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Education and Productivity in Developing Countries

An Aggregate Production Function Approach

Lawrence J. Lau
Dean T. Jamison
and
Frederic F. Louat

Education is an important determinant of aggregate real output and productivity, but its effect varies considerably across countries and regions — ranging from negative to more than 5 percent a year in this sample.

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The estimated rates of return to education are typically (often considerably) above 10 percent a year in real terms — a respectable rate of return. The rates of return are highest for primary education, and higher in countries where educated manpower is scarcer. And the durabili of educational capital can be as high as 50 years.

But the effect of education on real output has not been well documented. In particular, few published studies of aggregate production functions establish a statistically significant link between real GDP and the labor force's educational attainment. Lau, Jamison, and Louat found that education has had little effect on the aggregate real GDPs of a sample of Sub-Saharan African countries.

Now Lau, Jamison, and Louat have pooled data on 58 developing countries, from 1960 through 1986, to estimate an aggregate production function using as independent variables the quantities of capital, labor, land, average educational attainment of the labor force, and chronological time.

They measured the percentage change in a region's real GDP in response to an increase of one year in the average educational attainment of the working age population in 1985. The estimated effects range from negative to more than 5 percent a year.

The results suggest:

- A positive relationship between the level of primary schooling achieved and the size of its effect.

- A threshold of four years of schooling before primary school has an effect.

- The effect of secondary education seems to be independent of the level of secondary schooling attained, although local factors may predominate here — witness the negative effect estimated for South Asia.

They conclude that education is an important determinant of aggregate real output and productivity but that its effect varies considerably across countries and regions.

More research is needed to explain why education varies in its effectiveness, especially where the effect appears to be negative. They speculate that certain factors may influence the effect of primary and secondary education on aggregate real output — among them, a country's institutions, its organizations for production and distribution, the composition and skill requirements of its industries, the structure of education, and the incidence of war and pestilence.

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Education and Productivity in Developing Countries: An Aggregate Production Function Approach

Lawrence J. Lau, Dean T. Jamison and Frédéric F. Louat

1. Introduction

Education is well known to have a direct and positive effect on economic development, economic growth and productivity. For examples: Denison (1967, 1979), using a growth-accounting framework, found that between ten and fifteen percent of the growth in the real national income of the United States can be attributed to education[1]; Jamison and Lau (1982), summarizing more than thirty studies of the relationship between agricultural output and education around the world, estimated that each additional year of education achieved by the head of an agricultural household increases its annual agricultural output, holding the agricultural inputs constant, by an average of slightly less than two percent[2]; Lau and Yotopoulos (1989), on the basis of three years of intercountry data —— 1960, 1970 and 1980 —— assembled and constructed by Hayami and Ruttan (1985), estimated that every increase in the number of agricultural college and university graduates per ten thousand of the agricultural population of a country

[1]Denison also attributed similar, but somewhat smaller, percentages of the growth in real national income to education in other countries. See also Bowman (1980).

[2]See Jamison and Lau (1982), pp. 35-38.

increases annual agricultural output, holding the agricultural inputs constant, by approximately ten percent[1]. While the magnitudes of these effects are not exceptionally large, they can be economically significant because of the durability of educational capital which can be as high as fifty years.

There have also been numerous studies in which the economic benefit of education is measured in terms of its effect on the lifetime earnings of individual workers. The implied rate of return to the education is then estimated. This is the so-called "Human Capital" approach, pioneered by Schultz (1961). Psacharopoulos (1985) has summarized the many rate of return to education studies around the world. He found that the estimated rates of return to education are typically above, and sometimes considerably above, ten percent per annum in real terms, which is generally considered a very respectable rate of return. The rates of return are higher for lower levels of education, that is, they are the highest for primary education, followed, in descending order, by respectively secondary and higher education. They are also higher in countries where educated manpower is more scarce.

What are some of the channels through which education affects economic growth, productivity and development in general? First, education enhances the ability of an individual to perform standard tasks and to learn to perform new tasks. Second, education enhances the ability of an individual to receive and process new information. Third, education enhances the ability of individuals to communicate and therefore to coordinate activities with one another. Fourth, education enhances the ability of an individual to evaluate and adjust to changed circumstances. Fifth, education helps to reduce subjective uncertainty and unnecessary anxiety as well as fatalistic acceptance of the status quo and thereby enhances the probability of adoption of new technologies or practices by an individual. Finally, at higher levels, education also helps to bring about innovations in the production technology.

Moreover, there is evidence from the experience of many countries that education, by enabling the acquisition of the necessary skills by the workers, is in fact a complementary input to physical capital

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[1]See Lau and Yotopoulos (1989).

and technology. Having physical and financial capital as well as access to technology is not enough: there must be the skilled manpower to make use of these resources. For example, the successes of South Korea and Taiwan in developing their respective economies and the failure of Thailand, until recently, to develop hers, may be partially attributed to the relatively lower level of educational development in Thailand in the 1960's and 1970's. By the late 1980's, however, Thailand has finally caught up with the level of educational development achieved by South Korea and Taiwan in the early 1960's and is now well on her way to becoming the fifth "Newly Industrialized Economy" (NIE).

Despite the abundance of microeconomic level empirical evidence on the positive effect of education on productivity, at the aggregate, macroeconomic level, the effect of education on real output has not been well documented.[1] In particular, there are very few published studies of aggregate production functions that succeed in establishing a statistically significant direct link between real GDP and the educational attainment of the labor force. One reason why the effect of education is frequently found to be statistically insignificant in aggregate production function studies for individual countries is multicollinearity of the data on the inputs: capital stock, labor force (less so for employment), and educational attainment of the labor force. (The land input generally does not vary much.) The capital stock and labor force are usually heavily trended. Similarly, the average level of educational attainment of the working-age population typically shows slow and smooth increases over time. The consequence is that it is difficult if not impossible to identify the effects of capital and labor, let alone those of education and technical progress, separately, using time-series data from a single country. Moreover, the effects of scale are often confounded with those of technical change, especially if all the inputs have been increasing over time. Thus, additional restrictive assumptions (such as constant returns to scale in the physical inputs) frequently have to be made in order to obtain meaningful estimates.

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[1]Aggregate production function studies <u>for the agricultural sector</u> have found statistically significant positive effects of education on output. See, for example, Lau and Yotopoulos (1989).

