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The transition of education a cross-country macro analysis

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ABSTRACT

In cross-country data, income and key education variables are strongly correlated. This is mainly due to the long-run transition from traditional to modern society. The paper looks at a flow and a stock variable. The flow is the *E-share* of GDP for the annual public budget for education. When it is adjusted for the number of school-age children, it becomes the *EC-share*. The stock is *School*, which is the number of years the average person has been in school. Both variables are due to demand and supply. People and firms demand human capital needed by production. Governments supply education to increase production. The demand factor works better to explain the strong correlation. Countries with too much or too little education are identified by the deviations from the transition curves for education. Neither deviation has a clear impact on the growth rate. The explanation proposed uses the equilibrium properties of the transition path, where too much education is of no use, while too little is compensated by the private sector.

1. Introduction: Education policy and development

This paper looks at systematic long-run changes in education and the resulting human capital as countries go through the ***transition*** from poor traditional societies to become wealthy modern societies. Transitions are steady but slow movements.

The change is due to policy decisions on education of two types. (i) Quantitative decisions about budgets. (ii) Qualitative decisions about institutions. The literature suggests that (ii) is more important, but most politicians probably see (i) as the main policy instrument.

Two/three education variables are analyzed: the ***E/EC-share*** and ***School***. The *E-share* of GDP is the public education budget. It is the annual ***investment*** that accumulates to ***human capital***. When the *E-share* is adjusted for the number of school-age children, it becomes the *EC-share*. The *School* variable is people's years of schooling. It measures human capital.

The paper considers large cross-country datasets. Here the correlation between *income* and the education variables is 0.7 and 0.8 for the *EC-share* and *School*, respectively. This is due to well-determined transition paths – $K^E(y)$, $K^{EC}(y)$, and $K^S(y)$ – for the *E/EC-share* variable and *School*. Development increases the *EC-share* four times.

From the paths the excess values – D^E, D^{EC}, and D^S – are calculated. They say if the country has too much or too little education relative to the path. The second half of the paper shows that the excess matters little for the growth of the country. Thus, while the transition paths are strongly related to growth, the excess over or below the path is not related.

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Education is an investment that influences production with a long lag. Thus, there is a ***time-horizon*** problem. If primary enrolment increases, it can at most affect productivity after a decade. Education has two similar trends: (a) a trend due to rising income, and (b) a secular trend. Education varies in quality and type. While there is some homogeneity in primary education, it quickly vanishes at the higher levels. In addition, education has a component of consumption. As the analysis is cross-country and macro, it bypasses the discussion about the composition and the quality of education.

Transitions are explained by ***demand or supply.*** The demand side stresses that when countries grow, they need more human capital, and therefore it is produced. The supply side starts from the theories of growth. It sees human capital as a factor of production that governments increase to get development. Unsurprisingly, the relations are simultaneous, but it appears that *income* explains the two variables a little better than vice versa.

Fig. 1 is a stylized version of this complex. The black-framed boxes are production, and the parentheses enclose parts of the complex left out. The black arrows are the supply side, while the gray arrows are the demand side. Table 1 defines the variables.

Section 2 presents the theory behind the paper and gives a short introduction to the large literature on the economics of education and the technique used in the paper. Sections 3 and 5 look at the *E/EC-share* data, while sections 4 and 6 consider the *School* data. Sections 3 and 4 show the transition patterns, while sections 5 and 6 study if the excess *E-share* and excess *School* matter for growth. These results are negative, and section 7 provides an explanation. Section 8 concludes. A Net-Appendix (Ap) brings extra calculations, mostly robustness checks.

A caveat is necessary. During the last decade, the profession and science in general has been increasingly aware that priors generate publication bias in the form of exaggerated results. Almost everybody studying the effect of education on the economy is working in the sector. They have great incentives to believe that what they do is good for society and should have a larger budget. I am aware that I may have the same bias.

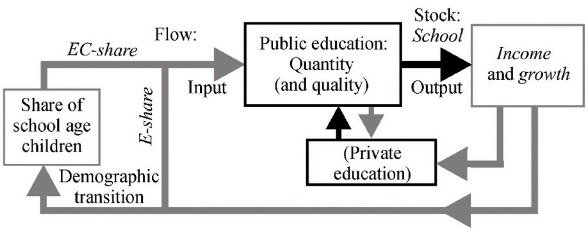

Fig. 1. The complex of education, and the parts discussed.

Table 1
The variables discussed.

Variable	Definition (variables are in italics)	Source
Income, y	Natural logarithm to *gdp*, real GDP per capita PPP-prices	Maddison
Growth, g	Growth of *gdp* in %	project
D^g	Excess growth $D^g = g - 2.05$ that is average growth	Estimated
Child, C	Fraction of population in school ages 6-15	WDI
E-share, E	General government spending on education in % of GDP.	UNESCO
	$N = 3{,}235$, annual, from 1970 to 2017 for 141 countries.	statistics
EC-share, EC	*E-share* adjusted for *Child*: *EC-share* = *E-share/Child*	Estimated
School, S	Average years of total schooling for 13 age groups. Each has	Barro-Lee
	$N = 1{,}077$, every 5th year, from 1970 to 2010 for 122 countries.	dataset
$K^E(y)$, $K^{EC}(y)$, $K^S(y)$	Transition paths, estimated by kernel regressions on unified data	Estimated
D^E, D^{EC}, D^S	Excess value: $D^x = x - K^x(y)$, for x = *E-share*, *EC-share*, and *School*	Estimated

Abbreviations: **LIC**, Low Income Country. **HIC**, High Income Country. **PISA**, the Programme for International Student Assessment done every third year. **TIMSS**, the Trends in International Mathematics and Science Study, assessing the mathematics and science knowledge of fourth and eighth grade learners. **Ln** is logarithmic points (for income) and **pp** is percentage points. **Av** is the arithmetic average.
N is the number of observations. Data for present or past members of OPEC are deleted. The average growth is for 1970–2017 for the 141 countries of the *E-share* sample. For simplicity, growth is taken to be independent of income, see however, Gundlach and Paldam (2020).

2. Theory and literature

The literature in the field is enormous. The reader may look at the 3560 pages of the five stately volumes of the Handbook of the Economics of Education that surveys several thousand articles. From a study of all abstracts and the most relevant chapters, it is concluded that the paper tries a new angle. Section 2.1 discusses the political economy, while section 2.4 introduces the method that follows from the theory. The new approach seems to add some – hopefully new – pieces of evidence. The literature uses many methods, which give somewhat different results. Section 2.2 looks at two main micro approaches, while section 2.3 turns to the macro side, considering three main approaches. The purpose of this mini survey is to answer the ***question***: *Does the results reached by the method suggest that more education leads to more growth?*

2.1. General equilibrium (GE) and the public choice views of education policies

The introduction distinguished between (i) quantitative decisions about budgets, and (ii) qualitative decisions about the structure of institutions. In the ideal world of GE-theory, all decisions are endogenous, and with certain well-known qualifications, welfare is optimized. Thus, the structure within the sector is optimal, and the budget has the optimal size relative to the GDP.

