Torge Middendorf

Human Capital and Economic Growth in OECD Countries

No. 30

RWI : Discussion Papers

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RWI : Discussion Papers
No. 30

Published by Rheinisch-Westfälisches Institut für Wirtschaftsforschung,
Hohenzollernstrasse 1/3, D-45128 Essen, Phone +49 (0) 201/81 49-0

Editor: Prof. Dr. Christoph M. Schmidt, Ph.D.
ISSN 1612-3565 – ISBN 3-936454-48-5

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Bibliografische Information Der Deutschen Bibliothek
Die Deutsche Bibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.ddb.de abrufbar.

ISSN 1612-3565
ISBN 3-936454-48-5

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Abstract
The results of the PISA 2000 study renewed the interest in the contribution of human capital to economic growth. So far the exploration of large country comparisons delivered rather mixed results. Concentrating on those OECD member countries which participated in PISA 2000, this paper uses panel data estimation techniques to refine this analysis. Estimation results reveal a positive impact of the human capital stock on economic growth suggesting that an increase in the average schooling years by one year yields a rise in the GDP growth rate of about 0.5 percentage points. However, when taking possible endogeneity into account in an instrumental variables approach, these conclusions on the impact of the level of human capital on economic growth is demonstrated to be rather fragile.

JEL-Classification: O40, I20, C23

Keywords: Human capital accumulation, Convergence, Fixed-effects estimation, Instrumental variable estimation

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* Torge Middendorf, RWI Essen. The author would like to thank Thomas Bauer, Roland Döhrn, Dirk Engel, Christoph M. Schmidt, Harald Tauchmann and in particular Michael Fertig (all RWI Essen) for helpful comments and suggestions as well as Claudia Lohkamp for research assistance. All correspondence to Torge Middendorf, Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI Essen), Hohenzollernstraße 1–3, 45128 Essen, Germany, Fax: +49-201-8149200, Email: torge.middendorf@rwi-essen.de.

1. Introduction

The results of the Programme for International Student Assessment (PISA 2000) (OECD 2001) resulted in a heavy debate on the determinants of the students' performance especially within countries showing a relative poor performance (e.g. Fertig 2003). But it has also renewed the interest in the linkage of human capital and economic growth (The Economist 2002).

Theoretically, seminal papers establishing the positive relationship between human capital and growth are Mankiw et al. (1992) as well as Lucas (1988). Empirically, Romer (1989) was among the first to run ad-hoc cross-country regressions with the growth rate of GDP as the dependent variable and incorporating a human capital proxy variable as one of the regressors. He found that adult literacy is positively associated with economic growth. Since then a large body of literature has investigated various education-related determinants of economic growth. Pinning down a robust relationship between variables measuring human capital and economic growth, however, turned out to be a rather difficult endeavor (Krueger, Lindahl 2001). Often, educational variables are insignificant or even display a negative association with growth.

This rather counterintuitive result could be due to methodological problems typical for empirical growth studies. The first is the likely endogeneity of the regressors in growth regressions stemming e.g. from the positive "education demand effect" of higher income (Mankiw 1997). In principle, this problem can be solved by instrumental variables estimation. The second problem is the lack of independence of education from other sources of growth. If, for instance, education is fostered together with other policy measures enhancing growth, this results in an omitted variable bias. Finally the data quality is often a matter of concern (De la Fuente, Doménech 2002). Nearly all data on educational stocks show anomalies like high variability over short periods of time, implausible values or trends.

This paper analyzes the impact of the human capital stock as well as its rate of accumulation on economic growth. Previous studies have concentrated on the influence of either the educational stock or its accumulation. Since theoretically both variables are related to economic growth, it seems counterintuitive to exclude one or another from the analysis. Furthermore the study focuses on OECD countries for three reasons. Firstly the data quality for developing countries seems to be less reliable as the non-market sector is presumably larger (Schneider, Enste 2000). Secondly, even if one accepts this drawback, it might be inappropriate to draw conclusions for industrialized countries out of samples dominated by developing countries (Temple 2001: 73). Thirdly, providing reliable evidence for OECD countries proves to be a serious empirical challenge in itself. Previous studies confined to the OECD deliver conflicting results. Krueger/Lindahl (2001: 1130) split their large cross-country sample and note that the educational stock is only positively associated with economic growth if the initial endowment with education was relatively low. In fact, their regression for OECD countries, where the educational level is relatively high[1], supports a negative impact of education on economic growth. In contrast OECD (2003) finds a significant positive relationship between the human capital stock and economic growth applying a dynamic panel approach.

However both results could be affected by econometric pitfalls. Whereas the former do not adequately account for further determinants of economic growth, the Pooled Mean Group approach of OECD (2003) is very sensitive to the modeling of short run dynamics to capture business cycle effects (Temple 1999: 132). In addition this method is plagued by data problems, since one has to interpolate the available data to obtain annual values, especially in the case of human capital variables. In this paper, a fixed-effects estimator is applied to accommodate omitted variables that are constant over time, as was first done in a growth regression context by Islam (1995). Furthermore, to meet concerns of the possible endogeneity of the independent variables, the results are further tested by an instrumental variables (IV) approach.

The remainder of the paper is organized as follows. The next section provides an overview on the theoretical relationship between human capital and economic growth and the available empirical evidence. Section 3 describes our own empirical analysis of education and growth in the OECD countries. Section 4 discusses the empirical results, and section 5 offers some conclusions.

2. Human capital and economic growth – theory and empirical evidence

The different schools of economic growth theory provide diverse answers on the question how the per capita growth rate of GDP depends on human capital or whether there is any relationship at all. Mankiw et al. (1992) present a human capital-augmented Solow model in which human capital serves as an ordinary production factor: it appreciates at the same rate as physical capital and is produced by the same technology. Due to diminishing returns to scale, as in the original Solow model, an increase in the time devoted to human capital accumulation has only a transitory effect on the growth rate which converges to its steady state level afterwards.