The multicollinearity and the resulting non-identification of the key parameters of the aggregate production function can be overcome by pooling the time-series data of several countries and by standardizing the measurements of the inputs. Such an attempt was made by Jamison and Lau in an unpublished study of the aggregate real outputs of the countries of sub-Saharan Africa for the period 1960-1985. They found, contrary to expectation, that education has had little effect on the aggregate real GDPs of these countries. This finding may, however, be attributed to the unfavorable local conditions, the lack of complementary inputs, insufficient institutional capability, or failure to reach a critical threshold, rather than the general ineffectiveness of education per se.

It is therefore of both academic and practical interest to ascertain whether the finding for sub-Saharan Africa is applicable elsewhere. In this study, the data of 58 developing countries from 1960 through 1986 are pooled to estimate an aggregate production function with the quantities of capital, labor and land, average educational attainment of the labor force, and chronological time as the independent variables.

2. The Model

Aggregate real output, the dependent variable of the production function, is measured as the real GDP in constant 1980 U.S. dollars. The independent variables consist of the quantity of the capital stock at the end of the previous year, also in 1980 U.S. dollars, multiplied by an estimated country-specific rate of utilization for the current year, and the quantities of labor force and arable land for the current year. In addition, there is a variable measuring the average number of years of schooling, both separately and together for primary and secondary education, per person of working age, defined to be 15-64. Tertiary education was omitted because data are available for very few countries.

The basic maintained hypothesis of the study is that all countries have the same underlying production function in terms of standardized inputs. However, countries may differ in terms of the definitions and qualities of their measured inputs and in their levels of technical efficiencies in production Thus,

$$(2.1) \qquad Y_{it} = A_{i0}(t)\ F(K^{*}_{it}, L^{*}_{it}, T^{*}_{it}, E^{*}_{it})$$

where Y_{it} is the quantity of real output of the ith country in period t, $A_{i0}(t)$ is an index of technical efficiency (the ability of producing output from given inputs) of the ith country in period t, and K^{*}_{it}, L^{*}_{it}, T^{*}_{it}, E^{*}_{it} are the standardized (or efficiency equivalent) quantities of physical capital, labor, land and educational capital of the ith country in period t respectively. Note that the production function, F(.), is the same for all countries.

However, the quantities of standardized inputs can not be directly observed. It is assumed that the quantities of measured inputs may be converted into standardized inputs through multiplicative factors called augmentation factors. Specifically,

$$(2.2) \qquad X^{*}_{it} = A_{iX} X_{it} \quad , \qquad X = K, L, T, E$$

Note that the augmentation factors are country as well as input specific. For one reference country, A_{iX} may be set equal to one for all X. This is equivalent to standardizing all inputs in terms of the inputs of that country. For example, if China is selected to be the reference country and Indian physical capital is fifty percent more effective than Chinese capital, then $A_{CK} = 1$ and $A_{IK} = 1.5$ where the subscripts C and I refer to China and India respectively. These augmentation factors are also not directly observable.[1]

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[1]It turns out that country and input-specific standardization or conversion factors can in fact be separately identified and estimated from the data under some circumstances. See Lau and Yotopoulos (1989) and Boskin and Lau (1990).

In this study, the aggregate production function is assumed to have the Cobb-Douglas form, so that :

$$\text{(2.3)} \qquad \ln Y_{it} = \ln A_{i0}(t) + \sum_{X=K,L,T,E} \beta_X \ln X^*_{it}$$

It is further assumed that the technical efficiency factors take the form :

$$\text{(2.4)} \qquad A_{i0}(t) = A_{i0} \exp(\delta_R D_{iR}.t)$$

where D_{iR} is a dummy variable which takes the value one if the ith country is in the Rth region and δ_R may be interpreted as the rate of growth of total factor productivity (or equivalently technical change) in the Rth region. Under these assumptions, the production function in equation (2.3) may be rewritten as:

$$\begin{aligned} \text{(2.5)} \qquad \ln Y_{iT} &= \ln A_{i0} + \sum_R \delta_R D_{iR}.t + \sum_{X=K,L,T,E} \beta_X \ln X^*_{it} \\ &= \ln A_{i0} + \sum_R \delta_R D_{iR}.t + \sum_X \beta_X (\ln A_{iX} + \ln X_{it}) \\ &= (\ln A_{i0} + \sum_X \beta_X \ln A_{iX}) + \sum_R \delta_R D_{iR}.t + \sum_X \beta_X \ln X_{it} \\ &= \ln A^*_{i0} + \sum_R \delta_R D_{iR}.t + \sum_X \beta_X \ln X_{it} \end{aligned}$$

Equation (2.5) relates the quantity of measured real output to the quantities of measured inputs and chronological time. Note that all the augmentation factors collapse into single country-specific multiplicative factors, which, upon the taking of natural logarithms, become country-specific intercept terms in the regression equation. Thus, the augmentation factors themselves cannot be separately identified in this case.[1]

In this study, the aggregate Cobb-Douglas production function is represented in the natural logarithmic form, with all the variables, except chronological time, expressed in terms of their natural logarithms. Thus, the parameters may be interpreted as production elasticities. The elasticity of educational capital is, however, allowed to differ across geographic regions. Five regions are distinguished: Sub-Saharan Africa, East Asia, Latin America, Middle East-North Africa, and South Asia. Three different measures of educational capital are used —— primary education, secondary education, and primary and secondary education together. In addition, the trend rates of growth of total factor productivity, or equivalently the trend rates of growth of output net of the growth of inputs, are also allowed to differ across regions as well as between pre- and post-1980. These trends reflect not only the influence of technical progress, but also other regional or worldwide factors, for example, the macro-climatic change in Sub-Saharan Africa, the slowdown of world trade and the drying-up of credit and aid flows to the developing world in the 1980s, depletion of natural resources, the rising public concern for the environment in the newly industrialized economies, and the decline in the average length of the workweek, etc.

