

# Human capital in a global and knowledge-based economy

## FINAL REPORT

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and

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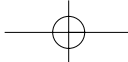
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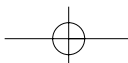
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## Foreword

I am pleased to introduce the public to this interesting work, which can be expected to reinvigorate the debate on the role of human capital in economic growth. Political decision-makers are showing an increasing interest in this issue.

At European level, the European Union has adopted a strategy for economic growth and social cohesion, called the 'Lisbon strategy' after the European Council of March 2000. This combines the pursuit of sustainable macroeconomics with a microeconomic approach which stresses the potential of a society based on knowledge, scientific research, human resources and entrepreneurship. Since Lisbon, the strategy has been enhanced as subsequent European Councils have taken up the theme.

The Lisbon strategy informs Community structural policy and promotes optimum allocation of financial resources. The European Commission has repeatedly emphasised the need to invest more in human capital. Its recent communications on lifelong learning, quality of work and mobility give a sharper focus to this message.

The study commissioned by the Directorate-General for Employment and Social Affairs seeks to show what contribution investment in human capital makes to economic growth and under what conditions. I would like to thank Professors Ángel de la Fuente and Antonio Ciccone for their review of the international literature and their personal contribution to the debate. They have succeeded in producing statistical series covering a long period and a substantial number of countries. This has allowed them to use robust econometric models to assess the importance of human capital to growth in both microeconomic and macroeconomic terms. Their findings agree with those of many other research workers and provide political decision-makers with valuable guidance. This is the ultimate aim of this publication.

In this report, the reader will find a second message, on the importance of certain contextual elements in economic growth processes. This forms part of a wider theory of social capital. Many economists and sociologists argue that, if societies are marked by a high level of mutual trust and cohesion, effective regulation of conflicts of interest, a high degree of civic mindedness and respect for law and standards of conduct, participation of individuals in community life and their involvement in public responsibilities, they will also deliver a higher standard of well-being. This concept of well-being is not merely economic in the strict sense of the term. Current research in this field is helping to give due weight to social policy.

According to this school of thought, social policy is not merely a necessary manifestation of solidarity but also contributes directly to increasing a country's overall productivity. Assessing the impact of social policy on growth and well-being is a new challenge for the research community.

Political and private decision-makers will find this report not only intellectually stimulating but also an aid to formulating novel approaches. What is needed is to improve the quality and structure of spending and to strengthen the systems which encourage investment in human capital.

Anna Diamantopoulou  
Commissioner

## Preface

The report by Professors Ángel de la Fuente and Antonio Ciccone looks into the economic return on investment in human resources as compared with other investments. It links this analysis with that of the relative yield of the productivity determinants and reviews the pertinent international literature.

The debate may be said to have evolved in three phases. Initially, the World Bank and the American Economic Research Bureau reached very positive conclusions on investment in human capital. In a second phase, various studies questioned that it could be proved empirically that investment in human capital was profitable. More recently, researchers have been able to dispel these doubts, using better statistics and more powerful models.

In recent years, the Organisation for Economic Cooperation and Development (OECD) has produced trail-blazing policy papers based on numerous empirical studies. An example is its 2001 report on the determinants of growth. This shows that a knowledge-based economy and the remarkable expansion of the service sector make human capital central to labour productivity and growth. This factor is combined with others, such as technological innovation, physical investment, especially in information and communications technologies, work organisation and modern methods of management. The OECD report particularly recommends investment in education and training.

Since the Lisbon European Council of March 2000, these principles have guided the European Union and, in particular, the Commission in devising the European strategy for economic growth, job creation and social cohesion. The goal set at Lisbon was to make the European Union the most competitive and dynamic economy in the world, capable of generating more and better jobs and achieving greater social cohesion. Progress in this strategy is monitored by means of indicators and periodic reports. While taking care to maintain a consistent and sustainable macroeconomic framework, the Commission has continued to promote the structural reforms linked to this strategy by means of initiatives such as the new social agenda, the relaunch of lifelong learning policies, and the strengthening of scientific research (sixth framework programme, 3 % of the gross domestic product (GDP) for research). The Commission's current concern is to reconcile 'the stricter budget constraint facing Member States in EMU' with 'efforts to raise the employment and growth performance as part of the Lisbon agenda', which 'requires that greater attention be paid to how public resources are spent'. The Commission therefore urges the Member States to improve the quality of public spending by gearing it to the Lisbon strategy. 'On this basis, Member States can promote growth and employment by redirecting public expenditure towards physical and human capital accumulation and research and development. Investment in human capital and infrastructure can have a robust effect on long-term growth and new innovative approaches to financing should be sought, including public-private partnerships.'<sup>(1)</sup>

The debate on human capital is taking a new turn, focusing on the role of human resources in producing, using and disseminating technological innovation, especially in the fields of information and communication.

The study also contributes to discussion of the development strategies adopted by the Member States. In this respect, the three Structural Fund programming periods between 1989 and 2006 have shown that each country has followed its own strategy. This is particularly striking as regards the Objective 1 regions, for which human resources funding varies between the Member States by a factor of two. Attempts to assess the impact of these different strategies have not produced conclusive results. This justifies adopting a new approach, which can yield general conclusions acceptable to all. This study makes a contribution by analysing national public expenditure in the relevant fields for a large number of countries over a long period.

These figures are used to enhance estimates of the return on investment in human capital at the microeconomic and macroeconomic levels. The following conclusions may be drawn.

At the microeconomic level, educational attainment is one of the main determinants of personal income and employment status. Recent research suggests that an additional year of schooling increases wages at the individual level by

<sup>(1)</sup> COM(2002) 209 final. SEC(2002) 518: 'Public finances in EMU — 2002'.

around 6.5 % across European countries and that this effect can be as high as 9 % in EU members with less regulated labour markets where pay scales presumably reflect productivity more closely. There is also a robust relationship between individual wages and on-the-job training, with some estimates indicating that a year of training increases wages by as much as 5 %. The literature also establishes that human capital and individual wages are more closely related in periods of rapid technological change.

Other empirical studies confirm the link between human capital and productivity in businesses. They show that workers with high human capital increase productivity and are a direct source of innovation and long-term competitiveness.

At the macroeconomic level, human capital contributes greatly to the growth of aggregate productivity, although there is still a great deal of uncertainty as to the exact size of this contribution because of the various econometric problems which complicate interpretation of the empirical results. According to the most plausible estimates, an extra year at the intermediate level of education — all other things being equal — increases aggregate productivity by about 5 % immediately and by a further 5 % in the long term. This long-term increase is explained by the contribution of human capital to technological progress through the development and adoption of new technology and the continuous improvement of existing production processes. Recent studies also suggest that the quality of education could be just as important to productivity as its quantity. The positive externalities of education and training expenditure should also be taken into account.

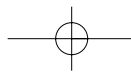
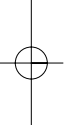
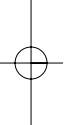
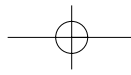
The authors compare their own estimates with the most recent work. On the basis of the most plausible estimates of the pertinent macroeconomic parameters, they estimate that, in a 'typical' OECD country, human capital accounted for 22 % of productivity growth in the period 1960–90 and for 45 % of the productivity differential with the sample average in 1990. About two thirds of each of these percentages reflect the direct impact of schooling on the level of productivity, while the remaining third reflects its contribution to technological progress. They also estimate that the direct economic returns to schooling investment that are captured by macroeconometric studies are comparable to those available from investment in physical capital.

The authors were aware of the possible impact of this study both on the general thrust of policy and on more detailed decisions aimed at improving the quality of public spending. They do not suggest an across-the-board increase in education spending irrespective of context. However, measures aimed at increasing the quantity and the quality of the stock of human capital should be an important part of any development strategy. This is particularly true for those regions of the EU that are lagging behind in productivity and income per capita.

They recommend taking a number of targeted steps, including:

- extending education and training to ensure that the technical and scientific personnel are available to allow new technologies to be developed and adopted;
- supporting lifelong learning in order to counter the increasingly rapid obsolescence of skills in a period of rapid technological change;
- improving the basis for accumulation of human capital for scientific research; since much of this capital derives from research itself, policy should strengthen the existing link between higher education and private and public research;
- concentrating public spending on improving the skills of those from disadvantaged backgrounds;
- promoting action to improve educational outcomes, both by reviewing teaching programmes and methods and by increasing expenditure, if necessary.

Antonis Kastrissianakis  
Director



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## CONTENTS

<b>Executive summary</b>	3
<b>1. Introduction</b>	6
<b>2. Human capital and productivity in the knowledge-based economy</b>	7
<b>3. Empirical evidence on human capital and productivity</b>	8
(a) Human capital and labour market outcomes: microeconomic evidence	9
(i) Methodological issues in estimating the effect of formal schooling on wages	10
(ii) Review of the estimates obtained with different methodologies	10
(iii) Trends of the Mincerian returns to schooling over time	11
(iv) Differences across European countries	11
(v) Female–male wage differentials	11
(vi) Effects of education on unemployment and labour force participation	12
(vii) The rate of return to education	13
(viii) On-the-job training, human capital and productivity at the firm level	13
(ix) Technological change and the effect of human capital on wages	14
(x) Technological change and employment	15
(xi) Non-market returns to schooling	15
(b) Human capital and growth: macroeconomic evidence	15
(i) Human capital in growth theory	15
(ii) Empirical formulations	16
(iii) Econometric issues	18
(iv) A brief review of the empirical evidence	20
(v) Externalities at the city and regional levels	21
<b>4. Social capital and growth</b>	22
<b>5. Some tentative conclusions</b>	23
(a) A plausible range of parameter estimates	23
(b) Implications for growth and cross-country disparities in the OECD	25
(c) Rates of return to schooling and some policy implications	28
<b>6. Concluding remarks</b>	33
<b>References</b>	34
<b>Appendix</b>	39
<b>1. Human capital, productivity and earnings: a survey of the microeconomic literature</b>	39
(a) Estimating the individual return to schooling: methodological issues	39
(b) Review of the estimates	40
(c) The return to schooling over time and across countries	41

(d) The role of schooling for male–female wage differentials	44
(e) Technological change	45
<b>2. Cross-country data on human capital</b>	<b>48</b>
(a) Data on schooling	48
Estimates of reliability ratios for different data sets	51
(b) Direct measures of skills and achievement	52
<b>3. Results of macroeconomic studies on human capital and growth</b>	<b>54</b>
(a) Ad hoc growth equations	54
(b) Results from structural convergence equations	59
Panel data specifications	62
(c) Production function estimates and related specifications	63
Rate effects and interaction with technological diffusion	64
(d) Data quality and measurement error	66
(e) Educational quality and test scores	68
Can quality be purchased?	71
(f) A plausible range of parameter estimates	72
<b>4. Selected educational indicators for the EU and other countries of interest</b>	<b>75</b>
<b>5. Social capital: a survey of the theoretical and empirical literature</b>	<b>88</b>
(a) What is social capital?	89
(b) Empirical evidence on social capital and aggregate performance	92
(c) Social capital accumulation	95
(d) Policy	97
<b>References</b>	<b>99</b>
<b>Tables A1.1 and A1.3</b>	<b>113</b>



## Executive summary

This report examines the rationale for putting investment in human capital at the forefront of policies aimed at promoting economic growth and social cohesion, as is done in the strategy outlined in the Lisbon Summit for turning the EU into the most competitive and dynamic knowledge-based economy in the world. On the basis of a review of the relevant academic literature, we reach the following broad conclusions. First, investment in human capital contributes significantly to productivity growth. Second, there is clear evidence that human capital plays a key role in fostering technological change and diffusion. Third, human capital investment appears attractive relative to alternative assets, both from the individual and from the aggregate perspectives. Fourth, policies that raise the quantity and quality of the stock of human capital are compatible with increasing social cohesion. On the whole, our findings suggest that investment in people is both a crucial growth factor, particularly in the current context of rapid technological change, and a key instrument for enhancing social cohesion, and are therefore supportive of the policy strategy set out in Lisbon.

### *A brief review of the academic literature*

There is a broad consensus in the academic literature that human capital is an important determinant of productivity and other economic outcomes, both at the individual and at the aggregate level, and that its role is particularly crucial in today's knowledge-driven economy. At the microeconomic level, there is very clear evidence that school attainment is a primary determinant of individual income and labour market status. Recent research suggests that an additional year of schooling increases wages at the individual level by around 6.5 % across European countries and that this effect can be as high as 9 % in EU members with less regulated labour markets where pay scales presumably reflect productivity more closely. There is also a robust relationship between individual wages and on-the-job training, with some estimates indicating that a year of training increases wages by as much as 5 %. These findings are supported by the empirical work that examines the connection between human capital and productivity at the firm level, which documents that high human capital workers increase productivity and are a direct source of innovation and long-term competitiveness. The literature also finds that the link between human capital and individual wages becomes stronger in times of rapid technological change.

At the macroeconomic level, there is evidence that the contribution of human capital to aggregate productivity growth is important, although considerable uncertainty remains about its exact magnitude because of various econometric problems that complicate the interpretation of the empirical results. What we consider to be the most plausible estimates in the literature suggest that, all other things being equal, an additional year of average school attainment increases the level of aggregate productivity by around 5 % on impact and by a further 5 % in the long run. This second effect reflects the contribution of human capital to technological progress, i.e. to the development and adoption of new technologies and to the continued improvement of existing production processes. Some recent research also suggests that the quality of education may be just as important for productivity as its quantity, although further work is needed before we have reliable estimates of the size of the relevant effects.

Theoretical models of human capital and growth suggest that some of the benefits of a more educated labour force will typically 'leak out' and generate macroeconomic benefits that cannot be appropriated in the form of higher earnings by those who undertake the relevant investment. These leakages are often called externalities, and they provide an important rationale for education subsidies and for other policies aimed at increasing human capital investment above its 'free market' value. The literature we have reviewed provides some clear indications that such externalities do exist and that they are likely to be quite large. A key finding supporting this view is that macroeconomic estimates of the individual returns to schooling tend to be significantly larger than their microeconomic counterparts (when the latter are corrected in a way that makes the two variables directly comparable). Since macroeconomic estimates will capture all the induced output gains and microeconomic estimates only the part of such gains that can be directly appropriated by the individual undertaking the investment, the difference between these two figures can be interpreted as a measure of the size of the externalities arising from human capital. In our view, the most plausible sources of these externalities are the link between human capital and the rate of technological change that has already been mentioned, and the indirect effect of education on productivity and employment through the quality of institutions that may be considered a component of social capital.

Two important limitations of the existing literature are (i) that it only provides precise quantitative estimates of some of the benefits from human capital and (ii) that it has relied almost exclusively on measures of the quantity of formal schooling. Existing estimates of the returns to education do not generally take into account its direct consumption benefits, its pecuniary and non-pecuniary returns in leisure and home production (although there are indications that these can be quantitatively important), or the contribution of educational policy to social cohesion. As a result, estimates of the rate of return to education as those discussed below should probably be seen as providing a lower bound on the social benefits that would accrue from increased investment in human capital. Another reason why the social benefits to education are likely to exceed economic estimates is the almost exclusive reliance of empirical work on data on years of formal schooling. This variable is used in practice for lack of better measures of the stock of human capital, i.e. of the skills and knowledge embodied in people that are useful in the production of goods, services and further knowledge. It is widely recognised, however, that school attainment will be at best an imperfect proxy for the true stock of human capital and that this generates a measurement error problem that will cause the statistical results to understate the strength of the connection between human capital and wages or productivity.

#### *Human capital, growth and disparities in industrial countries*

How important is human capital as a source of growth and cross-country differences in productivity? Working with the most plausible set of estimates of the relevant macroeconomic parameters, we estimate that, in the case of a 'typical' OECD country, human capital accounted for 22 % of observed productivity growth over 1960–90 and for 45 % of the productivity differential with the sample average in 1990. Roughly two thirds of each of these figures reflect the direct or immediate impact of schooling on the level of productivity, and the remaining third captures its contribution to technological progress.

#### *Rates of return to schooling and some policy implications*

Using the same set of estimates as in the previous exercise, we have calculated the private and social rates of return on schooling investment in a typical EU country and compared them with each other and with the rates of return on alternative assets. The objective of these comparisons has been to extract some conclusions about the optimality of observed investment patterns

that may be of interest for policy formulation. The exercise is somewhat involved because it requires a series of adjustments to make the various rates of return fully comparable to each other. Its results, moreover, should be interpreted with caution because there is considerable uncertainty regarding the correct parameter values, the relevant rates of return on alternative assets, and the size of the benefits from education that are not captured by the existing empirical estimates.

With this in mind, we believe our results support two broad conclusions, which should be understood as applying to the average EU country.

First, **a moderate increase in human capital investment is probably a good idea**. The direct economic returns to schooling investment that are captured by macroeconomic studies are roughly comparable to those available from investment in physical capital. When a reasonable allowance is made for non-market returns to education and for its benefits for social cohesion, human capital becomes a rather attractive investment alternative from a social point of view.

Second, **an across-the-board increase in general subsidies to formal education at the post-compulsory level is probably not necessary**. This conclusion may be somewhat surprising in view of our emphasis on the importance of human capital externalities, but it must be kept in mind that education in the EU is already heavily subsidised and that compulsory schooling laws also tend to counteract such externalities and the resulting tendency for underinvestment in education. An additional factor that helps to close the gap between the private and social returns to education is that individuals and firms, unlike countries, have unlimited access at given prices to complementary inputs whose use will raise the return on human capital investment. These factors help explain our finding that, in spite of the existence of important externalities, the private rate of return relevant for individual schooling decisions compares quite favourably with the social rate of return on education and with those on competing assets available to households.

Hence, the economic incentives for investment in schooling are probably adequate. If a further increase in post-compulsory enrolments is considered desirable, it may be more important to eliminate implicit barriers impeding access to advanced programmes (such as liquidity constraints and lower levels of basic skills for individuals from disadvantaged backgrounds) through policies specifically targeted at these problems, rather than further decrease already low tuition charges that imply a large subsidy for relatively privileged groups.