In contrast to the neoclassical growth theory in which long run growth is exogenously determined by technological change, the so-called new growth theory (Romer 1986) explains the level of growth within the model. In a closely related paper (Lucas 1988) human capital is labor-augmenting and characterized by constant returns to scale. This decisive assumption entails self-sus-

1 The mean average schooling years in 1995 was 8.98 years.

tained growth driven by human capital *accumulation*.[2] By contrast, steady state growth additionally depends on the human capital *stock* in Romer (1989). In his model, the skills of the workforce are the key determinant for the generation of new ideas and thus for the intensity of R&D. The same arguments hold for the models of Baumol (1986) and Barro (1991) in which countries with a better educated workforce find it easier to catch up to the technological leaders via imitation. Thus the level of human capital alters total factor productivity and thereby exhibits a positive impact on the growth rate of the economy.

In the empirical literature the discrimination between these theories is anything but clear-cut. The reason for this is the long-term character of the steady-state in the Solow model and the fact that economies seem to converge only slowly to the steady-state. Because of *conditional convergence*, i.e. all other things equal countries grow faster the further they are away from their steady-states, it is rather difficult to discriminate between long run and temporary growth effects on the way to the new steady state. This in turn implies that government policies or human capital accumulation affect even the *rate* of growth for some time. This would also be consistent with the model of Lucas (1988) as it suggests a positive linkage between the rate of human capital accumulation and economic growth.

Furthermore, due to the lack of adequate data, empirical studies have so far often used flow and stock variables interchangeably (Gemmell 1996: 12). School enrollment, for example, is rather a proxy for human capital accumulation than for the human capital stock but has been widely used in the context of both. This however renders a distinction between the hypotheses of the augmented Solow model, and the Lucas and Romer models impossible.

Moreover, the existing empirical studies are characterized by a change in the variables of interest. In the beginning stock variables have been incorporated into growth regressions and have turned out to be positively related to subsequent growth, especially in cross-country approaches. Romer (1989) finds a positive effect of adult literacy rates on economic growth. Barro/ Sala-i-Martin (2004) reveal a positive association between male secondary and higher schooling and economic growth. A similar result is reported by Gemmell (1996), who utilizes an especially constructed measure of school attainment. Panel data studies, however, deliver ambiguous results. In Islam (1995) the coefficient of average schooling years is significantly negative while the study of OECD (2003) yields a positive influence of the same measure on growth.

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2 Lucas (1988) even incorporates the average level of human capital to cover spillover-effects. Its one-time increase however has only an impact on the level of output and therefore works Hicks-neutral (Rudd 2000).

Traditional earnings functions though imply a role for the *change* in educational attainment (Pritchett 1996). This induced studies confined to the analysis of accumulation effects. Yet their results have been rather mixed. While de la Fuente/Doménech (2000) find positive effects of the change in educational attainment using their own compiled data for OECD countries, coefficients have either turned out to be insignificant (Romer 1989; Barro, Sala-i-Martin 1995) or display negative signs (Benhabib, Spiegel 1994; Caselli et al. 1996) in other studies.

Hence, the conflicting results in the existing literature suggest including both types of variables in growth regressions, the human capital stock as well as its change. This is exactly the approach taken in this paper. The next section describes the utilized data and the empirical strategy in more detail.

3. Data description and estimation procedure

Empirical findings demonstrate that the convergence process across countries is not identical across countries but *conditional* on the variation in countries' steady-states (Barro, Sala-i-Martin 1991). Therefore, neglecting the corresponding level of technology would cause omitted variable bias. A suitable way to avoid this problem is to apply a fixed-effects model (Temple 1999: 123) in order to control for the unobserved level of technology, resulting in the following model:

$$(1) \qquad \Delta y_{it} = \alpha + \beta X_{it} + \gamma_2 D_2 + \ldots + \gamma_N D_N + \delta_2 Z_2 + \ldots + \delta_T Z_T + \varepsilon_{it}$$

where Δy_{it} denotes the growth rate of per capita GDP for country *i* in period *t*. The matrix X_{it} represents observable explanatory variables and ε_{it} marks the error term, which is iid $(0, \sigma_\varepsilon^2)$. The disturbances are assumed to be independent across countries. The dummies D_i and Z_t denote the country- and time-fixed effects:

$$D_i = \begin{cases} 1 \text{ for country } i = 2, \ldots, N \\ 0 \text{ otherwise} \end{cases}$$

and

$$Z_t = \begin{cases} 1 \text{ for time period t} = 2, \ldots, T \\ 0 \text{ otherwise} \end{cases}$$

In the empirical application, data for 29 OECD countries (except Luxembourg) is utilized. The time period covers 36 years from 1965 to 2000 and is separated into five-year intervals to adjust for business cycle fluctuations.[3] Variables included comprise the annualized growth rate of real ratio of invest-

[3] While even longer time-spans mitigate the problem of cyclical behavior, it leaves little time series variation in the data (Temple 1999: 132).