The aggregate Cobb-Douglas production function is estimated, after the natural logarithmic transformation, in the first-differenced form, by ordinary least-squares. The rationale for using the first-differenced form lies in our assumption concerning the stochastic disturbance term in the production function. We assume that the stochastic disturbance term represents mostly technical change, which, while unpredictable, has persistent effects on current as well as future outputs once it has occurred. This may be contrasted to the case in which the stochastic disturbance term represents mostly weather, the

[1]The non-identification of input-specific augmentation factors is well-known for the Cobb-Douglas case. With other production functions, such as the transcendental logarithmic production function introduced by Christensen, Jorgenson and Lau (1973), the augmentation factors can in fact be separately identified and estimated.

effect of which is transitory and confined to the output of the current period. The use of ordinary least-squares may be justified by the fact that the capital stock of the previous year, the labor force and land are either pre-determined or exogenous and that whatever country-specific effect there may be have been taken into account. In principle, however, the rate of utilization is endogenous, and one may wish to use the method of instrumental variables. Finding a set of country-specific instrumental variables that work for the entire sample is no easy task. Limited experimentation suggests that the resul of the instrumental variables estimation will not be qualitatively different from those of ordinary least-squares as long as the chosen set of instrumental variables can explain the rate of utilization adequately.

3. The Data

The principal source of data used in this study is the Bank Economic and Social Database (BESD) of the World Bank, which consists of a compilation of various databases from different sources (including the International Labour Office (ILO), the International Monetary Fund (IMF), the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the World Bank itself).

The sample analyzed in this study consists of a set of 58 developing countries from five regions of the world. 26 countries are located in Sub-Saharan Africa, 7 in East Asia, 15 in Latin America, 6 in the Middle East-North Africa region (MENA) and 4 in South Asia. Other developing countries have been excluded from the sample solely on the basis of data unavailability, with the exception of four European countries (Hungary, Malta, Portugal and Yugoslavia) which have been excluded because their historical development experiences, both economic and educational, were not directly comparable with those of the more typical developing countries. The complete list of countries in the sample is presented in Appendix 1.

The aggregate real output of each country is measured by its real GDP in constant 1980 U.S. dollars, data on which are taken directly from BESD. The aggregate level of labor input is measured by its labor force. The aggregate level of land input is measured by its quantity of arable land. All of these variables are taken directly from BESD. Data on another possible measure of aggregate labor input, employment, are unfortunately not generally available for the countries and the time period under study.

The construction of the physical and the educational capital stocks deserves some explanation. The estimation of a time series of physical capital stocks for each country begins with the compilation and/or estimation of a time series of gross domestic investments (or gross domestic fixed investments whenever available) for each country for as long a time period as possible.[1] Once such a time series is available, the time series of physical capital stocks can be estimated by the perpetual inventory method given the capital stock of any benchmark year, assuming an annual depreciation rate of, say, 5 percent.[2] Unfortunately, benchmark year capital stocks are not generally available for the countries in the sample. It has therefore been necessary to estimate a benchmark year capital stock for each country.

The procedure used in this study is as follows. Both the capital stocks and gross domestic (fixed) investments of all countries in the sample are assumed to be zero in 1945. Linear interpolation is used to fill out the missing years of data on gross domestic (fixed) investments in 1980 U.S. dollars up to 1960 or the first year for which data are available. On the basis of the time series of investments so obtained, the perpetual inventory method is used to generate the time series of capital stocks, assuming that they

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[1]Gross domestic investment is the sum of gross domestic fixed investment and net change in stocks (inventory). It is generally larger than gross fixed investment, though not necessarily so. Thus, a time series of capital stocks constructed with a gross domestic investment series is likely to be different from that constructed with a gross domestic fixed investment series. However, as long as the ratio of gross domestic fixed investment to gross domestic investment is approximately constant for each country within the sample period, the estimation results for the aggregate production function will not be materially affected.

[2]The formula used to construct the capital stock is:

$$K_t = 0.95 \cdot K_{t-1} + I_t$$

were zero in 1945 and a rate of depreciation of 5 percent per annum.[1]

One may object to the realism of our assumption of a zero capital stock in 1945 for all the developing countries. Obviously not all of the physical capital stock vanished during World War II. However, with a rate of depreciation of 5 percent per annum, physical capital stock depreciates totally in approximately twenty years. The error introduced by assuming a zero capital stock in 1945 is likely to be small in the early 1960s and immaterial thereafter. In any case, given the presence of country-specific constant terms in the aggregate production function (prior to first-differencing), only the rates of growth of the physical capital stocks matter, the absolute values do not. Thus, our estimation results are unlikely to be sensitive to (reasonable) alternative estimates of the benchmark year capital stocks.

Finally, a time series of annual rates of utilization of the capital stock is estimated for each country as the ratios of actual real GDP to potential real GDP. The potential real GDP series is constructed with the "convex hull" method, a variant of the "peak-to-peak" method. Starting with a plot of the time series of actual real GDP against chronological time, the time series of potential real GDP is given by the lowest concave (with respect to time) curve the value of which in each period is greater than or equal to the actual real GDP for that period. The rate of utilization is then estimated as the ratio of actual real GDP to potential real GDP: its value is therefore always between zero and one. The time-series of utilization rates thus obtained for each country is multiplied to the estimated time series of capital stocks to generate a time-series of "utilized capital stocks" which are used in the actual estimation of the aggregate production function.

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[1]Other alternative methods can be used to provide estimates of the benchmark year capital stocks. For example, it is possible to use the average rate of growth of investment during the 1960s in each country to generate estimates of investments for years prior to 1960. The estimated time series of investments will reach zero not necessarily in 1945 and certainly not at the same time for all the countries. However, this method generates meaningful results only if the average rate of growth of investment during the 1960s is similar to the average rate prior to 1960. In certain countries with high rates of investment in the early 1960s, especially those which won independence at about the same time, this assumption is obviously unreasonable.

In the case of the educational capital stocks, the difference between stocks and flows is even more important because of the time lag between investment (school enrollment) and addition to the human capital stock (entry into the labor force) and because of the much longer durability of human capital compared to physical capital. The educational capital stock is defined as the total number of person-school years among the working age population (those aged 15-64). The estimation of a time series of educational capital stocks for each country begins, analogous to the case of the estimation of physical capital stocks, with the compilation and/or estimation of a time series of annual school enrollment figures separately for primary and secondary general education for each country for as long a time period as possible. Once such a time series is available, the time series of educational capital stocks can be estimated by the perpetual inventory method, assuming no depreciation, no mortality and no migration during the working lives of individuals. For the period 1900-1960 (which is generally the first year of availability of the data), annual school enrollments are separately estimated for primary and secondary general education, based on backward trend extrapolation from the available actual data. Ordinary least-squares regressions are used to estimate these country-specific trends. However, if any backcasted annual enrollment figure is negative, it is automatically set equal to zero. With the estimated time series of annual school enrollments, the total number of person-school-years in the population of working age (15-64 years), which is the total number of years of schooling completed by all individuals belonging to this age group, can be calculated.[1] The average number of years of schooling completed per person of working age is obtained by dividing the total stock of person-school-years by the size of the working age population in each period. Mortality during the working life is ignored in the estimation of the educational capital stock because of lack of data. Taking mortality into account would require age-specific mortality rates as a time-series for each country; in addition one would need to assume that they

[1]Unfortunately, the data available consist of only gross annual school enrollments at the primary and secondary levels and do not distinguish repeaters separately. Thus, the number of completed school years does not necessarily correspond to and in general will overstate the educational levels attained.

do not differ across levels of educational attainment. Because mortality is ignored, our estimates of both the educational capital stock and the average number of years of schooling completed per person of working age are likely to be biased upward.[1]

In the following tables we present the average years of schooling completed per person in the labor force, for primary, secondary, and total education, by region. The ratio of completed years of primary education to completed years of secondary education is also presented in Table 4.