The public choice view notes the weakness of the mechanisms pushing toward the GE especially in non-market sectors. One such sector is the public education sector, which has a long history and a large staff, who often spend the whole of their working life in the sector. It gives strong traditions and powerful lobby groups.[1] Such entrenched institutions have a life of their own, and they are difficult to change. The education system is a *bureau* according to the theory of bureaucracy[2]; see Mincer (1958, chpt. 15–17). The theory predicts that the bureau will fight for larger budgets and resist institutional reforms. Much evidence exists to show that bureaus are quite good at these endeavors. In many countries, the effects of reforms announced as big have turned out to be small after some time.[3] Thus, there are strong reasons to expect that the deviations from the GE-pattern are large, as indeed they are.

Paldam (2021) claims that all socioeconomic time series have strong and similar ***transition patterns*** in both wide cross-country samples and long time series. The paper shows that education series have such a pattern.[4] The said pattern has two steady states: a traditional and a modern. The transition curve diverges from the traditional level in LICs (Low Income Countries), and much later it converges to the modern level in HICs (High Income Countries), thus the path looks as .[5] Strictly speaking, one may only imagine GE in the two steady states, but as the transition path is well determined, it also has some GE-properties in being the optimal path from one steady state to another.

The working hypothesis of the paper is that the transition path is the equilibrium path that acts as an attractor for the education variables, and that the big deviations are due to a mixture of policies and the internal life of institutions. The joint hypothesis is difficult to test, but we shall see that it is not rejected by the facts, as the paper finds a strong transition path, so education is strongly related to development. However, even sustained deviations from the path are unimportant for development.

The reasons for the path are well known. The traditional level had a stable technology, where the necessary skills were learned within the extended family. A farmer or a blacksmith learned his trade from the family. Thus, literacy was low, and formal education was limited to a small fraction of the population. The LICs of today are already moving away from this situation, but it is a long process. In modern society, skills are complex, diverse, and keep developing, so much formal education is necessary.

Compare two kids who grow up, one in an African village and the other in a European town. Think of the use they have of the first 6 years of primary school. They both learn to read, write, basic calculus, etc. The African kid has nothing to read in his village, so reading is an esoteric skill of little use, and hence it gradually erodes. The European kid is surrounded by texts he must read. Thus, reading is an important skill that is constantly reinforced. Surely, the European kid will remain a much stronger reader for the rest of his life. However, over time also the African village will come to hold adequate reading material. Statistically, this means that the productivity of education is lower in Africa and higher in the west.

Data for education such as the *E-share* and *School* will consequently have transition curves. The data show that such curves are indeed strong and look as they should. As the transition curves in the investment per kid (Fig. 5) and in the human capital (Fig. 6b) are similar, they represent the long run, while the individual observations scatter around the path. Some of this variance is due to policies pursued by governments. It is often claimed that if a government expands education budgets, it will cause extra growth, i.e., a faster transition. The deviations from the transition curves are the excess *E-share* and excess *School.* Government activism and the internal dynamics of institutions explains the deviations.

[1] From Fig. 2 below follows that the education sector in HICs (High Income Countries) accounts for more than 5% of GDP. This means that it employs about 7% of the voters. In addition, everybody in the country has connections to the sector, so it is a politically powerful sector. See Gundlach et al. (2001) on the poor development of school productivity 1970–94 in the OECD countries.

[2] It is a simplification to see the educational sector as one institution. Thus, the internal fights for resources between the many institutions within the sector are not discussed.

[3] Most readers will know that what universities want is more money and more independence. Paldam (2015) is a study of a large university reform that did not work as expected.

[4] This paper uses cross-country data, but from historical accounts it appears that the results would generalize to long time series as well; see Barro and Lee (2015).

[5] The only strong exception to the general pattern is that (very) resource rich countries may become rich without a transition. Thus, the study excludes the OPEC-countries.

2.2. Micro: mincer equations and life income calculations

Mincer (1958) introduced a regression equation that explains the income of individuals by their education, controlling for other factors such as family background, etc. Since then, the core model has been extended, and it has been estimated with increasingly sophisticated methods. It seems that human capital always has a substantial explanatory power like 20%. Becker (1964) explains people's decision to invest in human capital by the expected gain.

A related approach is the life income literature. It looks at the costs and benefits of acquiring a skill for a representative member of the skill group. Ideally, it should follow the representative person across her/his life and calculate the income net of the cost of acquiring the human capital. In practice, it uses cross-age data one year for the representative member of the skill group and calculates the excess net income compared with an unskilled worker. The rate of return is the discount rate that sets the net present value equal to zero. For many skills, it is a rather high discount rate, like 20% as before. Both methods should sort out the value of human capital from the innate ability of people and the signaling value of exams.

These methods assume a production function where education enters as a factor of production. The typical result is that investments in human capital pay rather well. If an activity that pays well is increased, growth should result even if the activity has falling marginal productivity. Thus, the question posed is answered by yes, and the effect should be substantial.

2.3. Macro: growth accounting, income accounting, growth regression

The macro theory of human capital follows from the theory of economic growth by assuming that human capital is a factor of production. It disregards the consumption aspect of education. Production Y (GDP) is made by A knowledge, L labor, H and K human and physical capital.

$$Y = AF(L, H, K) \tag{1}$$

The derivative dY/dt of (1) divided with GDP yields:

$$(dY / dt) / Y = a + (\partial L / \partial t)/L\ (L / Y) + (\partial H / \partial t)/H\ (H / Y) + (\partial K / \partial t)/K\ (K / Y) \tag{2a}$$

if factor wages are their marginal productivities it becomes

$$g = a + w_L\, s_L + w_H\, s_H + w_K\, s_K \tag{2b}$$

Where growth, g, is the sum of factor shares s_L, s_H and s_K times their wages w_L, w_H and w_K.

Everything in (2b), except a, can be measured. The residual/constant, a, catches the effect of knowledge, economics of scale, and other (hopefully small) factors of production. Equation (2b) can be expanded by adding more factors of production and other refinements. It has been used in many studies such as Dennison (1967) and Jorgenson (2005).

The average wage rate $w = w_L + w_H$, where w_H is imputed by deducting the wage of workers without human capital. The combined factor shares of labor and human capital are approximately 75% of GDP. As the salary of workers with no human capital is low, it is a robust result that the share of H is large, such as 40% of GDP in the wealthy countries.

A closely related approach is the one of accounting for income differences; see Caselli (2005). The calculation uses an increasing refined growth model to simulate the growth paths for a set of countries. The starting point is the following Solow model:

$$Y = K^{\alpha}\ (Lh)^{1-\alpha}, \tag{3}$$

where h is human capital per capita.

The model is used to calculate a set of growth paths for a group of countries with different starting points, and the success of the simulation is calculated. While a first set of elementary factors give a poor fit, the model is then calibrated by a set of refinements of the K, and the h variables to fit better and better. The improvements that have the largest effects are ones for the quality of the h-variable. In the end, it finds a substantial effect, much as expected from the growth accounting literature.

Both methods suggest, once again, that an increase in education should generate more growth. Thus, the question posed is answered by yes, and the effect must be substantial.

A different approach is cross-country growth regressions; see Barro and Sala-i-Martin (2004). This approach has generated a large literature working with regressions using panel data with two dimensions: i for country and t for time:

$$g_{it} = a_{it} + a_1 F_{1it} + a_2 F_{2it} + \ldots + a_n F_{nit} + u_{it}, \tag{4}$$

where the Fs are growth factors.