Indeed, higher tuition fees coupled with a well-designed loan programme or with an increase in means-tested grants may be an efficient way to provide additional resources to increase the quality of post-secondary education while at the same time reducing the regressivity of its financing. Additional public funds, however, may be required at lower educational levels and for the expansion of adult training.

Our analysis offers some guidance in identifying the most productive uses of additional educational resources as well as changes in current practices that may increase efficiency. Since the main sources of non-privately appropriable 'excess returns' from human capital investment are likely to be this factor's complementarity with technology and its contribution to social cohesion, it may be argued that priority should be given to the following objectives. First, aim to give technology-related skills to a broad segment of the population and ensure an adequate supply of the technical and scientific personnel that is needed both for the development and for the adoption of new technologies. Second, support lifelong learning in order to counteract the accelerated depreciation of skills in times of rapid technological change. Third, improve conditions for the accumulation of research-related human capital. Much of this human capital is generated as a by-product of research itself and human capital policies should therefore strengthen the link between tertiary education and both private and public research. Fourth, focus on improving the educational opportunities and the skills of individuals from disadvantaged backgrounds. This is likely to require a focus on early education in order to prevent the gradual build-up of handicaps arising from an unfavourable home environment. Some recent international studies suggest, moreover, that performance at the bottom of the student distribution can be signifi-

cantly improved without lowering overall standards. Fifth, existing results on the close link between the quality of human capital and productivity suggest that an important contribution to growth may come from policies that raise student achievement. The existing literature suggests that progress in this area may come from improved curricula and teaching practices at least as much as from increased expenditure, although the latter may also be necessary.

### *Conclusion*

On the whole, the evidence we have examined is consistent with the view that measures aimed at increasing the quantity and quality of the stock of human capital should be an important part of any growth-promoting policy package. This is certainly so in the case of the Lisbon strategy, which echoes many of the recommendations found in the literature. Implementation of the human capital policies outlined in successive EU summits appears especially important for those regions of the EU that are lagging behind in productivity and income per capita. It is important to recognise, however, that successful action requires a clear picture of the quantity and quality of regional human capital stocks in order to understand local needs and to identify those policies that are likely to be most effective. For example, it would be important to extend to the regional level recent studies that have tried to assess the skill levels of younger cohorts and of the workforce at large, and to support further research into the determinants of the performance of education systems. These studies can be a useful input for the formulation of a systematic human resources policy that should be an important part of the EU's ongoing effort to increase regional cohesion.

# 1. Introduction

Two years ago, the European Union set for itself the ambitious goal of becoming within a decade the most competitive and dynamic knowledge-based economy in the world. To achieve this goal, the Presidency conclusions of the Lisbon Council outline a strategy for taking advantage of the growth and employment opportunities afforded by new technologies without sacrificing social cohesion. This strategy involves a broad set of measures designed to promote the development, adoption and use of new technologies through increased and more efficient investment in knowledge, skills and infrastructures, the development of an appropriate legal framework for innovation and for electronic transactions, increased deregulation and the promotion of competition in relevant sectors, and financial market reforms aimed at ensuring an adequate supply of risk capital. The document also underlines the need to improve employment policies and modernise social protection systems so as to promote social cohesion and gender equality while reducing disincentives and ensuring the sustainability of benefit levels.

Investment in people plays a key role in the Lisbon strategy because it is seen as both an essential growth factor and a key lever of social cohesion policy. Human capital is considered to be a crucial input for the development of new technologies and a necessary factor for their adoption and efficient use, but also a prerequisite for employability and an instrument for fighting social exclusion and gender discrimination. Accordingly, the Lisbon document calls for a substantial increase in per capita investment in human resources and sets out a long list of objectives and policy proposals that focus on four areas: the promotion of digital literacy, the increase in educational attainment beyond compulsory schooling, the development of a lifelong learning system geared to labour market needs, and the provision of an adequate supply of technical and R & D personnel.

The present report examines the rationale for putting investment in human capital at the forefront of policies aimed at promoting economic growth and social cohesion, as is done in the Lisbon strategy. On the basis of a review of the relevant literature, we reach the

following broad conclusions. First, investment in human capital contributes significantly to productivity growth. Second, there is clear evidence that human capital plays a key role in fostering technological change and diffusion. Third, human capital investment appears attractive relative to alternative assets, both from the individual and from the aggregate perspectives. Fourth, policies that raise the quantity and quality of the stock of human capital are compatible with increasing social cohesion. On the whole, our findings are therefore supportive of the policy strategy outlined in the Lisbon Summit and of the premises that underlie it. They are also consistent with the important role attributed to human capital by a recent OECD (2001a) study that advances similar policy recommendations.

The report is organised as follows. Section 2 defines human capital and discusses the reasons why it can be expected to be a key determinant of individual earnings and aggregate productivity, particularly in today's increasingly knowledge-based economy. Section 3 reviews the relevant evidence available in the academic literature. Microeconomic studies on the subject provide very clear evidence of a strong connection between human capital and labour market outcomes (including wages and employment probabilities) that makes education a key instrument for the preservation of social cohesion. At the macroeconomic level, the literature suggests that, while there is considerable uncertainty as to the exact magnitude of the growth effects of human capital, these are in any event sizeable and justify a high level of investment in education and training. Section 4 briefly discusses the recent literature on social capital. In Section 5, we analyse the importance of human capital as a source of growth and income disparities in a sample of developed countries, and provide estimates of the private and social rates of return to schooling that are used to draw some tentative policy conclusions. Section 6 closes the main report with some general remarks on the implications of our findings for the formulation of EU policies. An appendix contains a more detailed review of the relevant literature and a set of human capital indicators for the EU and its candidate countries.

## 2. Human capital and productivity in the knowledge-based economy

Human capital is a broad and multifaceted concept encompassing many different types of investment in people. Health and nutrition are certainly an important aspect of such investment, particularly in developing countries where deficiencies in these respects may severely limit the population's ability to engage in productive activities. For the purposes of this report, however, the key aspect of human capital has to do with the knowledge and skills embodied in people and accumulated through schooling, training and experience that are useful in the production of goods, services and further knowledge.

To flesh out this broad definition, it may be useful to distinguish between the following three components of human capital:

- **General skills** related to basic language and quantitative literacy and, more broadly, to the ability to process information and use it in problem-solving and in learning. Basic language literacy can be defined as the ability to retrieve information from written texts and other materials and to encode information in similar media in an understandable and organised manner. Quantitative literacy involves the mastery of the rudiments of mathematics and the skills required to formulate problems in such a way that they can be solved through the application of the relevant techniques. These skills may be seen as partial aspects of a more general capacity for information processing and abstract reasoning that involves the ability to retrieve information from various sources and combine it with relevant knowledge to draw valid inferences and to generate useful hypotheses or generalisations that may offer insight into the solution of practical problems.
- **Specific skills** are those related to the operation of particular technologies or production processes. Examples include the ability to work with computer program of different degrees of complexity, to operate, maintain or repair a specific piece of machinery, and the techniques required in planting and harvesting.

- **Technical and scientific knowledge**, finally, refers to the mastery of specific bodies of organised knowledge and analytical techniques that may be of relevance in production or in the advance of technology, such as physics, architecture or the principles of logical circuit design.

There is a growing consensus that human capital is an important determinant of productivity, both at the individual and at the aggregate level, and that its role is particularly crucial in today's knowledge-based economy. Workers with greater problem-solving and communications abilities should perform better than their less skilled counterparts at any task that requires more than the routine application of physical labour and will also learn faster. Hence, skilled workers can be expected to be more productive than unskilled ones for any given production process, and should be able to operate more sophisticated technologies that place greater demands on their capacities. If skill does carry with it a greater ability to learn and produce new knowledge, moreover, a more educated labour force will also be able to achieve faster productivity growth, both through gradual improvements in existing production processes and through the adoption and development of more advanced technologies.

The available empirical evidence suggests that the importance of human capital as an input has grown over time as production processes have become increasingly knowledge intensive. Today, relatively few occupations involve only mechanical physical tasks, and a large and growing fraction of jobs either reduce to the processing of information or require the application of specialised knowledge and skills to the production of increasingly sophisticated goods and services<sup>(1)</sup>. This is also true in relation to the production of the applied knowledge that underlies technical progress, which has gradually become more reliant on explicit R & D activities, more closely intertwined with formal science and, as a result, increasingly skill intensive.

The rapid improvement and spread of information and communications technologies (ICT) in recent years are an important event that has significantly contributed

(1) A recent OECD (1999) study finds that over half of the combined output of its member countries is produced in knowledge-intensive industries. These include not only advanced-technology manufacturing sectors such as ICT, but also intensive users of new technologies and of skilled labour, such as finance, insurance and communications services.

to the development of the knowledge-based economy and to the acceleration of the secular trends that underlie the rising significance of human capital<sup>(2)</sup>. The implications of ICT are far reaching because these are general-purpose technologies with potential applications in many sectors and because they have greatly increased human capacity to store, access and process information rapidly and at low cost. Hence, advances in ICT are likely to gradually spread to user sectors, making for rapid technological and organisational change throughout the economy, and can be expected to contribute to the acceleration of technical progress and to its diffusion by providing researchers with powerful new tools and practically instant worldwide access to information. ICT

are also likely to increase competition in many markets by giving firms the possibility to search for customers and suppliers all over the globe, and will further erode locational rents and advantages by greatly reducing transport costs for knowledge and information outputs. To use a currently fashionable term, ICT can contribute significantly to the process of globalisation (or to increased global competition) by making the world effectively smaller in many ways. This will increase competitive pressures on national economies, and make it particularly crucial for them to have access to an adequate supply of skilled labour in order to stay ahead in the technological race and to have access to the potential benefits of the new technologies.

### 3. Empirical evidence on human capital and productivity

The hypothesis that human capital is a key determinant of productivity has received considerable attention in the academic literature. Labour economists have long been concerned with the impact of schooling and skills on individual wages and other labour market outcomes. Building on this work, macroeconomists have been using growth accounting techniques to analyse the contribution of education to aggregate economic growth since the 1960s. Research in this second area has received a new impulse in recent years with the development of a new generation of theoretical models that attribute to the accumulation of knowledge and skills a central role in the process of economic development and with the construction of broad cross-country data sets that can be used in the empirical analysis of the determinants of economic growth. In this section, we review the relevant literature in both areas of research with the objective of determining to what extent the available empirical evidence supports the hypotheses laid out in the previous section about the micro- and macroeconomic links between human capital and productivity<sup>(3)</sup>.

Before getting into the specifics of each line of work, it is important to highlight some of the similarities, differences and interconnections between them. In both branches of the literature, the typical empirical exercise involves the use of statistical techniques (generally regression analysis) to try to determine how an increase in **educational attainment** will affect individual

earnings or average productivity at the aggregate level. Hence, 'years of schooling' is the measure of the stock of human capital most commonly used in both micro- and macroeconomic analyses. Sometimes, this choice reflects a direct interest on the impact of schooling per se, but this variable is often used for lack of better measures of human capital. It is widely recognised that school attainment will be at best an imperfect proxy for the true stock of human capital and that this generates a measurement error problem that will cause the statistical results to understate the strength of the connection between human capital and wages or productivity. It is expected, however, that (since many of the relevant skills are acquired through formal schooling) the correlation between years of education and human capital will be sufficiently high for analyses that use the former as a proxy for the latter to yield some useful information<sup>(4)</sup>.

In both the micro- and the macroeconomic literature, the theoretical framework that underlies the empirical analysis assumes a stable technical relationship between inputs and output that can be described by a production function. In the microeconomic case, the further assumption is commonly made that observed wages reflect marginal productivities. In both cases, the objective of the analysis is to obtain estimates of a technical coefficient measuring the contribution of schooling to productivity. This parameter turns out to be an important determinant of the return to invest-

<sup>(2)</sup> See OECD (2001a) for a more detailed analysis of some of the implications of the 'new economy'.

<sup>(3)</sup> There are a number of excellent surveys in the literature that cover many of the issues we will discuss. Among others, see Griliches (1997), Card (1999) and Temple (2001).

<sup>(4)</sup> Some recent studies that attempt to measure skills directly suggest that this assumption is broadly correct, but also that things other than formal education contribute to the development and maintenance of skills. See OECD and Statistics Canada (2000) and Section 2 of the appendix to this report.



ment in schooling and is often interpreted directly as such (even though some model-specific adjustments are typically required to obtain the exact rate of return) <sup>(5)</sup>.

Comparisons of micro- and macroeconomic estimates of the returns to education are potentially of great interest because discrepancies between them can alert us to the existence of externalities that drive a wedge between the private and public returns to schooling and may call for corrective policy action. For instance, if the productivity of each worker increases with average education at the aggregate level as well as with his/her own school attainment, the first of these effects will constitute an externality and will generate a tendency for underinvestment in education because individuals will fail to take into account the indirect social benefits that can arise from their schooling choices. In this context, microeconomic estimates of wage equations with individual cross-section data for a given country will only pick up the own-education effects of schooling (because the indirect aggregate effect does not vary across individuals within a given country), whereas macroeconomic estimates with cross-country data should also capture the externality. Hence, the finding that the return to education is higher at the aggregate than at the individual level may be interpreted as evidence of the existence of positive externalities that may justify public subsidies designed to raise investment in education to its socially optimal level. Conversely, the reverse finding may be interpreted as providing some support for signalling or screening theories in which education does not necessarily increase productivity per se but may still increase wages because it serves as a signal for ability (i.e. allows employers to identify high-ability individuals) or as a credential for access to privileged jobs.

Such comparisons have to be made with extreme care, however, because, even in the absence of externalities, micro- and macroeconomic estimates of the returns to schooling can differ for a number of reasons. A first reason, to which we return below, is that there are statistical problems (biases related to the omission of relevant variables, errors in the measurement of years of schooling and reverse causation from income to the demand for education) that may affect the two sets of estimates to different extents. Second, it must be kept in mind that micro- and macroeconomic estimates measure different things. Even if both sets of coefficients do indeed reflect the marginal productivity of schooling, microeconomic estimates will tell us what happens to the earnings of an individual as his/her

schooling rises, holding constant factor prices and the economy-wide average level of education, whereas macroeconomic estimates will capture the effects of changes in aggregate average schooling on labour productivity holding the aggregate stock of physical capital constant. Hence, the coefficients of micro and macro studies are not directly comparable and have to be adjusted (in a way that will depend on the chosen econometric specifications) before valid inferences can be drawn about their relative values <sup>(6)</sup>. Third, it may be that wage scales do not exactly reflect marginal productivities because of distortions introduced by labour market institutions. In societies with a high aversion to inequality, for instance, collective bargaining may lead to relatively flat pay scales ('wage compression') that are likely to make the estimated private return to education fall below its contribution to productivity. Some allowance must be made for this possibility when comparing microeconomic estimates of the gross return to schooling across countries or with their macroeconomic counterparts.

### **(a) Human capital and labour market outcomes: microeconomic evidence**

Labour economists often distinguish between human capital accumulated during three distinct phases of life: early human capital, mainly acquired at home, human capital acquired through formal education, and human capital accumulated through on-the-job training. Most of the work of empirical researchers has concentrated on the labour market consequences of human capital acquired through formal education, mainly because it is the component of human capital that is easiest to measure. In this section, we briefly review and summarise the main conclusions regarding the labour market effects of formal education. We also touch on the economic consequences of on-the-job training, both for the individual obtaining the training and for the firm doing the training.

The three basic conclusions emerging from the large body of empirical work on the labour market consequences of formal education are that higher levels of education are accompanied by higher wages, lower unemployment probabilities, and higher labour force participation rates. Most of the work has been done on the link between schooling and wages. This is because the resulting wage increase is the most important economic consequence of higher levels of formal education. Moreover, as we mentioned earlier, wages are often

<sup>(5)</sup> See Section 5(c) below.

<sup>(6)</sup> Essentially, the adjustment is needed to hold physical capital constant in the microeconomic estimates. Under reasonable assumptions, the required correction involves reducing microeconomic estimates by around one third. See de la Fuente (2002a).

seen as reflecting marginal labour productivity, which implies that the link between formal schooling and wages can be used to analyse the productivity effects of formal schooling.

*(i) Methodological issues in estimating the effect of formal schooling on wages*

Empirical work on the effect of formal schooling on wages estimates the percentage increase in wages implied by additional schooling. The main difficulty of estimating this effect correctly is that individuals with high and low levels of schooling differ in many respects, not just in their schooling levels. Examples of such characteristics are family background and ability. To the extent that these other differences are observable to researchers, they can be taken into account directly in the statistical analysis. Standard methods, i.e. least-squares estimation, can then be used to identify the percentage increase in wages implied by additional formal education, holding other observable characteristics like family background constant. But some characteristics of individuals are difficult to observe. For example, there is often little information about the ability of individuals. This raises difficulties, as it seems likely in some contexts that ability is positively correlated with both schooling and wages. Omitting ability from the analysis and using least-squares estimation will therefore tend to attribute some of the wage increase explained by ability to education. Hence, the effect of schooling on wages would be overstated. Another problem in estimating the percentage increase in wages implied by additional formal education is that individual schooling is often reported with error. As we have already mentioned, measurement error alone implies that least-squares results understate the effect of formal schooling on wages.

Empirical researchers have taken two different routes in trying to resolve the difficulties raised by unobservable determinants of wages and schooling as well as mismeasurement of individual schooling. The first route consists of estimating the effect of schooling on wages using data on (identical) twins. The basic idea is that twins are more similar in many dimensions than two randomly chosen individuals and omitted determinants of wages and schooling should therefore be less of a problem in estimating the effect of formal schooling on wages using least-squares techniques. The second route relies on a non-standard statistical technique called instrumental-variable (IV) estimation. The IV approach requires an additional variable, a so-called instrument, that affects years of schooling but is not correlated with omitted determinants of wages or the measurement error of individual schooling. Using this instrument, the researcher first obtains an estimate of

the effect of the instrument on schooling and then on wages. The instrumental-variable estimate of the effect of formal schooling on wages is obtained by dividing the latter by the former. Instruments used in practice include institutional changes affecting school leaving age or changes in tuition costs.

