43(y-n)_{-1}$	-.05
	(-.75)	(3.06)	(2.19)	(1.20)	(-.65)	(.327)	(.125)	(-1.33)	(.073)	(-1.71)	(4.12)	(-.70)
(14) y =	.48	.65	1.56	1.94	-.036	6.22	+.006	-.070	+.001	-.08	+.44	-.07
	(1.03)	(3.08)	(2.13)	(1.56)	(-.60)	(.47)	(.083)	(-1.65)	(.014)	(-1.49)	(4.27)	(-1.00)

Feed-Back Effects as Per Capita Income Growth Facilitates Increased Total Investment

	Income Growth	Interest Rate (r), or Anglophone (D76)	Oil Exporting	Oil Price Shock	Constant	R^2
(15) $I_{\overline{K}}/Y$ =	$.194(y-n)_{-1}$	-.01r	+.042D6	-.043D5	+.120	.34
	(3.91)	(-2.83)	(1.09)	(-1.29)	(5.97)	
(16) $I_{\overline{H}}/Y$ =	$.0001(y-n)_{-1}$	+.002D3	+.005D6	-.002D5	+.036	.33
	(.001)	(.415)	(.487)	(-.328)	(6.73)	
(17) $I_{\overline{HE}}/Y$ =	$.002(y-n)_{-1}$	-.003D3	-.005D6	-.004D5	+.008	.28
	(.61)	(-2.16)	(2.24)	(-3.10)	(6.82)	

	R^2
Eq. (13)	.44
Eq. (14)	.49

Investment data is available for 1970, 1975, and 1980 only, and is measured as gross investment, rather than as net investment (which would also require the nebulous procedure of estimating depreciation). This is based on the rationale offered above for including replacement investment in both physical and human capital as a major means by which the relevant technology and managerial knowledge is embodied.[2]

Investment in education includes investment by government but also that investment done by families in the form of foregone earnings. Foregone earnings are estimated for primary school children at zero. For secondary school children age 13 to 18, as well as for young adults in college, foregone earnings are calculated as the number of persons in school, or in college, obtained from the UNESCO Statistical Yearbook (various years) multiplied by the average annual wage or salary in manufacturing obtained from the Yearbook of Labor Statistics, International Labor Organization, (1983).

Investment in higher education includes not only the investment made by families and governments at indigenous institutions, but it also includes the investment made by donors such as the governments of the industrialized countries and the World Bank in the education of African students abroad. Data on support of these students is from the United Nations (Student Assistance, 1985). Finally, data on interest rates are from the International Financial Statistics published by the International Monetary Fund (1985) and from the World Development Report, World Bank (1985).

Empirical Results

The simultaneous equation estimates in Table 3 show that all of the explanatory variables discussed above in both the productivity growth equation and the three investment equations have an effect in the direction expected. Their signs are all consistent with the hypotheses. The same is true for the signs of the coefficients estimated for the recursive model by single equation least squares methods shown in Table 4. The t-statistics are smaller for the simultaneous equation estimates of the productivity growth equation (9) in Table 3, but this is to be expected because of the loss in the degrees of freedom due to the larger number of explanatory variables in the entire system. The t-statistics in Table 4 for 80 degrees of freedom indicate that all of the total capital deepening sources of productivity growth are significant. Investment in physical capital reaches the .001 level of significance, investment in primary education the 10% level, and investment in higher education including education of graduate students abroad the 20% level, all after controlling for the other effects in which we are less directly interested. Increased labor input contributes to aggregate growth with a coefficient of .48 in equation (14). But although raw labor's share of growing aggregate income is 52-65% (from Eqs. (14) and (13)), growing employment of unimproved labor alone does not contribute to per capita growth, (see Eq. (13)). Instead taken alone it reduces per capita growth by 35%, also as hypothesized.[3]

Rates of Return and Efficiency for Faster Growth

The logic of the recursive model in Table 4 is superior to that of the simultaneous equation model because it allows 1-5 years for investment in physical and human capital to affect productivity growth. Lagged effects in equations (13) and (14) also serve to pick up effects from total investment in prior periods. The coefficients therefore are very conservative in that they tend to underestimate, if anything, the true rates of return to each form of investment.

The growth increments on the left are five year increments, so the coefficients on the right must be converted to a rate that compounds over five years to appear as an annual rate of return. These rates are shown in Table 5.

Table 5

Social Rates of Return to Investment
in Physical and Human Capital
1970-1985

Returns to Investment in:	Annual Social Rates of Return: Recursive Model (from Table 4)	Annual Social Rates of Return: Country Study Average (from Table 1)
Physical Capital	10.5%	—
Human Capital (Average for Primary and Secondary)	21.2%	21.7%
Human Capital (Higher Education)	20.3%	13.9%

To compute the annual rate of return for Table 5 from the five year interval in equation (13):

(18) $(1+r^*)^t = r_K^* = 1.65$, from Eq. (13). So:

(19) $\ln(1+r^*)^t = (\ln 1.65)/5$

(20) $r^* = INV[(\ln 1.65)/5] - 1 = 10.5\%$, shown in Table 5.