[1]There are undoubtedly many other ways of estimating the annual enrollment figures for the pre-1960 period. It is our belief that short of attempting to collect actual school enrollment data on a country-by-country basis it is unlikely that there will be an unequivocally better method.

Table 1 Average years of primary education, by region

	Africa	East Asia	Mena	Latin America	South Asia
1965	0.85	2.26	1.51	1.78	2.47
1975	1.79	3.79	2.83	3.29	3.38
1985	2.91	4.80	4.01	4.79	3.81

Table 2 Average years of secondary education, by region

	Africa	East Asia	Mena	Latin America	South Asia
1965	0.03	0.13	0.16	0.17	0.12
1975	0.12	0.56	0.49	0.52	0.46
1985	0.34	1.18	0.99	0.98	0.96

Table 3 Average years of total education, by region

	Africa	East Asia	Mena	Latin America	South Asia
1965	0.88	2.38	1.67	1.95	2.59
1975	1.91	4.34	3.32	3.81	3.84
1985	3.25	5.98	5.00	5.77	4.77

Table 4 Ratio of primary education attainment to secondary education attainment

	Africa	East Asia	Mena	Latin America	South Asia
1965	31.72	18.02	9.28	10.52	21.00
1975	14.72	6.81	5.74	6.31	7.29
1985	8.60	4.08	4.07	4.89	3.99

We note that the ranking of educational attainment by regions has changed over time. For primary education, South Asia has apparently stagnated. East Asia has pulled ahead in both primary and secondary education. We also note that the educational structure of Africa is quite different from those of the other regions: Africa seems to have a much smaller ratio of secondary to primary educated individuals in its labor force.

Psacharopoulos and Arriagada (1986) have estimated mean years of schooling attained by the labor force for different countries around the world that can conceivably be used as a substitute for our estimated educational capital stocks.[1] However, they only provide data for isolated points in time for each country and not a time-series. It has not been possible to generate, from their data, a meaningful time-series for the countries and period covered in this study. Nor has it been possible to apply their methodology to fill in the data gaps, principally because census data are not available for many countries, especially for the early years. In Appendix 2 we present a more detailed comparison between the estimates of Psacharopoulos and Arriagada (1986) and ours.

For almost all of the countries in the sample[2], data are available for all of the variables from 1960 to 1987 and that is the period used for the estimation of the aggregate production function.

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[1]They use attainment rates provided by Kaneko (1986), who utilizes data from reports of the censuses undertaken worldwide from 1975 to 1984.

[2]The only exceptions are Hong Kong and Singapore, the education data for which are not available for 1987 at the time of the study.

4. The Estimation Results

The results for four alternative specifications of the educational capital stock variables —— primary education, secondary education, the sum of primary and secondary education, and primary and secondary education separately —— are presented in Tables 5 and 6. We first test the hypothesis that the educational effects are the same for all regions. This hypothesis can be rejected for all four specifications at the 0.01 percent level of significance. Similarly, the hypothesis of no educational effects can also be rejected. The hypotheses that the growth trends are independent of the regions and that there is no break in the trend between pre-1980 and post-1980 can also be rejected at the 0.01 percent level of significance (See Table 7).

Table 5 Alternative specifications of the aggregate production function with region-specific effects of education

Variable	Model with primary education	Model with secondary education	Model with total education	Model with both levels of education
Capital	.601 (49.8)	.608 (51.2)	.602 (50.1)	.608 (51.2)
Land	.047 (2.11)	.044 (2.01)	.049 (2.20)	.047 (2.15)
Labor	.191 (1.86)	.260 (2.61)	.223 (2.18)	.224 (2.20)
Primary Educ. (Africa)	-.009 (0.87)	—	—	-.038 (2.06)
Primary Educ. (East Asia)	.226 (5.10)	—	—	.144 (2.74)
Primary Educ. (Mena)	-.021 (0.75)	—	—	-.045 (1.57)
Primary Educ. (Lat. Americ)	.128 (3.29)	—	—	.062 (1.07)
Primary Educ. (South Asia)	.003 (0.07)	—	—	.062 (1.30)
Second. Educ. (Africa)	—	.012 (2.48)	—	.020 (3.20)
Second. Educ. (East Asia)	—	.061 (5.33)	—	.039 (2.80)
Second. Educ. (Mena)	—	.051 (4.09)	—	.056 (4.38)
Second. Educ. (Lat. Americ)	—	.037 (3.42)	—	.025 (1.52)
Second. Educ. (South Asia)	—	-.073 (2.92)	—	-.087 (3.23)
Total Educ. (Africa)	—	—	-.009 (0.80)	—
Total Educ. (East Asia)	—	—	.199 (4.05)	—
Total Educ. (Mena)	—	—	.075 (1.72)	—
Total Educ. (Lat. Americ)	—	—	.135 (3.51)	—
Total Educ. (South Asia)	—	—	.037 (1.05)	—
Dummy 1960-79 (Africa)	.004 (0.88)	-.003 (0.58)	.005 (0.97)	.006 (1.11)
Dummy 1980s (Africa)	.030 (5.57)	.028 (5.37)	.032 (5.74)	.031 (5.87)
Dummy 1960-79 (East Asia)	—	—	—	—
Dummy 1980s (East Asia)	—	—	—	—
Dummy 1960-79 (Mena)	.014 (2.33)	-.001 (0.14)	.005 (0.69)	.009 (1.40)
Dummy 1980s (Mena)	.029 (4.24)	.024 (3.64)	.027 (3.79)	.028 (4.07)
Dummy 1960-79 (Lat. Americ)	-.007 (1.27)	-.006 (1.33)	-.008 (1.30)	-.003 (0.59)
Dummy 1980s (Lat. Americ)	.016 (2.69)	.017 (3.08)	.016 (2.72)	.018 (3.10)
Dummy 1960-79 (South Asia)	.003 (0.50)	.016 (2.19)	.001 (0.18)	.018 (2.39)
Dummy 1980s (South Asia)	.031 (3.95)	.034 (4.53)	.031 (3.96)	.035 (4.62)
Dummy 1960-79	-.009 (1.59)	-.009 (1.72)	-.010 (1.80)	-.013 (2.41)
Dummy 1980s	-.038 (6.73)	-.039 (7.24)	-.040 (7.03)	-.040 (7.31)
Number of observations	1506	1477	1506	1477
Adjusted R-square	0.785	0.795	0.786	0.796