Many factors have been tried and a handful of estimators as well. The constant is often broken into fixed effects for countries and time. Even with all refinements, it has proved difficult to find a substantial effect of education. This is probably due to the time-horizon problem. Most of the literature uses 5-year periods, and one to two lags are often included. However, this is unlikely to be enough. Here the answer to the question is more dubious, but still Barro and Sala-i-Martin (2004) do answer yes to the question. Perhaps the weakness of the evidence presented was the reason for the work on the data summarized in Barro and Lee (2015), which certainly conclude that education matters for growth.

2.4. The school quality discussion and the production function for education

A large part of the discussion on the effect of education deals with the quality of the school system. Some dimensions in the quality complex are surely likely to matter. However, it has proved difficult to identify the causal factors from the input side. Data exists for some input factors, but they often give weak results. Think, e.g., of the modest results of the large literature on class size,[6] or on the competition of schools in mixed public/private systems.[7] However, some input factors seem to matter, such as teacher quality.

The weak results at the input side have caused many researchers to turn to output measures, such as PISA and TIMSS scores (defined in Table 1). They do explain growth better than school expenditure, but in a cross-country perspective, they are correlated with *income*. More seriously, they are not political decision variables, but an outcome of complex decisions and traditions. Most countries would surely increase their PISA-score if it were easy to do.[8]

School quality has been studied as a production function for education given a host of inputs. A representative example is Woessmann (2016, Table 2), who provides a production function for mathematical test scores of 219,794 students (in 29 countries) with 57 explanatory variables, divided in three groups: Family background, school resources and institutions. Barro and Lee (2015, Tables 6 and 6.7) are related regressions giving similar results. It appears the second group is the least important, much in line with our findings.

2.5. Analyzing transitions: Kernel regressions on unified data

The data are three panels: (1) *E-share*, *income*, (2) *EC-share*, *income*, (3) *School*, *income*, where (1) and (2) have many gaps (Ap). The unified data are large strings. Within strings the correlation is 0.4, 0.7 and 0.8 respectively, indicating the strong long-run connection. Kernel regressions (see the next paragraph) on the unified data sets are used to estimate the transition curves. The rows of the unified data have no particular order, but each kernel regression orders them by the explanatory variable. The data scatter around the curves estimated due to (A) short-run noise and (B) systematic deviations made by the unification. In large samples, (A) should even out and (B) remain. The 95% confidence intervals around the kernels are narrow, so (B) is small.

The kernel curve is a smoothed moving average with a fixed bandwidth, *bw*.[9] The kernel $x = K^x(y, bw)$ studies if y can explain x when the observations are sorted by y. The sorting scrambles the observation for other variables, such as time, which may also explain x. Thus, the kernel estimates the long-run relation disregarding the time dimension. The time dimension is analyzed in sections 5 and 6. It is important to also study the reverse kernel $y = K^y(x, bw)$. Due to the sorting, it is often strikingly different. The kernel technique has both advantages and disadvantages.

The main advantages are: (a1) It makes no assumption as to functional form, and the transition curve has a particular non-linear shape. If a curve with that shape can be drawn within the confidence intervals, it is a test of the transition theory. When the confidence intervals are narrow the test is strong. (a2) The method works irrespective of data gaps, which is crucial for the analysis of the *E-share* where the data has many gaps. (a3) When different theories predict that the two reverse kernels should look differently (section 3), this allows a 'beauty' test of the two theories, and the causality implied. When both curves look fine (section 4), it indicates simultaneity. (a4) The kernel technique allows us to solve the double-trend problem by calculating the kernel in x for *income*, $K^x(y, bw)$, where *time* is scrambled, and for *time*, $K^x(t, bw)$, where *income* is scrambled.

The main disadvantages are: (d1) It is a univariate technique. (d2) The unification of the data destroys the panel structure of the data, and hereby information may be lost.

To test the robustness of the kernel, the bandwidth and the country sample should be varied. Such experiments are bulky to report – thus the Net-Appendix.

The only strong exception to the general pattern is that resource rich countries become rich without a transition. Thus, the OPEC-countries are excluded from the study. Once a robust kernel such as (5) has been found, the excess amount of the variable compared to other countries at the same income level can be found by equation (6):

$$x = K^x(y, bw) \tag{5}$$

shows the ***transition path*** of x as a function of y

$$D^x = x - K^x(y, bw) \tag{6}$$

is the ***excess value*** of x at income y in the country.

Corresponding to the *E-share* and *School*, the variables D^E and D^S give the excess values. Here D^E should give more growth in the

[6] The intuition of most teachers is that class-size should have a clear negative effect on education, but the research has found it difficult to substantiate this intuition. Hence, the large effort. See Mischel and Rothstein (2002) for a survey and (a heated) discussion of the results of 277 estimates from 59 studies.

[7] The intuition of most economists is that competition should increase the quality of education. The evidence from 79 studied is mixed; see Urquiola (2016) and Woessmann (2016). For the literatures mentioned in this note and in note 6, the reader should recall the last paragraph of the introduction.

[8] Glewwe and Murelidharan (2016) survey the discussion on the quality of education in LICs.

[9] All kernels presented use the defaults in stata, i.e., the Epanechnikov kernel and a zero degree of polynomial smoothing. Stata estimates the 'best' bandwidth, by a reasonable criterion of optimality, but a slightly larger bandwidth is used to reduces the noise.

longer run, while D^S should work also in the short run.

3. The *E*- and the *EC*-shares

The *E-share* is public expenditure on education in percent of GDP, as compiled by the UNESCO.[10] The data cover the 48 years for 141 countries. It should give $N^* = 6{,}768$, but N is only 3,173, so the data have many gaps. Kernel regressions disregard the time dimension, except indirectly through the growth of income. Thus, the gaps do not prevent the estimate. Section 3.2 looks at the demand side, while section 3.3 looks at the supply side.

3.1. Is the E-share a good policy measure?

Education systems are, as mentioned, entrenched institutions. It is possible to reform such systems, but it is difficult. If the government wants to change teacher quality, it may take 15 years before the effect becomes strong, but the two budget shares discussed in this section are only about size, and they are easier to change.

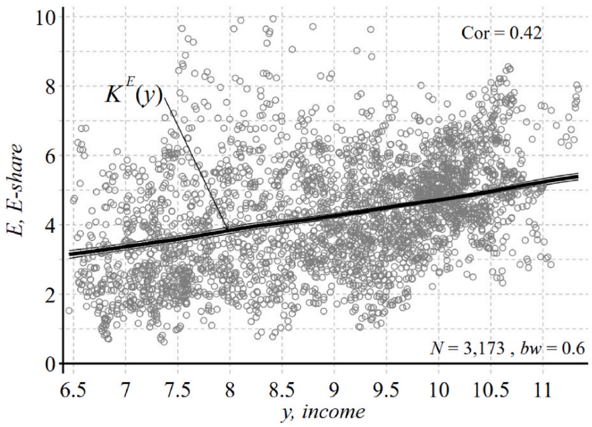

Fig. 2a. *Income* explains *E-share.*

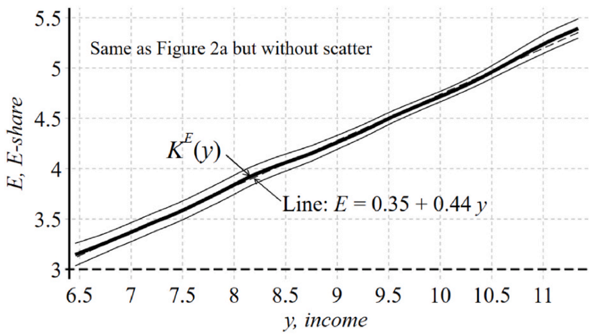

Fig. 2b. Transition curve from Fig. 2a (scatter omitted).
Recall that *income* is ln *gdp* (GDP per capita). The *E-share* is the public budget for education in % GDP. Cor is the correlation of the *N* observations, and *bw* is the bandwidth. The kernel is robust to the bandwidth (Ap). The 52 extreme observations do not matter for the curve.

