OECD Economics Department Working Papers No. 282

Does Human Capital Matter for Growth in OECD Countries? Evidence from Pooled Mean-Group Estimates

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https://dx.doi.org/10.1787/424300244276

OECD

Unclassified **ECO/WKP(2001)8**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development **31-Jan-2001**

English text only

ECONOMICS DEPARTMENT

ECO/WKP(2001)8
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JT00102034

English text only

ABSTRACT/RÉSUMÉ

This paper presents empirical estimates of human-capital augmented growth equations for a panel of 21 OECD countries over the period 1971-98. It uses an improved dataset on human capital and a novel econometric technique that reconciles growth model assumptions with the needs of panel data regressions. Unlike several previous studies, our results point to a positive and significant impact of human capital accumulation to output per capita growth. The estimated long-run effect on output of one additional year of education (about 6 per cent) is also consistent with microeconomic evidence on the private returns to schooling. We also found a significant growth effect from the accumulation of physical capital and a speed of convergence to the steady state of around 15 per cent per year. Taken together these results are not consistent with the human capital augmented version of the Solow model, but rather they support an endogenous growth model à la Uzawa-Lucas, with constant returns to scale to "broad" (human and physical) capital.

JEL classification: O11, O15, O41
Keywords: growth, human capital, panel data

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Ce document présente des estimations d'équations de croissance étendues pour tenir compte du capital humain estimées sur des données de panel pour 21 pays de l'OCDE pour la période 1971-98. Le document est basé sur des séries révisées de capital humain et une procédure économétrique nouvelle qui réconcilie les hypothèses d'un modèle de croissance avec les contraintes des régressions de panel. Contrairement à plusieurs études précédentes, nos résultats suggèrent un impact positif et significatif de l'accumulation du capital humain sur la croissance de la production par tête. Selon nos estimations, une année supplémentaire de niveau moyen d'études dans un pays aurait un effet positif à long terme sur la production (de 6 pour cent approximativement), ce qui est en accord avec l'évidence microéconomique sur le taux de rendement privé de l'investissement en éducation. On trouve également des effets significatifs de l'investissement en capital physique sur la production est une vitesse de convergence vers l'équilibre à long terme de 15 pour cent par an en moyenne. Dans leur ensemble, ces résultats ne sont pas cohérents avec le modèle de Solow étendu pour tenir compte du capital humain. Cependant ils sont compatibles avec un modèle de croissance endogène à la Uzawa-Lucas, avec des rendements d'échelle constants par rapport au capital au sens large (humain et physique).

Classification JEL : O11, O15, O41
Mots-Clés : croissance, capital humain, données de panel

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**DOES HUMAN CAPITAL MATTER FOR GROWTH IN OECD COUNTRIES?
EVIDENCE FROM POOLED MEAN-GROUP ESTIMATES**

Andrea Bassanini and Stefano Scarpetta[1]

Introduction

1. In the recent growth literature, the accumulation of human capital has gained a central role. Some scholars, like Lucas (1988), have postulated that human capital is an input in the production process like any other; its accumulation implies capital deepening with an associated period of accelerated growth towards a new steady state growth path of output. Drawing on the seminal contribution of Nelson and Phelps (1966), others (*e.g.* Romer, 1990, Aghion and Howitt, 1992) have gone forward in assuming that human capital is necessary for the discovery of new technologies and thus its *stock* is permanently related to the growth rate of output.

2. While there is strong theoretical support for a key role of human capital in the growth process, empirical evidence is not clear-cut. On the one hand, micro-economic studies based on Mincerian human capital earnings functions suggest significant returns to education: one additional year of schooling is invariably associated with between 5 and 15 per cent higher earnings across a wide range of countries (Card, 1999, Psacharopoulos, 1994). At the same time, growth accounting exercises (*e.g.* Jorgenson *et al*., 1987; Young, 1994, 1995) provide some additional support to a significant growth impact of human capital accumulation, although the magnitude of the impact depends on the estimation approach (Topel, 1999). On the other hand, growth regressions have generally failed to find a significant contribution of human capital to economic growth. In particular, while the initial stock of human capital matters -- and actually yields unreasonably high implicit output elasticities (*e.g.* Mankiw, *et al.*, 1992; Barro and Sala-i-Martin, 1995) -- the evolution of human capital over time is not statistically related to output growth (*e.g.* Benhabib and Spiegel, 1994; Pritchett, 1996, and Topel, 1999 for a review).

3. This paper aims at contributing to the debate over the role of human capital on growth along two main dimensions. First, we argue that the counterintuitive results on human capital in growth regressions has a lot to do with the poor quality of the data, even for the OECD countries. We use time-series of human capital from a version of the Barro and Lee (1996) data set that has been recently revised by de la Fuente and Doménech (2000). We have also updated this database with OECD data for the past decade. Second and more importantly, we use a novel econometric technique -- the Pooled Mean Group (PMG) estimator -- to assess the long-run relationships between factor inputs and output in a sample of OECD countries over the 1971-1998 period. PMG allows reconciling growth model assumptions with the needs of panel data regressions. In particular, we let short-term adjustments and convergence speeds to vary across

1. We are grateful to Angel de la Fuente, Jørgen Elmeskov, Michael Feiner, Philip Hemmings, Dirk Pilat, Ron Smith, Jonathan Temple, Nicholas Vanston and Ignazio Visco for many helpful comments on a previous version of the paper and Catherine Chapuis-Grabiner for excellent statistical assistance. The opinions expressed in the paper are those of the authors and do not necessarily reflect those of the OECD or its Member countries.

countries, and impose cross-country homogeneity restrictions only on the long-run coefficients. While there are indeed good reasons to believe in common long-run coefficients, given that OECD countries have access to common technologies and have intensive intra-trade and foreign direct investment, there is no reason to assume that the speed of convergence to the steady states, as well as technological progress, should be the same across countries (as in the many studies based on dynamic fixed effects estimators). To anticipate the results of our analysis, we find a robust positive relationship between human capital and output growth, with implied output elasticities that are consistent with the microeconomic evidence. Furthermore, our results lend some empirical support to endogenous growth models à la Lucas, that is to say, with constant returns to scale with respect to "broad" (physical and human) capital.

4. The paper is organised as follows. Section 1 recall the human-capital-augmented neoclassical growth model and indicates the general specification retained in the empirical analysis. Section 2 presents the data with a particular focus on the human capital indicators. The empirical results are in Section 3 that also contains a detailed sensitivity analysis to test the robustness of results across different specifications of the growth equations, different econometric procedures, and different sample sets. The final section concludes.

1. The growth model

5. The growth equation analysed in this paper is drawn from a neoclassical growth model augmented in order to take into account human capital as a factor of production. Let us consider a constant returns to scale production function that at time *t* is given by:

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} \left(A(t)L(t)\right)^{1-\alpha-\beta} \qquad [1]$$

where *Y*, *K* and *H* are output, physical and human capital respectively, *L* is labour and α and β are the partial elasticities of output with respect to physical and human capital. The time paths of the right-hand side variables is described by the following equations:[2]

$$\begin{aligned} \dot{k}(t) &= s_k(t)A(t)^{1-\alpha-\beta} k(t)^{\alpha} h(t)^{\beta} - (n(t)+d)k(t) \\ \dot{h}(t) &= s_h(t)A(t)^{1-\alpha-\beta} k(t)^{\alpha} h(t)^{\beta} - (n(t)+d)h(t) \\ \dot{A}(t) &= g(t)A(t) \\ \dot{L}(t) &= n(t)L(t) \end{aligned} \qquad [2]$$

where $y = Y/L$ and $k = K/L$ are output and physical capital in intensive terms, $h = H/L$ stands for average human capital, s_k and s_h for the investment rate in physical and human capital, *n* is the growth rate of labour, *g* is the rate of technological change and *d* is the common (time-invariant) depreciation rate. Under the assumption that $\alpha + \beta < 1$ (*i.e.* decreasing returns to reproducible factors), this system of equations can be solved to obtain steady-state values of k^* and h^* defined by:

2. Note that, while, the standard neoclassical growth model (Solow-Swan model) can be re-written in terms of the optimal behaviour of a representative consumer, subject to some restrictions on its utility (Ramsey-Cass-Koopmans model), as well as its stochastic version subject to some restrictions on the nature of stochastic shocks (Brock and Mirman model), this is not possible in the case of the augmented model discussed in this section (See Stokey and Lucas, 1989, and Barro and Sala-i-Martin, 1995).

$$\ln k^*(t) = \ln A(t) + \frac{1-\beta}{1-\alpha-\beta}\ln s_k(t) + \frac{\beta}{1-\alpha-\beta}\ln s_h(t) - \frac{1}{1-\alpha-\beta}\ln(g(t)+n(t)+d)$$
$$\ln h^*(t) = \ln A(t) + \frac{\alpha}{1-\alpha-\beta}\ln s_k(t) + \frac{1-\alpha}{1-\alpha-\beta}\ln s_h(t) - \frac{1}{1-\alpha-\beta}\ln(g(t)+n(t)+d) \quad [3]$$

6. Substituting these two equations into the production function and taking logs yields the expression for the steady-state output in intensive form. The latter can be expressed either as a function of s_h (investment in human capital) and the other variables or as a function of *h** (the steady-state stock of human capital) and the other variables (Mankiw *et al.*, 1992). From an empirical point of view, the choice between the two depends on the nature of available data. In this paper human capital is proxied by the average years of education of the working age population and thus the expression is in terms of human capital stock. Thus, the steady-state path of output can be written as:

$$\ln y^*(t) = \ln A(t) + \frac{\alpha}{1-\alpha}\ln s_k(t) + \frac{\beta}{1-\alpha}\ln h^*(t) - \frac{\alpha}{1-\alpha}\ln(g(t)+n(t)+d) \quad [4]$$