Notes :

1 All variables except dummy variables are in the form of first-differences of natural logarithms.

2 East Asia is chosen as the base region. Its dummy variables are therefore omitted from the regression equation.

3 Numbers in parentheses are t-ratios.

Table 6 Alternative specifications of aggregate production function without region-specific effects of education

Variable	Model with primary education	Model with secondary education	Model with total education	Model with both levels of education
Capital	.596 (49.4)	.600 (50.4)	.596 (49.4)	.600 (50.3)
Land	.046 (2.05)	.048 (2.16)	.047 (2.08)	.047 (2.14)
Labor	.210 (2.04)	.297 (2.96)	.223 (2.18)	.275 (2.70)
Primary Educ.	.008 (0.81)	—	—	-.019 (1.35)
Second. Educ.	—	.023 (5.74)	—	.026 (5.54)
Total Educ.	—	—	.016 (1.60)	—
Dummy 1960-79 (Africa)	-.015 (4.48)	-.015 (4.58)	-.015 (4.60)	-.014 (4.35)
Dummy 1980s (Africa)	.024 (4.46)	.024 (4.58)	.024 (4.44)	.024 (4.64)
Dummy 1960-79 (East Asia)	—	—	—	—
Dummy 1980s (East Asia)	—	—	—	—
Dummy 1960-79 (Mena)	-.006 (1.34)	-.004 (0.92)	-.005 (1.32)	-.003 (0.75)
Dummy 1980s (Mena)	.023 (3.35)	.023 (3.43)	.023 (3.34)	.023 (3.47)
Dummy 1960-79 (Lat. Americ)	-.014 (4.16)	-.013 (3.77)	-.014 (4.14)	-.012 (3.72)
Dummy 1980s (Lat. Americ)	.014 (2.51)	.015 (2.65)	.014 (2.51)	.015 (2.68)
Dummy 1960-79 (South Asia)	-.013 (2.84)	-.011 (2.44)	-.013 (2.82)	-.011 (2.42)
Dummy 1980s (South Asia)	.025 (3.30)	.026 (3.47)	.025 (3.31)	.026 (3.47)
Dummy 1960-79	.008 (1.74)	-.000 (0.01)	-.007 (1.49)	.001 (0.30)
Dummy 1980s	-.032 (5.86)	-.037 (6.74)	-.033 (5.98)	-.036 (6.54)
Number of observations	1506	1477	1506	1477
Adjusted R-square	0.781	0.790	0.781	0.790

Notes :

1 All variables except dummy variables are in the form of first-differences of natural logaritms.

2 East Asia is chosen as the base region. Its dummy variables are therefore omitted from the regression equation.

3 Numbers in parentheses are t-ratios.

Table 7 Tests of hypotheses

	Model with primary education	Model with secondary education	Model with total education	Model with both levels of education
Hypothesis (1)				
D.F.	4	4	4	8
F Value	9.42	9.33	9.32	6.60
Prob > F	0.0001	0.0001	0.0001	0.0001
Hypothesis (2)				
D.F.	5	5	5	10
F Value	7.67	14.20	7.76	8.86
Prob > F	0.0001	0.0001	0.0001	0.0001
Hypothesis (3)				
D.F.	8	8	8	8
F Value	6.34	5.82	5.73	6.11
Prob > F	0.0001	0.0001	0.0001	0.0001
Hypothesis (4)				
D.F.	5	5	5	5
F Value	6.67	7.46	6.15	5.59
Prob > F	0.0001	0.0001	0.0001	0.0001
Hypothesis (5)				
D.F.	1	1	1	1
F Value	2.26	0.72	1.43	1.28
Prob > F	0.133	0.395	0.233	0.259

Note :

D.F. are degrees of freedom of the constraint.

Hypothesis (1) : Educational effects are the same for all regions.

Hypothesis (2) : Educational effects are zero.

Hypothesis (3) : Growth trends are independent of region.

Hypothesis (4) : Growth trends are the same between pre-1980 and post-1980.

Hypothesis (5) : Constant returns to scale in capital, labor and land.

Table 8 Percentage change in real GDP in response to an additional year of education per person of working age in 1985

		Africa	East Asia	Mena	Latin America	South Asia
Primary	(1)	-0.31	4.71	-0.52	2.67	0.08
Secondary	(2)	3.55	5.17	5.13	3.82	-7.67
Total	(3)	-0.26	3.32	1.51	2.34	0.77
Primary	(4)	-1.32	3.01	-1.12	1.29	1.64
Secondary	(4)	5.79	3.28	5.65	2.52	-9.09

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(1) Calculated from Table 5, column 1.
(2) Calculated from Table 5, column 2.
(3) Calculated from Table 5, column 3.
(4) Calculated from Table 5, column 4.

The estimated capital, labor and land elasticities —— respectively 0.6, 0.2 and 0.05 approximately —— are quite stable across the different specifications and rather reasonable for developing countries. (For developed countries, the capital elasticity would have been expected to be much lower (0.4) and the labor elasticity much higher (0.6).) The land elasticity is low, but not unreasonably so, considering that the non-agricultural part of real GDP does not depend on the quantity of arable land.

The sum of the estimated production elasticities of the physical inputs, capital, labor and land, is 0.85, suggesting that there are perhaps decreasing returns to scale in the physical production inputs. However, the hypothesis of constant returns to scale cannot be rejected in all four of the specifications at the 10 percent level of significance.[1] Finally, the estimated regional trends of growth, net of the growth in inputs (or equivalently, the rates of technical progress) range between -4 and -1 percent per annum. They appear quite reasonable in light of what is known about the economic development of the different regions. For example, there was a significant slowdown in the growth of total world imports in the 1980's which affected adversely the rates of growth of the countries of the East Asian region.