[10] UNESCO's note (shortened): Total general government expenditure on education, expressed as a percentage of GDP. It includes expenditure funded by transfers from international sources to government. A higher percentage of GDP spent on education shows a higher government priority for education, but also a higher capacity of the government to raise revenues for public spending. In some countries, the private sector and/or households may fund a higher proportion of total funding for education.

Table 2
The trends in the *E-share* for income and time.

Income trend in *E-share* assessed from Fig. 2 – time scrambled
Income range: 11–6.5 = 4.5 lp or 90 times. *E-share* range 5.25–3.25 = 2 pp. One lp is 40 years with 2.5% growth pa. It raises the E-share with 0.44 pp. Thus, 2½% growth of income raises the *E-share* with 0.012 pp
Time trend in *E-share* assessed from Figure A5 (Ap) – income scrambled
Time range: 2017–1970 = 47 years. *E-share* range 4.52–3.98 = 0.54 pp. This is **0.011** years annually
Regression estimate (OLS), with t-ratios in parenthesis
$E = 0.56$ (25.4) $y + 0.006$ (3.4) $t - 13.29$ (3.8), for $N = 3129$ and $R^2 = 0.18$

Income is y and time is t. The abbreviations are lp for log points, and pp for percentage points. Ln(1.025) = 0.025, Thus, when gdp rises by 2½%, income goes up with 0.025 as well. Ln(1.05) = 0.049. Thus, 5% growth gives 0.024 pp growth of *E-share*.

The productivity of the education sector may have a complex relation to the share of the sector in GDP. Consider the growth of productivity in the sector g_e% pa. If it grows less than the aggregate growth of productivity g_a% pa, there is no steady state; see Baumol (1967, 1986). We know that there is productivity increases in the education sector, but it is difficult to measure the size, especially as the sector interacts with the rest of the economy. If the education sector grows relatively with the productivity difference, it may be a temporary equilibrium.

A related complication applies to teachers. In poor countries, it is a prestigious job and relatively well-paid job to be a teacher, and it may be the only higher education available for an ambitious kid. Most of the first generation of African leaders were teachers. In HICs, it is an intermediate education with corresponding salary. How this is reflected in the E-share is not clear. Thus, it is easy to come up with complications blurring the relation between input and output in the educational sector. The paper uses the *E-share* as a measure of the ***effort made*** by countries. Section 5 asks if the relative effort matters for development.

3.2. Demand: Income explains the E-share by a straight line

Fig. 2 explains the *E-share* by *income* as if there is no supply side. Fig. 2a show the full scatter, while Fig. 2b omits the scatter. The straight (dashed) line is fully within the 95% confidence interval. Thus, it cannot be rejected that the *E-share* grows along a straight line as *Income* increases. It has no flat sections for the LIC and HIC group as predicted but see section 3.4. Due to the linearity the kernel and the regression line estimated in Table 2 are close.

The time dimension is scrambled, so the figure estimates the pure income effect. Table 2 demonstrates that normal growth in one year gives 0.012 pp growth of the *E-share*. It increases by a further 0.011 pp due to the time trend. The development is slow indeed. However, it is linear, so it is a steady increase.

The curve is well determined, though it only explains a small part of the variation. The straight line goes through (3.25, 6.5) and (5.25, 11), so it has the formula (Ap):

$$K^E(y, bw) \approx 0.36 + 0.44\, y, \tag{7}$$

$E = K^E$ (y, bw) estimates the transition path,

$$D^E = E - K^E(y, bw), \tag{8}$$

which is less dependent of income; see Table 2.

3.3. Supply: The E-share explains income by a strange curve

Fig. 3 shows the reverse kernel of Fig. 2, and hence it follows standard theory explaining *income* by the *E-share*, as if there is no demand side. The kernels on Fig. 3 look very different from Fig. 2, which is the clearest one. This suggests that the demand side in the income/human capital nexus is stronger, as previously found by Bils and Klenow (1998). They sorted out causality by explicit models of the channels, calibrating and simulating. They found that the causal link from education to growth could not explain more than about 1/3 of the correlation between the two variables.

The first part of the curve from the share 0 to 8 looks as expected. It increases nicely and has narrow confidence intervals, and the curve even has falling marginal productivity, as it should. Here data are adequate. When spending becomes higher than 8%, the data are thin, and the effect falls, indicating that spending becomes counterproductive. It is probably due to the time horizon problem. It is not easy to expand the school system faster than the availability of teachers and classrooms allows. The *E-share* is rising by about 0.15% per year (Ap). In the same data, the average rate of economic growth is 2.08 per year, so real public spending on education grows by 2.24% per capita.

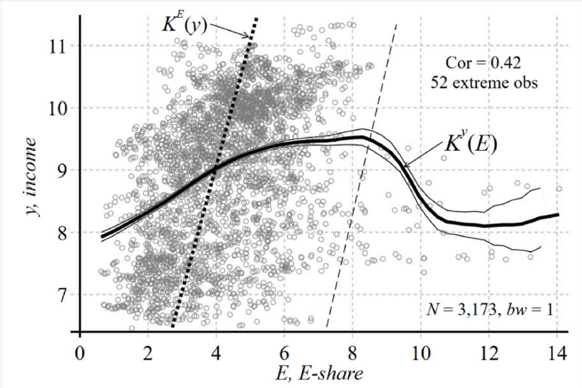

Fig. 3. *E-share* explains *income (y)*.
See note to Fig. 2. The Net-Appendix shows that if the extreme observations are excluded, the curve looks nicer. In addition, it shows that the robustness to the bandwidth is not great. The line $E = 0.35 + 0.44y$ from Fig. 2b becomes: $y = 2.7E – 0.79$ on Fig. 3 as drawn. Note the difference of $K^E(y)$ from Fig. 2 and $K^y(E)$.

3.4. Correcting for the share of children: The E-share becomes the EC-share

Fig. 4 shows the transition curve for the *Child* variable that is the share of school age children (6–15). The demographic transition gives these data a perfect transition curve. It is calculated for the same years and countries as Fig. 2.

From the two curves of Figs. 2 and 4, we can assess an education ***effort*** per child simply by dividing with *Child*: *EC-share* = *E-share/Child.* It gives the $K^{EC}(y)$-curve on Fig. 5 (note the scaling). While the transition in the *E-share* increases from 3.25 to 5.25, or by 1.6 times, the transition in the *EC-share* increases from 3 to 12.2, or by 4.1 times.[11] It is no wonder that education is much better in HICs than in LICs. The kernel curve is a fine transition curve with a correlation of no less than −0.86. It is very robust (Ap).