*h** is however unobservable. However, by solving the system of differential equations constituted by the first two equations [2], a relationship between the steady state of human capital and its actual level can be derived. In particular, by expressing the first two equations [2] in growth rates, and substituting out the respective investment rates by means of equations [3], yields:[3]

$$\frac{d\ln\frac{k}{A}}{dt} = (n+g+d)e^{-(1-\alpha)\ln\frac{k}{k^*}}e^{\beta\ln\frac{h}{h^*}}$$
$$\frac{d\ln\frac{h}{A}}{dt} = (n+g+d)e^{\alpha\ln\frac{k}{k^*}}e^{-(1-\beta)\ln\frac{h}{h^*}} \quad [5]$$

which, once linearised, yield a solution for $\ln h$ of the form:

$$\ln(h(t)/A(t)) = \psi(\ln(h^*(t)/A(t)) + (1-\psi)\ln(h(t-1)/A(t-1)) \quad [6]$$

where ψ is a function of (α, β) and the term $(n+g+d)$. Re-arranging equation [6] yields an expression for $\ln h^*$:

$$\ln h^*(t) = \ln h(t) + \frac{1-\psi}{\psi}\Delta\ln(h(t)/A(t)) \quad [7]$$

By replacing the term *ln h** with its expression [7] into equation [4], we obtain an expression for the steady state output in intensive terms as a function of investment rate and the actual human capital stock. As often stressed in the empirical literature, this would be a valid specification of the growth equation only if countries were in their steady-states or if deviations from the steady states were independent and identically distributed. If observed growth rates include out-of-the-steady-state dynamics, then transitional dynamics has to be modelled explicitly. A linear approximation of the transitional dynamics can be expressed as follows (Mankiw *et al.*, 1992):

3. To simplify the notation, the suffix *t* has been dropped.

$$\frac{d\ln(y(t)/A(t))}{dt} = \lambda(\ln(y^*(t)/A(t)) - \ln(y(t)/A(t))) \quad [8]$$

where $\lambda = (1-\alpha-\beta)(g(t)+n(t)+d)$. The solution of this differential equation is represented by:

$$\ln(y(t)/A(t)) - \ln(y(t-1)/A(t-1)) = \phi(\lambda)(\ln(y^*(t)/A(t)) - \ln(y(t-1)/A(t-1))) \quad [9]$$

where $\phi(\lambda) = 1 - e^{-\lambda t}$. Inserting in equation [9] in the expression for y^* and h^* (equations 4 and 7) yields:[4]

$$\begin{aligned}\Delta\ln y(t) &= -\phi(\lambda)\ln(y(t-1)) + \phi(\lambda)\frac{\alpha}{1-\alpha}\ln s_k(t) + \phi(\lambda)\frac{\beta}{1-\alpha}\ln h(t) \\ &+ \frac{1\text{-}\psi}{\psi}\frac{\beta}{1-\alpha}\Delta\ln h(t) - \phi(\lambda)\frac{\alpha}{1-\alpha}\ln(g+n(t)+d) + \left(1-\frac{\phi(\lambda)}{\psi}\right)g + \phi(\lambda)\ln A(0) + \phi(\lambda)gt\end{aligned} \quad [10]$$

7. To the extent to which g is not observable, its parameter cannot be distinguished from the constant term empirically. Hence, the estimated baseline growth equation could be expressed as follows:

$$\Delta\ln y(t) = a_0 - \phi\ln y(t-1) + a_1\ln s_k(t) + a_2\ln h(t) - a_3 n(t) + a_4 t + b\Delta\ln h(t) + \varepsilon(t) \quad [11]$$

8. Equation [11] can be estimated for any time interval. As discussed in Section 3, the use of five-year or ten-year time intervals represents a loss of information and, given data availability, in this paper a one-year time span has been retained. However, annual data contain short-run components that have to be accounted for. Taking the maximum lag as being one and adding short-run regressors, the equation can be written in a (linearised) error correction form:[5]

$$\begin{aligned}\Delta\ln y(t) &= a_0 - \phi\ln y(t-1) + a_1\ln s_k(t) + a_2\ln h(t) - a_3 n(t) + a_4 t \\ &+ b_1\Delta\ln s_k(t) + b_2\Delta\ln h(t) + b_3\Delta\ln n(t) + \varepsilon(t)\end{aligned} \quad [12]$$

To allow for non-constant rate of technological change the same equation can be estimated with a non-linear time trend proxied by a sequence of time dummies.

2. Specification of the growth equation and the data

2.1 The specification of the growth equation

9. Growth regressions have been estimated in the literature using either GDP per person employed or, more frequently, GDP per capita (generally referring to working age population to avoid problems related to differences in demographic structure). Under the assumption of full employment and stable participation rates, these two specifications yield the same results and the choice depends on the availability and quality of data on population and employment. However, as discussed in Scarpetta *et al.* (2000) employment rates (employment over population of working age) have changed significantly over

4. The equation has been simplified assuming a constant rate of technological change. Its version with non-constant technological change can be easily derived.

5. The condition for the convergence towards an equilibrium (*i.e.* $-1<-(1-e^{-\lambda t})<0$) is sufficient to express equation [12] as an error correction mechanism.

time in most OECD countries, and particularly so in Continental Europe where significant declines were recorded in the 1980s and 1990s. The resulting path of GDP per worker is strongly affected by short- and long-run fluctuations in the employment rate. Under these conditions, a specification in GDP per person employed is likely to yield different results from that in GDP per capita and to be less informative of both (conditional) convergence and the role of investment in physical and human capital on growth.

10. Symmetric to the choice of the dependent variable is the choice of the human capital variable. Education data often used to proxy human capital in (augmented) neoclassical growth models either refer to those in employment or the entire working age population, influencing the choice of the specification. For example, enrolment rates or education attainment levels in the popular Barro and Lee database (Barro and Lee, 1996) refer to the population from 25 to 64 years of age, suggesting that the preferred specification is the one in GDP per person in the working age. As shown in Scarpetta *et al.* (2000), human capital evolved differently between the employed population and the working age population in most OECD countries, with a tendency, especially in continental Europe, for a stronger up-skilling amongst people in employment than in the broader working age population.

11. Growth regressions have often used enrolment rates from UN sources instead of education attainment, because the former are closer to the concept of investment in human capital. However, changes in enrolment rates are likely to have an impact of GDP per capita growth only with a long lag: in a model with annual data and with relatively limited time series (25-27 observations) there are inherent limits to the number of lags to be included in the specification. Moreover, a number of authors have questioned the use of enrolment rates as a proxy for the concept of human capital that influence decisions about fertility, participation and so on (see amongst others, Barro and Lee, 1996; and Wolff and Gittleman, 1993).

12. In this paper we use a measure of average years of education in working-age population to proxy human capital stock. There are practical and theoretical reasons that suggest using level data instead of first differences as explanatory variable in the growth regressions. In fact, although the time series on human capital used in this study have been checked for consistency of definition over time, they are partially the result of linear interpolations from five-year observations which makes annual changes potentially misleading. More theoretically, change in average years of education represents net investment in human capital while the empirical implementation of the system of equations [2] would rather require a measure of gross investment. Finally, as noted by Temple (2000), reverse causality problems of the kind analysed by Bils and Klenow (2000) are less severe when a measure of human capital stock is considered.

2.2 The data

13. The growth equations analysed in this paper have been estimated for 21 OECD countries over the period 1971-1998.[6] The baseline variables used in the regression includes the following variables:

- *Dependent variable ($\Delta logY$)*. Growth in real GDP per head of population aged 15-64 years expressed in (1993) Purchasing Power Parities (PPP).
- *Convergence variable ($logY_{-1}$)*. Lagged real GDP per head of population aged 15-64 years, in PPP.

6. The country sample include: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany (western), Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States.

– *Physical capital accumulation ($logS_K$)*. The propensity to accumulate physical capital is proxied by the ratio of real private non-residential fixed capital formation to real private GDP.[7]

– *Stock of human capital (logH)* is proxied by the average number of years of schooling of the population from 25 to 64 years of age.

– *Population growth ($\Delta logP$)*. Growth in the working age population (15-64 years).

14. The data used in this paper are from the following sources:

– Data on GDP, working age population, and gross fixed capital formation are from the OECD *Analytical Data Base* (ADB). Purchasing Power Parity benchmarks for 1993 are from the OECD Statistics Department. In the case of Norway, data refer to the mainland economy. In the case of Greece and Portugal the ratio between total gross fixed capital formation and total real GDP was used as a proxy for the investment rate (*i.e*. the ratio of private non-residential fixed capital formation to business sector real GDP), due to data availability.

– Data on education attainment up to the early 1980s are interpolated from five-year observations from de la Fuente and Doménech (2000), while later observations are from the OECD *Education at a Glance* (various issues).[8] In particular: three educational groups were considered: below upper secondary education (ISCED 0 to ISCED 2); upper secondary education (ISCED 3); and tertiary education (ISCED 5 to ISCED 7). The cumulative years of schooling by educational level -- required to estimate the average number of years of total schooling used in the empirical analysis -- are from the OECD Education at a Glance -- 1997 (OECD, 1998). See also Annex Table.

15. The exact country coverage of the variables is presented in Table 1, while the basic statistics are in Table 2.

Table 1. Details on data availability

Variable	Start date	End date	Exceptions
Real GDP per person of working age (***Y***)	1971	1998	1971-1997 for Portugal and Spain; 1971-1996 for Greece; 1971-1994 for Western Germany.
Physical capital accumulation (***Sk***)	1971	1998	1971-1997 for Austria, Belgium, Ireland, Italy, New Zealand, Portugal, Spain and Sweden; 1971-1996 for the United Kingdom; 1971-1995 for Switzerland; 1971-1990 for Western Germany; 1975-1998 for Australia.
Human capital (*H*)	1971	1998	1971-1990 for Western Germany
Growth of working age population(Δ***logP***)	1971	1998	1971-1997 for Spain; 1971-1996 for Greece; 1971-1994 for Western Germany.

7. In the extended models, also government fixed capital formation is considered, but its impact on growth is allowed to differ from that of private fixed capital formation.

8. De la Fuente and Doménech (2000) revised the original series from Barro and Lee (1996) to eliminate anomalies in connection with attainment rates.