ment to GDP per capita as the dependent variable and GDP per capita ($y_{i,t-1}$) and the fertility rate ($fert_{i,t-1}$) at the beginning of the observation interval, the average ratio of investment to GDP ($inv_{i,t-1/t}$), the average ratio of government consumption to GDP ($gov_{i,t-1/t}$), the average ratio of exports plus imports to GDP ($tr_{i,t-1/t}$), as well as the average inflation rate ($p_{i,t-1/t}$) between t–1 and t as regressors. From the large list of possible determinants of economic growth these have emerged as a standard set of variables (e.g. Barro, Sala-i-Martin 2004; Temple 1999). The human capital variables incorporated are the average schooling years at the beginning of the interval as well as the secondary school attainment of the population aged 25 and over during the interval ($hc_{i,t-1}$ and Δhc_{it}).[4] Thus, the following regression is estimated:

$$(2)\qquad \Delta y_{it} = \alpha + \beta_1 \log y_{i,t-1} + \beta_2 inv_{it} + \beta_3 gov_{it} + \beta_4 tr_{it} + \beta_5 fert_{i,t-1}$$
$$+\beta_5 hc_{i,t-1} + \beta_6 \Delta hc_{i,t-1} + \beta_7 p_{it} + \sum_{i=1}^{N} \gamma_i D_i + \sum_{t=1}^{T} \delta_t Z_t + \varepsilon_{it}.$$

National Accounts figures are taken from the Penn World Table, Version 6.1 (PWT) by Heston et al. (2002). The GDP per capita at the beginning of the sample period approximates the „starting position" of the countries and is used instead of measures of the capital stock since different assumptions on depreciation rates render cross-country data hardly comparable (Barro, Sala-i-Martin 2004: 516 f.). Because of the logarithmic scaling the coefficient corresponds to the rate of conversion if the length of the observation period is negligible.[5] The investment ratio aims at approximating the impact of savings on economic growth and thus is expected to exhibit a positive effect on economic growth. Government consumption is assumed to disturb market outcomes and should therefore depress the growth rate. One further variable constructed from the PWT is the ratio of exports and imports to GDP as a measure of international openness. A higher openness signals a higher division of labor which is assumed to enhance growth.

The fertility rate stems from the Population Database of the United Nations (http://esa.un.org/unpp/). Since a higher fertility rate contributes to population growth, it has a negative effect on the steady-state capital endowment per worker. Therefore, we would expect a negative impact on economic growth. Furthermore, the average inflation rate in the sample period is included to approximate financial stability. High inflation would distort market outcomes and should therefore attenuate growth. This variable is provided by the International Monetary Fund Financial Statistics (IFS).

4 For a detailed description of the variables see table 5 in the Appendix.

5 In particular, the coefficient on the initial log of GDP is equal to $-(1-e^{-\omega T})/T$ with T representing the sample period and the convergence rate (Barro, Sala-i-Martin 2004: 517).

The stock of human capital is approximated by the average years of schooling of the population aged 25 and over which is provided by Barro/Lee (2001). This variable is supposed to measure the human capital stock and, therefore, corresponds to the beginning of the observation interval. As already mentioned, previous findings do not clearly indicate if only the stock of human capital should be relevant to economic growth. Therefore the change in average schooling years is also included. Finally, to test the robustness of the results, a second set of specifications is estimated in which human capital is approximated by (the level and change of) secondary school attainment of the population aged 25 and over from the same source. Clearly, it would be more appropriate to include variables that measure the human capital *output* rather than the input, as the educational systems can differ considerably with respect to efficiency.[6] Unfortunately, output variables like illiteracy rates are either not meaningful for a sample of industrialized countries[7] or not available for the full country sample.

One of the most challenging problems of growth studies is the likely endogeneity of the right hand side variables. This is especially true in the case of human capital variables as education may be highly income elastic and as service sector-dominated high-income economies may ask for a better educated workforce (Schultz 1986; Sianesi, van Reenen 2003: 169 f.). Even if human capital is measured at the beginning of the observation interval, the assumption of predetermination (e.g. Barro, Sala-i-Martin 2004: 524) may be violated. In the model of Bils/Klenow (2000) e.g. higher expected growth works like a lower interest rate attributing a higher value to *future* human capital levels and thus inducing higher schooling.

This paper uses IV-estimation to overcome this problem. However, finding a suitable instrument is anything but trivial since a variable has to meet two criteria to be a valid instrument. Firstly, it has to be correlated with the variable for which it should serve as an instrument, i.e. human capital, and secondly, it must not be correlated with the error term of the original equation. That is, conditional on the other variables included, their influence on the growth rate should exclusively operate through their impact on education. Previously proposed instrumental variables have proven to be only weakly correlated with the schooling variable. Bils/Klenow (1998) suggest using the life expectancy as an instrument as the return to schooling rises with a higher life expectancy. However, regressing average schooling years on the log of GDP per capita as well as the life expectancy (figures from the United Nations) yields insignificant results. Furthermore, the exogeneity of life expectancy is anything but

6 For an attempt using international student test scores see Hanushek/Kimbo (2000).

7 See Wößmann (2003) for a critique of literacy rates as a measure of the human capital stock.

guaranteed. The search for possible instruments is further limited because of the confinement to OECD countries.[8]

In the following, we apply two different instruments, school enrollment ratios[9] as well as lags of the schooling variable. The former variable has been used in the past as a human capital proxy in growth regressions. Since high enrollment rates are a prerequisite for high attainment levels, this variable is related to the human capital stock. Furthermore, enrollment into higher education alone does not imply any skills relevant for the labor market. Rather, the actual level of attainment obtained by those enrolled in secondary education reflects the skills of the workforce. Thus, enrollment rates should not exhibit any other impact on economic growth rather than via obtained schooling years. Consequently, lagged (10 years) enrollment rates meet the requirements for a valid instrument. As an alternative instrument, the 5-year lag of the respective schooling variable is used. This may be appropriate as the residual of the growth regression showed no signs of serial correlation[10] although it may not be adequate in the case of unobserved heterogeneity. Because of the application of a fixed-effects estimator this unobserved heterogeneity is restricted to time-variant factors, though.