One effect of the large increase in education effort is that the average years of school increase shown in the next section. On Fig. 6 (below), the increase for the average person is from 2 years of school in LICs to 12 years in HICs.

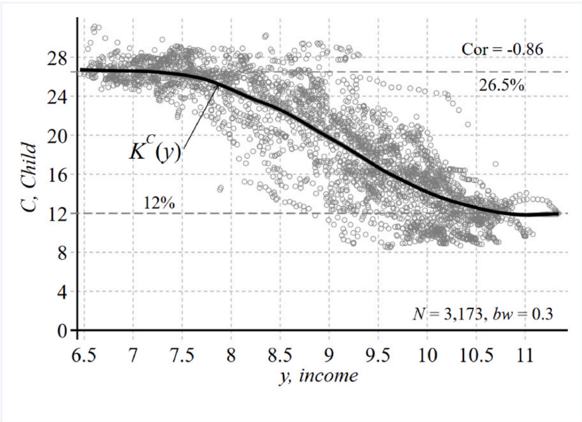

Fig. 4. *Child*, i.e., Children ages 6–15 as fraction of population.

[11] In the PPP-data income is roughly 60 times higher in HICs than in LICs. Thus, education expenditures are almost 350 times higher per child. Teacher salaries and other factor wages are higher too, but probably not by 60 times.

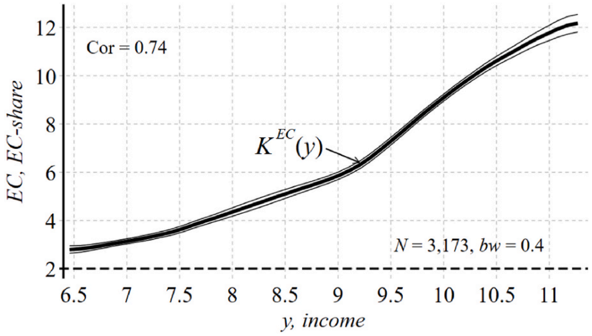

Fig. 5. The *EC*-share: Fig. 2b corrected for *Child* from Fig. 4.
The transition curve $K^{EC}(y)$ is scaled so that the average for income 6.5–7 is the same as on Fig. 2. Hereby the scale on the vertical axis becomes close to the one of Fig. 6b below.

4. The *school* variable

The Barro-Lee dataset gives the variable *School*, the average years of schooling, for the population of 122 non-OPEC countries, which can be combined with the *income* data used. They cover 13 age groups and 9 years–5 years apart. This gives a high *bw*-value and, as mentioned, some flattening at the ends. The next two subsections report two sets of graphs: one showing the set of all 13 kernels for the age groups, and another for all age groups merged.

4.1. Can income explain school

Fig. 6a shows that *income* does well explaining *School*. The curves generated for the 13 age groups all look like typical transition curves. In LICs, the average person had only 1–2 years of *School* in the past, which means that the great majority never went to school, while only a small group had a more adequate schooling. This situation is changing.

The 13 curves on Fig. 6a are roughly parallel, indicating an increase of School of about 4 years in the 60 years between the lowest and highest age group. Most are for the last 50 years used in Table 3. Thus, the increase is by 1 year every 12th year. The same result is found from kernels calculated over time (Ap). The curves look like the typical transition curves. In addition, it is noteworthy that from an *income* of 7½ points, the curves are almost linear, though they are perhaps starting to bend downwards at the top. There may be limits to how much *School* people can and will absorb.

Table 3 demonstrates that normal growth in one year gives 0.06 years increase in School. It increases by a further 0.1 years due to the time trend. The development depicted on Fig. 2 is slow, but after 25 years, it amounts to 4 years, as observed. Here the regression result is the same for income, but the time trend is smaller.

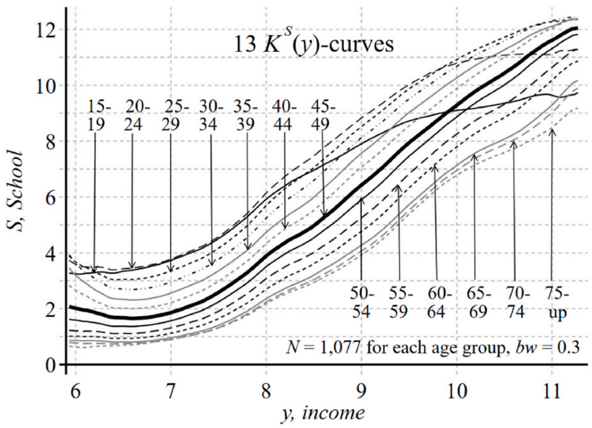

Fig. 6a. *Income* explains *School*. For each of the 13 age groups.

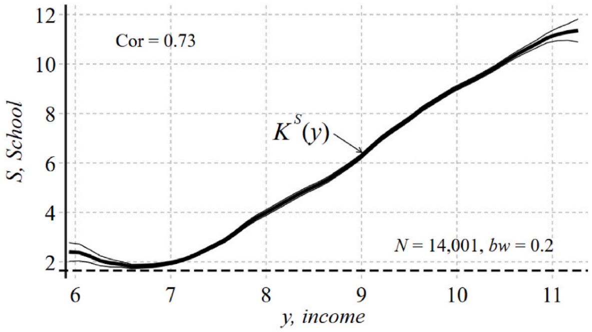

Fig. 6b. *Income* explains *School*. All age groups merged.
The highest curves on Fig. 6a are for the youngest age groups. As the age increases, the curves have a lower path. Fig. 6b is for the unified data, with $N = 14'001$. The merger reduces the correlation from 0.76 (ap) to 0.73, but as N increases 13 times, the 95% confidence intervals narrow. Note that Fig. 6b looks much like Fig. 5.

Table 3
The trends in *School* for income and time, assessed in two ways.

Income trend *in School assessed from Fig. 6b – time scrambled*
Income range: 11 – 7 = 4 lp or 55 times. School range: 11.2 – 2 = 9.2 pp. One lp is 2.72 times. It is 40 years of growth with 2.5% pa. It raises School by 2.3 pp. Thus, 2.5% growth raises School by 0.06 years
Time trend *in School calculated from Fig. 6a – vertical distance between age-group curves*
The distance from age group 15–19 and 65–69 is 50 years. It raises *School* by 4 years. i.e., by **0.08 years** annually
Time trend *in School calculated from A6* (Ap) *– income scrambled*
Time range: 2017–1970 = 47 years. *School* range: 7.7–3.2 = 4.5 years. This is **0.1 years** annually
Regression *estimate* (*OLS*), with t-ratios in parenthesis
School = 2.26 (126.1) *income* + 0.06 (38.4) time – 136.8 (−43.1). For N = 14,001 and $R^2 = 0.59$

4.2. Can school explain income?

Fig. 7a and b are the reverse kernel regressions – and the ones suggested by standard theory. They explain *income* by human capital. It seems to go as well. However, the curves are less parallel. *Income* rises more when *School* rises from 3 to 7 years than when it rises from 8 to 12 years. It is also interesting to note that the effect is higher on the old than on the young age groups. This has to do with the lags. Old people have used their *School* longer than the young people have. Thus, the curves are in the opposite order on Fig. 7a than on Fig. 6a.