Table 2. Basic statistics

Variables	Sample mean	Standard Deviation
Y : GDP in 1995 $US (in '000) (expressed in 1993 EKS PPPs)	24.0	5.8
Sk – Investment rate (per cent of GDP)	17.11	4.46
H; average years of education	10.18	1.68
ΔlogP per cent growth	0.79	0.62

3. The econometric approach

16. In this paper a standard growth equation corresponding to the human-capital augmented model is estimated on the base of annual data and considering pooled cross-country time series. The growth equation [12] has been re-written as follows:

$$\begin{aligned}\Delta \ln y_{i,t} &= a_{0,i} - \phi_i \ln y_{i,t-1} + a_{1,i} \ln s_{i,t}^K + a_{2,i} \ln h_{i,t} - a_{3,i} n_{i,t} + a_{4,i} t \\ &+ b_{1,i} \Delta \ln s_{i,t}^K + b_{2,i} \Delta \ln h_{i,t} + b_{3,i} \Delta n_{i,t} + \varepsilon_{i,t}\end{aligned} \qquad [13]$$

where most acronyms are defined above and t is the time trend while subscripts indicate country and time (i, denotes countries, t time); the *b-regressors* capture short-term dynamics and ε is the usual error term.

3.1 From cross-section to panel data analyses

17. The empirical analysis of the growth model in equation [13] above generally involves a system of $N*T$ equations (N countries and T time observations) that can be examined in different ways. The choice of the econometric approach partially depends upon the size of N and T and the quality of data across these two dimensions. The main econometric approaches used in the empirical literature include cross-section regressions and different forms of pooled cross-section time-series regressions. These are discussed below with emphasis on the advantages/disadvantages with respect to the specific characteristics of the OECD sample.

Cross-section regressions

18. The bulk of growth regressions uses cross-section data for a large number of countries (amongst the most well known contributions, see Barro and Sala-i-Martin, 1992, 1995; Mankiw *et al.*, 1992) where the dependent variable is the average growth rate over a fairly long period (usually 20 or more years), and the explanatory variables are either long-run averages (*e.g.* investment shares) or variables relating to the beginning of the period (*e.g.* initial level of output per capita, educational enrolment, etc). The limited data requirement allows cross-section analyses to focus on large sets of countries. Moreover, the straightforward econometric procedure allows testing for different specifications and check the robustness of coefficients to changes in the specification, *e.g.* using Leamer's extreme bound approach (*e.g.* Levine and Renelt, 1992) or the distribution of coefficients (Sala-i-Martin, 1997, Sala-i-Martin *et al.*, 2000; Fernandez *et al.*, 1999).

19. Cross-section regressions offer consistent estimates of the average long-run relations only under quite severe conditions, *i.e.* that country-specific parameters are distributed independently of the regressors

and the regressors are strictly exogenous (see Pesaran and Smith, 1995). These conditions are necessarily violated in the dynamic framework of growth regressions as in equation [13] above. In particular, the country-specific effects ($a_{0,i}$) in the equation cannot be identified: these effects are, by construction, correlated with the lagged level of output per capita, leading to an upward bias in the estimated convergence coefficient, or equivalently, a downward bias in the estimated speed of adjustment to steady-state. Moreover, cross-section regressions ignore the possible heterogeneity of technological progress.

Panel data regressions

20. When studies have focused on smaller numbers of countries, such as those in the OECD area, researchers have often exploited the time dimension of the data. In order to reduce the influence of short-run variation in the form of business-cycle effects and other processes, the most common technique has been to take averages of the data, typically 5 years (see, for example Englander and Gurney, 1994; Islam, 1995; Caselli *et al.*, 1996). There are only few examples of growth regressions based on cross-section and *annual* time-series data (*e.g.* Cellini, 1997, Lee *et al.*, 1997; Crain and Lee, 1999).

21. The main advantage of panel data for the analysis of growth equations is that the country-specific effects can be controlled for, for example by using dynamic fixed-effect estimators (DFE). Instrumental variables (*e.g.* Arellano and Bond, 1991 and Arellano and Bover, 1995) are also applied to overcome the usual small-sample downward lagged dependent variable bias (see Nickell, 1981). However, the dynamic-fixed-effects estimator generally imposes homogeneity of all slope coefficients, allowing only the intercepts to vary across countries. In other words, DFE imposes $(N-1)(2k + 2)$ restrictions on the unrestricted model in equation [13]: *i.e.* k long-run coefficients, k short-run coefficients plus the convergence coefficient and the common variance. The validity of DFE, in particular, depends critically on the assumptions of common technology and common convergence parameter that in turn requires both common technological change and population growth across countries.[9] While population growth is manifestly different across countries, the assumption on technological change is difficult to reconcile with evidence of multifactor productivity growth patterns across countries (see *e.g.* Scarpetta *et al.*, 2000). Pesaran and Smith (1995) suggest that, under slope heterogeneity, estimates of convergence are affected by an heterogeneity bias.

22. At the other extreme is the mean-group approach (MG) that consists of estimating separate regressions for each country and calculating averages of the country-specific coefficients (*e.g.* Evans, 1997; Lee *et al.*, 1997). In particular, there are $N(2k + 3)$ parameters to be estimated: each equation has $2k$ coefficients on the exogenous regressors, an intercept, a coefficient on the lagged dependent variable and a variance. The small-sample downward bias in the coefficient of the lagged dependent variable remains. Moreover, while consistent, this estimator is likely to be inefficient in small country samples, where any country outlier could severely influence the averages of the country coefficients.

23. An intermediate choice between imposing homogeneity on all slope coefficients (DFE) and imposing no restrictions (MG) is the pooled mean group estimator (PMG) that allows short-run coefficients, the speed of adjustment and error variances to differ across countries, but imposes

9 . Instrumental variable estimators *à la* Arellano and Bond (1991) are particularly suited for dealing with dynamic panel data when N is large and T relatively small. As shown by Nickell (1981) the downward lagged dependent variable bias depends on 1/T and it is less of a concern when T is large and of the same order of magnitude of N. In this latter case, heterogeneity of individuals (countries) is a more serious problem and imposing homogeneity of all (short and long-run) parameters risk leading to inconsistent results (see Lee *et al.*, 1997).

homogeneity on long-run coefficients.[10] In other words, the PMG imposes *(N-1)k* restrictions on the unrestricted model shown in equation [13]. Given the access to common technologies, and the intense trade relations, the assumption of a common long-run production function parameters is reasonable. By contrast, it is more difficult to assume homogeneity of speed of convergence and short-term dynamics as in dynamic fixed effects estimators. Under the long-run slope homogeneity the PMG estimator increases the efficiency of the estimates with respect to mean group estimators (Pesaran *et al.*, 1999). Formally, conditional on the existence of a convergence to a steady state path, the long-run homogeneity hypothesis permits the direct identification of the parameters of factors affecting steady state path of output per capita ($a_{s,i}/\phi_i = \theta_s$, see below). In other words, with the PMG procedure, the following restricted version of equation [13] is estimated on pooled cross-country time-series data:

$$\begin{aligned}\Delta \ln y_{i,t} &= -\phi_i \left(\ln y_{i,t-1} - \theta_1 \ln s_{i,t}^K - \theta_2 \ln h_{i,t} + \theta_3 n_{i,t} - a_{4,i} t - \theta_{0,i}\right) \\ &\quad + b_{1,i} \Delta \ln s_{i,t}^K + b_{2,i} \Delta \ln h_{i,t} + b_{3,i} \Delta n_{i,t} + \varepsilon_{i,t}\end{aligned} \qquad [14]$$

24. The hypothesis of homogeneity of the long-run policy parameters cannot be assumed *a priori* and is tested empirically in all specifications. In particular, in the next section, the Hausman test (Hausman, 1978) is used for this purpose: under the null hypothesis, the difference in the estimated coefficients between the MG and the PMG are not significantly different and PMG is more efficient.

4. The empirical results

4.1 Model selection and sensitivity analysis

Baseline equation

25. This paper deals with panel data regression analysis of equations [13] and [14]. Table 3 presents different specifications of the baseline growth regression using Mean Group estimators. The latter are more suited to test model specification and to gauge the basic properties of the growth equations on a country by country basis. It is indeed important to check that the model is sufficiently well specified on a country basis before more efficient (but potentially inconsistent) estimation procedures could be implemented and tested against a reliable benchmark (see Pesaran *et al.*, 1999). The coefficient on average years of education turns out statistically significant (at 1 per cent level) in the specification without a time-trend and it is still high, although not statistically significant, in the specification with a linear time-trend. Conversely, the results indicate that a time-trend is weakly significant when the human capital variable is omitted and even negative on average, although not significant, when the human capital variable is included. Furthermore, in the specification that includes the human capital variable, the time trend is not significant in 13 out of 21 country equations at the 10 per cent confidence level.[11]

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10. The Seemingly Unrelated Regression (SURE) approach is not feasible in the present context for two main reasons: 1) SURE requires the estimation of $N*k$ coefficients plus ½$N*(N+1)$ elements of the covariance matrix, and, for N of the same order of magnitude of T, there is a problem of degrees of freedom; and 2) SURE is generally concerned with linear cross-equation restrictions, whereas common long-run coefficients in equation [13] above imply non-linear restrictions across different country equations.

11. The presence of a linear trend in the sample risks to bias downwards the estimate of the coefficient of the human capital variable (as the latter is affected by a trend). In fact, generally when the estimated linear time trend is positive the estimated long-run coefficient of human capital is negative and vice versa. Three

Table 3. **Selection of the baseline growth equations**
(Mean-group estimators[1])

Dependent variable: ΔlogY				
Convergence coefficient				
logY$_{-1}$	**-0.37** ***	**-0.11** ***	**-0.48** ***	**-0.36** ***
	(0.05)	*-(0.11)*	*(0.06)*	*(0.05)*
Long-Run Coefficients				
logSk	**-0.19**	**-0.19**	**0.26** ***	**0.09**
	(0.37)	*(0.76)*	*(0.09)*	*(0.11)*
logH			**1.16**	**1.93** ***
			(2.12)	*(0.53)*
ΔlogP	**-9.73** **	**-63.78**	**-10.08** *	**-8.44** *
	(4.70)	*(52.71)*	*(5.27)*	*(4.74)*
time trend	**0.022** *		**-0.001**	
	(0.012)		*(0.019)*	
Short-Run Coefficients				
ΔlogSk	**0.12** ***	**0.14** ***	**0.09** ***	**0.11** ***
	(0.02)	*(0.02)*	*(0.02)*	*(0.03)*
ΔlogH			**1.57**	**-1.76** ***
			(2.13)	*(0.67)*
Δ^2 logP	**0.75**	**0.70** *	**1.07** **	**0.83**
	(0.53)	*(0.42)*	*(0.52)*	*(0.58)*
No. of countries	21	21	21	21
No. of obs.	540	540	540	540
Log likelihood	1550	1496	1599	1555

All equations include a constant country-specific term. Standard errors are in brackets.
*: significant at 10 % level; ** at 5% level; *** at 1 % level.
1. No restrictions on short and long-run coefficients.