The estimated educational elasticities vary significantly across regions. For East Asia and Latin America, they are almost always consistently statistically significant and positive. For both Africa and Middle East and North Africa, primary education appears to have negative, but mostly statistically insignificant effects whereas secondary education has consistently statistically significant positive effects. For South Asia, primary education is generally statistically insignificant whereas secondary education has a statistically significant negative effect. It is interesting to note from Table 6 that if the educational elasticities are constrained to be the same across regions, primary education is not statistically significant whereas secondary education is positive and statistically significant.

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[1]The estimation results do not change materially when the restrictions implied by the hypothesis of constant returns to scale in the physical inputs are imposed on the aggregate production function. These results are presented in Appendix 3.

5. Concluding Remarks

What do these educational elasticities mean? In Table 8 the estimated mean percentage change in the real GDP of the region in response to an increase of one year in the average educational attainment of the working age population in 1985 are presented for each category of education. The estimated effects range from negative to over 5 percent per annum. The estimated effects are plotted against the average educational attainments in Figures 1 through 3. The results are suggestive of a positive relationship between the size of the effect of primary education and the level of its attainment, indicating the possible existence of a threshold of 4 years for primary education to have a significant impact. Similar thresholds for the effectiveness of primary education have been found in microeconomic level studies. The effect of secondary education appears to be independent of the level of secondary educational attainment, although here local factors may predominate, as witnessed by the large negative estimated effect for South Asia.

We conclude that education is an important determinant of aggregate real output and productivity but that its effect varies considerably across countries and regions. Further research is necessary in order to explain the variability of its effectiveness, especially where the effect appears to be negative. It is speculated that the institutions, the organizations for production and distribution, the industrial composition and its skill requirements, the structure of education[1], and war and pestilence may all have played a role in determining the effect of primary and secondary education on aggregate real output.

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[1]This includes the composition of the educational capital stock by primary, secondary and tertiary as well as the rate of progression through the educational process. For example, students who continue to advance educationally are effectively removed from the labor force for the duration. The educational system may also select out the best students to continue. All of these considerations tend to lower the effective educational capital stock in the short to intermediate term.

Figure 1

Effect of one Additional Year of Primary Education per Person on Real GDP (%)

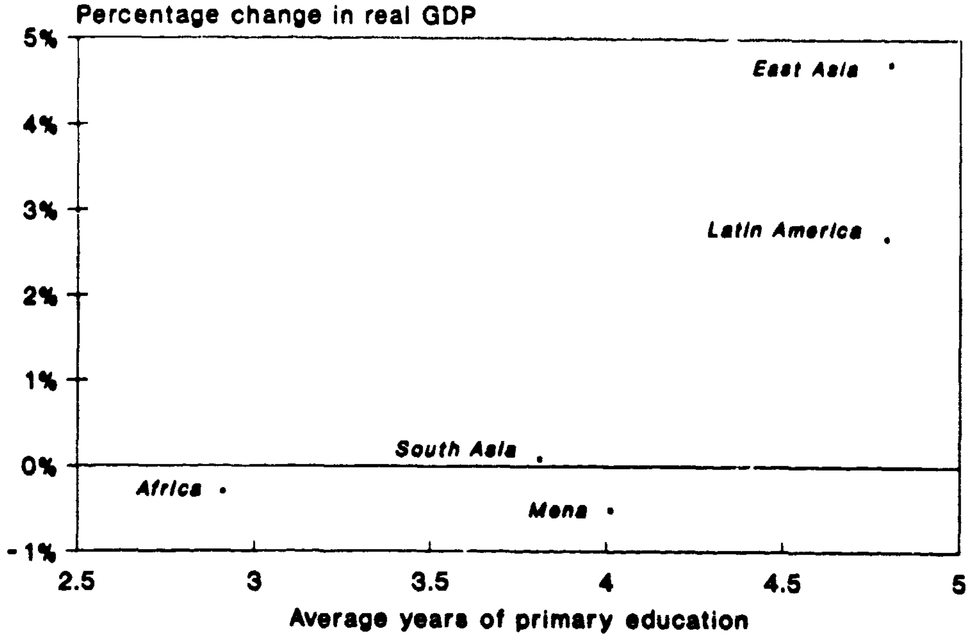


Figure 2

Effect of one Additional Year of Secondary Education per Person on Real GDP (%)