The time horizon problem has an additional aspect when poor countries are considered. Recall the discussion of the alphabetizing of the African village in section 3.1. When a youngster learns to read, there is nothing to read in the village, so reading is a useless skill. Thus, alphabetization starts by an uphill fight, but the hill has a crest after which the effort goes down. When many can read, written material becomes common, and it becomes embarrassing to be unable to read. This may explain the nonlinear nature of the curves. In the beginning, an increase in *School* has a small effect, and later the effect becomes larger, but at the end where everybody can read the effect falls once again.

The curves on Fig. 6 looks slightly nicer than the ones on Fig. 7, but both sets of curves are so much alike that it points to much simultaneity between supply and demand.

Finally, a ***data-critical*** point should be made. The *E-share* measures the investments into human capital and hence it should accumulate to the stock variable *School.* Thus, the average *E-share* for the 5 years t to t+4 should be reflected in the increase in *School* from t to t+4 in the lowest age groups. This effect has not been found, so the data are not consistent. However, both the *EC-shares* on Fig. 5 and the *School* variable on Fig. 6b do contain fine transition curves. They even look alike.

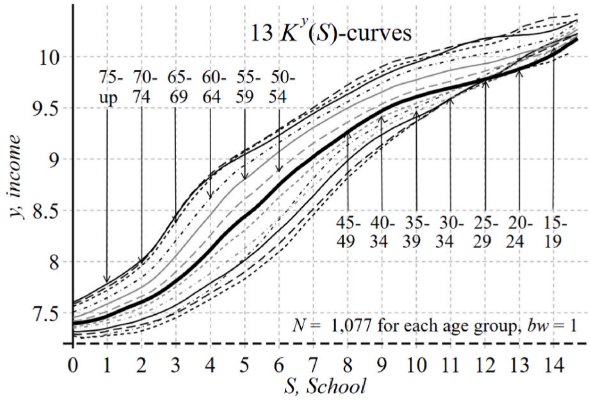

Fig. 7a. *School* explains *income*. For each of the 13 age groups.

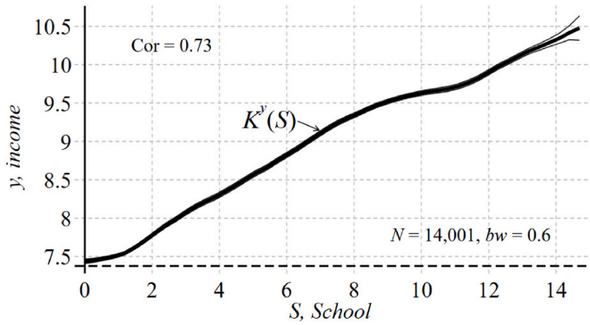

Fig. 7b. *School* explains *income*. All age groups merged.
The curve on Fig. 7b looks as the middle curve on Fig. 7b, but with narrower confidence intervals (Ap).

5. The D^E-variable: Countries with too high and too low *E-share*

Fig. 2 showed the observations with too much and too little education. From Fig. 3 it is already clear that extreme values of the *E-share* are not very productive. As before, the data does not include the OPEC countries, and the D^g-variable for excess growth is used.[12]

5.1. *The D^E variable for excess E-share*

From each (*E-share*, *income*) observation, we have calculated the 'normal' value $K^E(y)$ from the average linear approximation to the kernel of Fig. 2. Recall equations (9) and (10):

$$K^E(y) = 0.36 + 0.44\,y, \tag{9}$$

this provides the deviation:

$$D^E = E - K^E(y), \tag{10}$$

the D^E-variable is termed the excess *E-share*.

If the $D^E > 0$, the country builds 'too' much human capital in that year. If the $D^E < 0$, the country builds 'too' little human capital in that year. The *E-share* is the policy variable. The D^E-data allow us to single out countries where the public sector consistently produces too much and too little education, at their level of income.

5.2. *The country groups and a note on East Asia*

Table 4 divides the 141 non-OPEC countries in the usual six groups. The groups are used in Fig. 8, which points to a problem. D^E, the

[12] The D^g variable is calculated as $D^g = g - \text{Av}(g)$. The average is 2.05%, calculated for all 6693 available observations of the growth rate for the 141 (non-OPEC) countries with *E-share* data, 1970–2017. However, if only the 3217 observations where an *E-share* observation is available the Av(g) is 2.63. No explanation of the highly significant difference has been found.

Table 4
D^E, the excess *E-share* for six country groups.

	West	Africa	Ex-soc	Lat Am	Asia	MENA+
Average for countries in group (see Fig. 8a)						
Av D^E	0.311	0.186	−0.067	−0.212	−0.769	−0.291
Count	25	37	27	23	16	13
Se	0.208	0.249	0.204	0.330	0.276	0.496
t-test	1.5	0.7	−0.3	−0.6	**−2.8**	−0.6
Growth	2.333	0.890	1.981	1.978	3.734	2.582
All observations for each group unified (see Fig. 8b)						
Av D^E	0.380	0.267	−0.016	−0.259	−0.729	−0.442
Count	862	723	480	464	369	279
Se	0.013	0.010	−0.001	−0.012	−0.038	−0.026
t-test	**29.4**	**26.9**	**21.9**	**21.5**	**19.2**	**16.7**
Growth	2.333	0.890	2.053	1.978	3.724	2.582

Se is standard error. The bolded t-tests differ from zero. West includes Israel. Africa is the Sub-Saharan countries, including Cabo Verde and Comoros. Ex-soc is the countries of the former Soviet Bloc, Yugoslavia, Albania, and Mongolia. Latin America includes Caribbean. Asia includes Mauritius and the Seychelles. MENA is the Middle East and North African countries, where the + indicates the inclusion of Afghanistan, Pakistan, and Bangladesh.

average excess *E-share,* is negatively correlated to the growth rate. As seen from Fig. 8, five of the country groups are along the straight line depicted with a clear negative slope. The only outlier relative to that line is the West, which has a small positive D^E and average growth.

The most puzzling observation is that Asia is an outlier, with high growth and the most negative excess *E-share*. [13] This is also the case for the famous high-growth countries such as China (−2.15), Japan (−0.79), South Korea (−0.97) and Singapore (−1.75) - the number in the brackets is the D^E-variable. Unfortunately, this dataset does not cover Hong Kong and Taiwan. The data for Thailand

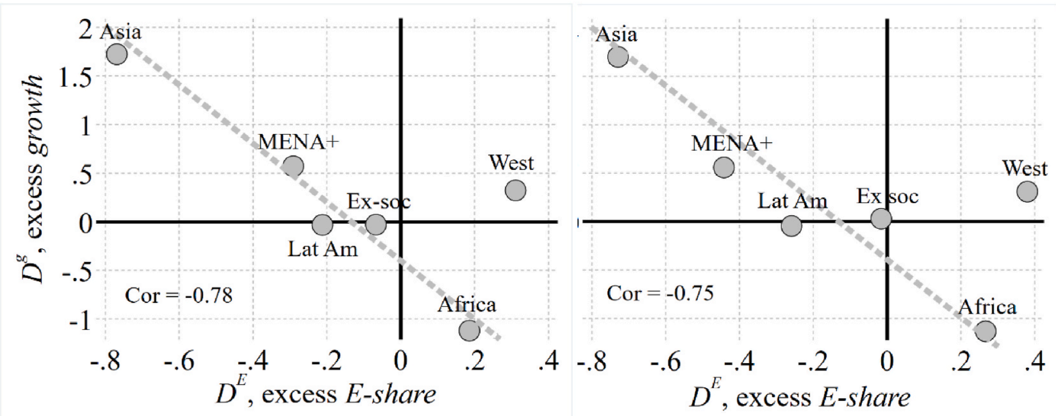

Fig. 8. The correlation of D^E, excess education, and D^g, excess growth, 1970–2017, a. Country averages, b. All observations. Excess growth is defined as growth minus average growth of 2.05%.