In both cases the remaining variables are instrumented by their corresponding values in t–1 (log real GDP per capita, log fertility rate) and their averages over the preceding observation interval (investment ratio, government consumption ratio, inflation rate) respectively. The trade share is perceived as the only variable being largely exogenous to economic growth[11] and, thus it is used as its own instrument.

Table 1 provides some summary statistics for the variables in our sample. The OECD countries grew on average at an annual rate of 3.3 per cent over the whole sample period. The utilized variables do not display variability as large as in samples including developing countries. Nevertheless, the sample comprises a period of severe economic downturn with an annualized decline of

8 A possible instrument for the schooling variables would be the Gini coefficient measuring income inequality. The latter should be correlated with schooling as higher income inequality induces higher schooling. Furthermore, existing studies (Deininger, Squire 1998; Ravallion, Chen 1997) have shown that there seems to be no systematic impact of growth on inequality so that the instrument would be valid. However, even the large dataset of Deininger/Squire (1996) exhibits too few observations for the OECD country sample to render such an approach feasible.

9 That is, gross enrolment ratios for secondary education of both genders. Source: UNESCO World Education Indicators.

10 For the models in table 2 and table 3 the null of no first order serial correlation could not be rejected at conventional significance levels applying the Wooldridge test for autocorrelation in panel data.

11 Barro/Sala-i-Martin (2004: 530). In fact, the trade share seems to dependent on the country size which is allowed for by the fixed-effects estimator.

Table 1

Summary statistics

	Mean	Std. dev.	Min	Max	Obs
Dependent variable					
Growth rate of the log of real GDP per capita	0.033	0.025	-0.058	0.133	197
Human capital proxies					
Average schooling years	7.700	2.234	2.050	12.180	190
Δ average schooling years	0.078	0.095	-0.122	0.490	191
Secondary school attainment	0.344	0.151	0.039	0.696	190
Δ secondary school attainment	0.005	0.011	-0.045	0.064	191
Control variables					
Log of real GDP per capita	9.454	0.495	7.533	10.445	197
Investment ratio	0.236	0.051	0.108	0.397	197
Fertility rate	2.136	0.895	1.180	6.820	195
Government consumption ratio	0.125	0.052	0.043	0.262	197
Trade share	0.510	0.403	0.061	2.462	197
Inflation rate	11.794	18.862	0.412	149.508	196
Instrumental variable					
Net enrolment ratio secondary education	76.152	16.845	16.700	98.400	101

Authors' calculations. – See table 5 in the Appendix for a description of the variables.

5.8% (Slovak Republic in the first half of the 90s) as well as a period of hyperinflation (Mexico in the second half of the 80s; Czech Republic and Poland in the first half of the 90s). The accumulation of human capital (measured in average schooling years) reaches its maximum in the case of Norway in the second half of the 80s with an annualized increase in average schooling years of 0.49. Yet, this is an exceptional case since average schooling years of the working force on average exhibit much smaller changes over time in our sample.

4. Estimation results

Since coefficient estimates of variables included in growth regressions are highly sensitive to the inclusion of additional explanatory variables (Levine, Renelt 1992) it is common practice to assess the variables of interest in a reduced model first and then add variables that are also assumed to be related to economic growth. Therefore, we firstly estimate a reduced model consisting only of the GDP per capita at the beginning of the observation interval, the investment ratio and the average schooling years at the beginning of the observation period as explanatory variables. In the following steps we successively add the change in average schooling years, the fertility rate and the ratio of government consumption. The final specification additionally contains the openness variable and the inflation rate. If one of the variables displays a counterintuitive sign, further analysis is indicated. For example, one of the

Table 2

Schooling years and economic growth: panel estimates
Dependent variable: annualized change in log GDP per capita

Variable	Fixed-effects regression				
	(1)	(2)	(3)	(4)	(5)
Average schooling years	0.005** (0.003)	0.006* (0.003)	0.005* (0.003)	0.006** (0.003)	0.005* (0.003)
Δ average schooling years	–	–0.003 (0.018)	–0.008 (0.018)	–0.007 (0.017)	–0.006 (0.017)
Log real GDP per capita	–0.085*** (0.012)	–0.082*** (0.013)	–0.085*** (0.013)	–0.088*** (0.012)	–0.089*** (0.012)
Investment ratio	0.203*** (0.046)	0.192*** (0.047)	0.164*** (0.049)	0.149*** (0.047)	0.131*** (0.048)
Fertility rate	–	–	–0.006* (0.004)	–0.004 (0.004)	–0.005 (0.004)
Government consumption ratio	–	–	-0.099** (0.044)	-0.072* (0.042)	–0.047 (0.043)
Trade share	–	–	–	0.075*** (0.020)	0.075*** (0.020)
Inflation rate	–	–	–	–	–0.001** (0.001)
Constant	0.774*** (0.112)	0.740*** (0.114)	0.805*** (0.114)	0.778*** (0.110)	0.799*** (0.114)
R^2	0.488	0.468	0.492	0.535	0.543
N	190	188	187	187	185
F-test					
country-fixed effects	3.60	2.98	3.11	3.69	2.99
time dummies	8.37	5.73	4.50	3.36	3.16

Authors' calculations. – Standard errors in parentheses. ***/**/*: significant at 1%, 5% and 10% level, respectively. Regressions were estimated for 5-year changes from 1965 to 2000 including 6 time dummies. Maximum number of countries is 29. F-test (country-fixed effects): testing the hypothesis that the country-fixed effects are jointly zero. The critical value of the F-distribution (1% significance) is 1.85. F-test (time dummies): testing the hypothesis that the time dummies are jointly zero. The critical value of the F-distribution (1% significance) is 2.95.

other regressors could be highly correlated with this problematic variable. As already noted, the estimation has been carried out including country- and time-fixed effects.