26. Tests of model specification, yield similar results with and without the linear time trend in the case of the human-capital-augmented model (see Table 4). In particular, at conventional statistical level, there is evidence of serial correlation of residuals in four countries (five without the trend); functional form misspecification in three; evidence of non-normality of residuals in three (four without the trend); and evidence of heteroskedasticity in one.[12]

27. Specifications without average years of education perform somewhat worse that those including it. In particular, in the specification with a linear time-trend, there is evidence of serial correlation in five countries, functional form misspecification in six, non-normality of residuals in five and heteroskedasticity in three. Without a time-trend there is evidence of serial correlation of residuals in four countries, of functional form misspecification in four, of non-normality of residuals in three and of heteroskedasticity in four.

28. On the basis of these diagnostics, there seems to be sufficient evidence that average years of education should be included in the retained specification. More debatable is whether a linear time-trend should also be included. As the number of independent variables required to estimate the model are anyway limited (therefore no serious degrees of freedom problem arises), a linear time trend is retained in

countries are the exception to this rule (Austria, Spain and the United Kingdom), for which however neither of the two coefficients turns out significantly different from zero at the 10 per cent level.

12. This evidence is based on results from Godfrey's test of residual serial correlation; Ramsey's RESET test of functional form; Jarque-Bera's test of normality of regression residuals; and the Breusch-Pagan Lagrange multiplier test for homoscedasticity.

the main specification.[13] The fit of both human-capital augmented equations is rather good: about 50 per cent of the change in the logarithm of per capita output is explained on average (*i.e*. the average adjusted R^2 is 0.50). In addition, the estimated convergence coefficient (ϕ) is negative in all countries (as required for a long-run relationship to exist) and statistically significant in 15 out of 21 countries.

Table 4. **Tests of model specification: augmented model**
(Mean Group Estimators)

	Without time trend					With time trend				
	χ^2_{SC} 1	χ^2_{FF} 2	χ^2_{NO} 3	χ^2_{HE} 4	$\bar{R}^2$ 5	χ^2_{SC} 1	χ^2_{FF} 2	χ^2_{NO} 3	χ^2_{HE} 4	$\bar{R}^2$ 5
Australia	1.62	0.19	0.97	6.66	0.13	2.81	1.05	0.11	3.02	0.50
Austria	2.30	2.30	0.65	0.25	0.50	2.14	4.71	0.54	0.01	0.49
Belgium	7.10	3.32	1.05	0.02	0.36	7.18	3.31	1.06	0.02	0.33
Canada	0.44	0.76	2.04	2.75	0.43	1.21	3.42	0.43	1.79	0.51
Denmark	0.02	0.06	1.64	0.60	0.22	0.98	0.64	1.14	0.41	0.38
Finland	5.81	10.91	2.21	1.80	0.50	1.94	6.94	2.03	0.29	0.55
France	0.08	0.58	1.24	0.33	0.60	0.11	0.01	0.87	1.59	0.59
West Germany	0.15	1.80	0.94	3.83	0.72	0.17	1.92	0.94	3.90	0.70
Greece	4.10	1.78	1.03	0.30	0.65	3.68	2.26	0.81	0.34	0.66
Ireland	0.31	0.48	0.59	0.13	0.03	1.04	1.48	0.17	0.41	0.13
Italy	7.94	0.18	12.86	0.24	0.46	6.77	0.01	7.61	0.22	0.47
Japan	0.62	2.89	17.09	0.02	0.35	0.83	0.00	0.49	0.61	0.73
Netherland	3.24	0.93	11.46	3.57	0.31	1.38	0.32	5.68	2.64	0.36
New Zealand	1.09	4.96	1.65	0.82	0.49	1.40	3.17	0.94	0.25	0.48
Norway	1.54	4.61	1.06	0.75	0.34	0.61	7.39	1.27	0.28	0.44
Portugal	0.84	0.12	0.98	0.00	0.75	0.98	0.05	0.92	0.03	0.74
Spain	0.42	0.97	0.01	1.16	0.83	0.42	0.58	0.44	1.47	0.83
Sweden	4.62	0.15	8.60	0.36	0.51	5.52	0.18	10.59	0.31	0.48
Switzerland	0.51	0.01	0.57	3.03	0.61	0.05	0.04	0.83	1.61	0.62
United Kingdom	3.04	0.02	0.26	0.03	0.18	3.37	0.07	0.41	0.00	0.13
United States	0.72	0.06	2.66	2.93	0.16	6.33	0.33	7.74	0.76	0.30

1. Godfrey's test of residual serial correlation.
2. Ramsey's RESET test of functional form.
3. Jarque-Bera test of normality of regression residuals.
4. Lagrange multiplier test of homoscedasticity.
5. Adjusted R^2.

The estimation approach

29. As discussed above, results are also likely to vary significantly with respect to the estimation method -- *i.e* from the least restrictive, but potentially not efficient (MG), to PMG and to the DFE than only allows intercepts to vary across countries. Table 5 reports results using these three approaches to specifications with and without country-specific linear time trend. Moving from MG to PMG (*i.e.* imposing long-run homogeneity to all but the time trend) reduces the standard errors and reduces significantly the measured speed of convergence, with some impact on the size and the statistical significance (but not the sign) of the estimated long-run coefficients. This restriction cannot be rejected at the 1 per cent level by the Hausman test statistics in the specification with a linear trend. The next step is to test for homogeneity in the speed of convergence and short-term dynamics, *i.e.* from PMG to DFE estimators. The latter yield a much lower speed of convergence due to a downward bias in dynamic

13. In a companion paper (Bassanini *et al*., 2001), the linear time trend has been dropped due to scarcity of degrees of freedom in the MG specification once policy and institutional variables are added to it.

heterogeneous panel data. Moreover, restricting the short-term dynamics affects the sign and significance of the long-run coefficients. In the specification with linear time trend, the coefficient on human capital is negatively signed although not significant, a result that is consistent with those from other studies based on DFE estimators. Conversely, the equation without a linear time trend appears to be more robust, with homogeneity assumptions not affecting the long-run elasticities of output to physical and human capital in a massive way.

Table 5. **Selection of the estimation method**

Dependent variable: ΔlogY	Without time trend				With time trend			
	Mean group (MG)	**Pooled mean group (PMG)**	*Hausman-test*	**Dynamic fixed effects**	**Mean group (MG)**	**Pooled mean group (PMG)**	*Hausman-test*	**Dynamic fixed effects**
Convergence coefficient								
logY$_{-1}$	**-0.36** ***	**-0.11** ***		**-0.07** ***	**-0.48** ***	**-0.30** ***		**-0.09** ***
	(0.05)	*(0.02)*		*(0.01)*	*(0.06)*	*(0.04)*		*(0.02)*
Long-Run Coefficients								
logSk	**0.09**	**0.18** ***	*0.72*	**0.15**	**0.26** ***	**0.23** ***	*0.12*	**0.07**
	(0.11)	*(0.04)*		*(0.11)*	*(0.09)*	*(0.02)*		*(0.08)*
logH	**1.93** ***	**0.97** ***	*3.33* *	**0.79** **	**1.16**	**0.64** **	*0.06*	**-0.22**
	(0.53)	*(0.10)*		*(0.31)*	*(2.12)*	*(0.26)*		*(0.46)*
ΔlogP	**-8.44** *	**-12.16** ***	*0.72*	**-15.75** ***	**-10.08** *	**-3.82** ***	*1.44*	**-10.19** ***
	(4.74)	*(1.82)*		*(4.57)*	*(5.27)*	*(0.79)*		*(3.21)*
time trend					**0.00**	**0.04** *		**0.01** ***
					(0.02)	*(0.02)*		*(0.00)*
Short-Run Coefficients								
ΔlogSk	**0.11** ***	**0.14** ***		**0.14** ***	**0.09** ***	**0.11** ***		**0.14** ***
	(0.03)	*(0.02)*		*(0.01)*	*(0.02)*	*(0.02)*		*(0.01)*
ΔlogH	**-1.76** ***	**-1.28** ***		**-0.36**	**1.57**	**-1.25** **		**-0.01**
	(0.67)	*(0.47)*		*(0.35)*	*(2.13)*	*(0.55)*		*(0.38)*
Δ^2 logP	**0.83**	**0.89** **		**0.12**	**1.07** **	**0.95** **		**0.11**
	(0.58)	*(0.42)*		*(0.25)*	*(0.52)*	*(0.45)*		*(0.25)*
No. of countries	21	21		21	21	21		21
No. of obs.	540	540		540	540	540		540
Log likelihood	1555	1470		1339	1599	1503		1342

All equations include a constant country-specific term. Standard errors are in brackets.
*: significant at 10 % level; ** at 5% level; *** at 1 % level.