**Box 1: Mincerian wage regressions and the 'return' to schooling**

Following Mincer (1974), the specification used to estimate the effect of individual schooling on individual wages has been

$$(1) \ln W_i = \alpha + \theta S_i + \gamma e_i + \mu e_i^2 + \phi X_i + u_i$$

where  $W$  is the (hourly) wage,  $S$  schooling,  $e$  experience,  $X$  a set of other individual characteristics, and  $u$  the variation in log wages not captured by the right-hand-side variables. The parameter  $\theta$  measures the percentage increase in wages associated with an additional year of schooling and is assumed to be independent of the level of schooling (although this specification seems quite restrictive a priori, it has been shown to fit the data well in many developed countries (e.g. Heckman, Lochner and Todd, 2001)). Mincer shows that under certain conditions, which include that there are no direct costs of education,  $\theta$  can be interpreted as the proper private return to schooling. This is why estimates of  $\theta$  are often referred to as the 'return to schooling'. Generally, however,  $\theta$  will not be equal to the proper return to schooling for several reasons, including the fact that there is a direct cost of education (see Box 5 below). This is why we will refer to  $\theta$  as the **Mincerian return to schooling** (sometimes  $\theta$  is also referred to as the schooling wage premium or as the gross return to schooling).

*(ii) Review of the estimates obtained with different methodologies*

There are many circumstances where the only estimates of the Mincerian return to schooling available are obtained using standard statistical techniques. It is therefore important to understand whether estimates of the Mincerian return to schooling obtained with least-squares techniques are systematically different from estimates relying on twins or an IV approach. The growing literature on this issue suggests that, overall, the estimates obtained using twins or an IV approach are somewhat greater than estimates using least-squares techniques. The question of whether these differences are significant is analysed in Ashenfelter, Harmon and Oosterbeck (1999). Examining the results



of several studies in the United States and seven non-US countries between 1974 and 1995, they find that IV estimates and twin studies estimates exceed least-squares estimates by 3.1 and 1.6 percentage points. This difference decreases, however, once they control for the fact that studies producing no interesting results — insignificant difference between the IV and the least-squares estimates for example — are less likely to be published. The corrected differences are 1.8 and 0.9 percentage points respectively.

*(iii) Trends of the Mincerian return to schooling over time*

It is well documented that the Mincerian return to schooling in the United States decreased during the 1970s and increased during the 1980s, generating a U-shaped time pattern of educational wage differentials. There is a consensus that these changes may be interpreted as outcomes of shifts in the supply and demand for human capital. The basic idea is that the increase in the supply of high human capital workers dominated demand growth during the 1970s, reducing the Mincerian return to schooling. During the 1980s, however, the increase in the demand for high human capital workers dominated supply growth, raising the schooling wage premium (e.g. Katz and Murphy, 1992). The growth in the demand for human capital is commonly attributed to technological change.

The Mincerian return to schooling in Europe as a whole followed a U-shaped time pattern similar to the United States. In the 1960s, the Mincerian return to schooling was higher than in the 1970s. In the 1980s, the Mincerian return to schooling dropped further, but started to rise again during the 1990s. Denny, Harmon, and Lydon (2001) confirm this pattern by reviewing a large number of studies on the Mincerian return to schooling for different European countries and time periods. Comparing the United States with Europe, they show that the Mincerian return to schooling in Europe exceeded the return in the United States in the early 1960s. In the course of the 1960s and 1970s, estimates of the Mincerian return to schooling in Europe and in the United States fell at a similar rate. But the estimates reached their minimum at the end of the 1970s, while European estimates continued to decline until the mid-1980s. The subsequent increase in estimates of the Mincerian return to schooling was much more pronounced in the United States. By 1997, the Mincerian return to schooling in the United States was about 3 percentage points higher than in Europe. It is important to keep in mind, however, that, while the overall pattern of change in Europe was similar to the United States, behaviour across European countries differed widely.

*(iv) Differences across European countries*

The Mincerian return to schooling varies considerably across European countries. For example, Harmon, Walker and Westergaard-Nielsen (2001) find that the Mincerian return to schooling is lowest in Scandinavian countries (around 4 % in Norway, Sweden and Denmark; Finland is an exception) and highest in Ireland and the UK (around 12 %). Reviewing a large number of studies, they find an average Mincerian return to schooling of around 6.5 % in Europe. Similar evidence is provided by Denny, Harmon and Lydon (2001), who estimate the Mincerian return to schooling using homogenised data for different European countries. They find large differences, with Norway at the bottom and Ireland and the UK at the top. But there remains considerable uncertainty on how European countries rank in the schooling wage premium (European Investment Bank study by Heinrich and Hildebrand, 2001).

*(v) Female–male wage differentials*

In most industrialised countries, the gender wage differential has decreased during the last decades. This is partly explained by the fact that differences in years of schooling among male and female full-time workers have largely disappeared (e.g. Blau and Kahn, 1997; Harkness, 1996). Not only schooling of women, but also female labour force participation and consequently women's accumulated labour force experience have increased. These changes in experience seem to have been even more important in closing the gender wage differential than the increase in years of education. Today, it is not the amount of schooling, but rather differences in what men and women study as well as differences in aptitudes and achievement scores across subjects through which schooling appears to affect gender wage differentials. For example, recent results of the programme for international student assessment (PISA; OECD, 2001c) indicate that while males are likely to underperform in reading, women seem to have a disadvantage in mathematics.

Less working hours and fewer years in the labour market lead according to standard human capital theory to less investment in general human capital. Furthermore, women have traditionally a higher turnover rate than men. Expected job separation may discourage investment in employer-specific human capital. Empirical evidence supports the notion that women are less likely to receive training (e.g. Lynch, 1992). Furthermore, men receive a higher training duration and are more likely to have jobs requiring longer training periods (e.g. Altonji and Spletzer, 1991; Barron, Black and Lowenstein, 1993).

There has been a growing amount of research on the impact of part-time and temporary work on the wages of women. Women are heavily over-represented in part-time and temporary jobs, which typically pay lower hourly wages than full-time or permanent jobs. While differences in schooling among male and female full-time workers have disappeared completely for younger cohorts, part-time working women continue to be less qualified than full-time working men or women. As a result, the relative earnings position of women working part-time has changed little over the last decades (e.g. Harkness, 1996).

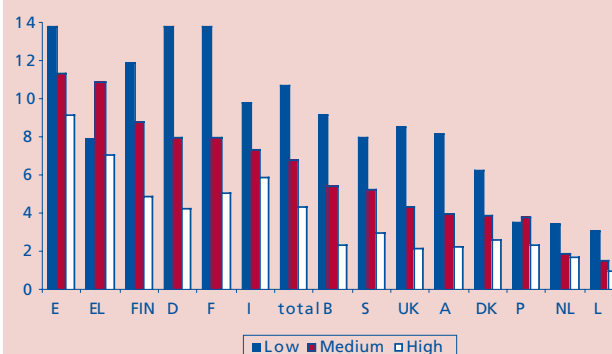
There is considerable evidence that the Mincerian return to schooling is greater for women than men in European countries. For example, Harmon, Walker and Westergaard-Nielsen (2001) find that the effect of schooling on female wages exceeds the effect on male wages by 5 percentage points in Ireland and by 2 or more percentage points in Italy, (West) Germany, Greece and the UK. Denny, Harmon and Lydon (2001) argue that the differential is greater in countries with lower female labour force participation.

#### *(vi) Effects of education on unemployment and labour force participation*

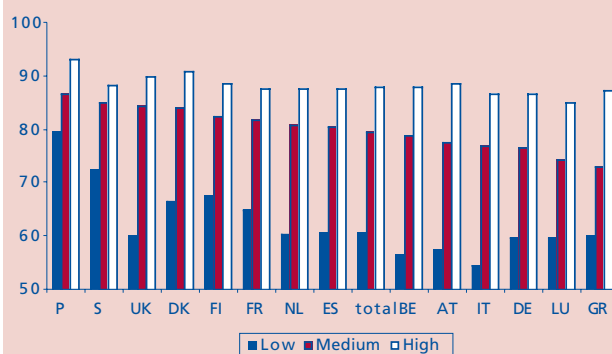
Formal education affects lifetime earnings also through the probability of unemployment. For example, according to a study of the European Investment Bank (Heinrich and Hildebrand, 2001), male university graduates have lower unemployment rates than workers with less education in all European countries except Denmark. Moreover, the differences are sometimes very large. In Ireland, for example, the unemployment rate among men with basic education is five times the unemployment rate of male university graduates. In Finland, male workers with a basic education are twice as likely to be unemployed as those with an upper-level secondary education. The pattern among women is more complex. Still, in the majority of European countries, the unemployment rate among women falls with their education levels.

Education also affects labour force participation. For example, according to the European Investment Bank (EIB) study, Belgian women with a university education are 42 % more likely to participate in the labour force than those with a basic education; similarly, Dutch women with an upper secondary education are 22 % more likely to participate in the labour force than those with a basic education. The only exception to this rule seems to be the UK, where women with a secondary education are less likely to participate in the labour force than those with a basic education.

**Figure 1: Unemployment by educational attainment level**



**Figure 2: Labour force participation by educational attainment level**



**Notes:**

– The data refer to the population aged 25 to 64. **Low** attainment includes primary and lower secondary education and elementary vocational training (ISCED levels 1 and 2); **medium** refers to higher secondary education and vocational programmes (ISCED levels 3 and 4); and **high** to post-secondary training (ISCED level 5 or higher). There are no data for Ireland.

– Key: Total = entire sample; B = Belgium; DK = Denmark; D = Germany; EL = Greece; E = Spain; F = France; I = Italy; L = Luxembourg; NL = Netherlands; A = Austria; P = Portugal; FIN = Finland; S = Sweden and UK = United Kingdom.

– Source: Eurostat, Labour force survey, spring 2000.

Recent data from Eurostat also confirm the existence of a strong connection between educational achievement and employment and participation rates. As illustrated in Figures 1 and 2, unemployment rates decrease and participation rates increase as we move from low to high educational attainment levels in practically all EU countries (with Greece and Portugal being partial exceptions in terms of the unemployment rate, which is highest in these countries for intermediate attainment levels). For the sample as a whole, moving from low to intermediate attainment reduces the unemployment rate by 3.95 points and increases the labour force participation rate by 18.8 points. When we consider the

difference between the highest and the lowest attainment categories, these figures increase to 6.33 and 27.2 points respectively.

### *(vii) The rate of return to education*

So far we have only dealt with the Mincerian return to schooling. Now we turn to the proper return to schooling, i.e. to the return on the resources invested in education <sup>(7)</sup>. The literature distinguishes two rates of return: the private rate of return and the social rate of return. The private rate of return relates the resources invested by those obtaining the education (the opportunity cost as well as direct costs) to the private benefits of education. The social return includes the public cost of education in these calculations. Notice that while the social return accounts for the total (private and public) resources invested in education, it relates these resources to the private benefits of education only (i.e. it does not account for possible externalities). Ideally, the social rate of return to education would relate all resources invested in education to all benefits of education.

According to a recent OECD study (OECD, 2001b), the private return of a tertiary education for men in Europe averages more than 12 %. The country with the highest return is the UK (17.3 %), followed by Denmark (13.9 %) and France (12.2 %). Italy (6.5 %) is at the bottom of the ranking. The average rate of return to upper secondary education for men is also around 12 %, with the UK (15.1 %) and France (14.8 %) at the top of the ranking and Sweden (6.4 %) and the Netherlands (7.9 %) at the bottom. The average rate of return for women is similar when it comes to tertiary education, but the rankings differ. The country with the highest private return of a tertiary education for women is the UK (15.2 %), followed by the Netherlands (12.3 %) and France (11.7 %). The average private return of an upper secondary education for women in Europe is around 11 % with France (19.2 %) and Denmark (10.5 %) at the top and Germany (6.9 %) at the bottom (data for the UK were not available in this case).

The social rates of return are generally somewhat lower than the private ones. For example, the social rate of return of a tertiary education for men is on average around 2 percentage points lower than the private return (the outliers are Denmark and Sweden where it

is 4 or more percentage points below). For women, the gap between the social and the private return is similar (but the Netherlands now joins the outliers, with the private return exceeding the social return by 6 percentage points). Comparing the social and private rates of return of upper secondary education yields a very similar pattern.

It should be kept in mind that these rates of return are most likely lower bounds for two reasons. First, these returns are based on least-squares estimates of the Mincerian return to schooling. We have already seen that estimates of the effect of education on wages using more sophisticated techniques yield effects that are 1 to 2 percentage points higher on average. Second, the social rates of return do not include social benefits in excess of private benefits of education (e.g. Arias and McMahon, 1999). We argue later that, although there is considerable uncertainty regarding these benefits, they are potentially large.

### *(viii) On-the-job training, human capital and productivity at the firm level*

The literature on on-the-job training has examined three basic questions. First, does on-the-job training increase productivity and profitability at the firm level? Does on-the-job training increase wages? Who obtains on-the-job training?

There is clear evidence that on-the-job training increases productivity at the firm level (e.g. Bartel, 1991; Lynch and Black, 1995). Moreover, on-the-job training is also a source of innovation and therefore long-term competitiveness of firms (e.g. Blundell, Dearden, Meghir and Sianesi, 1999). When it comes to firm profitability, the evidence is mixed, with some studies arguing that profitability increases and others that profitability is unaffected <sup>(8)</sup>. This is not surprising, as the theoretical link between productivity growth at the firm level and profitability is complex.

Individual workers receiving on-the-job training have consistently been found to earn higher wages (e.g. Blundell, Dearden, Meghir and Sianesi, 1999). For example, individuals undertaking on-the-job vocational training in the UK earn on average 5 % more than individuals who have not undertaken such training.

<sup>(7)</sup> See Section 5(c) below for a more detailed discussion of the calculation of the proper rate of return to schooling.

<sup>(8)</sup> For example, Bassi, Harrison, Ludwig and McMurrer (2001) show that firms investing in training pay extra-normal returns to shareholders. They also emphasise, however, that while this correlation is consistent with a causal effect, it may also reflect that training is a leading indicator of other factors translating into high profitability.

Regarding the question of who obtains on-the-job training, the evidence indicates that on average training is given to workers with higher ability and more education. Hence, the three components of human capital (early human capital, formal education, and on-the-job training) tend to be complementary over the life cycle of workers (e.g. Lynch and Black, 1995). Still, on-the-job training of workers with low qualifications has large effects on their productivity (e.g. Blundell, Dearden, Meghir and Sianesi, 1999). There is also evidence that training is especially productive in a rapidly changing technological environment (e.g. Bartel and Sicherman, 1998).

Empirical work at the firm level also indicates a clear link between human capital and productivity at this level (e.g. Lynch and Black, 1995; Blundell, Dearden, Meghir and Sianesi, 1999). Moreover, high human capital workers are a direct source of innovation and hence long-term competitiveness. This is not too surprising, of course, as firms employ more expensive, high human capital workers only if their productivity offsets the higher cost.

*(ix) Technological change and the effect of human capital on wages*

The most important explanation suggested for the positive link between wages and schooling is that education enables individuals to adopt, implement, or work with more advanced technologies. After briefly summarising the main theories, we review empirical evidence on the association between technology on the one hand and the demand for human capital, wages and employment on the other. We restrict ourselves to the analysis of studies using direct measures of technology.

The last few decades have witnessed major technological changes, such as the rapid spread of computers, the expansion of computer-assisted production techniques and robots, and new information and communications technologies. How do these changes affect the relative demand for high human capital workers? Basically two hypotheses exist, which try to explain the relation between the relative demand for high human capital workers and technological change. The first hypothesis relates the rate of technological change and the demand for high human capital workers. If highly educated workers have a comparative advantage in adjusting to new technologies and implementing them, then the spread of these new technologies is likely to increase the demand for high human capital workers relative to low human capital workers. If the increase in the demand for high human capital workers outstrips the increase in supply, the Mincerian return to schooling

increases. The second hypothesis claims that new technologies introduced in the last few decades are skill biased, i.e. they replace labour-intensive tasks and are complementary to high human capital workers. Hence, the transition to new technologies results in an increase in the demand for human capital holding output and relative prices constant.

Clear evidence exists that more computerised or R & D-intensive industries increased their demand for college-educated workers at a faster rate in the 1980s. For example, Machin and Van Reenen (1998), using R & D intensity at the industry level as a measure of technology, provide evidence for skill-biased technological change in Denmark, France, Germany, Japan, Sweden and the UK. Berman, Bound and Griliches (1994) and Autor, Katz and Krueger (1998) document a strong positive correlation between the level of computer investment and the demand for human capital at the industry level. Using a cross-section of US plants, Doms, Dunne and Troske (1997) also come to the conclusion that better technologies are accompanied by a higher demand for human capital. Looking at the same plants at different points in time, however, reveals that plants that adopt new technologies have a higher proportion of high human capital workers even **before** the adoption of new technologies. Human capital is therefore a prerequisite for the implementation of new technologies. Aguirregabiria and Alonso-Borrego (1997), Duguet and Greenan (1997), and Haskel and Heden (1999) come to similar conclusions using data on Spanish, French and British plants.

While evidence exists that technological change affects the relative demand for high human capital workers, only a few studies examine the exact mechanisms. Some authors conjecture that organisational change might play a key role (e.g. Dunne, Haltiwanger and Troske, 1996; Machin and Van Reenen, 1998). In most industrialised countries, there has been a trend towards less hierarchy and more flexible organisational forms, as workers are given more autonomy and perform a wider range of tasks. Caroli and Van Reenen (1999) use a panel of British and French plants in order to investigate whether organisational changes such as the decentralisation of authority, delayering of managerial functions, and increased multitasking affect the demand for human capital. They find these changes tend to reduce the demand for low human capital workers and lead to greater productivity growth (especially in establishments with higher average levels of human capital).