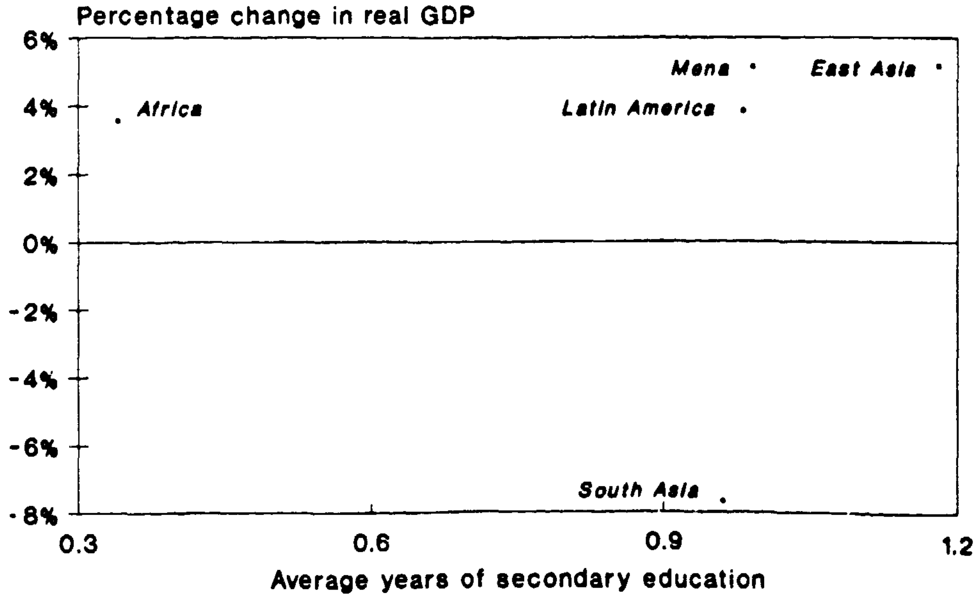
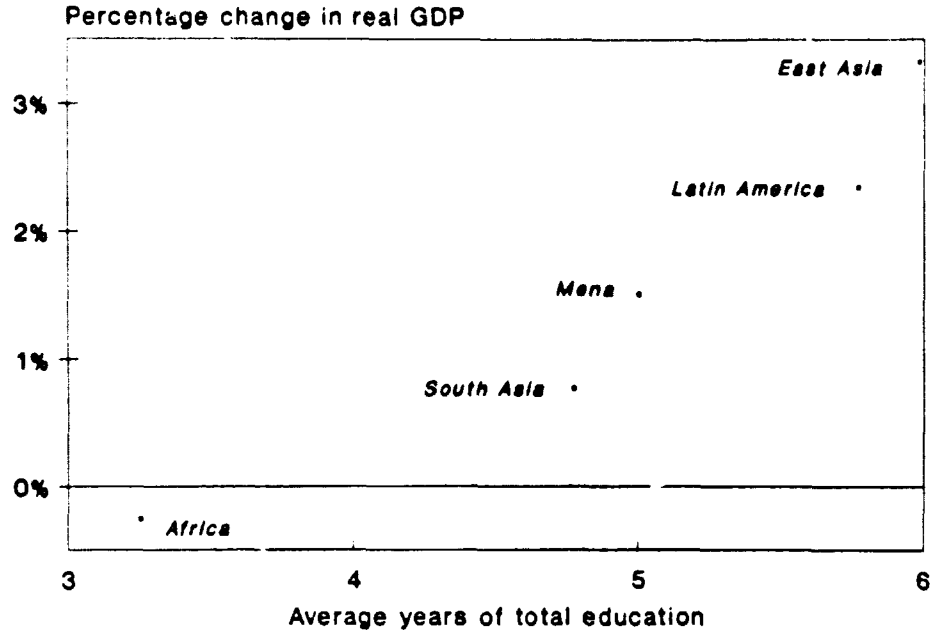


Figure 3

Effect of one Additional Year of Total Education per Person on Real GDP (%)



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APPENDIX 1

List of Countries in the Sample, by Region

AFRICA

Benin
Burkina Faso
Burundi
Cameroon
Central African Republic
Congo, People's Republic of
Cote d'Ivoire
Ethiopia
Gabon
Kenya
Liberia
Madagascar
Malawi
Mali
Mauritania
Mauritius
Nigeria
Rwanda
Senegal
Sudan
Tanzania
Togo
Uganda
Zaire
Zambia
Zimbabwe

EAST ASIA

Hong Kong
Indonesia
Korea, Republic of
Malaysia
Philippines
Singapore
Thailand

LATIN AMERICA

Argentina
Bolivia
Brazil
Chile
Colombia
Costa Rica
El Salvador
Guatemala
Haiti
Jamaica
Mexico
Nicaragua
Panama
Peru
Venezuela

MIDDLE EAST-NORTH AFRICA

Algeria
Egypt, Arab Republic of
Israel
Morocco
Syrian Arab Republic
Turkey

SOUTH ASIA

Bangladesh
India
Pakistan
Sri Lanka

APPENDIX 2

Comparison of Estimates of Educational Capital Stocks

In this Appendix we compare the estimates of educational capital stocks used in this study with those constructed by Psacharopoulos and Arriagada (1986). In Appendix-Table 1, we present both sets of estimates of total years of education side by side for the years for which the latter estimates are available.

The two sets of estimates appear quite different. There are many reasons why they should be expected to be different. The first reason has to do with the differences in the definitions of total education. Psacharopoulos and Arriagada (1986) include in their estimate of total education not only primary and secondary school years but tertiary (post-secondary) as well. By construction, our estimates of total education are simply the sums of our estimates of primary and secondary education and do not include post-secondary school years. Thus, the Psacharopoulos and Arriagada (1986) estimates can be expected to be higher, which they generally are, with some exceptions. For example, except for South Asia, our regional averages are between 17 and 26 percent lower than those of Psacharopoulos and Arriagada (1986). For South Asia, our regional average is much higher than that of Psacharopoulos and Arriagada (1986), due principally to the difference in the estimates for Sri Lanka (with ours being 9.0 and theirs being 6.2). The omission of post-secondary schooling years from our estimates also accounts for the generally lower variability (as reflected by the standard deviation) of our estimates of educational capital intensity across countries within the same region. However, the estimates of Psacharopoulos and Arriagada (1986) refer to years of education attained, whereas our estimates refer to years of education completed. In general, we expect the latter to be slightly higher than the former because of the presence of repeaters. Differences in mortality and survival rates between the educated and the uneducated may also have an effect on our estimates.

The second reason has to do with the source of the data. Psacharopoulos and Arriagada (1986) rely ultimately on census data, which depend on the accuracy and reliability of the individual recall and responses. Our estimates depend only on the accuracy of the educational statistics and our "backcasting" procedure.

In order to assess the degree of agreement between the estimates of Psacharopoulos and Arriagada (1986) and ours, we compute the correlation coefficient as well as the Spearman's rank correlation coefficient between the two sets of estimates for comparable years. The results are presented in Appendix Table 2. The general agreement is reasonably good, although on a region-by-region basis the correlation between the two sets of estimates is weak for sub-Saharan Africa and East Asia.

In any case, given the presence of country-specific constant terms in the aggregate production function (prior to first-differencing), only the rates of growth of the educational capital stocks matter, the absolute values do not. However, Psacharopoulos and Arriagada (1986) typically present data for a country for only a single year. Thus it is not possible to make a comparison between the estimates of the growth rates.