The lag structure

30. We have also conducted a sensitivity analysis of the PMG results to changes in the lag structure of the main variables. Table 1 reports the estimated coefficients of $logS_k$ and *logH* with different structures of the ARDL of equation [14]. In particular, the sensitivity analysis considers a maximum of 3 lags for all but one variable, population growth with a maximum of 10 dynamic terms.[14] Amongst the possible combinations of lags for the four variables, we have adopted the following criteria: the number of lags for population growth is less or equal that for *logH*, and the number of lags of the latter is assumed to be less or equal that for the investment rate; the number of lags for the dependent variable has been chosen to be equal to that of $logS_k$, as their business-cycle fluctuations could be assumed of the same length. Overall the PMG point estimates of long-run coefficients do not seem to be strongly affected by the choice of the lag structure, even if in some cases the model has to be estimated without constraining the coefficient of population growth to be equal across countries since the Hausman test rejected the hypothesis of long-run slope homogeneity. Conversely, the width of confidence intervals is somewhat affected by the lag structure

14. 10 dynamics terms represent a maximum in order to avoid too serious problems of lack of degrees of freedom for the benchmark MG estimates. Moreover, only one lag was considered for population growth because it is not likely to be significantly affected by business cycle fluctuations.

(although all long-run coefficients remain statistically significant at the 5 per cent level), and it tends to be larger the longer the lag structure. Furthermore, diagnostics tests of country-specific regressions perform better when only one lag per variable is retained. Consequently, only one lag will be considered hereafter.

From a linear trend to country-specific time dummies

31. As suggested by the theoretical derivation discussed in section 1, the likelihood that a non-linear trend could affect the data is *a priori* relatively high. One standard way to test the robustness of results in the presence of a suspected non-linear time-trend relies on the introduction of (common) time dummies. However such a solution implies that all countries in the sample have been affected by common shocks. When multiple-year time dummies are employed instead of one-year time dummies, this hypothesis can be tested against the alternative that one or more of these dummies reflect country-specific shocks. In fact with multiple-year time dummies it is possible to estimate equations wherein dummies are kept country-specific without running out of degrees of freedom.

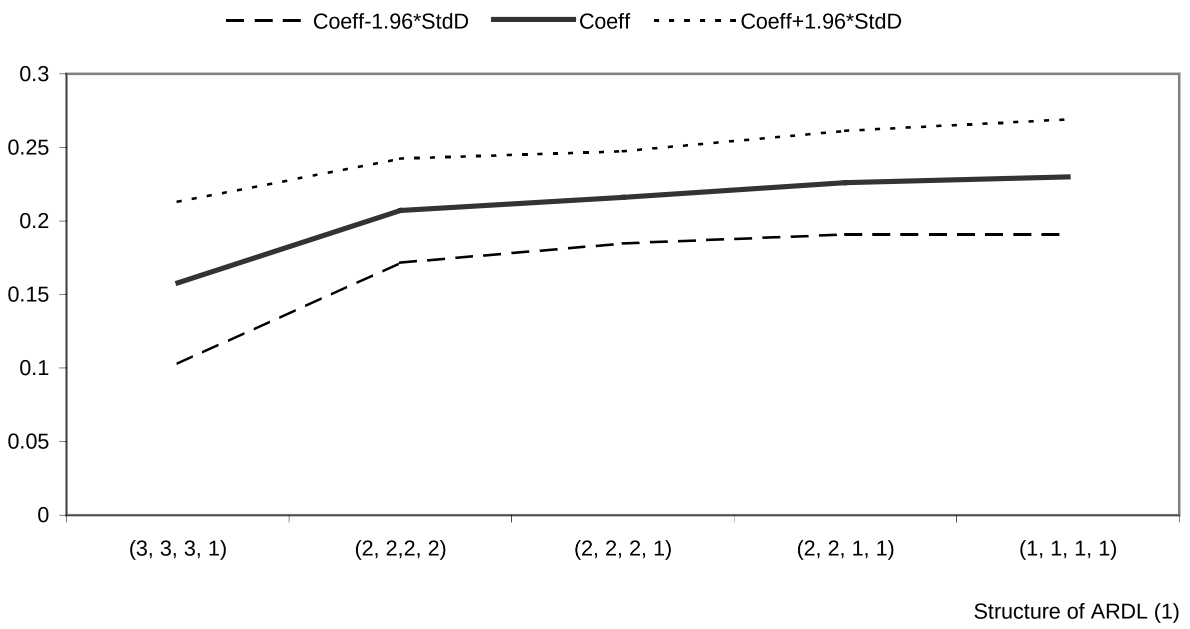
32. Table 6 reports the PMG results of the growth equation under different hypotheses concerning the 5-year time dummies.[15] The dummy 1984-88 is omitted to identify the other dummies (*i.e*. the 1984-88 period is taken as reference). Column A reports the estimates of convergence and long-run coefficients obtained from a specification with no homogeneity restriction on time dummies. These estimates are consistent although they might be inefficient insofar as common shocks characterised the growth of output per capita across countries. The latter hypothesis is tested for each individual dummy by means of Hausman tests on a sample that excludes Australia and Western Germany (Column C).[16] The tests reject the homogeneity restriction on the two 5-year dummies around the two oil shocks (1972-73 and 1979-83) at a conventional significance level. In other words, the empirical results suggest that the two oil shocks had a different impact on the OECD countries that cannot be ignored. The homogeneity restriction on the 1979-83 dummy is rejected even when Australia is added to the sample and the 1972-73 dummy is not constrained (Column D). Hence, the equation is re-estimated imposing the homogeneity restrictions on the three other dummies (1974-78, 1988-93 and 1994-98) with the inclusion of Australia (Column E). In the last case the tests cannot reject the long-run restrictions on these three dummies even at the 10 per cent level.

15 To have a reliable test of the hypothesis that there are common shocks, period dummies need to be in a limited number. Otherwise MG estimates of benchmark country-specific equations would be so imprecise that the Hausman test would never reject the common shock assumption.

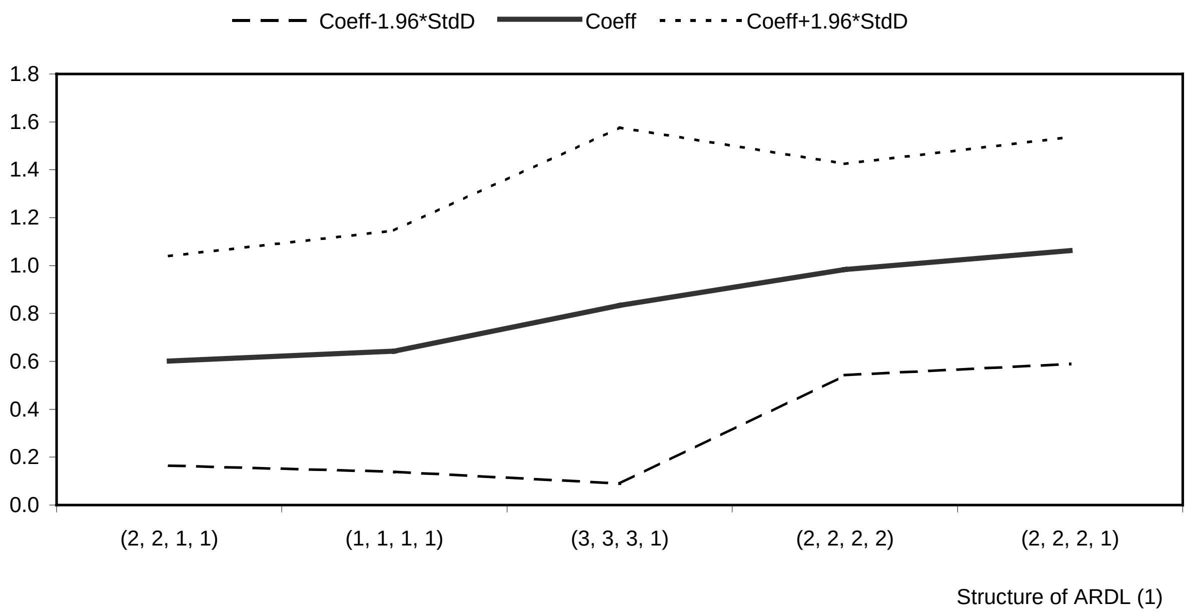
16. In the case of these countries the test cannot be performed for the 1994-98 dummy (Western Germany) and the 1972-73 dummy (Australia) due to the shorter time coverage of the samples. For the matter of comparison the table also reports the estimated equation with country-specific time dummies on a sample that excludes Western Germany (Column B).

Figure 1. **Sensitivity of long-run coefficients to the lag structure**
(Pooled Mean Group Estimators)

Coefficient of *logS k*



Coefficient of *logH*



Models with (2, 2, 2, 1) and (2, 2, 1, 1) are estimated without homogeneity restriction on the long-run coefficient of population growth.

1. The order of variables is as follows: dependent variable, investment rate (S_k), human capital (H) and population growth.

Table 6. **Regressions with 5-year time dummies**

(Pooled Mean Group Estimators)

	country-specific time-dummies				cross-country restrictions on time-dummies					
Dependent variable: ∆logY	A		B[1]		C[2]		D[3]		E[4]	
Long-Run Coefficients		*Hausman test*		*Hausman test*		*Hausman test*		*Hausman test*		*Hausman test*
logSk	**0.23** ***	0.69	**0.22** ***	0.55	**0.04**	7.06 **	**0.06**	1.26	**0.15** ***	0.01
	(0.02)		*(0.02)*		*(0.04)*		*(0.04)*		*(0.03)*	
logH	**0.62** ***	0.02	**0.82** ***	0.02	**0.78** ***	0.34	**0.85** ***	0.05	**0.95** ***	0.13
	(0.11)		*(0.11)*		*(0.23)*		*(0.27)*		*(0.24)*	
∆logP	**-0.31**	0.91	**-0.61**	0.79	**-11.41** ***	0.88	**-10.64** ***	1.48	**-11.47** ***	1.91
	(0.45)		*(0.54)*		*(2.16)*		*(2.35)*		*(2.23)*	
Convergence coefficient										
logY$_{-1}$	**-0.40** ***		**-0.39** ***		**-0.12** ***		**-0.12** ***		**-0.13** ***	
	(0.07)		*(0.07)*		*(0.02)*		*(0.02)*		*(0.03)*	
No. of countries	21		20		19		20		20	
No. of obs.	540		521		498		521		521	
Log likelihood	1630		1560		1386		1466		1491	

Hausman tests for time dummies	C[2]	D[3]	E[4]
dummy 1994-98	0.04	0.23	0.68
dummy 1989-93	0.13	7.57 **	1.43
dummy 1979-83	9.27 ***	8.08 ***	free
dummy 1974-78	0.00	0.36	1.65
dummy 1972-73	7.23 **	free	free

All equations include short-term dynamics and a constant country-specific term. Standard errors are in brackets. *: significant at 10 % level; ** at 5% level; *** at 1 % level.