Estimation results are reported in table 2. The human-capital augmented model fits the data quite well, more than 50% of the variation in the growth rate of per capita GDP is explained by the final specification. The GDP per capita at the beginning of the observation interval as well as the investment ratio display the expected signs and are highly significant throughout the estimations. The coefficient on initial GDP per capita of –0.085 to –0.092 implies that convergence occurs at a rate between 11.1% and 12.3% per year if all other variables are held constant. This is noticeably higher than in time series approaches where it is relatively stable around 2% – 3% per year. An explanation for this result, which is typical for panel estimates, is their ability to accurately capture differences in institutional settings by accounting for country-fixed effects (Islam 1995).

Beginning with the variables of interest, the human capital stock displays the expected positive impact. This implies that the human capital stock positively affects economic growth by increasing a country's ability to adopt new technologies as proposed by Romer (1990). The magnitude of the coefficient is a bit larger than in previous studies and implies that an increase in average schooling years of one standard deviation (1.90 years in 1995) raises the growth rate by 0.9 percentage points, all other things equal. However, this result stands in contrast to previous panel data approaches where the coefficient on the human capital stock is often negative (de la Fuente, Doménech 2000: 1). When the change in average schooling years is added to the growth equation, it exhibits no significant impact. This result is insensitive to the specification of the growth regression and it is in line with the previous studies of Romer (1989), Benhabib/Spiegel (1994) and Barro/Sala-i-Martin (1995), although these are directed towards larger country samples. These findings thus provide arguments in favor of level effects of human capital in OECD countries. This would be consistent with education working through an alteration of total factor productivity.

The control variables display the expected signs although the significance seems to depend on the concrete specification. In a first regression, the fertility rate exhibits a negative impact on growth. A one standard deviation rise in the live births per woman (0.211 in 1995) reduces growth by 0.4 percentage points, all other things equal. Yet augmenting the equation by the trade share and the inflation rate leaves the fertility rate insignificant. The significance of the government consumption ratio seems to depend on the model specification, too. If the inflation rate is added to the regression, the size of government consumption can no longer explain a significant part of the per capita growth rate of GDP. Inflation itself is significant at the 5%-level and attenuates growth by 0.6% points if it rises by one standard deviation (24.4 in 1995).

To test the robustness of the results, the schooling variables were replaced by secondary school attainment rates (table 3). The investment in human capital is accordingly represented by the change in secondary school attainment. From the results in table 3 it becomes transparent that the findings are largely robust to the change of the human capital variable. The most noticeable difference to the first model is the higher coefficient on the investment rate. The proxy for the human capital stock still shows the positive impact on economic growth although significance drops to the 10%-level in the full model. A one standard deviation in secondary school attainment (0.128 in 1995) raises the growth rate by 0.5 percentage points, all other things being equal. The change in the schooling variable however is again insignificant in all specifications.

Table 3

School attainment and economic growth: panel estimates

Dependent variable: annualized change in log GDP per capita

Variable	Fixed-effects regression		
	(1)	(2)	(3)
Secondary school attainment	0.044**	0.056**	0.042*
	(0.022)	(0.024)	(0.024)
Δ secondary school attainment	–	–0.181	–0.134
		(0.141)	(0.133)
Log real GDP per capita	–0.088***	–0.087***	–0.092***
	(0.013)	(0.013)	(0.013)
Investment ratio	0.233***	0.229***	0.161***
	(0.049)	(0.049)	(0.052)
Fertility rate	–	–	–0.005
			(0.004)
Government consumption ratio	–	–	–0.048
			(0.043)
Trade share	–	–	0.069***
			(0.020)
Inflation rate	–	–	–0.001**
			(0.001)
Constant	0.819***	0.807***	0.847***
	(0.117)	(0.119)	(0.119)
R^2	0.489	0.473	0.544
N	190	188	185
F-test			
country-fixed-effects	3.58	3.03	2.96
time-dummies	10.91	8.42	3.69

Authors' calculations. For annotations see table 2.

As already noted, some of the coefficients are likely to be affected by endogeneity bias. To account for this, we apply a fixed-effects IV-estimator. Since the change in schooling seems to play no role for economic growth, these regressions are focusing on the level effects of the human capital proxy. In the first set of IV-estimates the human capital variables are instrumented by their respective values in *t*–1. The corresponding instruments for the remaining endogenous variables are values in *t*–1 for the variables measured at the respective beginning of the sample period (log real GDP per capita, log fertility rate) and averages over the preceding observation interval for the variables measured as ratios (investment ratio, government consumption ratio, inflation rate). The trade share enters as its own instrument. As the first stage of the IV-estimation shows (table 6 in the Appendix), the basic condition of a statistically significant correlation between the instruments and the proposed endogenous regressors is met. Nearly all instruments are correlated with their regressors at the 1% significance level.[12]

12 The lagged value of the inflation rate seems to be a weak instrument though. To test the robustness of the results the index of capital controls (Source: IMF) has been utilized as another instrument with no fundamental change in the results. Estimation results are available from the author upon request.