The increase in the Mincerian return to schooling and the rise in wage inequality in the United States

during the 1980s, combined with the widespread notion that technological change may be the driving force behind it, triggered a large number of studies on the link between wages and technological change. The consensus emerging from these studies is that the increase in the schooling wage premium and the rise in wage inequality are driven by technological change. For example, Mincer (1993) shows that the relative earnings of college graduates in the United States increased with the aggregate R & D intensity between 1963 and 1987. Krueger (1993) argues that the wage structure has been changed by the widespread introduction of computers. Allen (2001) finds that the schooling wage premium between 1979 and 1989 rose most in industries with a greater R & D and high-tech capital.

At the firm and industry level, there appears to be no robust positive correlation between technological change and wages of high human capital workers (e.g. DiNardo and Pischke, 1997; Entorf and Kramarz, 1998). This is not too surprising, however, as skill-biased productivity growth at the level of a single firm or industry will translate into increased demand for human capital but not into wages in a competitive environment.

#### *(x) Technological change and employment*

To understand the theoretical effect of technological change on employment, assume that a firm decides to implement a computer-assisted production process. The implementation of this new process allows the firm to produce the same amount of output with a lower level of employment, generating a negative employment effect. This translates into a cost reduction and lower prices. Lower prices may translate into larger demand and therefore output, generating a positive employment effect. Whether employment is higher before or after the adoption of the new technology depends on a variety of factors. The positive employment effect tends to increase with competition in the sector experiencing technological change, the extent of economies of scale, and the elasticity of demand. These considerations imply that the relationship between technological change and employment at the firm and industry level is a priori unclear. Empirical studies on the relationship between employment and technology have been relatively scarce. Analysing manufacturing industries in the OECD, Blechinger, Kleinknecht, Licht and Pfeiffer (1998) show that industries with higher R & D intensity expanded more quickly. Firm-level studies provide a wide variety of results from different countries however. It appears that product innovation has a positive effect on employment growth in Germany but a nega-

tive effect in France (e.g. Entorf and Pohlmeier, 1990; Greenan and Guellec, 2000). Evidence concerning process innovations is also mixed (e.g. Blanchflower and Burgess, 1998; Blechinger et al., 1998).

#### *(xi) Non-market returns to schooling*

So far we have only discussed the return to education related to improved labour market performance. There is much literature identifying additional non-market returns for individuals and families (e.g. McMahon, 1998). The main component of these additional returns is usually taken to be the positive effect of education on own health and on the health of families headed by better educated individuals. For example, better educated men have a lower risk of death from heart disease, and children of better educated women have lower mortality rates (e.g. Feldman, Makuc, Kleinman and Cornoni-Huntly, 1989). Some studies argue that health benefits can add up to 40 % to the labour market return of schooling (e.g. Wolfe and Zuvekas, 1997). Another important non-market component of the return to schooling is the efficiency of home production, including the management of household finances and the education of children. For example, households headed by more educated individuals achieve higher returns on financial assets and the children of better educated parents stay longer and do better in school (e.g. Solomon, 1975; Angrist and Lavy, 1996). Moreover, better educated individuals are more efficient learners later in life (e.g. Mincer, 1993). These non-market returns imply that the private and social labour market returns to human capital should be seen as lower bounds when making investment decisions.

### **(b) Human capital and growth: macroeconomic evidence**

This section surveys the macroeconomic evidence on the growth effects of education. After briefly reviewing the role of human capital in recent theories of growth, we discuss the specifications most commonly used in empirical work in this area, some econometric issues that arise in their estimation, and the main results of the literature. A more detailed literature review is contained in Section 3 of the appendix to this report <sup>(9)</sup>.

#### *(i) Human capital in growth theory*

One of the most distinctive features of the 'new' theories of growth developed in recent years has been the broadening of the relevant concept of capital.

<sup>(9)</sup> This section and parts of Section 5 are based on de la Fuente (2002a).



While traditional neoclassical models focused almost exclusively on the accumulation of physical capital (equipment and structures), more recent contributions have attributed increasing importance to the accumulation of human capital and productive knowledge and to the interaction between these two factors <sup>(10)</sup>.

Theoretical models of human capital and growth are built around the hypothesis discussed in Section 2, namely that knowledge and skills embodied in humans directly raise productivity and increase an economy's ability to develop and to adopt new technologies. In order to explore its implications and open the way for its empirical testing, this basic hypothesis is generally formalised in one of two (not mutually exclusive) ways. The simplest involves introducing the stock of human capital (which will be denoted by  $H$  throughout this report) as an additional input in an otherwise standard production function linking aggregate output to the stocks of productive inputs (generally employment and physical capital) and to an index of technical efficiency or total factor productivity (TFP). The second possibility is to include  $H$  in the model as a determinant of the rate of technological progress (i.e. the rate of growth of TFP). This involves specifying a technical progress function that may include as additional arguments variables related to R & D investment and the gap between each country and the world technological frontier. We will refer to the first of these links between human capital and productivity as **level effects** (because the stock of human capital has a direct impact on the level of output) and to the second one as **rate effects** (because  $H$  affects the growth rate of output through TFP). As will be emphasised later, the distinction between these two types of effects, while conceptually clear, is often less sharp in practice than may appear from the preceding discussion, particularly in models that allow for the diffusion of technology across countries.

Some recent theoretical models also suggest that the accumulation of human capital may give rise to important externalities, as some of the benefits of a more educated labour force will typically 'leak out' and generate benefits that cannot be appropriated by those who undertake the relevant investment in the form of higher earnings, thereby driving a wedge between the relevant private and social rates of return. Lucas (1988), for example, suggests that the average stock of human capital at the economy-wide level increases productivity

at the firm level holding the firm's own stock of human capital constant. It is also commonly assumed that the rate effects of human capital through the technical progress function include a large externality component because it is difficult to appropriate privately the full economic value of new ideas. Azariadis and Drazen (1990), and implicitly Lucas (1988) as well, stress that younger cohorts are likely to benefit from the knowledge and skills accumulated by their elders, thus generating potentially important intergenerational externalities that operate both at home and in school. The literature also suggests that human capital can generate more diffuse 'civic' externalities, as an increase in the educational level of the population may help reduce crime rates or contribute to the development of more effective institutions.

### *(ii) Empirical formulations*

Empirical studies of the productivity effects of human capital (or more broadly, of the determinants of economic growth) have followed one of two alternative approaches. The first involves the specification and estimation of an ad hoc equation relating growth in total or per capita output to a set of variables that are thought to be relevant on the basis of informal theoretical considerations. The second approach is based on the estimation of a structural relation between the level of output or its growth rate and the relevant explanatory variables that is derived from an explicit theoretical model built around an aggregate production function and, possibly, a second function that describes the determinants of technical progress.

This basic framework for the 'structural' analysis of the determinants of growth can give rise to a large number of empirical specifications. As explained in greater detail in Box 2, the production function can be estimated directly with the relevant variables expressed in levels or in growth rates when reliable data are available for the stocks of all the relevant production inputs. Alternatively, its parameters can be recovered from other specifications (convergence and steady state equations) that are designed for estimation when only data on investment flows (rather than factor stocks) are available. These specifications can be derived from production functions by replacing factor stocks or their growth rates by convenient approximations constructed using observed investment rates.

<sup>(10)</sup> See especially Lucas (1988), Romer (1989), Azariadis and Drazen (1990), Mankiw, Romer and Weil (1992) and Jones (1996). Some recent studies in this literature draw on earlier work by Uzawa (1965), Nelson and Phelps (1966) and Welch (1970) among others.

### Box 2: Some commonly used growth specifications

Many studies of the determinants of growth assume an aggregate Cobb-Douglas production function of the form

$$(1) Y_{it} = A_{it} K_{it}^{\alpha_k} H_{it}^{\alpha_h} L_{it}^{\alpha_l}$$

where  $Y_{it}$  denotes the aggregate output of country  $i$  at time  $t$ ,  $L_{it}$  is the level of employment,  $K_{it}$  the stock of physical capital,  $H_{it}$  the average stock of human capital per worker, and  $A_{it}$  an index of technical efficiency or total factor productivity (TFP) which summarises the current state of the technology and, possibly, omitted factors such as geographical location, climate, institutions and endowments of natural resources. The coefficients  $\alpha_i$  (with  $i = k, h, l$ ) measure the elasticity of output with respect to the stocks of the different factors. An increase of 1 % in the stock of human capital per worker, for instance, would increase output by  $\alpha_h$  %, holding constant the stocks of the other factors and the level of technical efficiency.

For estimation purposes it is generally convenient to work with equation (1) in logarithms or in growth rates. Using lower case letters to denote logarithms, and the combination of lower case letters and the symbol ' $\Delta$ ' to denote growth rates, this yields the following two specifications:

$$(2) y_{it} = a_{it} + \alpha_k k_{it} + \alpha_h h_{it} + \alpha_l l_{it} + \varepsilon_{it}$$

$$(3) \Delta y_{it} = \Delta a_{it} + \alpha_k \Delta k_{it} + \alpha_h \Delta h_{it} + \alpha_l \Delta l_{it} + \Delta \varepsilon_{it}$$

where  $\varepsilon_{it}$  and  $\Delta \varepsilon_{it}$  are stochastic disturbances.

One difficulty that arises at this point is that both equations (2) and (3) contain terms that are not directly observable (in particular, the level of TFP,  $a_{it}$ , or its growth rate,  $\Delta a_{it}$ ). To proceed with the estimation, it is necessary to make further assumptions about the behaviour of these terms. Different assumptions will generate different econometric specifications. The simplest possibility is to assume that the rate of technical progress is constant over time and across countries, i.e. that  $\Delta a_{it} = g$  for all  $i$  and  $t$ . In this case,  $g$  can be estimated as the regression constant in equation (3) and  $a_{it}$  is replaced in equation (2) by  $a_{i0} + gt$ , where  $a_{i0}$  and  $g$  give rise to country-specific constants and a common trend respectively.

An alternative and more sophisticated approach is to specify  $\Delta a_{it}$  in equation (3) as a function of other variables. A relatively general specification of this

technical progress function (that reflects those used in the studies reviewed in the appendix to this report and allows for rate effects from human capital) would be given by

$$(4) \Delta a_{it} = \gamma_{i0} + \gamma_b b_{it} + \gamma_h H_{it} + \gamma_{bh} H_{it} b_{it} + \gamma_r RD_{it}$$

where  $H$  is the average stock of human capital,  $RD$  a measure of R & D expenditure and  $b_{it}$  is some proxy for the technological gap between country  $i$  and the world best practice frontier.

When data on factor stocks or their growth rates are not available (or are not considered reliable), observed investment rates can be used to construct approximations to the variables that enter equations (2) and (3). These approximations are typically obtained by using a generalised Solow model in the manner suggested by Mankiw, Romer and Weil (1992). In such a model, long-term equilibrium values of factor ratios are simple functions of investment rates, and the behaviour of these ratios away from such an equilibrium can be approximated as a function of investment rates and initial income per worker. If we are willing to assume that most countries are reasonably close to their long-run equilibria, equation (2) can be replaced by an equation relating output per worker to investment rates in physical and human capital. Otherwise, the equation will also include initial output per worker as an additional regressor in order to pick up transitional dynamics along the adjustment to the long-run equilibrium. Two rather standard specifications of the resulting **steady state and convergence equations** (which do not allow for rate effects) would be

$$(5) q_{it} = a_{i0} + gt + \frac{\alpha_k}{1 - \alpha_k - \alpha_h} \ln \frac{s_{kit}}{\delta + g + n_{it}}$$

and

$$(6) \Delta q_{it} = g + \beta \left( \frac{\alpha_k}{1 - \alpha_k - \alpha_h} \ln \frac{s_{kit}}{\delta + g + n_{it}} + \frac{\alpha_h}{1 - \alpha_k - \alpha_h} \ln \frac{s_{hit}}{\delta + g + n_{it}} \right) + \beta (a_{i0} + gt) - \beta q_{it}$$

where  $s_k$  and  $s_h$  stand for investment in physical and human capital, measured as a fraction of GDP,  $n$  for the rate of growth of employment or the labour force and  $\delta$  for the rate of depreciation (which is assumed to be the same for both types of capital). The parameter  $\beta$  measures the speed of convergence towards the long-run equilibrium and can be shown to be a function of the degree of returns to scale in both types of capital considered jointly and of the length of the period over which we are taking observations.

So far, we have implicitly assumed that the stock of human capital per worker,  $H$ , is directly observable. In practice, however, what we observe is typically average years of schooling,  $YS$ , and the estimation of the empirical model requires some assumption about the form of the function relating these two variables,  $H = g(YS)$ . Substituting this function into equation (1), we obtain a reduced-form production function relating  $Y$  to  $YS$ . To avoid any confusion, we will refer to the elasticity of this reduced-form production function with respect to years of schooling as  $\alpha_{YS}$  (notice that this parameter will generally be different from  $\alpha_h$ ). Similarly, when  $YS$  replaces  $H$  in the technical progress function (4), we will use the notation  $\gamma_{YS}$  for the rate effects parameter that measures the contribution of an additional year of schooling to the rate of TFP growth.

A fairly common assumption in the literature about the nature of  $g()$  is that  $H = YS$ . In this case, all the equations shown above remain valid, with  $H$  replaced by  $YS$  and  $\alpha_h$  replaced by  $\alpha_{YS}$ . A second possibility is to assume that

$$(7) H = \exp(\theta YS).$$

In what follows, we will be particularly interested in the values of three technical parameters that can be recovered from structural specifications. The first two are alternative measures of the intensity of level effects: the elasticity of aggregate output with respect to average educational attainment ( $\alpha_{YS}$ ) and what we will call the macroeconomic or aggregate Mincerian return to schooling ( $r$ ). The first of these parameters measures the percentage increase in output that would result from a 1 % increase in average schooling, and the second the percentage increase in output that would follow from an increase of one year in average attainment. We can go from  $\alpha_{YS}$  to  $r$  by dividing the first coefficient by average attainment in years and vice versa. The third parameter of interest ( $\gamma_{YS}$ ) measures the intensity of rate effects, i.e. the contribution of one additional year of schooling to the growth rate of total factor productivity.

### (iii) *Econometric issues*

As we have already noted, measurement error is always an issue in the literature we are reviewing because the years of schooling variable used in most empirical applications is surely a rather imperfect measure of human capital. But even abstracting from this, poor data quality is likely to be an important problem because most existing data sets on cross-country educa-

This is often called a Mincerian specification because it is consistent with the functional form commonly used in the microeconomic wage equations pioneered by Mincer (1974). (See Box 1 above.) In this case, the exponential in equation (7) undoes the logarithm in the Cobb-Douglas and the equations above have to be modified accordingly. In particular, logs of  $H$  must be replaced by levels of  $YS$  and growth rates of  $H$  by average changes in  $YS$ . Notice that if we embed equation (7) into the Cobb-Douglas function given in equation (2), the coefficient of  $YS$  in the resulting equation,  $\rho = \alpha_h \theta$ , will measure the percentage increase in output that follows from an increase of one year in average school attainment. We will refer to  $\rho$  as the aggregate or macroeconomic Mincerian return to schooling. As will become clear later, this variable must be distinguished from the 'proper' rate of return to schooling, which will be defined and calculated in Section 5(c).

tional attainment seem to contain a considerable amount of noise arising from various inconsistencies in the primary data used to construct them <sup>(1)</sup>. Such noise can generally be expected to introduce a downward bias in the estimated human capital coefficients (i.e. a tendency to underestimate their values) because it generates spurious variability in the measured stock of human capital that will not be matched by changes in productivity.

Krueger and Lindahl (2001) discuss some techniques that can be used to construct approximate measures of the quality of different schooling data sets and to correct for measurement error. The information content of a noisy indicator of human capital ( $H$ ) can be measured by its **reliability ratio**, defined as the ratio of signal to signal plus measurement noise in the data. Estimates of this ratio can be obtained when several measures of schooling are available, and the results can be used to estimate the size of the biases generated by errors in measurement. It turns out, in particular, that the expected value of the coefficient obtained by standard methods (ordinary least squares) when  $H$  is measured with error will be the product of the true value of the parameter and an 'attenuation' coefficient that increases with the reliability ratio of the  $H$  series used in the estimation <sup>(2)</sup>.

<sup>(1)</sup> See Section 2 of the appendix for a discussion of the data sets most commonly used in empirical growth analyses.

<sup>(2)</sup> When  $H$  is the only regressor, this coefficient is the reliability ratio itself. Otherwise, the error is larger and increases with the  $R^2$  of a regression of  $H$  on the rest of the explanatory variables in the productivity equation.



### Box 3: Reverse causation

Technically, the source of the reverse causation bias is that the feedback effects of income on education can generate a correlation between schooling and the disturbance of the production function, thereby violating the conditions that are necessary for the consistency of least-squares estimators. To illustrate the nature of the problem, suppose that we are trying to estimate a per capita production function in logs

$$(1) q_{it} = a_i + gt + \alpha_k(k_{it} - l_{it}) + \alpha_h h_{it} + \varepsilon_{it}$$

where  $q$  is log output per worker and the rest of the notation is as in Box 2, and that the demand for education is an increasing function of  $q$  given by

$$(2) h_{it} = X_{it}\beta + \eta q_{it} + v_{it}$$

where  $X$  is a vector of other relevant variables and  $\varepsilon_{it}$  and  $v_{it}$  are disturbance terms. In this set-up, a positive shock to income in the first equation (a positive value of  $\varepsilon_{it}$ ) will increase ( $q_{it}$  and hence)  $h_{it}$  through the second equation. As a result, the regressor  $h_{it}$  will be positively correlated with the disturbance of the production function and its coefficient will be biased upward.