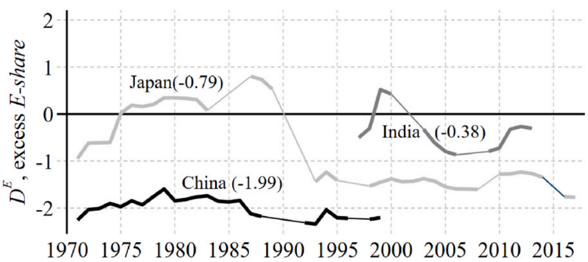

Fig. 9a. D^E, the excess *E-share* in China, Japan, and India.

[13] The same observation is made in Gundlach and Wössmsnn (2004) and Hanushek and Woessmann (2016). They argue that the paradox disappears when school quality is included. However, this finding increases the paradox as it argues that these countries got an amazingly large output for their input.

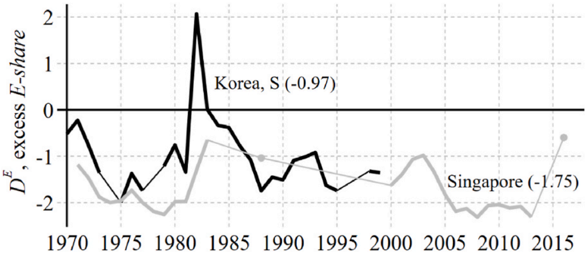

Fig. 9b. D^E, the excess *E-share* in South Korea and Singapore.
The bold lines and circles are the observations, while the thin lines are interpolations. The numbers in the parentheses are the means of the available D^Es. If the peak for South Korea in 1982 is a coding error, it is not mine.

(−0.75) and Sri Lanka (−1.58) are low too.

One of the big debates in economic development is the explanation of the 'miraculous' growth of the East Asian 'tiger' economies as surveyed by Paldam (2003). The miracle started in Japan and then spread to South Korea, Taiwan, Hong Kong, and Singapore, and later to China and now India. It is frequently stated that one reason why these countries did so well was that they gave a high priority to education. This is contrary to the *E-share* data. See Fig. 9a and b. One main reason for the low *E-shares* in these countries is likely to be the large private education sectors in these countries.

5.3. *The extreme observation with $D^E > 4$*

The 53 extreme *E-shares* in 12 countries are listed in Table 5. They are compared with D^g that measure excess growth. Most have high *N*s. Two statistics are: The average excess growth D^g is −0.38 and Cor (D^E, D^g) = 0.06 (see Table 6).

This is as expected from Fig. 8. Two countries are shaded in Gray: Tajikistan, as the mean of the available observations, is negative, so that the extreme observation is indeed extreme. Yemen has only three observations, but the unfortunate country has perennial civil war anyhow. The deletion of the two countries changes the two statistics marginally only.

Table 5
The 53 largest observations for D^E, the excess *E-share* and D^g excess *growth*.

Country	*N*	*Ne* D^E	*Av* D^E	Av D^g	Country	*N*	*Ne* D^E	*Av* D^E	*Av* D^g
Botswana	21	3	2.05	4.29	Moldova	18	4	2.68	−2.30
Côte d'Ivoire	35	1	1.10	−1.32	Namibia	8	1	2.68	−1.24
Cuba	17	11	5.24	0.19	Sao Tome	15	2	1.45	−0.80
Djibouti	13	8	3.29	−2.24	Seychelles	24	5	1.59	2.62
Ghana	29	1	0.90	−0.48	Tajikistan	19	1	−0.43	−2.26
Lesotho	23	14	5.00	0.08	Yemen	3	2	3.93	−1.11

Other variables: *N* is the number of observations. *Ne* D^E is the number of extreme observations (above 4).

Table 6
For country groups.

Color of circles	*N*	Cor
West, light gray	19	0.31
Africa, dark gray	9	0.03
Rest, black [a]	22	−0.27
All (minus two) [a]	50	−0.17
All	52	−0.23

[a] Afghanistan and Syria are left out due to civil war.

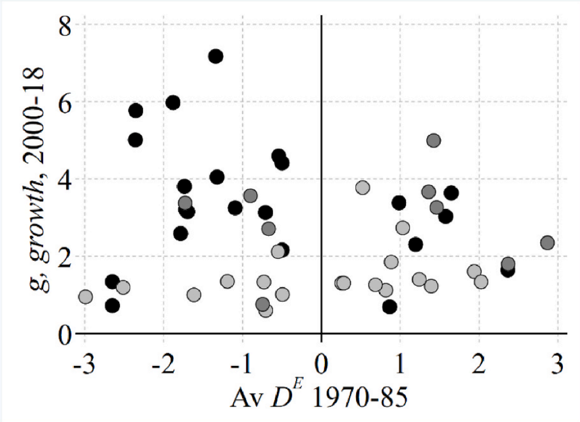

Fig. 10. Excess *E-share* and future growth.

5.4. Including a long lag: can D^E from 1970–85 explain growth 2000–18?

The *E-share* data for 1970-85 have $N = 702$, so it is only 4.6 per country. To be included in the analysis, two criteria should both be passed: (C1) N should be at least 5. This reduces the 141 countries to 64. (C2) The N observations deviate from zero. This reduces the countries to 52.

The two criteria cause two of the five countries on Fig. 9 to be omitted. India falls on (C1) and Japan on (C2). In most cases where C1 holds, C2 also holds. Thus, D^E is remarkably stable in the countries. The correlation between the D^E-variable from 1970–85 and the growth from 2000–18 is -0.23 for the 52 countries. Two countries in war – Afghanistan and Syria – are deleted, and the correlation is -0.17. Some experiments with a classification into country groups – see Fig. 10 – did not change the result. This concludes the analysis of the share of public expenditures for education and growth: The relative level of public investments in education does not explain the future level of growth.

6. The D^S-variable: Countries with too high and too low *school*

Figs. 2 and 5 demonstrated that *School* grows with income and time. Thus, to find the countries with too much and too little school, the data should be adjusted to both variables. This is done in section 6.1. Section 6.2 looks at the relation of the relative School data and economic growth, finding low correlations. The calculations are done for the 6 age classes from 35 to 64, where the transition curves on Fig. 2a are parallel, and the population is sure to be in the labor force.

6.1. The D^S variables for excess school

The transition curve for the *School* variable has a non-linear path as it should, and to make no assumptions about the functional form, the kernel has been generated for all 1077 income observations. Thus, the calculation of the excess School variable D^S is:

$$S^j = K^{Sj}(y), \tag{11}$$

for age group j, where $N = 1077$

$$D^{Sj} = S - K^{Sj}(y), \tag{12}$$

for age group j. We also calculate the average for all age groups

$$D^S = \text{Av}\left(D^{Sj}\right), \tag{13}$$

for all $N = 122$ country observations in the age group.