1. Western Germany excluded from the sample.
2. With time-dummies constrained to be identical across countries, Australia and Western Germany excluded from the sample.
3. With 4 time-dummies (1994-98, 1989-93, 1979-83, 1974-78) constrained to be equal across countries, Western Germany excluded from the sample.
4. With 3 time-dummies (1994-98, 1989-93, 1974-78) constrained to be identical across countries, Western Germany excluded from the sample.

33. Overall, taking into account the width of confidence intervals, the presence of time dummies does not seem to affect significantly the estimated long-run coefficients of the parameters of interest (investment rate and average years of education). This is particularly remarkable since in all specifications one or more time dummies are significantly different from zero but do not grow in a way that is strictly monotone with respect to time (not shown in the table), pointing to some evidence in favour of a non-linear trend.

Outliers

34. It could be argued that in small country samples, one individual country could significantly affect the estimated parameters, even when the Hausman tests do not reject the hypothesis of common long-run coefficients. A sensitivity analysis is thus performed on our preferred specification (corresponding to Column E of Table 6) in order to assess the robustness of results to variation of country coverage, by eliminating one country at a time and re-running the PMG estimation procedure. However when the Hausman test rejected the hypothesis of long-run slope homogeneity the equation has been re-estimated without constraining the coefficient on the growth rate of population to be equal across countries. This has turned out to be sufficient to avoid the Hausman test rejecting the restriction on the remaining long-run coefficients. Figure 2 reports the results of the sensitivity analysis on long-run coefficients for $logS_k$ and *logH.*

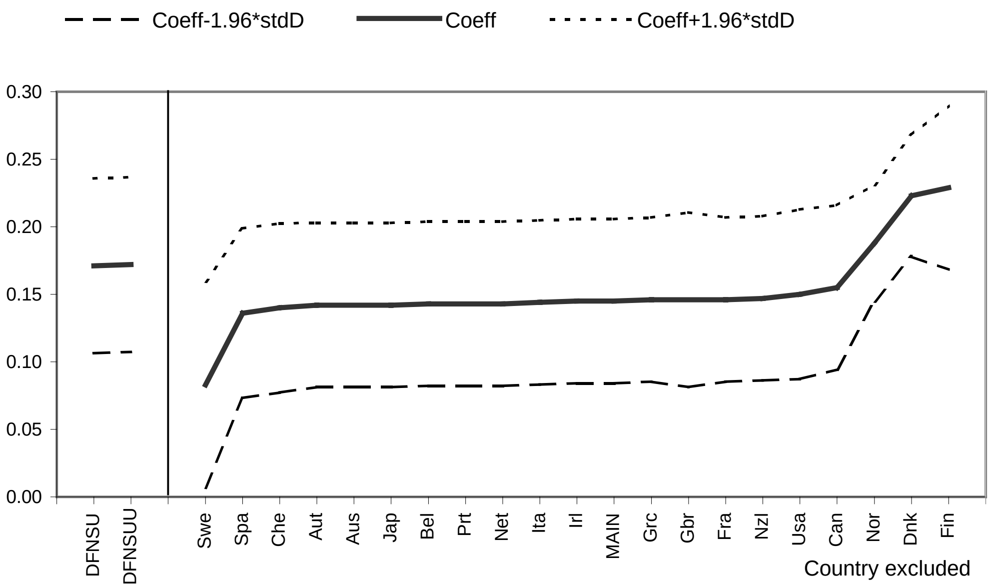
35. Taking into account the width of confidence intervals these estimates seem sufficiently stable to exclusion of countries from the sample. Interestingly, the countries whose exclusion shifts point estimates belong to two well-identified groups: Nordic countries and the two larger English-speaking economies (UK and US). The figure therefore displays also the impact on estimated coefficients of removing from the sample all Nordic countries and the United States, and this group plus the United Kingdom, respectively. As it can be seen from the figure, the precision of the point estimates increases considerably in the case of the human capital variable, when these country groups are eliminated from the sample. The point estimates of both coefficients remain however in the bounds of the confidence intervals of baseline estimates, although they are somewhat higher in the case of the investment rate (0.17 instead of 0.15) and lower in the case of human capital (0.67 instead of 0.95). Interestingly these estimates are nearer to those obtained with a country-specific linear time trend on the full country sample.

36. Taking into account the whole set of regression results, it can be concluded that the long-run elasticity of output per working-age population to average years of education turns out to be significantly different from zero. Its estimated value (around 0.6 in the most reliable estimates) is more in line with the microeconomic literature on private returns from schooling than previous growth regression studies that found unrealistically high elasticities of the initial level of human capital and no (or negative) effect from the accumulation over time. (see Krueger and Lindahl, 2000, Topel, 1999, and Temple, 2000). In particular, using our estimated long-run elasticity of output per capita to human capital (0.6), one additional year of schooling is expected to raise output per capita by slightly less than 6 per cent (the sample average for *h* is 10.2). Using an (average) estimate of the private returns to one additional year of schooling of about 8 per cent and a labour share of 0.6, Topel (1999) suggested an upper bound value for the impact of schooling on output per capita of about 13 per cent.[17] As clarified by the comparison of estimates across different estimation methods (see Table 5), this result is not only due to better human capital data but also to an estimation technique (the PMG approach) which makes better use of the available information without imposing restrictions that are *a priori* inconsistent with theoretical assumptions of growth models.

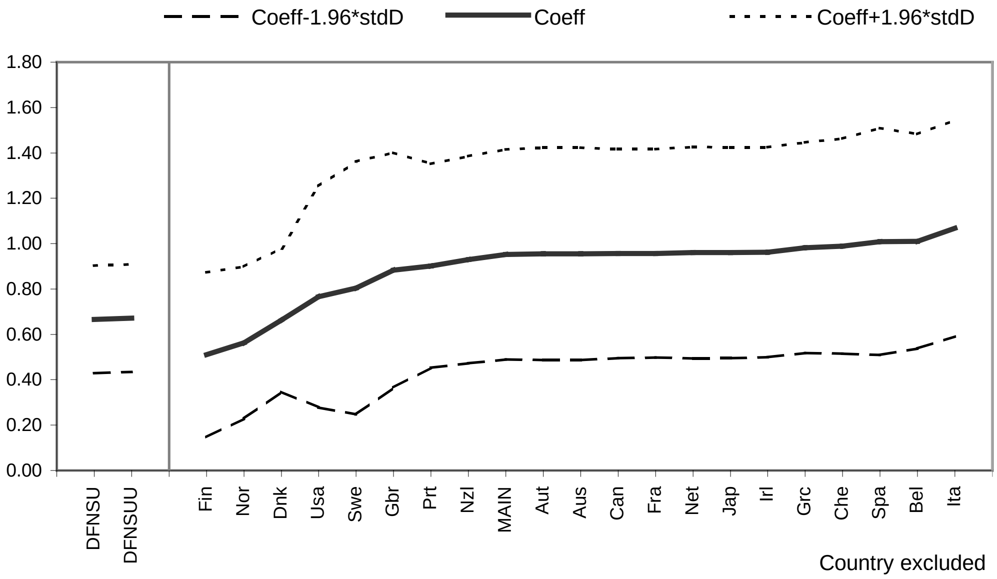
17 . It should be stressed that the results reported in Barro and Sala-i-Martin (1995) yield an estimated long run effect of one year of schooling on output per capita that exceeds 30 per cent.

Figure 2. **Sensitivity of long-run coefficients to reduction of country coverage**
(Pooled Mean Group Estimators)

Coefficient of *logS*$_k$



Coefficient of *logH*



MAIN indicates the baseline estimation (cf. Table 6, Column E).
DFNSU (Denmark, Finland, Norway, Sweden and United States), DFNSUU (Denmark, Finland, Norway, Sweden, United States and United Kingdom), Nor and Swe are estimated without homogeneity restriction on the long-run coefficient of population growth.

4.2 Consistency of results with different theoretical models

37. As discussed in Section 1 above, the standard augmented neoclassical model makes precise predictions on the value of the estimated long-run parameters of the human and physical capital, as well as on population growth. Thus, it is important to compare our estimated coefficients with the values predicted by the different models to see which of the latter is more consistent with the observed OECD data.

38. Conditional to the human-capital augmented model to hold, the parameters of the production function can be derived from the estimated long-run coefficients by comparing equation [10] with equation [14]. Denoting the long-run estimated coefficient of the logarithm of the investment share with $\hat{\theta}_{sk}$ and that of average years of schooling with $\hat{\theta}_h$, then the derived estimate of α is equal to $\hat{\theta}_{sk}/(1+\hat{\theta}_{sk})$ while that of β is equal to $\hat{\theta}_h/(1+\hat{\theta}_{sk})$. Moreover, from the definition of $\phi(\lambda)$, an estimate of the speed of convergence λ can be obtained as $-\log(1-\hat{\phi})$, where $\hat{\phi}$ is the estimated average convergence coefficient. Furthermore, as discussed in Section 1, in this model λ can be expressed formally as a function of the rate of technological progress, the rate of growth of the population, the depreciation rate of physical and human capital as well as output elasticities to human and physical capital.[18] The consistency of empirical results with the theoretical implications of the augmented neoclassical model can therefore be verified on this basis. Table 7 presents output elasticities and average values for λ as derived from the estimated equations. The first column reports values corresponding to the baseline specification with period dummies (see Table 6, Column E) and the second column reports those corresponding to the same specification but excluding Finland from the sample (that is the estimate that resulted in the lowest estimated returns to "broad" capital). Furthermore, for each estimated equation, the last two lines of the table reports the "predicted" theoretical value of λ that would be compatible with the derived output elasticities, if the correct model were the closed-economy model (line before the last), or the open-economy model (last line).