In practice, things are not necessarily quite as bad as the previous discussion may suggest because average schooling is a stock variable that evolves slowly over time and the level of income should only affect it with a lag through changes in enrolment rates. Thus, we should probably replace equation (2) by something like the following system:

$$(3) e_{it} = X_{it}\beta + \eta q_{it} + \phi E_t g_{it+k} + v_{it}$$

$$(4) h_{it} = g(e_{it-1}, \dots, e_{it-k}, Z)$$

where  $e_{it}$  stands for the enrolment rate and the unspecified function  $g()$  describes the determination of  $h_{it}$  as a function of past enrolments. Notice that we are making the enrolment rate a function of the expected future rate of technical progress ( $E_t g_{it+k}$ ) because, as Bils and Klenow (2000) show, increases in this variable increase the return to schooling and therefore its demand. Notice that

with this specification, the problem disappears. Now, a positive shock to income in equation (1) will increase the enrolment ratio through equation (3), but this will not feed back into  $h$  until some time in the future, implying that  $h_{it}$  can still be uncorrelated with the contemporaneous disturbance in equation (1).

It would be too hasty, however, to dismiss the problem in this way, for it may very well arise in many of the specifications used in the literature, even when direct measures of educational stocks are used in the estimation rather than enrolment rates. For instance, the omission of fixed effects in the production function in levels is likely to cause trouble even in the model described by equations (3) and (4). In this case, the composite error term in equation (1) would be of the form  $(a_i + \varepsilon_{it})$  and its time invariant component (the fixed effect) would indeed affect it because it will have influenced enrolment in all previous periods. Hence,  $h_{it}$  is very likely to be correlated with  $(a_i + \varepsilon_{it})$ , which will again bias its coefficient.

Reverse causation can also be a problem when the production function is estimated in differences (as is often done, partly to remove the fixed effects bias). We now have

$$(5) \Delta q_{it} = g_i + \alpha_k \Delta(k_{it} - l_{it}) + \alpha_h \Delta h_{it} + \Delta \varepsilon_{it}$$

where we are allowing for the possibility that the rate of technical progress,  $g$ , may differ across countries. If equation (5) is well specified, its disturbance term  $\Delta \varepsilon_{it}$  should only contain true random shocks to the growth rate that cannot be anticipated by agents and should not therefore feed back to  $\Delta h_{it}$  through equations (3) and (4). But if this is not the case and the error term contains some systematic component of the growth rate that agents can anticipate (e.g. a fixed country effect in rates of technical progress), we may well find that  $\Delta h_{it}$  is again correlated with the (enlarged) disturbance, particularly if the period over which we are computing growth rates is long enough for changes in enrolments to affect the stock of schooling of the labour force.

Using these techniques, we estimate (see Section 2(a) of the appendix) that the average reliability ratio of the available cross-country schooling data sets ranges, for a sample of industrial countries, between 10 and 60 % depending on how the data are measured (i.e. in levels, logarithms or growth rates). This implies that the coefficients estimated in most empirical studies, which do not correct for this problem, are likely to suffer from very significant downward biases and will underestimate the true impact of schooling on growth. The bias will tend to be smaller for estimates obtained using the data in levels or logs, but is likely to be extremely large in specifications that use growth rates of schooling calculated over relatively short periods <sup>(13)</sup>.

A second standard concern when we are trying to estimate the impact of education on productivity is that reverse causation from income to schooling may generate an upward bias in the estimated coefficient of human capital in the production function. The nature of the problem is discussed in greater detail in Box 3, but it essentially arises because the feedback effects of income on the demand for education can make it difficult to determine to what extent the observed correlation between income and schooling reflects the fact that rich countries demand more education for consumption purposes as well as the contribution of education to productivity that we want to measure.

Since the upward bias arising from reverse causation will work to offset the downward bias from measurement error and may even be larger, there is always some uncertainty about the net bias that remains in any given estimate of the relevant human capital coefficients. While we are not aware of any simple way of estimating the size of the reverse causation bias, the discussion in Box 3 suggests that it may not be very large, particularly in models that control for TFP differences across countries and/or for the determinants of the rate of technological progress and that make use of variables measured in levels or in growth rates calculated over relatively short periods. The main reason for this cautious optimism is that average schooling is a stock variable that evolves slowly over time and should be affected by the level of income only with a considerable lag following changes in enrolment rates (which should indeed be sensitive to income levels). Hence, while reverse causation is likely to be a serious problem when we consider average growth rates over long periods, changes in income over shorter periods should not have time to feed through to schooling stocks. A careful spec-

ification of other aspects of the model is also important because the reverse causation problem arises when the residual of the productivity or growth equation is not a 'clean' random disturbance but contains systematic components of income or the growth rate that will enter the enrolment equation describing the demand for education because they can be anticipated by individuals. If such contamination can be avoided by controlling for all or most of the relevant factors, the model should yield more accurate estimates of the effects of schooling on productivity.

The preceding discussion suggests that the choice of specification involves a complex trade-off between different econometric problems, for some of the things that may be done to reduce the reverse causation bias are likely to increase measurement error and vice versa. An additional consideration has to do with the ability of different specifications to capture indirect productivity effects from human capital that involve uncertain and possibly long delays. Specifications that make use of growth rates computed over relatively short periods are unlikely to pick up what we have called rate effects unless these start to work almost immediately, which seems rather implausible. In order to estimate these indirect effects, it may be preferable to work with average growth rates over longer periods or with the data in levels, but it is difficult to be sure that the higher human capital coefficients typically generated by these specifications <sup>(14)</sup> are not the result of reverse causation bias.

#### *(iv) A brief review of the empirical evidence*

Section 3 of the appendix to this report contains a detailed survey of the macroeconomic literature on growth and human capital. The picture that emerges from this review of the empirical evidence is somewhat mixed but ultimately encouraging. As we have seen, academic economists have traditionally been inclined to consider educational expenditure a key component of national investment with a substantial pay-off in terms of output growth, and have often assigned to the accumulation of human capital a central role in formal models, particularly in the recent literature on endogenous growth. This optimism seemed to be confirmed by a first round of cross-country empirical studies of the determinants of growth, where a variety of educational indicators were consistently found to have the expected positive effect <sup>(15)</sup>. A second round of such studies, however, produced rather disappointing results using more

<sup>(13)</sup> The average reliability ratio is only 0.278 for the data in quinquennial growth rates, and 0.098 for level differences taken at the same frequency.

<sup>(14)</sup> See, for instance, Topel (1999) and Krueger and Lindahl (2001).

<sup>(15)</sup> See, among others, Landau (1983), Baumol, Batey Blackman and Wolf (1989), Barro (1991) and Mankiw, Romer and Weil (1992).

sophisticated econometric techniques and even led some researchers to explicitly question the link between education and growth <sup>(16)</sup>. In recent years, the evidence seems to be accumulating that such negative results were largely due to poor data and various econometric problems <sup>(17)</sup>. Recent studies that make use of improved data sets or allow for measurement error strongly suggest that investment in education does have a substantial impact on productivity growth <sup>(18)</sup>.

Our review of the empirical literature shows that it has proved surprisingly difficult to separate level from rate effects, with different studies reaching opposite conclusions about their relative significance. This may be partly an estimation problem, as the high correlation between schooling levels and growth rates and of these variables with other regressors can make it difficult to untangle their separate effects in a growth regression <sup>(19)</sup>. But there are also plausible theoretical specifications in which the two effects may be difficult to identify separately. In particular, the distinction between them tends to become blurred once we allow for technological diffusion. In this context, an increase in human capital does make for faster technological change, but this effect gradually exhausts itself as the country comes closer to the world technological frontier and TFP growth stabilises. As a result, the rate effect becomes a level effect over the medium or long run and, if convergence to the 'technological equilibrium' is sufficiently fast, the two effects cannot be separated.

As the previous discussion suggests, there remains considerable uncertainty about the size of the relevant macroeconomic human capital coefficients and about the relative importance of level and rate effects. The range of existing estimates is extremely large even when we restrict ourselves to recent studies that make use of the latest available data sets and find evidence of positive growth effects. In Section 5(a) we draw on our discussion of the relevant econometric and specification issues and on the detailed literature review contained in the appendix to try to identify a plausible range of parameter values. What we consider to be the most plausible estimates in the literature suggest that, all other

things being equal, an additional year of average school attainment increases the level of aggregate productivity by around 5 % on impact and by a further 5 % in the long run. This second effect reflects the contribution of human capital to technological progress, i.e. to the development and adoption of new technologies and to the continued improvement of existing production processes.

So far, we have concentrated on studies that have tried to measure the contribution of increases in the quantity of schooling to productivity growth. Some interesting recent research, however, provides strong evidence that the quality of schooling may be just as important for growth as its quantity, if not more. These studies include mean national scores in standardised achievement tests as explanatory variables in standard growth equations and find large and significant productivity effects. Some of these studies have also analysed the relationship between student achievement and school expenditure with mixed results. Measures of school resources such as pupil to teacher ratios and average teacher salaries are found to have a significant positive effect on performance in some studies but not in others <sup>(20)</sup>. Another important recent finding is that most countries with high average performance of students approaching the end of compulsory schooling are also very successful in raising the performance of students from the most disadvantaged backgrounds (OECD, 2001c). Hence, there is scope for education policies that both raise the average quality of human capital and improve social cohesion.

#### *(v) Externalities at the city and regional levels*

As we mentioned earlier, comparisons between micro- and macroeconomic estimates of the Mincerian returns to schooling may provide a way to assess whether there are externalities associated with the accumulation of human capital. One problem with such comparisons, in addition to those noted above, is that both types of studies generally use quite different data sources. A series of recent studies sidesteps this problem by using the same data source to estimate the

<sup>(16)</sup> Studies that report largely negative findings include Kyriacou (1991), Benhabib and Spiegel (1994), Pritchett (1999, whose first version is from 1995), Islam (1995) and Caselli, Esquivel and Lefort (1996).

<sup>(17)</sup> One of these problems is that the fixed effects specifications used in most of these studies waste all the information contained in the cross-sectional variation of the data. See Section 3 of the appendix.

<sup>(18)</sup> See, for instance, de la Fuente and Doménech (2000), Krueger and Lindahl (2001), Cohen and Soto (2001) and Bassanini and Scarpetta (2001).

<sup>(19)</sup> For instance, the correlation between the log and the growth rate of years of schooling is -0.6 in de la Fuente and Doménech's (2001) data set. Using Spanish regional data, de la Fuente (2002b) finds evidence of both level and rate effects in a specification in differences that allows for technological diffusion; the rate effects, however, lose their significance when regional fixed effects are introduced. The author attributes this finding to the high correlation (0.92) between the human capital variable in levels used in this specification and a set of regional dummies.

<sup>(20)</sup> See Lee and Lee (1995), Barro (2000), Hanushek and Kimko (2000) and Lee and Barro (2001).

returns to schooling within a given country both at the individual level and at the level of cities or regions. (See, for instance, Acemoglu and Angrist (2000) and Rudd (2000) at the regional level, and Rauch (1993), Ciccone and Peri (2000) and Moretti (2000) at the city level.)

These studies estimate human capital externalities in two steps. The first step consists of estimating the wage differential between identical individuals working in different cities or regions. This is done using standard Mincerian wage regressions. The second step relates estimated wage differentials between identical individuals in different cities or regions to differences in the average level of human capital between cities or regions. If wage differentials can partly be explained by differences in the average level of human capital, then these studies conclude that there are human capital externalities. Because of the lack of appropriate data, none of these studies is done at the country level.

The findings in this literature range from no human capital externalities to moderate and large externalities. For example, Rauch (1993) finds that a one-year increase in average years of schooling at the city level is associated with an external effect on city productivity of 3 %.

## 4. Social capital and growth

Social capital as a determinant of economic growth has received much attention in the last decade. It is important to understand at the outset, however, that social capital research is still at its beginning and that it should be seen as a collection of suggestive arguments and pieces of empirical evidence, rather than as a set of conclusions that can be of direct use in the formulation of economic policy.

The term social capital was rendered popular by the contributions of Coleman (1988, 1990) and Putnam (1993a and 1995b) and by now the World Bank (2002) has a web site with an entire electronic library on the subject. There are many subtle aspects to defining social capital. For our purpose, it is sufficient to see social capital as the norms and social relations embedded in the social structure of a group of people that enable the group or individuals participating in it to achieve desired goals. This definition misses what is sometimes called individual social capital, which is the (social) skills that enable an individual to reap market and non-market returns from interaction with others. These skills might best be seen as a part of the individual's human capital.

Knack and Keefer (1997) examine various possible empirical proxies for social capital and assess their

This finding may, however, be driven by high-productivity cities attracting highly skilled workers, and not by human capital externalities. In fact, Acemoglu and Angrist (2000), Ciccone and Peri (2000) and Rudd (2000) do not find any externalities when they take this possibility into account. Moretti (2000), however, argues that there are large externalities to the share of college-educated workers in US cities. Still, the weight of the evidence suggests that human capital externalities are unlikely to explain a significant part of regional productivity differences.

As all of these studies are done at the city or regional level, they are likely to miss externalities that operate at the country level. For example, suppose that there are human capital externalities at the country level because a greater supply of high human capital workers increases the demand for new technologies and hence the incentives to invest in R & D. These externalities will not be picked up at the level of cities or regions because new technologies are developed for larger markets. Human capital externalities at the country level must therefore be assessed by comparing estimates of the effect of human capital on individual wages with estimates of its effect on country-level productivity.

impact on economic growth at the country level. They discuss two main relationships: between trust and civic norms on the one hand and economic growth on the other, and between associational activity and growth. Trust at the country level is basically measured as the percentage of people responding affirmatively to the following world value survey question: 'Generally speaking, would you say that most people can be trusted, or that you can't be too careful in dealing with people?' To capture the strength of norms of civic cooperation, they construct a variable based on answers to various questions about how individuals evaluate anti-civic behaviour. Their main finding is that trust and civic cooperation are associated with stronger economic performance, but that associational activity is unrelated to economic growth. This result is quite robust in their sample but it is still unclear whether it also holds in OECD countries (e.g. Helliwell, 1996a; Zak and Knack, 2001). Temple and Johnson (1998) show that indices of 'social capability' for the early 1960s, adapted from the work of Adelman and Morris (1967), are good predictors of long-run growth for a wide set of developing countries. La Porta, Lopez-de-Silanes, Shleifer and Vishny. (1997) find that social capital improves government performance, including the quality of the bureaucracy and the judicial system. In a study on the development of

secondary education in the United States, Goldin and Katz (1999) argue that social capital affects and is affected by human capital accumulation. Guiso, Sapienza and Zingales (2000) use data on Italian regions to show that social capital enhances financial development and access to credit <sup>(21)</sup>.

What determines social capital (or how is it accumulated)? A full answer to this question is not available, but there are some suggestions. For example, DiPasquale and Glaeser (1999) argue that geographical mobility reduces individual incentives to participate in social capital accumulation, and Alesina and La Ferrara (2000a) find that participation in associational activities like religious groups, sport groups, hobby clubs, etc. is higher when income inequality and racial segmentation are lower. Alesina, Baqir and Easterly (1999) document that more ethnically diverse jurisdictions in the United States devote lower shares of spending to core public goods like education and roads, which is consistent with the idea that ethnic diversity translates into less social capital. There are also some studies on the determinants of trust. Knack and Keefer (1997) find that trust and norms of civic cooperation are stronger in countries with formal institutions that effectively protect property and contractual rights, and in countries that are less

polarised along lines of class or ethnicity. Helliwell and Putnam (1999) document that higher average education increases trust. Alesina and La Ferrara (2000b) sketch five broad factors influencing how much people trust others: (1) individual culture, traditions and religion; (2) how long an individual has lived in a community with a stable composition; (3) recent personal history of misfortune; (4) the perception of being part of a discriminated group; (5) several characteristics of the composition of one's community, including its racial and income heterogeneity. Glaeser, Laibson, Scheinkman and Soutter. (2000) combine survey and experimental data to identify separately the determinants of trust and of trustworthiness. Two of their findings are that a smaller social distance among individuals, for instance due to joint group membership or the same 'race' or nationality, increases both trust and trustworthiness.

Combining the positive effect of social capital on institutional quality and economic growth with the determinants of social capital suggests that human capital policies that reduce *ex ante* inequality as well as the social distance between individuals, i.e. that increase social cohesion, are likely to improve economic performance.

## 5. Some tentative conclusions

The literature surveyed in Section 3 and in the appendix to this report provides a broad range of estimates of the coefficients that measure the contribution of human capital to individual earnings and to aggregate productivity. In this section, we attempt to narrow this range by identifying an interval of plausible values for the relevant micro- and macroeconomic parameters. These figures are then used to discuss the contribution of human capital to growth and to cross-country income disparities in a sample of industrial countries, and to construct estimates of the private and social rates of return to schooling from which some tentative policy conclusions are drawn.

### (a) A plausible range of parameter estimates

On the whole, the range of variation of existing estimates of the Mincerian returns to schooling is considerably smaller at the microeconomic than at the macroeconomic level. While results vary significantly across

countries and periods for reasons that have already been discussed, there is less uncertainty in the microeconomic literature about the extent to which estimates for a given sample may be biased in an upward or a downward direction by different econometric problems. There is widespread agreement, for instance, that the measurement error and ability biases roughly offset each other, and that reverse causation is unlikely to be a major problem because higher wages are more likely to increase the demand for education of the children of currently active workers than that of the workers themselves.

A recent study by Harmon, Walker and Westergaard-Nielsen (HW&W, 2001) provides an estimate of the individual Mincerian returns to schooling parameter ( $\theta$ ) in 15 European countries (mostly EU members) that is based on a meta-analysis of a large number of wage equation estimates undertaken or collected as part of a large research project on the returns to education in Europe. These authors report that the average value of

<sup>(21)</sup> Besides Putnam's seminal contribution (Putnam, 1993a), these are the only two empirical studies on the role of social capital at the regional level that we are aware of. The scarcity of work in this area is due to the fact that there is very little data on institutional quality at the regional level.



$\theta$  in Europe is 6.5 % <sup>(22)</sup> and that country means range from around 4.5 to 10 %, with the Scandinavian countries and Italy at the lower end of the distribution and the UK and Ireland at the top.