Since the coefficients in equations (13) and (14) are very similar, the rates of return computed from them will be similar and need not be shown separately.

These rates of return to investment in primary and secondary education for 1970-85 of 21.2% compare very closely to the 21.7% rate that is the average of those obtained from the individual country studies that is shown in the second column. Since the new rates in Table 5 are based on totally different data, they constitute independent confirmation of substantial returns to investment in primary and secondary education in the last 15 years, returns of over 21% per annum in growth of real output per capita for the funds invested.

With respect to higher education, we have stressed the embodiment and transfer of technology from the industrialized countries. The externalities of this technology transfer do raise GDP and therefore are reflected in the 20.3% rate of return in Table 5 but are not necessarily reflected in the private money earnings of students returning from abroad. This effect from dissemination of science and technology could easily explain why the 20.3% is above the 13.9% rates of return obtained by studies that are based on salary data alone. This may be especially true in these African countries since so many educated Africans enter teaching, and some enter government service.

Finally, investment in R&D and disembodied technical change has not been treated separately. Consistent data to test the effects of investment in R&D directly do not exist. But there is justification for treating most effective technical change as embodied through investment in human and physical capital. It appears in a study of the sources of productivity growth in the 15 industrialized OECD nations for which consistent data on public and private business enterprise investment do exist. There McMahon (1984) found that investment in R&D (creating disembodied technology) consistently revealed a coefficient that both was small and also was insignificant or at best of marginal significance. The conclusion on this point was that the lags are too long before the disembodied technology produced by R&D affects productivity growth significantly. They are so long that data for the 15-20 years for which consistent data exists is not long enough to accommodate the lag structure while also controlling for other sources of productivity growth. Much of the measured effect of technical change and technology transfer therefore is picked up as it is transmitted via embodiment in physical and human capital. This is an effect that was first noted by Solow in relation to investment in physical capital. Here it increases the impact on growth of both physical and human capital formation.

Individual Country Difference

The main results of this analysis in Table 4 reveal a number of other effects on per capita growth after controlling for other things. They also reveal effects on the rates of investment that also are relevant to the growth process. Some of these effects apply to all of the 30 African countries, some to subsets of the group, and others apply differently to individual countries as will be developed below.

The variable distinguishing between Anglophone and Francophone countries reveals that productivity growth is a bit higher in the

Anglophone countries. But this difference is not significant when controlling for all of the other effects (see D76 in equations (13) and (14)). However this same variable reveals that there is a somewhat larger "effort" for primary and secondary education in the Anglophone countries (equation (16)), but very significantly smaller relative to investment in higher education there as compared to the Francophone countries (equation (17)). This is probably the result of the relatively high degree of public subsidies for higher education (and relatively low parental contribution), in the Francophone countries, even though most of the college students are from the highest income families. The waste implicit in this practice is developed in detail by Mingat and Psacharopoulos (1985) as well as by Jimenez (1986).

A second differential effect may be seen in the higher growth in the oil exporting countries in this period (see D6 in equations (13) and (14)). Although this effect is not very significant, the higher rate of investment in the oil exporting countries in physical capital and in higher education is quite significant. (See D6 in equations (15) and (17).) The oil exporting countries have benefitted in investment and in growth at the expense of the oil importing countries in the 70's and 80's.

For these African countries taken as a group, it is clear that the restriction of oil production resulting in higher oil prices and less cheap energy had a significantly adverse effect on per capita growth (D5 in equations (13) and (14)). The oil shock also depressed investment in physical capital, as well as investment in higher education

(D5 in equations (15) and (17)). The higher interest rates that were brought on by the oil price increases and high inflation rates after 1973 further constrained investment in physical capital by significant amounts (see r in equation (15)). The lower utilization rates that followed also contributed to slower growth (u/Y in equations (13) and (14)), although this lower utilization rate effect was less significant. Now utilization is rising, oil prices are lower, and interest rates are falling, all of which should help to restore per capita growth rates to the pre-oil-shock levels. But the onset of drought is continuing to slow growth (see variable D4 in equations (13) and (14)), with coefficients that are larger in absolute terms than those of all of the other dummy variables combined.