Table 4

Human capital stock and economic groth: fixed-effects IV-estimates
Dependent variable: annualized change in log GDP per capita

Variable	Instrument for the human capital variable[1]		
	Lags	Lags	Gross enrolment ratios
	(1)	(2)	(3)
Average schooling years	0.007 (0.005)	–	0.011 (0.015)
Secondary school attainment	–	0.085** (0.042)	–
Log real GDP per capita	–0.092*** (0.015)	–0.099*** (0.017)	–0.119*** (0.047)
Investment ratio	0.127* (0.077)	0.252** (0.111)	–0.176 (0.553)
Fertility rate	–0.004 (0.006)	–0.002 (0.007)	–0.005 (0.036)
Ratio of government consumption	–0.052 (0.073)	–0.047 (0.072)	–0.109 (0.165)
Trade share	0.084*** (0.027)	0.067*** (0.022)	0.145*** (0.051)
Inflation rate	–0.001 (0.001)	–0.001 (0.001)	–0.001 (0.002)
Constant	0.801*** (0.144)	0.878*** (0.153)	1.072*** (0.276)
R^2	0.536	0.512	0.459
N	181	181	105
F-test	2.70	2.70	2.23
χ^2-test	22.45	23.14	12.75

Authors' calculations. – Standard errors in parentheses. ***/**/*: significant at 1%, 5% and 10% level, respectively. Regressions were estimated for 5-year changes from 1965 to 2000 including time dummies. – [1]Instruments for the other variables are the values in 1960, 1965, 1970, 1975, 1980, 1985, 1990 of the log of per capita GDP and the fertility rate; averages for 1960–1964, 1965–1969, 1970–1974, 1975–1979, 1980–1984, 1985–1989, 1990–1994 of the investment ratio, government consumption ratio and the inflation rate; the trade share serves as its own instrument. Maximum number of countries is 27. F-test: testing the hypothesis that all country-fixed effects are jointly zero. The critical value of the F-distribution (1% significance) is 1.85. χ^2-test: testing the hypothesis that all time-dummies are jointly zero. The critical value of the χ^2-distribution (1% significance) is 16.81 (regression (1) and (2)) and 11.34 (regression 3) respectively.

In the IV-approach, one of the human capital proxies, average years of schooling, no longer affects economic growth significantly whereas secondary school attainment is significant at the 5%-level (table 4 columns (1) and (2), respectively). In the case of the latter variable the coefficient even doubles in size compared to the fixed-effects estimation. The results suggest that a one standard deviation rise in the human capital stock (0.128% in the case of secondary school attainment in 1995) raises growth by 1.0%. In consequence, the convergence rate increases to 13.13% – 14.34% whereas both the inflation rate and the share of government consumption become insignificant. The trade share still exhibits a positive impact on growth.

Thus previous OLS estimates could be partly affected by endogeneity problems as well as unobserved heterogeneity. To test the robustness of results the human capital variables are furthermore instrumented by school enrolment rates. However, since the first stage of the IV-estimation displays only a weak correlation of secondary school attainment with lagged gross enrolment ratios[13] we confine ourselves to the IV-estimates to average schooling years[14]. Estimation results (table 4, column 3) indicate that the latter does not exhibit a significant impact on economic growth, once unobserved heterogeneity is taken into account. However, one of the most stable variables so far, the investment ratio, becomes insignificant. The estimation results thereby cast doubt on the validity of the instruments.

5. Conclusions

The analysis of the contribution of human capital to economic growth has been inspired by the contributions of Lucas (1988) and Romer (1989) and the emergence of comparable cross-country data. Recently the question of returns to human capital investment regained interest by the publication of the results from PISA 2000. The existing literature, focusing on large country samples, generated rather mixed results. Roughly speaking the stock of human capital seems to matter for economic growth in cross-country regressions while the change in education does not. So far even the positive relationship between the human capital stock and economic growth has been questioned in panel data studies.

Hence, this paper focused on the examination of human capital and growth in a smaller, more homogenous sample of OECD countries. At first glance the positive link between the human capital stock and growth seems to be confirmed in a panel data framework. In a fixed-effects model an increase in average schooling years of one standard deviation (1.90 years in 1995) raises the growth rate by 0.9 % perctentage points, all other things equal. Furthermore, the results are robust to the replacement of the human capital variable and the extension of the set of explanatory variables.

From a theoretical point of view though it is not clear if economic growth is affected only by the human capital stock or supplementary by accumulation effects. In the empirical application variables covering the change in human capital, however, have proven to be not significantly related to economic growth, which confirms the findings of Romer (1989); Benhabib/Spiegel (1994); Barro/Sala-i-Martin (1995).

13 Estimation results are available from the author upon request.

14 See table 6 in the Appendix for the results of the first stage of the IV-estimation.

Finally, taking the likely endogeneity of the explanatory variables as well as possible unobserved heterogeneity into account by implementing an IV-approach casts some doubts on these results. Overall the impact of the human capital level on economic growth appears to be fragile. If at all, the positive association seems to depend on the chosen human capital variable. The findings thereby question the role of human capital for economic growth even in the more homogenous country sample of the OECD. Besides that the explicit effect of human capital on economic growth is still under consideration (Krueger, Lindahl 2001: 1112) as a positive relationship between the human capital stock and economic growth could either be of temporary nature (not affecting the steady-state growth rate but only steady-state income) or could only reflect changes in the returns to schooling.

References

Barro, R.J. (1991), Economic Growth in a Cross Section of Countries. *Quarterly Journal of Economics* 106 (2): 407–444.

Barro, R.J. and J.-W. Lee (2001), International Data on Educational Attainment: Updates and Implications. *Oxford Economic Papers* 53: 541–563.

Barro, R.J. and X. Sala-i-Martin (1991), Convergence across States and Regions. *Brookings Papers on Economic Activity* 1991 (1): 107–182.

Barro, R.J. and X. Sala-i-Martin (1995), *Economic Growth*. Cambridge, MA: MIT Press.

Barro, R.J. and X. Sala-i-Martin (2004), *Economic Growth*. Second Edition. Cambridge, MA: MIT Press.

Baumol, W.J. (1986), Productivity Growth, Convergence, and Welfare: What the Long-Run Data Show. *American Economic Review* 76: 1072–1085.