As we have already noted, wage equation coefficients have to be treated with some precaution when interpreted as estimates of the technical parameter that measures the contribution of schooling to productivity because it is likely that pay scales will reflect labour market institutions and social norms as well as relative productivities. Making some allowance for the distortions created by wage-setting practices, it may be expected that the true value of the Mincerian parameter will lie somewhere between HW&W's central estimate of 6.5 % and their average estimate of 9 % for the Anglo-Saxon countries that appear to have the most flexible labour markets in Europe. Table 1 gathers these two benchmark estimates of the individual 'raw' returns to schooling ( $\theta$ ) and the values that result after the adjustment for physical capital that is required to make them comparable to the relevant macroeconomic returns to schooling coefficient ( $\rho$ ) <sup>(23)</sup>.

**Table 1: Benchmark estimates of the individual Mincerian returns parameter ( $\theta$ ) and values adjusted for comparison with macroeconomic estimates ( $\rho$ )**

	Raw	Adjusted
	$\theta$	$\rho$
min. (average)	6.50 %	4.33 %
max. (Anglo-Saxon countries)	9.00 %	6.00 %

At the macroeconomic level, identifying a plausible range of values for the relevant parameters is a much more difficult task because the available estimates vary from negative to very large positive values. Drawing on our discussion of the literature, we argue that the elasticity of output with respect to average years of schooling ( $\alpha_{YS}$ ) can be expected to lie between 0.394 and 0.535 and that the rate effects coefficient ( $\gamma_{YS}$ ) should be between 0.0 and 0.9 %. The first set of figures implies that the Mincerian level effects parameter ( $\rho$ ) can be

expected to fall between 3.98 and 5.41 % for the case of the average EU country in 1990, as shown in Table 2 <sup>(24)</sup>.

**Table 2: Benchmark estimates of the macroeconomic level and rate effects parameters**

	Level effects	Rate effects
	$\rho$	$\gamma_{YS}$
min.	3.98 %	0.00 %
max.	5.41 %	0.90 %

A detailed discussion of how these figures are obtained from various estimates in the literature is included in Section 3(f) of the appendix. To arrive at this range of values, we disregard the most pessimistic results in the literature as the result of poor data quality. Our lower bound estimate comes from an updated version of de la Fuente and Doménech (2000) that makes use of a recently constructed data set which appears to have a relatively high signal to noise ratio. This paper estimates a production function using growth rates calculated over five-year intervals and contains a fairly complete specification of the technical progress function that allows for technological diffusion and for country fixed effects that should help control for omitted variables such as R & D investment. As a result of both the high frequency of the observations and the specification used, these estimates are very unlikely to suffer from a significant upward bias arising from reverse causation. It is more likely that they will underestimate the true returns to schooling because of remaining measurement error and because the shortness of the period over which the growth rates are computed can make it difficult to detect productivity effects that may involve considerable lags — as is likely to be the case with the technology-related rate effects.

A conservative correction for measurement error brings de la Fuente and Doménech's estimate of the value of  $\rho$  in the EU to 5.41 % <sup>(25)</sup>. Since this figure is well within the range of the (adjusted) microeconomic

<sup>(22)</sup> This is very similar to the average estimate of 6.8 % for the OECD countries reported by Psacharopoulos (1994).

<sup>(23)</sup> We estimate  $r$  as  $(1-\alpha_k)\theta$  with  $\alpha_k = 1/3$ . See Section 3 for a discussion of the nature of the adjustment.

<sup>(24)</sup> This calculation assumes that the aggregate production function is Cobb-Douglas in years of schooling, i.e. that  $H = YS$ . The value of  $r$  is obtained by dividing the relevant estimate of  $\alpha_{YS}$  by average 1990 school attainment in years in the sample of 14 EU countries (all but Luxembourg) for which de la Fuente and Doménech (2001) provide data.

<sup>(25)</sup> The correction is conservative because it is based on the estimated reliability ratio for this schooling series (0.736) without taking into account the further adjustment that would be required because of the correlation between schooling and other regressors included in the equation. The full correction would lower the attenuation factor to 0.2 and increase fivefold the original estimate of the parameter. On the other hand, it is very likely that this procedure will lead to the overestimation of the true parameter, as measurement error in the other regressors is likely to offset partially the downward bias on schooling.

estimates shown in Table 1, we will use it as an upper bound on the likely value of the level effects <sup>(26)</sup>. Hence, coefficients of schooling variables in growth equations that imply higher values of  $\rho$  must be picking up something else than the direct productivity or level effects that are likely to translate into higher wages.

There are essentially two possibilities: one is the upward bias from reverse causation, and the other what we have called rate effects, i.e. the indirect contribution of human capital to growth via faster technical progress that constitutes the most plausible source of externalities linked to education <sup>(27)</sup>. The pattern of results in the studies that produce large estimates of  $\rho$  suggests that both factors are at work. Schooling coefficients are generally larger when they come from steady state level equations (where reverse causation can be a serious problem if we do not control for differences in TFP levels across countries) or from differenced specifications that use growth rates computed over long periods (where again there is greater danger of reverse causation bias as there is time for changes in enrolments to affect schooling stocks). On the other hand, these specifications are also more likely to pick up productivity effects that involve long gestation lags, and there are reasons to expect that not all of the observed increase in the coefficients is due to reverse causation. In particular, some of the relevant studies that estimate steady state equations include proxies for TFP or other control variables that should at least reduce the endogeneity bias (e.g. Cohen and Soto, 2001; Barro, 2000) and one of them (Bassanini and Scarpetta, 2001) estimates very high schooling coefficients with annual data using an error correction specification that probably permits a better characterisation of long-term relationships by allowing short-term deviations from them.

The range of values shown in Table 2 for the rate effects parameter,  $\gamma_{YS}$ , is obtained by imposing the assumption that  $\alpha_{YS} = 0.535$  and solving for the value of  $\gamma_{YS}$  that is consistent with the schooling coefficients

obtained in different studies, when these coefficients are interpreted within the context of a model allowing for technological diffusion (see Box 4 below and Section 3(f) of the appendix). The coefficient estimates we use are taken from the studies cited above and from a paper by Jones (1996) that attempts to estimate directly the rate effects (essentially by assuming that there are no level effects). The values of  $\gamma_{YS}$  obtained in this manner range from 0.24 % in Cohen and Soto (2001) to 0.87 % in Barro (2000).

### (b) Implications for growth and cross-country disparities in the OECD

How important is human capital as a source of growth and cross-country productivity disparities? In this section, we provide a tentative answer to this question for a sample of 21 industrial countries. In particular, we calculate the contribution of human capital to (i) the observed growth in productivity (measured by output per employed worker) over the period 1960–90 and (ii) the productivity differential with the sample average in 1990, working in both cases with a ‘typical’ OECD economy. This fictional typical economy is constructed by averaging across countries the contributions of human capital to the variables of interest using regression-based weights so as to reduce the impact of outliers (see Box 4). The exercise will be repeated for the range of values of the schooling coefficients identified in the previous section. This will allow us to illustrate the implications of the different parameter estimates available in the literature in terms of magnitudes that are easy to interpret, and may serve as a check on the plausibility of these estimates. All our calculations are made with the data set used in the updated version of de la Fuente and Doménech (2000) and these authors’ estimates of the parameters of the production and technical progress functions (except in the case of the schooling coefficients, which are allowed to vary over the entire range of values discussed above).

<sup>(26)</sup> An additional reason for this choice is that, under the assumption that the reduced-form production function is Cobb-Douglas in schooling (i.e. that  $H = YS$ ), the output elasticity that corresponds to this estimate ( $\alpha_{YS} = 0.535$ ) implies that the returns to schooling account for 82 % of labour income. Under the same assumption, any significantly higher estimate of  $\rho$  would imply a negative coefficient for raw labour in the aggregate production function and a negative share of this factor in labour compensation. The Cobb-Douglas assumption, however, is crucial for this argument because it implies that  $\alpha_{YS} = \alpha h$  (see Box 2). With a Mincerian specification ( $H = \exp(\theta YS)$ ), the share of skill in total labour compensation cannot be inferred from the parameters of the reduced-form production function relating output to schooling. The reason is that, while this share still depends on  $\alpha h$ , this parameter is now different from  $\alpha YS$  and cannot be identified separately because it enters the reduced-form production function multiplying  $q$ .

<sup>(27)</sup> A third possibility is that schooling may act as a proxy for R & D investment, which is highly skill intensive. While this is not exactly the idea behind the rate effects, a positive coefficient arising through this mechanism would also be consistent with the view that human capital contributes to the creation of useful knowledge.

#### Box 4: Measuring the contribution of schooling to growth and cross-country disparities

The contribution of human capital to growth in country  $i$  ( $ch_i$ ) is calculated using an aggregate production function (which is assumed to be Cobb-Douglas in average years of schooling,  $YS$ ) and a technical progress function that allows for rate effects from human capital and technological diffusion. Hence,  $ch_i$  will have two components in the general case. The first captures level effects and is given by

$$(1) ch_{li} = \alpha_{ys} \Delta ys_i$$

where  $\alpha_{ys}$  is the elasticity of output with respect to average schooling and  $\Delta ys_i$  is the observed growth rate of average years of schooling in country  $i$  over the sample period. The second component captures the contribution of rate effects and is calculated using a technical progress function of the form

$$(2) \Delta x_{it} = \gamma_{io} - \lambda x_{it} + \gamma_{ys} YS_{it}$$

where  $x_{it}$  is the log of country  $i$ 's TFP level at time  $t$ , measured as a fraction of the world technological frontier. For this calculation, we assume that in 1960 all countries were in the technological steady states (relative to the world frontier) corresponding to their estimated schooling levels in 1955. These are obtained by projecting backward the value of  $YS$  in 1960 using the growth rate of this variable between 1960 and 1965. These initial values are then projected forward until 1990 using equation (3) and the values of  $YS$  observed during the sample period. Finally, the annualised difference between the initial and final values of  $x_{it}$  is used as our estimate of the contribution of rate effects to growth in country  $i$ .

The share of human capital in growth in country  $i$  is then given by the ratio  $a_i = ch_i / \Delta q_i$  where  $\Delta q_i$  is the observed value of the growth rate of output per worker over the period 1960–90. To reduce the weight of outliers, rather than computing the simple average of this quantity across countries, we estimate a regression of the form

$$(3) ch_i = a \Delta q_i + e_i$$

where  $e_i$  is a disturbance term. The coefficient  $a \equiv ch_i / \Delta q_i$  measures the fraction of observed growth that can be attributed to human capital in the case of a typical country in the sample.

To measure the contribution of human capital to productivity differentials in 1990, we proceed in a similar way. We define country  $i$ 's relative productivity ( $qrel_i$ ) as the difference between country  $i$ 's log output per employed worker in 1990 and the average value of the same variable in the sample and regress human capital's estimated contribution to  $qrel_i$  on  $qrel_i$  itself to obtain a coefficient, analogous to  $a$  in equation (3), that measures the fraction of the productivity differential that can be attributed to human capital in a typical country in the sample. As before, the contribution of human capital to relative productivity will have two components that reflect level and rate effects respectively. The first component is computed by multiplying  $\alpha_{ys}$  by the country's relative level of schooling (measured in log differences with the (geometric) sample average) and the second is obtained as the difference between the 1990 value of  $x_i$  estimated above and the sample average of the same variable.

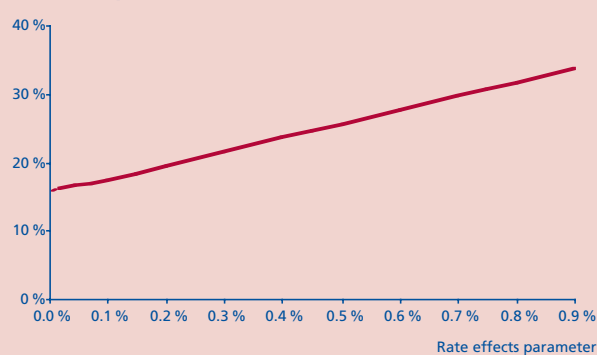
Figures 3 and 4 show the share of human capital in observed growth and in the productivity differential with the sample average ('relative productivity', from now on) in the case of a typical OECD country. Both shares are shown as functions of the assumed value of the rate effects parameter,  $\gamma_{ys}$ . The vertical segment of each curve, drawn along the vertical axis, corresponds to the range of values implied by our maximum and minimum estimates of the level effects parameter. If we consider only level effects, human capital accounts for between 11.31 and 15.36 % of productivity growth over 1960–90 and for between 19.52 and 26.51 % of the productivity differential with the sample average in 1990. These are respectable figures, and they increase rapidly when the contribution of the rate effects is added,

reaching 33.71 % of growth and 79.10 % of relative productivity for  $\gamma_{ys} = 0.9$  %. These results indicate that human capital is relatively more important in accounting for remaining productivity disparities than in explaining past growth. The reason for this is that the stock of physical capital has grown more rapidly than average years of schooling and has converged at a faster pace across countries, thereby reducing the contribution of this factor to observed productivity disparities.

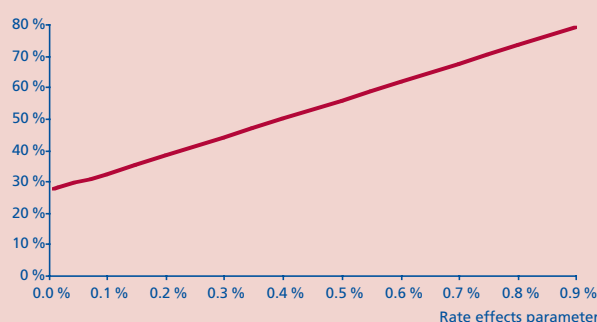
Following Bils and Klenow (2000), the following calculation may be helpful in narrowing down the plausible range of values of the rate effects parameter. Subtracting from observed productivity growth and



**Figure 3: Percentage of growth in output per worker during 1960–90 explained by human capital in a typical OECD country as a function of the rate effects parameter**



**Figure 4: Percentage of disparities in output per worker in 1990 explained by human capital in a typical OECD country as a function of the rate effects parameter**



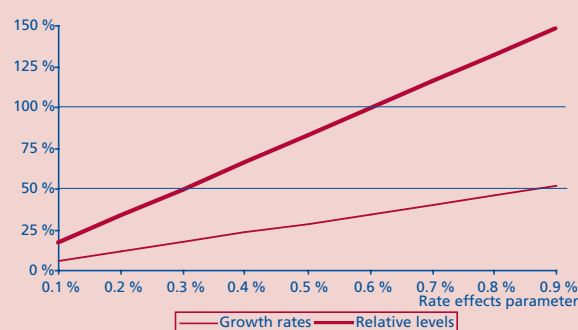
**Table 3: Immediate sources of productivity growth and cross-country productivity differentials**

	1960–90 growth rates	1990 relative levels
Contribution of: physical capital schooling (level effect)	49.39 %	38.02 %
Total $k + ys$ level	64.75 %	64.53 %
Rest = due to TFP	35.25 %	35.47 %

Note: Shares of different factors in observed growth and relative productivity in a typical OECD country as defined in Box 4.

from relative productivity the contribution of physical capital and (the upper bound on) the level effects from human capital, we obtain the share of total factor productivity (TFP) in these variables which, as shown in Table 3, is around one third in both cases. Figure 5 then plots the contribution of rate effects to growth and to relative productivity as a fraction of the estimated TFP share. A 'large' value of either of these ratios will render the underlying rate effects coefficient suspect. For instance, the finding that rate effects are greater than observed total TFP growth would imply that other components of this variable (which would capture among other things the contribution of R & D investment) must have declined over time, which seems rather implausible. A similar finding in the cross-section dimension would imply that the component of TFP levels not related to human capital would have to be negatively correlated with labour productivity which, again, seems unlikely. Turning to Figure 5, the growth decomposition does not help narrow the range of values of  $gYS$  as even the most optimistic estimates available in the literature imply that human capital accounts for less than half of the observed growth in TFP. On the other hand, the cross-section relative productivity comparison suggests that we should rule out estimates of  $gYS$  greater than 0.6%, and that values of this parameter over 0.3 to 0.4% are unlikely because they would imply that more than half of the observed cross-country TFP differentials are induced by human capital<sup>(28)</sup>.

**Figure 5: Impact of the rate effects from human capital as a % of the total contribution of TFP to growth and relative productivity**



(28)

It should be noted that not all analysts would agree with this criterion. Wössmann (2000), for instance, performs a similar levels accounting exercise with a Mincerian measure of the stock of human capital that corrects for quality differences using an indicator constructed by Hanushek and Kimko (2000) on the basis of international test scores (see Section 3(e) of the appendix). He finds that practically all differences in output per worker across OECD countries are explained by human capital (leaving a negative share for TFP that roughly offsets the share of physical capital). While Wössmann argues that this result should be taken at face value, we think it is too 'optimistic' because it leaves virtually no room for other factors that are likely to be important sources of productivity disparities.

It should also be noted that a value of  $ak$  somewhat lower than the one used in our computations would still be consistent with national accounts data on factor shares (particularly when capital income is corrected for the earnings of self-employed workers). A lower value of this parameter will reduce the share of physical capital in growth and productivity differentials and raise that of TFP, thus leaving more room for human capital. For plausible values of  $ak$ , however, this would not greatly affect our conclusions.

### (c) Rates of return to schooling and some policy implications

In this section, we compute the ‘proper’ rates of return to schooling implied by the micro- and macro-economic parameter estimates discussed above. This calculation is necessary in order to turn our estimates of technical parameters into measures of the net private and social economic benefits of schooling that can be compared with each other (by combining level and rate effects into a single indicator) and with the returns on alternative assets. As we have already noted, such comparisons can yield information that will be of interest for policy formulation because they may alert us to under- or overinvestment in education, or to the existence of externalities that may call for corrective action.

Box 5 discusses the methodology used for the calculation of these rates of return. We compute the internal

rate of return to schooling, defined as the discount rate that makes the net present value of the increase in earnings generated by a marginal change in schooling equal to the present value of the relevant stream of costs. We distinguish between gross and net rates of return. Gross rates of return are obtained by ignoring the direct costs of schooling (but not its opportunity costs in terms of foregone earnings), while net rates of return take into account the relevant direct costs (either those paid directly by the individual or the sum of the former and government educational expenditures). Our estimates of direct costs are based on recent data on total and government expenditure on secondary and higher education in the average EU country and try to approximate the cost of a marginal increase in enrolments, which would have to come at the upper secondary and university levels since attendance at lower levels is already compulsory in these countries.