APPENDIX - TABLE 1

Alternative Estimates of Mean Years of Schooling

	Year	Psacharopoulos and Arriagada (1986)		This Study	
Côte d'Ivoire	1978	3.2		1.6	
Cameroon	1976	2.2		2.4	
Ethiopia	1978	2.6		0.4	
Kenya	1980	3.5		3.4	
Liberia	1974	1.3		1.4	
Mali	1976	0.5		0.6	
Mauritius	1972	4.5		5.3	
Nigeria	1967	0.8		4.4	
Rwanda	1978	2.2		2.8	
Sudan	1974	5.5		0.9	
Senegal	1976	2.9		1.1	
Zambia	1979	5.5		3.4	
Regional Average	—	2.9	(1.66)	2.3	(1.58)
Hong Kong	1981	8.8		4.2	
Indonesia	1978	3.9		3.2	
Korea	1980	8.0		5.2	
Malaysia	1967	5.0		5.2	
Philippines	1980	7.0		5.0	
Singapore	1974	5.3		4.8	
Thailand	1974	4.1		4.8	
Regional Average	—	6.0	(1.93)	4.6	(0.72)
Algeria	1977	4.0		2.8	
Egypt	1976	3.3		3.3	
Morocco	1971	1.2		1.3	
Syrian Ar	1975	4.1		3.2	
Turkey	1980	5.1		3.8	
Regional Average	—	3.5	(1.46)	2.9	(0.95)
Argentina	1960	6.2		4.5	
Bolivia	1976	6.3		3.4	
Brazil	1980	5.6		3.8	
Chile	1981	8.1		6.1	
Colombia	1978	5.0		3.7	
Costa Rica	1973	6.4		3.5	
Guatemala	1973	3.0		1.6	
Haiti	1982	1.6		3.2	
Jamaica	1978	6.9		6.8	
Mexico	1977	4.5		3.8	
Nicaragua	1971	4.4		1.8	
Panama	1970	4.6		3.5	
Peru	1981	7.0		5.0	
Venezuela	1979	6.2		5.3	
Regional Average	—	5.4	(1.71)	4.0	(1.45)
Bangladesh	1981	2.4		2.8	
India	1981	1.9		3.3	
Sri Lanka	1971	6.2		9.0	
Pakistan	1975	1.2		1.3	
Regional Average	—	2.9	(2.24)	4.1	(3.38)

Standard deviations of regional means are in parenthesis.

APPENDIX - TABLE 2

Correlation between the Estimates of Total Years of Schooling

Type of observations	Sample size	Spearman's rank correlation coefficient	Correlation coefficient
All Comparable Countries	42	.712 (.087)	.644 (.082)
Regions	5	.700 (.351)	.694 (.237)
Countries Sorted by Region			
Africa	12	.216 (.320)	.199 (.307)
East Asia	7	.273 (.473)	.277 (.351)
Mena	5	.700 (.351)	.932 (.068)
Latin America	14	.736 (.147)	.728 (.095)
South Asia	4	.800 (.300)	.987 (.012)

Asymptotic standard errors are in parentheses.

APPENDIX 3

Estimation Results under Constant Returns to Scale

In Appendix Table 3 we present the estimation results of the aggregate production function with region-specific effects of education when the restriction implied by constant returns to scale in the physical inputs is imposed[1]. Constant returns to scale imply that the production elasticities of capital, labor and land sum to unity. A comparison of Appendix Table 3 and Table 5 indicates that the estimation results are qualitatively very similar.

[1]The restriction appears in the regression as a Lagrangian multiplier of a constrained optimization problem.

APPENDIX - TABLE 3

Alternative specifications of the aggregate production function with region-specific effects of education, under constant returns to scale

Variable	Model with primary education	Model with secondary education	Model with total education	Model with both levels of education
Capital	602	609	603	.610
	(50.1)	(51.6)	(50.3)	(51.5)
Land	.056	.049	.056	.054
	(2.65)	(2.36)	(2.64)	(2.58)
Labor	.341	.342	.341	.337
	(16.1)	(16.3)	(16.1)	(16.2)
Primary Educ. (Africa)	-.007	—	—	-.037
	(0.67)			(2.01)
Primary Educ. (East Asia)	.229	—	—	.165
	(5.16)			(2.75)
Primary Educ. (Mena)	-.011	—	—	-.037
	(0.42)			(1.35)
Primary Educ. (Lat. Americ)	.131	—	—	.067
	(3.36)			(1.17)
Primary Educ. (South Asia)	.005	—	—	.063
	(0.11)			(1.30)
Second. Educ. (Africa)	—	.013	—	.020
		(2.65)		(3.33)
Second. Educ. (East Asia)	—	.061	—	.039
		(5.37)		(2.83)
Second. Educ. (Mena)	—	.051	—	.056
		(4.16)		(4.36)
Second. Educ. (Lat. Americ)	—	.037	—	.023
		(3.41)		(1.45)
Second. Educ. (South Asia)	—	-.072	—	-.086
		(2.87)		(3.17)
Total Educ. (Africa)	—	—	-.007	—
			(0.63)	
Total Educ. (East Asia)	—	—	.202	—
			(4.12)	
Total Educ. (Mena)	—	—	.084	—
			(1.96)	
Total Educ. (Lat. Americ)	—	—	.136	—
			(3.54)	
Total Educ. (South Asia)	—	—	.034	—
			(0.98)	
Dummy 1960-79 (Africa)	.005	.002	006	.006
	(1.08)	(0.48)	(1.13)	(1.25)
Dummy 1980s (Africa)	.030	.028	032	.031
	(5.63)	(5.40)	(5.80)	(5.91)
Dummy 1960-79 (East Asia)	—	—	—	—
Dummy 1980s (East Asia)	—	—	—	—
Dummy 1960-79 (Mena)	.014	-.000	.005	.009
	(2.35)	(0.04)	(0.70)	(1.42)
Dummy 1980s (Mena)	.029	.024	.026	.027
	(4.16)	(3.61)	(3.71)	(4.01)
Dummy 1960-79 (Lat. Americ)	-.007	-.006	-.007	-.003
	(1.18)	(1.25)	(1.22)	(0.52)
Dummy 1980s (Lat. Americ)	.016	.017	.016	.018
	(2.66)	(3.07)	(2.71)	(3.08)
Dummy 1960-79 (South Asia)	.005	.016	.003	.019
	(0.73)	(2.30)	(0.41)	(2.53)
Dummy 1980s (South Asia)	.031	.035	.032	.036
	(4.05)	(4.58)	(4.06)	(4.69)
Dummy 1960-79	.014	-.011	-.014	-.017
	(3.00)	(2.82)	(2.97)	(3.75)
Dummy 1980s	-.042	-.042	-.043	-.043
	(8.50)	(8.69)	(8.61)	(9.00)
Lambda	-.014	-.008	-.011	-.010
	(1.50)	(0.85)	(1.19)	(1.13)
Number of observations	1506	1477	1506	1477
Adjusted R-square	0.785	0.795	0.786	0.796

Notes :

1 All variables except dummy variables are in the form of first differences of natural logarithms.

2 East Asia is chosen as the base region. Its dummy variables are therefore omitted from the regression equation.

3 Numbers in parentheses are t ratios.

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