39. The estimated speed of convergence to the steady state path of output per capita in the baseline equation is too high with respect to what would be implied by the estimated value of the elasticity of output with respect to "broad" capital (which would imply very slow convergence). When some appropriately chosen country is excluded from the sample, the gap between estimated and predicted speed of convergence is narrowed. However, even taking into account the width of confidence intervals, predicted and estimated speed of convergence are still of a somewhat different degree of magnitude.

18. Recall from Section 1 that in the human-capital augmented neoclassical model, λ is a function of technological progress (g), population growth (n) and the depreciation rate of physical and human capital (δ - assumed to be constant across countries and over time) as well as on output elasticities with respect to physical and human capital (α,β), *i.e.* $\lambda_i = (n_i + g + \delta_i)(1-\alpha-\beta)$. In the case of the open economy, the formula is more complex and depends on assumptions about which type of capital can be used as collateral in international financial transactions. As a first approximation, the system behaves as if the share of broad capital were smaller than what it actually is, the extent of this reduction being an increasing function of the share of capital that can be used as collateral (see Barro and Sala-i-Martin, 1995). For the computation in Table 7, it has been assumed that all physical capital can be used as collateral while human capital cannot.

Table 7. **Derived parameters and consistency with augmented neo-classical model**
(Pooled Mean Group Estimates)

derived parameters	Baseline	Baseline, no Finland
α^1	0.13	0.19
β^2	0.82	0.41
average λ^3	0.14	0.17
theoretical λ (**closed economy**)[4]	0.01	0.05
theoretical λ (**open economy**)[4]	0.01	0.06

Notes:
All equations include a constant country-specific term and 5-year dummies (cf. Table 6, Column E).
1. Derived partial output elasticity to physical capital.
2. Derived partial output elasticity to human capital.
3. Estimated average speed of convergence coefficient (derived from the estimated coefficient of $\log Y_{-1}$).
4. The value of λ that would be compatible with estimated output elasticities if, respectively, the closed-economy augmented neoclassical model, the open-economy augmented neoclassical model were true. The value is computed by taking a depreciation rate of 10% (as estimated by Jorgenson and Stiroh, 2000), and assuming standard values for unknown parameters (2% as rate of technological change, 2% as rate of time preference, and 3 as elasticity of substitution in consumption, see Barro and Sala-i-Martin, 1995).

40. Taken at face value, these results might be more compatible with an endogenous growth model *à la* Uzawa-Lucas with constant returns to scale to "broad" capital. Endogenous growth theory is frequently associated with constant returns to factors that can be accumulated. Models with constant returns to one single type of capital (*e.g.* Romer, 1986, or Rebelo, 1991) are generally characterised by instantaneous convergence to the steady state growth path. Thus, these models are inconsistent with empirical estimates that yield statistically significant (negative) convergence coefficients. Conversely, *AK* models that explicitly consider different types of capital goods (*e.g.* physical and human) - each characterised by its own accumulation process (*e.g.* investment and education), such as Uzawa (1965) and Lucas (1988) (see also Barro and Sala-i-Martin, 1995, for a generalised version) -- admit specific transitional dynamics. In other words, these models are consistent with statistically significant (negative) convergence coefficient. In particular, the Uzawa-Lucas model is characterised by the following two aggregate production functions for output and human capital, respectively:

$$Y(t) = K(t)^{\alpha}\left(A(t)u(t)H(t)\right)^{1-\alpha}$$
$$\dot{H}(t) = B(1-u(t))H \qquad [15]$$

where $u(t)$ stands for the average time used in production rather than in the formation of human capital. Physical capital formation depends on the investment rate and corresponds to foregone consumption as in the neoclassical model. Conversely, human capital formation depends only on time devoted to education, which corresponds to foregone directly-productive use of human capital rather than consumption. Both $u(t)$ and the investment rate are jointly determined by intertemporal maximisation of the utility function of the representative consumer. It can be shown that first-order conditions imply that the *K*/*H* ratio will reach a steady-state equilibrium where *Y*, *K* and *H* grow at the same rate. If the actual *K/H* ratio is lower than its steady state value, there will be a transition period in which there will be declining marginal product of physical capital and declining growth rates of output per capita, *i.e*. the usual patterns of the neoclassical growth model.

41. Transitional dynamics of the Uzawa-Lucas model are however rather complicated (see Barro and Sala-i-Martin, 1995). To illustrate the fact that this model can yield an estimatable equation similar to [14] above, it can be assumed that the investment rate is constant throughout the transition (the conditions on the intertemporal elasticity of consumption substitution that are necessary for this to hold true are discussed in Barro and Sala-i-Martin, 1995). Furthermore, it can be assumed that the same occurs for the allocation of time between production and human capita formation ($u(t)$). The latter assumption can be rationalised if capital markets are imperfect and public supply of education is constrained such that $u(t)$ is always below or equal to the value it would attain in the unconstrained Uzawa-Lucas model. Subject to these assumptions, the dynamics of human capital are exogenous to the dynamics of output and physical capital. Hence, the dynamics of physical capital, human capital and exogenous variables can be described as follows:

$$\begin{aligned}
\frac{d\,\frac{k}{h}}{dt} &= s_k\,(A(t)u)^{1-\alpha}\left((k(t)/h(t)\right)^{\alpha} - (r(t)+d)(k(t)/h(t)) \\
\dot{A}(t) &= g(t)A(t) \\
\dot{H}(t) &= r(t)H(t) \\
r(t) &= B(1-u)
\end{aligned} \qquad [16]$$

42. The system of equations [16] is identical to a standard non-augmented (Solow-Swan) neoclassical model with the exception that there appears *k/h* instead of *k*, and *r* instead of *n*. Thus, by a redefinition of variables, the analysis of Section 1 can be repeated to obtain the steady-state output path (in intensive form):

$$\ln y^*(t) - \ln h(t) = \ln A(t) + \frac{\alpha}{1-\alpha}\ln s_k - \frac{\alpha}{1-\alpha}\ln(g(t)+r(t)+d) \qquad [17]$$

and the expression for output growth:

$$\begin{aligned}
\Delta \ln y(t) - r(t) = &-\phi(\lambda)\ln y(t-1) + \phi(\lambda)\ln h(t-1) + \phi(\lambda)\frac{\alpha}{1-\alpha}\ln s_k \\
&-\phi(\lambda)\frac{\alpha}{1-\alpha}\ln(g(t)+r(t)+d) + (1-\phi(\lambda))g(t) + \phi(\lambda)\ln A(0) + \phi(\lambda)\int_0^t g(v)dv
\end{aligned} \qquad [18]$$

with $\lambda = (1-\alpha)(g(t)+r(t)+d)$. Taking into account that, as an identity, the growth rate of aggregate human capital (*H*) is equal to the sum of the growth rate of labour (*L*) and the growth rate of average human capital (*h=H/L*), a possible empirical implementation of equation [18] is represented by equations [12] or [14] (or their analogous version with period dummies), with the prediction that the value of the ratio between the coefficient of human capital and the convergence coefficient will not be statistically different from -1.

43. Only for the sake of illustration, we can compute the value of λ that is compatible with the derived output elasticities if the simple version of the Uzawa-Lucas model described by the system of equations [16] were true. In the case of the baseline equation, we find a predicted value of λ equal to 0.12, while in the case of the equation without Finland we find 0.11.[19] Without pushing the interpretation of

19. To compute these values the growth rate of average human capital $\Delta\log h$ is set at its cross-country average annualised growth rate over the period (0.8 per cent).

these numbers too far, it might be worth noticing that, taking into account the width of confidence intervals, these numbers look consistent with estimated speed of convergence. Furthermore, the required restriction on the human capital coefficient is not rejected at the 10 per cent level in the case of the baseline equation although only at the 1 per cent level upon elimination of Finland.

5. Concluding remarks

44. In this paper, we have investigated the role of human capital accumulation in explaining growth paths across 21 OECD countries over the 1971-98 period. We proxied human capital by the average number of years of formal education of the working age population from a revised and extended version of the Barro and Lee (1996) database. Moreover, the human-capital-augmented growth equation was estimated using a consistent econometric technique (PMG) that allows for the speed of convergence as well as for the short-term dynamics and variances to vary across countries, unlike most panel-data approaches that impose homogeneity restrictions on all these parameters.

45. The results confirm our priors that data quality and econometrics do matter in explaining the often disappointing results on the link between human capital and growth. Unlike several previous attempts, our results point to a positive and significant impact of human capital accumulation to output per capita growth. The estimated long-run effect on output of one additional year of education (about 6 per cent) is also consistent with microeconomic evidence on the private returns to schooling. We also found a significant growth effect from the accumulation of physical capital, and a speed of convergence to the steady state output per capita growth path of around 15 per cent per year. Taken together these results are not consistent with the human-capital-augmented version of the Solow model, but rather they might support an endogenous growth model *à la* Uzawa-Lucas, with constant returns to scale to “broad” (human and physical) capital. These findings survive a robustness check using different specifications and country coverage. The choice of the estimation approach was, however, crucial: imposing cross-country homogeneity restrictions on short- as well as long-run parameters and speeds of convergence -- as in standard dynamic fixed effects estimations -- yields a weaker human capital effect on output and, more generally, a greater sensitivity of results to changes in the specification.

REFERENCES

AGHION, P. and P. HOWITT (1998), *Endogenous Growth Theory*, The MIT Press, Cambridge, Mass.

ARELLANO, M. and S. BOND (1991), “Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations”, *Review of Economic Studies,* 58, pp. 277-297.

ARELLANO M. and O. BOVER (1995), “Another look at the instrumental variable estimation of error components models”, *Journal of Econometrics,* 68, pp. 29-52.

BARRO, R.J. and J.W. LEE (1996), “International measures of schooling years and schooling quality”, *American Economic Review, Papers and Proceedings*, Vol. 86, No. 2, pp. 218-223.

BARRO, R.J. and X. SALA-I-MARTIN (1992), “Convergence”, *Journal of Political Economy*, 100, pp. 223-251.

BARRO, R.J. and X. SALA-I-MARTIN (1995), *Economic Growth*, McGraw-Hill.