#### Box 5: The rate of return to schooling

Consider an individual who goes to school the first  $S$  years of his adult life and retires at time  $T$ . If each year of schooling has a direct cost  $c$ , the net present value (at time zero) of earnings over his working life is given by

$$(1) \quad v(s) = \int_0^T A(t) f(S) e^{-rt} dt - \int_0^S c(t) e^{-rt} dt$$

where labour income at time  $t$  is given by the product of a technical efficiency index  $A(t)$  and a function  $f(S)$  that increases with schooling. The net marginal value of schooling will be given by the derivative of this function,  $V'(S)$ . By setting this derivative equal to zero and solving the resulting equation for the value of the discount rate,  $r$ , we will obtain an estimate of the proper rate of return to schooling.

We will use this approach to compute the individual and social rates of return to schooling distinguishing between gross and net rates of return as defined in the text. When we apply this procedure to an individual to compute the private rate of return, we will consider technical progress to be exogenous (i.e. assume that the evolution of  $A(t)$  is not affected by the individual's schooling choice). To compute the social rate of return, we will apply the same procedure to a hypothetical average individual. This must be regarded as an approximation

because the computation implicitly assumes that a one-year increase in average attainment will be obtained by immediately sending the entire labour force to school for a year (rather than by gradually raising the attainment of younger cohorts). When computing social rates of return, we will allow for rate effects (i.e. assume that the average value of  $S$  in the aggregate can have an effect on technical progress). In this case, an additional term must also be added to  $V(S)$  in equation (1) above to capture the impact of current schooling on TFP beyond the working life of the currently active cohorts. The specific technical progress function underlying our calculations is the same one used in Box 4, i.e.

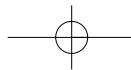
$$(2) \quad \Delta x_{it} = \gamma_{io} - \lambda x_{it} + \gamma_{YS} S_{it}$$

where  $-x_{it}$  measures the distance to the world technological frontier, which is assumed to shift out over time at a constant rate  $g$ , and  $\lambda$  can be interpreted as the speed of technological diffusion.

Under the assumption that the direct costs of schooling are a given fraction  $\mu$  of output per employed worker, the net social rate of return to education will be given by <sup>(29)</sup>

$$(3) \quad r = R + g$$

<sup>(29)</sup> See de la Fuente (2002a) for a derivation of this result.



where  $g$  is the world rate of technological progress and  $R$  solves the following equation:

$$(4) \quad R = \frac{1 - e^{-RU}}{1 + \mu} \left( \rho + \frac{\gamma_{YS}}{R + \lambda} \right)$$

In this expression,  $\rho = f'(S)/f(S)$  is the aggregate Mincerian returns to schooling parameter (for the EU),  $U = T - S$  the duration in years of the working life of the representative individual and the rest of the terms have been defined above. This formula can be applied with suitable modifications to the other cases of interest. To obtain the gross social rate of return, we set  $\mu = 0$  in equation (4); to calculate private returns, we set  $\gamma_{YS} = 0$  and replace  $\rho$  by the relevant (adjusted or unadjusted) individual Mincerian parameter ( $\theta$ ).

For the calculations reported in this section, we assume that  $\gamma = 0.015$ ,  $\lambda = 0.074$ , and  $U = 42$ . The first estimate is taken from Jones (2002), the second from an updated version of de la Fuente and Doménech (2000) and the third is chosen as a plausible value for industrial countries, where younger cohorts often leave school in their 20s and workers tend to retire before turning 65.

The values of  $\mu$  used in the social and private returns calculation are 12.45 and 0.93 % respectively. The first figure is derived as a weighted average

of total expenditure on secondary and university education (with weights of 2/3 and 1/3 respectively) in the average EU country (excluding Luxembourg) as reported in the 2000 edition of the OECD's *Education at a glance*. This source reports expenditure as a fraction of GDP per capita in 1997. We estimate  $\mu$  as a fraction of output per worker by multiplying the original figure by the ratio of employment to the total population in 1990, taken from an updated version of Doménech and Boscá (1996). The value of  $\mu$  relevant for the private returns calculation is estimated by multiplying the previous figure by the share of educational expenditure financed by the private sector in the same sample of countries, which is taken from the same OECD source. The OECD reports these data separately for tertiary studies and for all other educational levels combined, so we again take a weighted average with a weight of 1/3 for higher education.

Our calculations of private returns are based on Mincerian estimates that capture the average return to one more year of schooling across all educational levels and are therefore not comparable to estimates based on wage premiums for specific levels of education. They can also differ from the realised returns over specific periods because wage trends for different educational categories may deviate from the overall rate of technical progress assumed here.

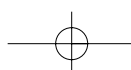
It should be noted that the rates of return we compute do not incorporate the non-market returns to schooling in home production and leisure (see Section 3(a)(xi)) and fail to take into account the direct consumption value of education and its impact on labour force participation and employment probabilities. As a result, they will underestimate the true returns to schooling by an amount that may be large but which is extremely difficult to measure with precision.

The formula given in equation (4) of Box 5 shows that the technical parameter we have called the Mincerian returns to schooling is a proper rate of return only under very special assumptions that do not hold in practice. To obtain proper rates of return, the estimated Mincerian coefficients have to be adjusted for the direct costs of education, for the finiteness of individuals' working lives, for technical progress and for rate effects, whenever these are relevant.

Table 4 shows the proper gross and net rates of return implied by the range of parameter values given in Tables 1 and 2 above for the average EU-14 country in 1990. At the individual level, we report rates of return based on both the unadjusted and the adjusted Mincerian parameters. The first set of values measures the private incentives to invest in formal education and the second set can be compared with macro-estimates for the purpose of quantifying the importance of externalities. The last block of the table contains estimates of the rate of return on alternative assets. The returns on US stocks and government bonds are taken from Arias and McMahon (2001) and are average values for the period 1975–95<sup>(20)</sup>. The rate of return on physical capital is calculated as  $r_k = MP_k - \delta + g$  where  $MP_k$  is the marginal product of this factor,  $\delta$  the rate of depreciation and  $g$  the rate of technical progress<sup>(21)</sup>. Our estimate of  $MP_k$  (= 13.1 %) is the average value of the marginal product of capital in 1990 in a sample of 14 EU countries

<sup>(20)</sup> We use data for the United States because we have not found comparable data for the EU, but we do not expect that existing differences will be large enough to affect our conclusions.

<sup>(21)</sup> This formula comes out of a calculation analogous to the one described in Box 5, which is much simpler in the case of physical capital because of the absence of delays and rate effects.



computed using the production function estimated in the updated version of de la Fuente and Doménech (2000) and the data used by these authors, which include an estimate of the stock of physical capital. We assume a depreciation rate of 5 % and a value of  $g$  of 1.5 % (as in the calculations of the rate of return to education). This is in rough agreement with the estimate of 15 % for the United States given in McMahon (1991) for the marginal product of (non-residential) capital based on Bureau of Economic Analysis data on capital income and the capital stock.

**Table 4: Rates of return to schooling and on some alternative assets**

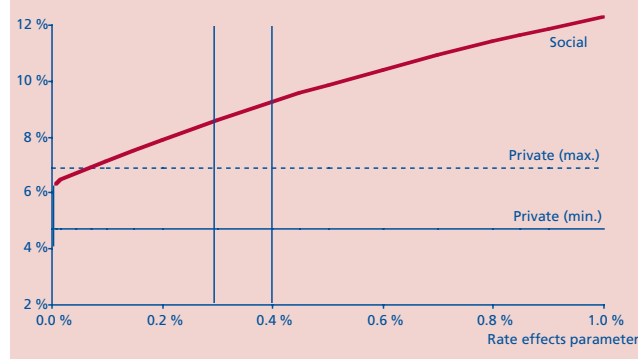
	Gross	Net
Unadjusted private returns:		
<i>min.</i> ( $\theta = 6.5\%$ )	5.97 %	5.90 %
<i>max.</i> ( $\theta = 9\%$ )	8.77 %	8.68 %
Adjusted private returns:		
<i>min.</i> ( $\rho = 4.33\%$ )	4.71 %	4.65 %
<i>max.</i> ( $\rho = 6.00\%$ )	6.87 %	6.80 %
Social returns:		
<i>min.</i> ( $\rho = 3.98\%$ , $\gamma_{YS} = 0$ )	4.20 %	3.53 %
<i>interm.</i> ( $\rho = 5.41\%$ , $\gamma_{YS} = 0$ )	6.15 %	5.36 %
<i>max.</i> ( $\rho = 5.41\%$ , $\gamma_{YS} = 0.90$ )	11.85 %	10.89 %
Returns on alternative assets:		
<i>large company equity (US)</i>		7.70 %
<i>US government bonds</i>		2.60 %
<i>physical capital</i>		9.60 %

Note: Unless otherwise indicated, these figures refer to an average EU country around 1990.

A number of pairwise comparisons between these different rates of return can be informative. Figure 6 displays the gross social and (corrected) private rates of return to schooling, with the former shown as a function of the rate effects parameter,  $\gamma_{YS}$ . The figure illustrates the implications of the broad spread of parameter estimates found in the literature for the importance of externalities. At the lower end of the range, our macroeconomic parameter estimates are consistent with their microeconomic counterparts and suggest that the productivity effects of human capital, while sizeable, are fully reflected in wages. The upper range of the estimates, however, implies that technology-related externalities are extremely large, and account for up to one half of the social return to education. For the more plausible intermediate estimates of the rate effects parameter (0.3 to 0.4 %), technological externalities add between 2 1/2 and 3 points to the social return to education.

In the absence of public intervention, the existence of externalities of the type the macroeconomic esti-

**Figure 6: Gross social and adjusted private returns to schooling as a function of  $\gamma_{YS}$**



mates seem to be picking up would generate a tendency for private underinvestment in schooling. Most governments, however, heavily subsidise education and have enacted compulsory schooling laws. Since both types of measures will tend to raise educational investment, thus counteracting the effects of the externalities, the level of schooling we observe may be either too high or too low when compared with the social optimum. A comparison of the returns to schooling with those available from alternative productive assets can potentially give us some information about the optimality of the outcome observed in the average EU country.

In principle, the relevant comparison would be between the net social returns to education and the returns on physical capital. In practice, there is considerable uncertainty about the values of the relevant rates of return. In addition to the existing uncertainty about the size of the external effects of education that have been emphasised in this report, there are two considerations. The first is that, as we have already noted, our estimates are likely to understate the social rate of return to education because they only consider direct productivity effects. The second is that it is not entirely clear how we should measure the return on physical capital. Our production function-based estimate of this magnitude is significantly larger than observed stock returns (which, incidentally, include the returns on all corporate assets, and not only on physical capital). One possible reason for this is that we may be underestimating the relevant rate of depreciation or overestimating the coefficient of physical capital in the production function,  $ak$ , and a second one that stock returns are net of intermediation costs that may be considerable and should probably not be counted as part of the net return on capital. At any rate, it may be expected that the relevant rate of return on physical capital should fall somewhere between these two magnitudes.

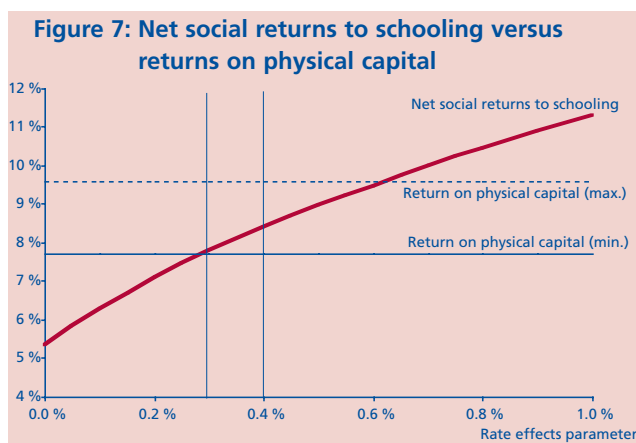


Figure 7 plots the net social returns to schooling as a function of the rate effects parameter ( $\gamma_{rs}$ ) together with the plausible range of rates of return on physical capital. Values of  $\gamma_{rs}$  that fall about halfway within the range of existing estimates suggest that the direct economic returns to schooling are probably in line with those available from investment in physical capital. Since our measure of the social returns to education does not include its non-market benefits, or those derived from its contribution to social cohesion, a plausible case can be made for the view that an increase in human capital investment may be justified. This argument, however, relies on the existence of significant rate effects or other non-market returns to education, as the direct level effects that are reflected in wages imply rates of return to schooling that are significantly below those available from alternative assets.

A comparison between net private and social returns is also of interest to determine to what extent private and social incentives may be misaligned in Europe. But once again, it is not entirely clear what specific rates of return should be used in the comparison. Private incentives are best captured by the unadjusted net private rates of return (5.90 to 8.68 %) given in the first block of Table 4, as these reflect the expected benefits that are available to individuals through increased wages. As noted above, these unadjusted private rates of return do not hold physical capital constant, whereas the social rates of return we have computed do. To make them comparable, we need to make some assumption about how the aggregate stock of physical capital will respond to increased investment in education because, given the complementarity between the two types of capital, an increase in the physical capital stock will raise the returns to schooling.

The simplest assumption to make is that the country is a small open economy that has unlimited access to capital at the going world interest rate. Since this is

essentially the assumption we made at the microeconomic level, the required adjustment would involve multiplying the social rate of return shown in Table 4 by the inverse of the coefficient we used above to adjust the private rates of return down and would leave the social rate of return above the private return (even taking into account subsidies) starting with relatively low values of the rate effects parameter. At the regional level, where the small open economy assumption is probably a good approximation, this result suggests that there may be reasons for shifting investment priorities from physical to human capital. Indeed, increased subsidies to human capital formation in backward regions may be an effective component of cohesion policies, but two important qualifications to this conclusion should be kept in mind. The first is that there is an element of zero-sum game in this, as the inflow of mobile resources that is likely to follow the increase in human capital investment will come at the expense of other regions. The second is that, as suggested by our discussion of regional externalities in Section 3(b)(v), it is very likely that technology-related externalities operate at the country level rather than at the regional level. Hence, some of the benefits of additional investment in human capital in backward regions may spill over to more advanced ones, thereby reducing the desired impact on regional cohesion.

The case for additional subsidies is considerably weaker when examined from a national or EU-wide perspective. At this level of aggregation, the assumption of perfect capital mobility is probably quite inadequate, as suggested by the high correlation observed between national savings and investment rates. Since these are large economies, they would face an upward sloping supply schedule for capital and would have to rely at least partly on domestic accumulation for increases in the stock of physical capital. As a result, the social return to schooling when we do not hold capital constant may not be much higher than the estimate shown in Table 4 (because the aggregate stock of this factor will increase only gradually and possibly at a higher cost). In this situation, there is a factor that partially offsets the externality and it has to do with the fact that individuals and firms (or even regions) are in a better position than countries to exploit the potential benefits of human capital investment because, unlike countries, they have rapid and unlimited access at given prices to complementary inputs whose use will raise the return to educational investment.

Finally, it is worth noting that the (unadjusted) private returns to schooling investment compare rather favourably with the returns on debt and equity, especially if some allowance is made for non-market returns



and employment effects. Human capital, however, is a risky asset because there is considerable variation in wages across workers with the same level of educational attainment. Although part of this variation will reflect differences in ability and pay differentials that compensate for various job attributes, individuals are likely to require a sizeable risk premium to invest in human capital. Since we lack good measures of the riskiness of such investment, it is not obvious whether the observed pattern of returns makes education a sufficiently attractive investment alternative from an individual point of view. The observed premium over the riskless rate of return (3.2 to 5 percentage points) is comparable to the one on equity or is even higher and seems large enough to provide reasonable incentives for investment in education. But it is also true that the expected return on human capital is probably lower than the rate of interest on unsecured personal loans that may be used to finance educational expenditures, when these loans are available at all. Hence, liquidity constraints are more likely to be a problem than low returns per se, particularly in those countries where public student loan programmes do not exist.

Although caution is clearly needed for a number of reasons that have already been discussed (and include the considerable uncertainty that remains about the values of the relevant macroeconomic parameters and the size of the social benefits from human capital not captured by the existing empirical estimates), we believe that the preceding discussion supports the following tentative conclusions.

First, **a moderate increase in human capital investment is probably a good idea.** The direct economic returns to schooling investment that are captured by macroeconomic studies are comparable to those available from investment in physical capital. When a reasonable allowance is made for the non-market returns to education and for its benefits for social cohesion, human capital becomes a rather attractive investment alternative from a social point of view.

Second, **an across-the-board increase in general subsidies to formal education at the post-compulsory level is probably not necessary.** This conclusion may be some-

what surprising in view of our emphasis on the importance of human capital externalities, but it must be kept in mind that large subsidies are already in place and that compulsory school attendance also helps to counteract the effects of such externalities. An additional consideration that works in the same direction is that, as we have seen, individuals and firms are in a better position than countries to exploit the potential benefits of human capital investment. These factors help explain our finding that the private rate of return relevant for individual schooling decisions compares quite favourably with the social rate of return on education and with those on competing assets available to households.

Hence, the economic incentives for individuals to invest in education are probably adequate. If a further increase in post-compulsory enrolments is considered desirable, it may be more important to eliminate implicit barriers to access to advanced programmes (such as liquidity constraints and lower levels of basic skills for individuals from disadvantaged backgrounds) through policies specifically targeted at these problems, rather than further decrease already low tuition charges that imply a large subsidy for relatively privileged groups<sup>(32)</sup>. Indeed, higher tuition fees coupled with a well-designed loan programme or with an increase in means-tested grants may be an efficient way to provide additional resources to increase the quality of post-secondary education while at the same time reducing the regressivity of its financing. Additional public funds, however, may be required at lower educational levels and for the expansion of adult training.