The sources of individual differences in growth rates among countries are further revealed in the analyses reported in Tables 6 and 7. In Table 6, "slope" and "intercept" dummies are introduced for Zaire, the slowest growing country in the group, and Botswana, the fastest growing country. The main result shown in Table 6 is that with respect to the returns per "dollar" invested, whether in Zaire or in Botswana, there is no significant difference in the returns to comparable investment from the returns in the other 29 African nations. This lack of significant difference in the slope coefficients especially is shown by the very small t-statistics for all of the country-specific dummy variables in columns 4-6 of Table 6. The intercept term also is not significantly different for Zaire, one of the poorest and slowest growing countries. But the intercept is significantly higher for Botswana.

Table 6

Individual Country Differences
Zaire (slowest growth) and Botswana (fastest growth)
1970-1985, t-statistics in parentheses

	Total Capital Deepening Effects 30 Countries			Zaire and Botswana Dummy Variables (No Significant Differences in Slopes)			Raw Labor's Share	Controlling for:[1]			
	IK/Y	IH/Y	IHE/Y	D·IK/Y	D·IH/Y	D·IHE/Y	$MPP_N \cdot N$	Oil Shock	Drought	Constant C	D·C
Zaire	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(y-n) =	1.07 (5.08)	1.36 (1.74)	3.99 (1.14)	-.173 (.52)	6.40 (.45)	-2.57 (.47)	.78	-.93 (2.05)	-.86 (1.42)	.03 (.41)	
(y-n) =	1.07 (5.11)	1.36 (1.76)	3.91 (1.13)		2.51 (.12)		.78	-.93 (2.06)	-.84 (1.42)	-.06 (.79)	-1.13 (.94)
(y-n) =	1.07 (5.10)	1.37 (1.76)	3.92 (1.13)			-1.80 (.43)	.78	-.98 (2.20)	-.88 (1.47)	-.58 (.77)	.12 (.16)
Botswana											
(y-n) =	.27 (1.22)	1.02 (1.48)	2.66 (.86)	1.36 (.88)	-1.53 (.73)	2.48 (.61)	.74	-.45 (1.13)	-.98 (1.78)	.29 (.41)	
(y-n) =	.36 (1.59)	1.06 (1.51)	2.84 (.90)		-.96 (.74)		.78	-.52 (1.26)	-.67 (1.25)	.48 (.67)	2.04 (2.72)

Notes:

1) All equations in this table contain variables identical to the full set of control variables shown in Table 4, although all are not shown here. These lower the t statistics somewhat below what they are in Table 4 because of the smaller degrees of freedom.

Examining these two more extreme cases further, Zaire has actually had negative per capita growth during the last 25 years. Typical of all lower income areas (e.g., Mississippi and Alabama within the U.S.), it is making a larger "effort" in the form of investment in primary and secondary education as a percent of its income than some of the higher income countries (see Table 7). But Zaire is not making a larger "effort" for basic education than Botswana (Table 7), which now has almost achieved universal primary education, close to the first nation to have done so in Africa. The adult literacy rates furthermore remain very low in Zaire, illustrating that even the larger "effort" is still small in relation to the scope of the problem. If anything, the rates of return to primary and secondary education in Zaire are higher than the African average as shown by the larger (but insignificantly so) primary and secondary slope coefficients (see Table 6, col. (5)). But in spite of high rates of return, there are considerable inefficiencies and some wasteful corruption in Zaire. When the government took over the primary and secondary schools from the missionaries, it initially was a disaster. Zaire's effort for higher education furthermore (Table 7) involves considerable waste since the universities are all free, and there are tremendous queues for admission, with no community college alternatives for those who are turned down.

Both physical capital investment and higher education appear to return somewhat less in Zaire than in other countries in Africa, although again the difference is not very significant (Table 6, cols. (4) and (6)). But the 31% rate of investment as a percent of GDP is

Table 7

Fast Growth and Falling Per Capita Output Patterns

Countries Rank Ordered by Growth Rates:	Annual[1] Growth of Real GDP Per Capita	Percent Enrolled[1] 1980			Investment Rates 1980, in Percent		
		Primary	Secondary	Higher	IH/Y	IHE/Y	IK/Y
Fastest in Asia	1960-1981						
Korea	6.9	107	85	14	3.5	3.4	32
Japan	6.3	101	91	30	3.9	.4[4]	32
Indonesia[3]	4.1	98	28	5	3.9	.7[4]	
Fastest in Africa[2]	1960-1985						
Botswana	5.6	86.9	40.3	6.0	5.5	1.2	44
Swaziland	4.0	79.8	66.1	15.8	3.5	1.2	31
Congo	3.6	100.0	97.5	20.0	4.8	2.3	41
Slowest in Africa[2]	1960-1985						
Zambia	.4	68.4	56.3	3.8	3.3	1.6	23
Ghana	.2	42.5	48.6	8.1	1.8	.1	8
Central African Republic	.2	56.8	25.2	2.4	7.2	3.2	7
Zaire	-.4	65.7	48.3	3.7	4.1	2.0	31