Benhabib, J. and M.M. Spiegel (1994), The Role of Human Capital in Economic Development: Evidence from aggregate cross-country data. *Journal of Monetary Economics* 34: 143–173.

Bils, M. and P.J. Klenow (1998), Does Schooling cause growth or the other way around? NBER Working Paper 6393. Cambridge, MA.

Bils, M. and P.J. Klenow (2000), Does Schooling cause Growth. *American Economic Review* 90: 1160–1182.

Caselli, F., G. Esquivel and F. Lefort (1996), Reopening the Convergence Debate: A new look at cross-country growth empirics. *Journal of Economic Growth* 1: 363–389.

Deininger, K. and L. Squire (1996), A new dataset measuring income inequality. *World Bank Economic Review* 10: 565–591.

Deininger, K. and L. Squire (1998), New ways of looking at old issues: Inequality and Growth. *Journal of Development Economics* 57: 259–287.

De la Fuente, A. and R. Domenech (2000), Human Capital in Growth Regressions : How much difference does data quality make? CEPR Discussion Paper 2466. CEPR, London.

De la Fuente, A. and R. Domenech (2002), Human Capital in Growth Regressions : How much difference does data quality make? An Update and further Results. CEPR Discussion Paper 3587. CEPR, London.

Fertig, M. (2003), Who's to blame? The Determinants of German Students' Achievement in the PISA 2000 Study. RWI Discussion Papers 4. RWI, Essen.

Gemmell, N. (1996), Evaluating the Impacts of Human Capital Stocks and Accumulation on Economic Growth: Some new evidence. *Oxford Bulletin of Economics and Statistics* 58: 9–28.

Hanushek, E.A. and D.D. Kimko (2000), Schooling, Labor-Force Quality, and the Growth of Nations. *American Economic Review* 90: 1184–1208.

Heston, A., R. Summers and B. Aten (2002), *Penn World Table Version 6.1*. Centre for International Comparisons at the University of Pennsylvania (CICUP).

Islam, N. (1995), Growth Empirics: A Panel Data Approach. *Quarterly Journal of Economics* 110: 83–116.

Krueger, A.B. and M. Lindahl (2001), Education for Growth: Why and for whom? *Journal of Economic Literature* 39: 1101–1136.

Levine, R. and D. Renelt (1992), Sensitivity analysis of cross-country growth regressions. *American Economic Review* 82: 942–963.

Lucas, R. (1988), On the Mechanics of Economic Development. *Journal of Monetary Economics* 22: 3–42.

Mankiw, N.G. (1997), Comment. In B. Bernanke and J. Rotemberg (eds.), *NBER Macroeconomics Annual*. Cambridge, MA: MIT Press, 103–106.

Mankiw, N.G., D. Romer and D.M. Weil (1992), A Contribution to the Empirics of Economic Growth. *Quarterly Journal of Economics* 107: 407–437.

OECD (ed.) (2001), *Knowledge and Skills for Life: First results from PISA 2000*. Paris.

OECD (ed.) (2003), *The Sources of Economic Growth in OECD Countries*. Paris.

Pritchett, L. (1996), Where has all the education gone? World Bank Policy Research Working Paper 1581. World Bank, Washington, DC.

Ravallion, M. and S. Chen (1997), What can new survey data tell us about recent changes in distribution and poverty? *World Bank Economic Review* 11: 357–382.

Romer, P. (1986), Increasing Returns and Long-run Growth. *Journal of Political Economy* 94: 1002–1037.

Romer, P. (1989), Human Capital and Growth: Theory and Evidence. NBER Working Paper 3137. NBER, Cambridge, MA.

Rudd, J. (2000), Empirical Evidence on Human Capital Spillovers. Federal Reserve Board Finance and Economics Discussion Series 46. Federal Reserve Bank, Washington, DC.

Schneider, F. and D.H. Enste (2000), Shadow Economies: Size, Causes, and Consequences. *Journal of Economic Literature* 38: 77–114.

Schultz, T.P. (1986), The Value and Allocation of Time in High-Income Countries: Implications for Fertility. In K. Davis et al. (eds.), Below Replacement Fertility in Industrial Societies: Causes, Policies, Population and Development Review Supplement 1986, 87–108. Cambridge, MA.

Sianesi, B. and J.v. Reenen (2003), The Returns to Education: Macroeconomics. *Journal of Economic Surveys* 17: 157–200.

Temple, J. (1999), The New Growth Evidence. *Journal of Economic Literature* 37: 112–156.

Temple, J. (2001), Growth Effects of Education and Social Capital in the OECD Countries. *OECD Economic Studies* 33: 57–101.

The Economist (2002), The education shibboleth. June 6th 2002.

Wößmann, L. (2003), Specifying Human Capital. *Journal of Economic Surveys* 17: 239–270.

Appendix

Table 5

Description of variables

Variable	Description	Source
	Dependent Variable	
Growth rate of the log of real GDP per capita	Annualized; PPP adjusted	PWT 6.1
	Explanatory variables	
Average schooling years	Average schooling years of the population over 25 years of age	Barro, Lee 2001
Δ average schooling years	Annualized change in average schooling years of the population over 25 years of age	Barro, Lee 2001
Secondary school attainment	Percentage of the population aged 25 and over having attained secondary school as the highest level	Barro, Lee 2001
Δ secondary school attainment	Annualized change in secondary school attainment	Barro, Lee 2001
Log of real GDP per capita	At the beginning of the sample period; PPP adjusted	PWT 6.1
Investment ratio	Ratio of real investment to real GDP (PPP adjusted) in the sample period	PWT 6.1
Fertility rate	Births per woman	United Nations
Government consumption ratio	Ratio of government consumption to GDP (PPP adjusted)	PWT 6.1
Trade share	Ratio of exports and imports to real GDP (PPP adjusted)	PWT 6.1
Inflation rate	Average inflation rate over the sample period (in %)	IMF International Financial Statistics
Gross enrolment rate	Total enrolment in secondary education (both genders), regardless of age, expressed as a percentage of the corresponding population	UNESCO