Adjustment for time trend (10) gives a 6 *x* 122 matrix of D^S observations, where the rows are for one age group and the columns are for each country. As seen from Fig. 6a, the transition curves for the age groups included are almost parallel. The distance between the transition curves reflects the increase in education for the age group compared to the age group five years earlier; that is, the improvement in education over time.

Think of the 40–44 age group. They were in school 20–28 years earlier, when tertiary education is disregarded. The next age group from 45 to 49 were in school 25–32 years earlier. Thus, the increase in the transition curve from 45 to 49 to 40–45 reflects the difference of the education system from 25 to 33 years ago to 20–28 years ago. This is mainly the increase that took place between 20 and 25 years before. The *School* variable has an almost linear increase from 1970 to 2010 (Ap). The parallel paths of the 6 transition curves suggest that the linear path can be extended backwards.

Therefore, we adjust for time simply by subtracting the average of all observations in each row in the D^S-matrix. This gives the D^{ST}-

matrix. It shows if the country is doing well relatively at its level of development and over time. Thus, the variable should explain growth.

6.2. Growth and the D^{ST}-variable

Fig. 11 gives the relation between the excess School variable adjusted and the average growth rate for all years and per five-year intervals. As the average growth is within the 95% confidence interval, it cannot be rejected that there is no connection at all, as is also shown by the coefficient of correlation.

Table 7 further demonstrates the lack of connection of the two variables. This concludes the analysis of the number of years of schooling and growth. The relative level of schooling does not explain the level of growth.

7. Explaining the missing effect of too much and too little education

The high correlation of both education variables and income is due to the strong transition paths of the variables, as seen on Figs. 5 and 6. Surely, education is crucial for development, but the variables have the character of a piece of rope. It is pulled by development, but it is not so good at pushing development.

Recall section 2.1 that argued that the transition path might represent equilibrium development paths. That is, if development would stop at an income level, both the *E-share* and hence *School* would converge to the point on the paths given by that income. Development does not stop, so this is a hypothetical equilibrium. However, it is likely that this path determines the optimal amount of education/human capital as a function of income. Think of the two deviations:

An *E-share* ***above*** the equilibrium path means that the country produces more education than needed. One may imagine that the labor market adjusts the wage structure so that the excess educated can be employed, but thanks to the insider-outsider mechanism, such adjustment may be incomplete. That will give unemployment, first at a secondary level and then at a tertiary level. This has

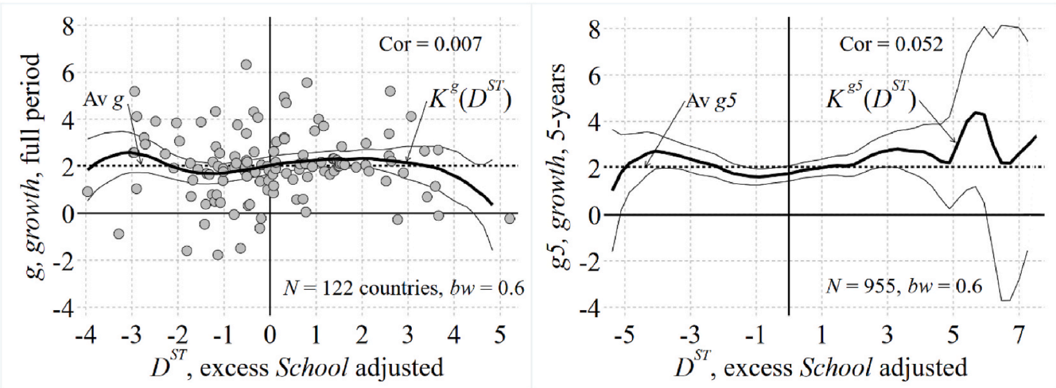

Fig. 11. The relation between the D^S-variable and growth, 1970–2010, a. Country averages, b. 5-Year periods, scatter suppressed. If growth outliers are deleted on Fig. 11b, the curve remains the same, but the confidence intervals become marginally narrower.

Table 7
Correlation of D^S and *growth* for country groups.

	For country averages		For 5-year periods	
	Count	Correlations	Count	Correlations
Africa SS	29	0.204	232	0.121
Asia	15	−0.194	120	−0.169
Ex-soc	21	−0.342	147	0.199
La Am	21	0.007	168	0.087
MENA+	11	0.324	88	0.064
West	25	−0.084	200	−0.067
All	122	0.007	955	0.052

The ex-soc countries are missing 21 observations for 1970, 1975, and one observation for 1980. The country groups are defined in the note to Table 4.

happened in many countries and is known to be politically destabilizing. In addition, of course, over-education means that funds could be better spent.[14]

An *E-share* ***below*** the equilibrium path means that there will be an excess demand for graduates. It is likely that the private sector will strive to fill the gap, and maybe it can. In that case, the effect will also be small. Woessmann (2016) argues that competition between public and private schools is good for school quality, so perhaps it is even an advantage for the full education system if public spending is too low.

It is also arguable that the public sector may supply more education that is consumption oriented than the private sector. This may explain the low *E-shares* in the high growth East-Asian countries. It seems that the private education sector in these countries has acted as an important supplement to the public sector. Consequently, the effect of the small public budgets for education was (much) less harmful than one should expect.

8. Conclusions

The paper deals with two key education variables: the *E/EC-share,* which measures the public education budget in percent of GDP, and the share of the budget per school age kid. It is an investment in human capital, and it should affect the growth rate of the economy with a (long) lag. *School* measures the human capital in the form of the average number of years of education for the population divided into 13 age groups. Both variables have a clear transition path so that they grow systematically with income in a cross-country perspective. The causality behind the transition is simultaneous. (1) Education grows because growing production demands more human capital, and (2) income grows because governments increase human capital.

The evidence for (2) proved weak, in the sense that it does not seems to affect future growth if countries invest more or less than demanded by the transition. In the same way it does not appear to affect growth if countries have accumulated unusually much or less human capital. Thus, in a policy perspective the results are negative.

The easiest way to interpret the results is that the data are too poor to show anything. The critical data comment at the end of section 4 gives some support to such a view. However, both sets of data are plentiful, and they do show rather neat transition curves, much as expected.

Another way to interpret the findings is to claim that the transition curves have some optimality, as argued in section 7. Too much education relative to the transition paths is of little use to the country. Too little public education is compensated by the private sector.

Note on replicability

The data are downloaded from the World Bank data page (*E-share, School*, *Child*) and the Maddison Project (*gdp*) in May 2022. Data for present and past OPEC countries are deleted. The only other deletions are non-overlapping observations in each of the three samples; see Table 1 in the Net-Appendix.

Declaration of competing interest

I am not aware of any conflict.

Data availability

Data will be made available on request.

Acknowledgements

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejpoleco.2023.102362.

[14] The author was in Northern Nigeria in 1973/74 and saw how a very rapid expansion of primary enrolment rates spread the teaching resources so thin that teaching in many schools collapsed, pupils left schools, etc. See also Leuven and Oosterbeek (2011) for a survey on over-education mainly dealing with the USA.

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[15] Wößmann, Wossmann and Woessmann are the same person. Several of the papers by Hanushek or Woessmann are also (parts of) chapters in the handbook they have edited.