BASSANINI, A. S. SCARPETTA and P. HEMMINGS (2001), “Economic Growth: The role of policies and institutions - Panel evidence from OECD countries”, *OECD Economics Department Working Papers*, No. 283.

BENHABIB, J. and M. SPIEGEL (1994), “The role of human capital in economic development: Evidence from aggregate cross-country data”, *Journal of Monetary Economics* 43, pp. 143-174.

BILS, M and P.J. KLENOW (1998), “Does schooling cause growth or the other way around?“, *NBER Working Paper* No. 6393.

CARD, D. (1999), *“The causal effects of schooling on earnings”*, in O. Ashenfelter and D. Card (eds.) “Handbook of Labor Economics”, Amsterdam, North Holland.

CASELLI, F., G. ESQUIVEL and L. FERNANDO (1996), “Reopening the convergence debate: a new look at cross-country growth empirics”, *Journal of Economic Growth*, 1, 363-389.

CRAIN, W.M. and K.J. LEE (1999), “Economic growth regressions for the American states: A sensitivity analysis”, *Economic Inquiry*, 37, pp. 242-257.

DE LA FUENTE, A. and R. DOMÉNECH (2000), “Human capital in growth regressions: How much difference does data quality make?” *OECD Economics Department Working Papers* No. 262.

DURLAUF, S.N. and D. QUAH (1999), “The new empirics of economic growth” in J. Taylor and M. Woodford (eds), *Handbook of Macroeconomics*, Amsterdam, North-Holland.

ENGLANDER, S. and A. GURNEY (1994), “Medium-term determinants of OECD productivity”, *OECD Economic Studies,* No. 22, spring.

EVANS, P. (1997), "How fast do economies converge", *The Review of Economics and Statistics*, 79(2), pp. 219-25.

HAUSMAN, J. (1978), "Specification tests in econometrics", *Econometrica*, 46, pp. 1251-1271.

ISLAM, N. (1995), "Growth Empirics: A Panel Data Approach", *Quarterly Journal of Economics*, 110, pp. 1127-1170.

JORGENSON, D.W., F.M. GOLLOP and B.M. FRAUMENI (1987), "*Productivity and U.S. economic growth*", Cambridge, MA. Harvard Univ. Press.

JORGENSON, D.W. and K.J. STIROH (2000), "Raising the Speed Limit: U.S. Economic Growth in the Information Age", *Brookings Papers on Economic Activity*, August.

KRUEGER, A.B. and M. LINDAHL (2000), "Education and Growth: Why and for whom?", Princeton Working Paper No. 429, Princeton University, January.

LEE, K., M.H. PESARAN and R. SMITH (1996), "Growth and convergence in a multi-country empirical stochastic Solow model", *Journal of Applied Econometrics*, 12, pp. 357-392.

LEVINE, R. and D. RENELT (1992), "A sensitivity analysis of cross-country growth regressions", *American Economic Review*, 82 (4), pp. 942-963.

LUCAS, R.E. (1988), "On the mechanics of economic development", *Journal of Monetary Economics*, 22.

MANKIW, G.N., D. ROMER and D.N. WEIL (1992), "A contribution to the empirics of economic growth", *Quarterly Journal of Economics*, 107, pp. 407-37, May.

NELSON, R. and E. PHELPS (1966), "Investment in humans, technological diffusion and economic growth", *American Economic Review*, 56, pp. 69-75.

NICKELL, S. (1981), "Biases in dynamic models with fixed effects", *Econometrica*, 49, pp. 1399-1413.

OECD (2000), *Education at a Glance*, Paris.

PESARAN, M.H. and R. SMITH (1995), "Estimating long-run relationships from dynamic heterogeneous panels", *Journal of Econometrics*, 68, (1), pp. 79-113.

PESARAN, M.H., Y. SHIN and R. SMITH (1999), "Pooled Mean Group estimation of dynamic heterogeneous panels", *Journal of the American Statistical Association*, 94, pp. 621-634.

PRITCHETT, L. (1997), "Where has all the education gone? ", *Policy Research Working Paper* No. 1581, The World Bank, Washington D.C., June.

PSACHAROPOULOS, G. (1994), "Returns to Investment in education: A global update", *World Development* 22(9), pp. 1325-1343.

REBELO, S. (1991), "Long-run policy analysis and long-run growth", *Journal of Political Economy*, 99 (3), pp. 500-512.

ROMER, P.M. (1986), "Increasing returns and long-run growth", *Journal of Political Economy*, 94 (5), pp. 1002-1037.

ROMER, P.M. (1990), "Endogenous technological change", *Journal of Political Economy* 98(5) Part 2, pp. 71-102.

SALA-I-MARTIN, X. (1997), "I just ran two million regressions", *AEA Papers and Proceedings,* May.

SALA-I-MARTIN, X., G. DOPPELHOFER and R. MILLER (2000), "Determinants of long-run growth: a Bayesian Averaging of Classical Estimates (BACE) approach" *NBER Working Paper* No. 7750.

SCARPETTA, S., A. BASSANINI, D. PILAT and P. SCHREYER (2000), "Economic growth in the OECD area: recent trends at the aggregate and sectoral level", *OECD Economics Department Working Papers*, No. 248.

STOKEY, N. and R. LUCAS (1989), "*Recursive Methods in Economic Dynamics*, Cambridge, Harvard University Press.

TEMPLE, J. (2000), "Growth regressions and what the textbooks don't tell you", *Bulletin of Economic Research*, 52, pp. 181-205.

TOPEL, R. (1999), *"Labor markets and economic growth"*, in O. Ashenfelter and D. Card (eds.), "Handbook of Labor Economics", Amsterdam, North Holland.

UZAWA, H. (1965), "Optimum technical change in an aggregative model of economic growth", *International Economic Review*, 6, pp. 18-31.

YOUNG, A. (1994), "Lessons from the East Asia NIC's: a contrarian view", *European Economic Review*, 38, pp. 964-973.

YOUNG, A. (1995), "The tyranny of numbers confronting the statistical realities of the East", *Quarterly Journal of Economics*, 110, pp. 641-680.

Annex table. **Average years of education of the working age population, 1971-98**

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Australia	11.1	11.1	11.2	11.2	11.3	11.4	11.4	11.5	11.5	11.6	11.6	11.7	11.8	11.8	11.9	11.9	12.0	12.0	12.1	12.1	12.2	12.2	12.2	12.3	12.3	12.3	12.3	12.3
Austria	9.8	9.8	9.9	10.0	10.0	10.1	10.2	10.3	10.3	10.4	10.5	10.6	10.7	10.8	10.9	10.9	11.0	11.1	11.2	11.3	11.3	11.4	11.4	11.4	11.5	11.6	11.7	11.8
Belgium	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.2	9.3	9.3	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.7	9.8	9.9	10.0	10.1	10.3	10.4	10.6	10.7	10.8
Canada	11.4	11.5	11.5	11.6	11.6	11.7	11.8	11.9	12.0	12.1	12.1	12.2	12.2	12.2	12.3	12.3	12.4	12.4	12.4	12.5	12.5	12.6	12.6	12.7	12.7	12.8	12.9	12.9
Denmark	9.9	10.0	10.1	10.2	10.2	10.3	10.4	10.5	10.5	10.6	10.7	10.7	10.8	10.8	10.9	10.9	10.9	11.0	11.0	11.0	11.1	11.1	11.2	11.2	11.3	11.3	11.4	11.4
Finland	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.7	9.8	9.9	10.0	10.1	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2
France	8.8	8.9	9.0	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.8	9.9	9.9	10.0	10.0	10.2	10.3	10.4	10.5	10.6	10.6	10.6
Germany	9.7	9.9	10.1	10.3	10.5	10.7	10.8	11.0	11.2	11.4	11.5	11.7	11.8	11.9	12.1	12.2	12.4	12.6	12.7	12.9	13.1	13.1	13.2	13.3	13.4	13.4	13.5	13.5
Greece	7.5	7.5	7.6	7.6	7.7	7.7	7.8	7.8	7.9	7.9	8.0	8.1	8.2	8.2	8.3	8.4	8.5	8.6	8.7	8.8	9.0	9.1	9.2	9.3	9.5	9.6	9.7	9.9
Ireland	7.9	8.0	8.0	8.1	8.2	8.2	8.3	8.4	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	10.0	10.1	10.2	10.3
Italy	6.7	6.8	6.8	6.9	7.0	7.1	7.1	7.2	7.3	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.4	8.5	8.6	8.8	9.0	9.2	9.4	9.6	9.8
Japan	9.5	9.5	9.6	9.7	9.8	9.9	10.0	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.4	11.5	11.6	11.7	11.9	12.0	12.1	12.3
Netherlands	9.1	9.2	9.3	9.4	9.5	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.5	11.6	11.7	11.8	11.9
New Zealand	10.3	10.4	10.4	10.5	10.6	10.6	10.7	10.8	10.9	10.9	11.0	11.0	11.1	11.1	11.2	11.2	11.2	11.3	11.3	11.4	11.4	11.5	11.5	11.6	11.7	11.7	11.7	11.8
Norway	9.9	10.0	10.1	10.2	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.4	11.5	11.6	11.7	11.7	11.7	11.8	11.8	11.9	11.9	12.0
Portugal	6.5	6.6	6.6	6.7	6.7	6.7	6.8	6.8	6.9	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.4	7.5	7.5	7.6	7.7	7.7
Spain	5.8	5.8	5.9	6.0	6.0	6.1	6.1	6.2	6.3	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.5	7.6	7.8	7.9	8.1	8.3	8.5	8.7
Sweden	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.3	11.4	11.5	11.5	11.6	11.6
Switzerland	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.7	12.8	12.8	12.9	12.9	12.9	12.9
United Kingdom	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.4	10.5	10.6	10.7	10.7	10.8	10.9	11.0	11.2	11.3	11.6	11.6	11.7	11.8	11.9
United States	11.6	11.7	11.8	11.8	11.9	12.0	12.0	12.1	12.2	12.2	12.3	12.3	12.4	12.4	12.5	12.5	12.5	12.5	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.7	12.7	12.7

Source: de la Fuente and Doménech (2000) and OECD, Education at a Glance, various issues.

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