Table 6

First stage of fixed-effects IV-estimation

Explanatory variables	Dependent variable						
	Log real GDP per capita	Invest-ment ratio	Average schooling years	Fertility rate	Govern-ment con-sumption ratio	Trade share	Inflation rate
	Regression (1)						
Log real GDP per capita (t–5)	0.697***	–0.057***	0.464	–0.379**	0.001	–	–0.823
	(0.050)	(0.018)	(0.322)	(0.158)	(0.019)		(10.186)
Investment ratio (t–5)	0.608***	0.572***	–0.358	0.655	0.113	–	35.124
	(0.198)	(0.072)	(1.28)	(0.630)	(0.075)		(40.668)
Average schooling years (t–5)	0.011	–0.003	0.607***	0.077**	0.006	–	–1.834
	(0.011)	(0.004)	(0.072)	(0.035)	(0.004)		(2.277)
Fertility rate (t–5)	–0.015	–0.010*	–0.176*	0.791***	0.007	–	–1.854
	(0.016)	(0.006)	(0.103)	(0.051)	(0.006)		(3.268)
Government consumption ratio (t–5)	–0.168	0.034	0.553	–0.700	0.696***	–	19.611
	(0.185)	(0.067)	(1.20)	(0.589)	(0.070)		(38.051)
Trade share	0.120	0.016	–0.366	–0.162	–0.052*	1.000	–15.837
	(0.078)	(0.028)	(0.510)	(0.249)	(0.030)		(16.099)
Inflation rate (t–5)	–0.001	–0.001	0.001	–0.005***	0.001**	–	0.325***
	(0.001)	(0.001)	(0.003)	(0.001)	(0.001)		(0.089)
Constant	2.74***	0.697***	–0.202	3.374**	–0.051	–	29.853
	(0.468)	(0.170)	(3.043)	(1.489)	(0.177)		(96.094)
R^2	0.953	0.541	0.867	0.890	0.660	1.000	0.198
	Regression (2)						
Log real GDP per capita (t–5)	0.695***	–0.056***	0.067**[1]	–0.382**	0.002	–	–1.117
	(0.049)	(0.018)	(0.033)	(0.157)	(0.019)		(10.173)
Investment ratio (t–5)	0.662***	0.552***	–0.318**[1]	0.991	0.130*	–	29.015
	(0.201)	(0.073)	(0.136)	(0.638)	(0.077)		(41.415)
Secondary school attainment (t–5)	0.142	–0.050	0.562***[1]	0.853**	0.041	–	–14.922
	(0.107)	(0.039)	(0.072)	(0.339)	(0.040)		(22.008)
Fertility rate (t––5)	–0.018	–0.010*	–0.016[1]	0.771***	0.005	–	–1.359
	(0.016)	(0.006)	(0.011)	(0.049)	(0.006)		(3.199)
Government consumption ratio (t–5)	–0.181	0.040	–0.014[1]	–0.770	0.693***	–	20.575
	(0.185)	(0.067)	(0.125)	(0.588)	(0.071)		(38.163)
Trade share	0.109	0.020	0.016[1]	–0.237	–0.057*	1.000	–14.271
	(0.078)	(0.028)	(0.053)	(0.248)	(0.030)		(16.090)
Inflation rate (t–5)	–0.001	–0.001	–0.001[1]	–0.005***	0.001**	–	0.323***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)		(0.089)
Constant	2.795***	0.646***	–0.419***[1]	3.67***	–0.011	–	15.362
	(0.422)	(0.153)	(0.053)	(1.34)	(0.161)		(86.963)
R^2	0.953	0.545	0.587[1]	0.891	0.657	1.000	0.197
	Regression (3)						
Log real GDP per capita (t–5)	0.741***	–0.027	2.062***	0.231	0.001	–	0.316
	(0.095)	(0.032)	(0.627)	(0.168)	(0.045)		(23.425)
Investment ratio (t–5)	0.549*	0.223**	–5.666***	–0.198	0.190	–	19.353
	(0.317)	(0.105)	(2.085)	(0.557)	(0.148)		(77.876)
Gross enrolment ratio (t–10)	–0.001	–0.001	0.014**	0.001	0.001	–	0.128
	(0.001)	(0.001)	(0.007)	(0.002)	(0.001)		(0.263)
Fertility rate (t–5)	–0.042*	–0.024**	–0.500***	0.645***	0.006	–	7.474
	(0.025)	(0.010)	(0.179)	(0.048)	(0.012)		(6.673)
Government consumption ratio (t–5)	–0.027	–0.084	1.323	0.106	0.543***	–	19.449
	(0.027)	(0.100)	(1.702)	(0.455)	(0.121)		(63.585)
Trade share	0.249*	–0.013	–0.321	0.200	–0.103	1.000	5.410
	(0.138)	(0.048)	(0.910)	(0.243)	(0.065)		(33.992)
Inflation rate (t–5)	–0.001	0.001	–0.002	–0.003***	0.001*	–	0.026
	(0.001)	(0.001)	(0.004)	(0.001)	(0.001)		(0.134)
Constant	2.400***	0.464	–9.989*	–1.874	0.011	–	–29.926
	(0.911)	(0.302)	(5.998)	(1.603)	(0.427)		(224.081)
R^2	0.861	0.240	0.710	0.848	0.565	1.000	0.092

Authors' calculations. – For annotations see table 4. – [1]Dependent variable: Secondary school attainment.