Sources and Notes:

1. Enrollment data, and 1960-81 growth rates from the World Bank (1985).
2. African data is the same as that used in the regressions with sources cited in the text.
3. Indonesian data from McMahon (1986), p. 85 (H1) allocated between higher and common schools based on data on p. 70.
4. Foregone earnings not included in these two cases only.

substantial (Table 7). The problem may be that there also is waste in these forms of investment (col. (4), Table 6). There are considerable underdeveloped hydroelectric power and copper resources, almost no beasts of burden which cannot survive the tetse fly, and hence insufficient investment in small tractors. The latter, together with the restraints placed on agricultural prices have impeded the growth of productivity in agriculture. Combined with the significant adverse effects on per capita growth of oil shocks (Table 6, col. (8)), drought (Table 6, col. (9)), and population growth (Table 4, eq. (13)), the positive effects of total capital deepening have been insufficient (Table 6, cols. (1), (2), and (3)). The result has been negative per capita growth.

Botswana on the other hand has had one of the highest, if not the highest, per capita growth of any nation in Africa. It is not typical, with most of its small population strung out along the rail line, a very large 5.5% rate of investment in primary and secondary education (Table 7), and the near-universal primary education mentioned earlier. It also has one of the highest rates of investment in physical capital (see the 44% in Table 7), part of which has been due to the encouragement to foreign investors to come in and develop its natural resources. Swaziland and the Congo, two more of the faster growing countries, also display (in Table 5) very high rates of investment in primary and secondary education with high percentages enrolled, accompanied by high 31-41% rates of investment in physical capital.

IV. Conclusion

New estimates of rates of return to investment in primary and secondary education of 21.2% based on different kinds of data provide independent confirmation of both the high growth pay-off from this type of investment and of the 21.7% average rates obtained in individual country studies. Differences in rates of return to education for individual countries (if any) demonstrate a dummy variable technique capable of estimating rates of return for the 18 African countries for which as of this date individual country-specific rate of return studies do not exist.

Returns to investment in higher education are also found to be high, and at 20.3%, also above the rates of return to investment in physical capital. This suggests continuing serious underinvestment in education, including higher education in Africa, perhaps partly because of the inefficiency and inequity implicit in the failure to recover more resources from the families of higher income students in many of these countries, resources that could be used to expand access through two year non-residential colleges, higher primary and secondary retention rates, improved quality, and other means.

Science and technology as well as technology transfer for development is treated here within the context of a vintage human and physical capital model. Embodiment of the new knowledge and technology through investment that brings it to bear on production can help to explain the larger contribution of investment in higher education and in other forms of physical and human capital to per capita growth.

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Footnotes

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[1]Gross investment ($I_{\overline{K}}$, $I_{\overline{H}}$, and $I_{\overline{HE}}$) can be regarded as a reasonable and close first approximation of a change in a capital stock that exists when the capital stock is measured in current efficiency units ($\overline{K}$, $\overline{H}$, and $\overline{HE}$). This can be shown by differentiating the capital stocks with respect to time:

$$\partial\overline{K}/\partial t = e^{(\phi_1/\varepsilon_1)t} I_{\overline{K}} - \delta_K K$$

$$\partial\overline{H}/\partial t = e^{(\phi_2/\varepsilon_2)t} I_{\overline{H}} - \delta_H H, \text{ etc., (see Gapinski, 1982, p. 291).}$$

Here ϕ is the rate at which the new technology is embodied via gross investment ($I_{\overline{K}}$ and $I_{\overline{H}}$), and ε is the elasticity of output with respect to physical or human capital inputs.

The current period t serves as a base, since $\overline{K}$, $\overline{H}$, and $\overline{HE}$ are in current efficiency units. Therefore the unit weight, $e^{(\phi/\varepsilon)t} = 1$, applies to period t such that: $e^{(\phi/\varepsilon)(v-t)} = e^{(\phi/\varepsilon)(t-t)} = e^0 = 1$.

For the current period's investment:

$$\partial\overline{K}/\partial t = e^{(\phi_1/\varepsilon_1)t} I_{\overline{K}} - \delta_K K = e^0 I_{\overline{K}} - (\text{constant})$$

$$\partial\overline{K}/\partial t = I_{\overline{K}} \text{ less a constant.}$$

[2]See footnote 1.

[3]When the lag is eliminated, in results not shown here, the coefficient of the labor growth term in the productivity growth equation is exactly = $\left(\frac{MPP_N \cdot N}{Y} - 1\right)$ when labor's share is estimated as shown in equation (4), exactly as hypothesized. That is, the first coefficient in equations (13) and (14) add exactly to unity when the lag is eliminated.