It should be stressed that our conclusions are drawn from the analysis of a hypothetical average EU country and, consequently, may have to be modified depending on the particular circumstances of specific countries or regions. In general terms, the case for additional investment in human resources is likely to be stronger in those territories where expenditure is low and/or human capital is scarce relative to other productive assets. Similarly, the need for additional subsidies will vary across countries depending on existing financing arrangements and on the extent to which pay scales provide adequate incentives for private investment in education.

<sup>(32)</sup> See, for instance, OECD (2001b).

## 6. Concluding remarks

Our analysis offers some guidance in identifying the most productive uses of additional educational expenditure as well as changes in current practices that may increase efficiency. Our review of the literature indicates that the most important source of non-privately appropriable 'excess returns' from human capital investment is likely to be this factor's complementarity with technology. This suggests the following broad objectives for human capital policies. First, aim to give technology-related skills to a broad segment of the population and ensure the adequate supply of technical and scientific personnel needed both for development and for adoption of new technologies. Second, support lifelong learning in order to counteract the accelerated depreciation of skills in times of rapid technological change. Third, improve conditions for the accumulation of research-related human capital. Much of this human capital is generated as a by-product of research itself and human capital policies should therefore strengthen the link between tertiary education and both private and public research.

The second most important source of aggregate excess returns to human capital is likely to come from its contribution to social cohesion and social capital. Our review of the literature suggests that the objective of enhancing social cohesion and building social capital does not stand in contradiction with human capital policies targeting complementarities between human capital and technology. Giving technology-related skills to a broad majority of the labour force will require policies supporting the acquisition of such skills in segments of the population with historically low levels of human capital and is therefore an opportunity for increasing social cohesion. The complementarity between early human capital and formal education as well as on-the-job training documented in the literature suggests, however, that the success of such policies will depend crucially on generalising access to early-learning opportunities. Research on non-market returns to human capital indicates that early-learning policies will also generate benefits in terms of lifelong learning. The complementarity between formal education and on-the-job training suggests, moreover, that human capital policies should enhance adult learning to prevent marginalisa-

tion of individuals who have missed the educational opportunities of formal schooling.

Another point that comes out of our review of the literature is that the quality of human capital is likely to be crucial for economic growth. Raising the quality of education should therefore be at the centre of human capital policies. Empirical work points towards some concrete steps to accomplish this objective, but considerable uncertainty remains and more research is necessary to identify the determinants of school performance and student achievement. It is already clear, however, that the objective of raising the average quality of human capital does not stand in contradiction to the objective of enhancing social cohesion, as international educational assessment exercises demonstrate that countries with relatively high average achievement are also relatively more successful in raising the performance of students from disadvantaged backgrounds<sup>(33)</sup>.

On the whole, the evidence we have reviewed is consistent with the view that measures aimed at increasing the quantity and quality of the stock of human capital should be an important part of any growth-promoting policy package. This is certainly so in the case of the Lisbon strategy, which echoes many of the recommendations found in the literature. Implementation of the human capital policies outlined in successive EU summits appears especially important for those regions of the European Union that are lagging behind in productivity and income per capita. It is important to recognise, however, that successful action requires a clear picture of the quantity and quality of regional human capital stocks in order to understand regional needs and to identify those policies that are likely to be most effective. For example, it would be important to extend to the regional level recent studies that have tried to assess the skill levels of younger cohorts and of the workforce at large, and to support further research into the determinants of the performance of education systems. These studies can be a useful input for the formulation of a systematic human resources policy that should be an important part of the EU's ongoing effort to increase regional cohesion.

<sup>(33)</sup> See OECD and Statistics Canada (2000) and OECD (2001c).

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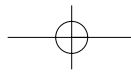
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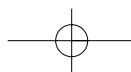
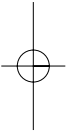
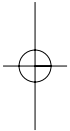
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## APPENDIX

### 1. Human capital, productivity and earnings: a survey of the microeconomic literature

#### (a) Estimating the individual return to schooling: methodological issues

Schooling costs time, effort and money, but at the same time it augments an individual's earnings capacity. Hence, expenditure on schooling can be considered an investment and the extra income earned due to the completion of an additional year of schooling as part of its return.

The most recent studies of education and wage determination are embedded in Mincer's framework discussed in Box 1 in the main text and a large amount of research has estimated the Mincerian earnings equation for different countries and time periods. The common estimation method is ordinary least squares (OLS). Estimating returns to schooling by OLS is an easy task but has the drawback that the estimated return may be biased, i.e. the OLS return may not reflect the 'true' reward the labour market places on an additional year of schooling. In what follows, we first discuss why OLS estimates on returns to education may be biased and then discuss possible remedies.

When estimating returns to education by OLS, the econometrician encounters basically three problems. The first problem is that schooling attainment is not randomly determined, but is rather the result of an optimising decision influenced by individual characteristics such as ability, taste for schooling or access to funds. For example, if more able individuals spend more time in school and receive higher earnings, then differences in earnings of individuals who have different levels of education overestimate the true causal effect of schooling on earnings or, put differently, the returns to education will be upward biased. The most straightforward approach to tackle the issue of unobserved ability is to include measures that proxy for unobserved ability in the earnings equation, such as IQ or other test scores (Griliches, 1977). But schooling itself determines this kind of ability measure leading to a downward bias in the estimated returns to schooling. Another method, which attempts to directly control for unobservable factors, adds information on family background variables such as education or earnings of the parents to the Mincerian earnings equation. Controlling for family background in the OLS estimates may reduce the upward bias in the OLS estimates, but may be unable to

eliminate it completely unless the family background variables absorb all unobservable components. The second problem is that returns to education may be heterogeneous, i.e. may vary across individuals, which will usually lead to biased estimates. The third problem is measurement errors in the schooling variable, which are likely to bias the OLS estimator of the returns to schooling downward.

One approach taken to resolve these econometric problems is the use of twin studies. These studies exploit the fact that members of the same family such as siblings or twins are more alike than randomly selected individuals. Twins (or siblings) are less likely to face differences in home environment or financial support and for identical twins even genetic variation in ability may be ruled out. Differences in schooling and earnings of siblings and twins can thus be used to estimate returns to schooling. But even this setting only yields unbiased estimates of returns to schooling if twins face no heterogeneity in any factor that may be correlated with the schooling variable and if the distribution of abilities among twins equals the distribution of abilities in the population as a whole. If these requirements are not satisfied, then the OLS estimator may have a smaller upward bias than the within-twin estimator. Another problem of twin studies is that they are likely to exacerbate measurement errors in the schooling variable.

The instrumental-variable (IV) approach is a further strategy to solve the bias in the OLS estimates on returns to education. Generally, an IV approach requires an exogenous instrument that is the existence of an observable variable that affects the variable of interest, i.e. years of schooling, but is not correlated with the earnings residual. The IV approach proceeds in two stages: first, the researcher obtains an estimate of the effect of the instrumental variables on schooling and then on earnings. Dividing the effect of the instrumental variable on earnings by the effect of the instrumental variables on schooling will yield an unbiased estimator of the returns to schooling if the exogenous instrument only affects earnings through schooling.

Researchers obtained instrumental variables from natural experiments or family background. The identification of natural experiments provides the researcher with variables that are likely to influence the level of



schooling but are independent of unobserved individual characteristics. Natural experiments exploit natural variations in the data such as institutional changes, which affect, for example, the minimum school leaving age or tuition costs for higher education or factors. Alternatively, variables such as geographic proximity to colleges or quarter of birth have been used (Card, 1995; Angrist and Krueger, 1991). The instrumental-variable estimator has the advantage that if the instrumental variable is not correlated with the measurement error, then measurement errors do not introduce a bias in the IV estimator. However, if returns to education are heterogeneous, the existence of an exogenous instrument is not sufficient to guarantee that the IV approach yields unbiased estimates of the average return to schooling. Consider, for example, a natural experiment that affects mostly a certain subgroup of the sample. Card (1999) shows that, in this case, the IV estimate may reflect the return of this subgroup and not the average return in the population.

### (b) Review of the estimates

We now present a selective review of the evidence on the return to education with a special focus on Europe. We start by providing evidence on instrumental variables based on natural experiments. These findings are presented in Table A1.1 (which is enclosed at the end of the appendix, along with Table A1.3). Next, we summarise estimates obtained from twin studies and then turn to returns to education whose estimation uses information on family background.

Using college proximity as the instrumental variable, Card (1999) obtains estimates of returns to schooling for the United States which are nearly twice as large as the corresponding OLS estimates of returns to schooling. He further finds that college proximity affects children of less educated parents more and therefore interacts college proximity with family background as the instrumental variable, adding college proximity as a direct control variable to the earnings equation. Returns to education using this IV procedure are 0.097, which compares to OLS estimates of 0.073. Similarly, Conneely and Uusitalo (1997) find for Finland that IV estimates of the returns to schooling based on college proximity instrumental variables are 20 to 30 % higher than the corresponding OLS estimates.

In Britain, the minimum school leaving age was raised from 14 to 15 years in 1947 and from 15 to 16 years in 1973. Harmon and Walker (1995) use these institutional changes as instruments and obtain IV esti-

mates, which are about 2.5 times higher than the corresponding OLS estimates. However, as Card (1999) points out, their IV estimates may be upward biased due to the fact that the effect of the 1947 law change cannot be separated from the changes in educational attainment induced by World War II. Changes in compulsory education are also used as an instrumental variable by Vieira (1999) to estimate the return to schooling in Portugal. Again, IV estimates exceed standard OLS estimates. For Italy, Brunello and Miniaci (1999) exploit the fact that in 1969 the possibility to enrol in a college was no longer determined by the curriculum chosen in secondary school. Using family background variables on the parental education level and actual occupation as additional instruments, they obtain IV estimates that exceed OLS estimates by nearly 20 %.

Angrist and Krueger (1991) propose an individual's quarter of birth as an instrument. They find that individuals who are born earlier in the year reach the minimum school leaving age at a lower grade than people born later in the year. Hence, individuals who are born earlier in the year and want to drop out legally leave school with less education. Levin and Plug (1999), however, find that Dutch individuals born later in the year have significantly lower schooling. They explain this by the fact that within classes older students are likely to receive higher marks, which encourages further schooling. Hence, the net effect of quarter of birth on schooling attainment is *ex ante* not clear. An alternative explanation is that, in the Netherlands, students are obliged to finish the school year they have started, even if they reach the minimum leaving age during the course of this year. Levin and Plug find that returns to education increase by about 10 % relative to standard OLS estimates when season of birth is used as an instrument.

Recently, there has been a large increase in estimates of the return to schooling based on studies of twins because of the availability of new, relatively large data sets. The data set used by Ashenfelter and Rouse (1998), for example, consists of 340 pairs of identical (monozygotic) twins. It provides the response of each twin about his/her own and his/her sibling's schooling level. Hence, the difference in schooling between twins according to one twin can be used as an instrument for the response on the difference in schooling for the other one. As can be seen in Table A1.2, Ashenfelter and Rouse find that within-twins estimates of the returns to education are about 30 % lower than the corresponding OLS estimates. Once they control for measurement errors, within-twins estimates increase by about 25 %, still remaining below the cross-sectional OLS estimates.



**Table A1.2: Estimates based on studies of twins**

Author	Controls	Data	Specification	Cross-section OLS	Differences OLS	IV
Isacsson (1999) Sweden	Gender, marital status, quadratic in age and residence in a large city.	Swedish Twin Registry. Administrative and survey measures of schooling.	Identical twins	0.046 (0.001)	0.022 (0.002)	0.027/0.060 (0.003/0.007)
			Fraternal twins	0.047 (0.002)	0.039 (0.002)	0.044/0.060 (0.002/0.003)
			Subsample Identical twins	0.049 (0.002)	0.023 (0.004)	0.027 (0.008)
			Fraternal twins	0.051 (0.002)	0.040 (0.003)	0.054 (0.006)
Ashenfelter and Rouse (1998) United States	Gender, race, quadratic in age. Additional controls tenure, marital and union status.	Princeton twin survey, 1991–93. Identical male and female twins.	Without additional controls.	0.110 (0.010)	0.070 (0.019)	0.088 (0.025)
			With additional controls.	0.113 (0.010)	0.078 (0.018)	0.100 (0.023)

Isacsson (1999) uses a data set, taken from the population of twins born in Sweden between 1926 and 1958, which consists of 2 492 pairs of identical (monozygotic) and 3 368 pairs of fraternal (dizygotic) twins. Furthermore, information on two measures of schooling (administrative and self-reported level of education) is available for a subsample of the data and allows him to correct for measurement error. Isacsson finds that for the subsample with both education measures, the within-twins estimate is about 50 % (20 %) lower than the OLS estimate for identical twins (fraternal twins). For fraternal twins, the measurement-corrected within-twins estimate exceeds the OLS estimate by 35 %.

This review suggests that estimates of returns to education obtained from the instrumental-variable approach or studies of twins usually exceed OLS estimates and confirms the results of Ashenfelter, Harmon and Oosterbeek (1999). Analysing estimations from 1974 to 1995 in the United States and seven non-US countries (Finland, Honduras, Indonesia, Ireland, the Netherlands, Portugal and the United Kingdom), they find that IV estimates and twin study estimates differ from OLS estimates by 3.1 and 1.6 percentage points respectively.

### (c) The return to schooling over time and across countries

Many developed countries have witnessed major changes in their wage distribution during the last few decades. In the United States, returns to education decreased during the 1970s and rose sharply during the 1980s. Average returns to education in Europe followed a similar pattern. When looking at European countries one by one, different trends in returns to education can be observed. In this section, we provide evidence on the evolution of changes in returns to education during the last few decades for the United States, Europe and selected European countries. We try to identify the driving forces behind these changes in returns to education and explain why these patterns of change were so different across European countries. Finally, we provide evidence on returns to education for various European countries and discuss the country-specific determinants of these returns.

Returns to education are usually estimated from cross-sectional data and consequently correspond to the wage differential among different skill groups. In a competitive labour market, wages are determined by supply and demand. The supply of skilled workers is determined by the educational attainment of the workforce. Demand for skilled workers may change, for example, due to technological change or trade.

It is a well-documented fact that returns to education in the United States decreased during the 1970s and increased during the 1980s generating a U-shaped time pattern of educational wage differentials. There seems to be some consensus that these changes in the returns to education may be interpreted as outcomes of shifts in the supply of and demand for human capital. The basic idea is that increases in the supply of skilled workers dominated during the 1970s, while demand growth was the driving force in the 1980s. Katz and Murphy (1992), for example, argue that the deceleration in the growth of highly educated labour supply in the United States during the 1980s relative to the 1970s may explain the rise in returns to education during this decade. Katz and Murphy's hypothesis is based on the assumption that the relative demand for skilled workers increased. The prime candidate for explaining the increase in the demand for skilled workers is skill-biased technological change. New technologies have been introduced during the last few decades, such as computers or robots, and organisational changes have taken place within firms that have often replaced labour-intensive tasks and increased the demand for skilled labour.

For Europe, Harmon, Walker and Westergaard-Nielsen (2001) find that estimates of returns to education were higher in the 1960s as compared with the 1970s. During the 1980s, returns dropped even further, but started to rise again in the 1990s. This describes a U-shaped pattern, similar to that observed for the United States. Performing a meta-analysis of the data, Denny, Harmon and Lydon (2001) confirm these results. A meta-analysis is basically a regression that takes as dependent variables the estimates of different studies that focus on the same topic and similar methodology. The explanatory variables of this regression describe the characteristics of the estimation such as equation specification, sample size and years of estimation. A meta-analysis thus controls for the effect of study-specific features on the estimated returns to education. Comparing the change in the US returns to education with Europe, Denny, Harmon and Lydon (2001) show that rates of returns to education in Europe exceeded US returns in the early 1960s. In the course of the 1960s and 1970s, returns to education in Europe and in the United States fell at a similar rate. US returns to education reached their minimum at the end of the 1970s, while European returns continued to decline until the mid-1980s. The subsequent increase in returns to education was much more pronounced in the United States. By 1997, returns to schooling in the United States were about 3 percentage points higher than in Europe.

Although the pattern of change in the returns to education was strikingly similar in Europe as a whole and

the United States, behaviour across European countries differed widely. Returns to schooling in Austria, Switzerland and Sweden decreased, but increased in Denmark, Portugal and Finland. Other countries had no trend at all or different behaviour of male and female returns to education (Harmon, Walker and Westergaard-Nielsen, 2001). In what follows, we provide some evidence on the evolution of returns to education for selected European countries and try to identify the underlying forces. We start with Great Britain, whose behaviour largely mirrors that of the United States and then turn to Spain and Portugal, which also faced increases in the returns to education during the 1980s. Next, we discuss why wage inequality in France, Germany and Italy remained stable. We conclude with Austria, whose returns to education seem to have declined.

Great Britain largely shares the pattern of change in wage inequality with the United States. Similarly to the United States, the supply of university-educated workers in Great Britain grew rapidly during the 1970s and differentials across skill groups narrowed. During the 1980s, wage inequality and university wage premiums increased substantially. Katz, Loveman and Blanchflower (1995) explain this by the deceleration in the pace of growth of the relative supply of highly educated workers during the 1980s and the decline in employment in mining, manufacturing, construction and utilities which affected particularly male, manual, low-skilled workers.

Spain underwent profound changes in the 1980s. It joined the European Union and consolidated its democratic institutions. The share of workers in the heavy and manufacturing industries declined substantially, whereas the share of employment in the commerce, finance and service industries rose. During the 1980s, the average educational attainment of the workforce increased remarkably in Spain. In 1981, 74.2 % of the employed population had a primary education or less and only 7.6 % had completed higher education. By 1991, the population with primary education or less had fallen to 48.5 %. The percentage of employed with a secondary school degree had more than doubled and 12.5 % held a higher education degree. The generation of employment lagged behind the rapid increase in the Spanish labour force. Unemployment was and still is high, affecting particularly younger and less educated people, as well as women. Vila and Mora (1998) find that from 1981 to 1991 Spanish skill wage differentials increased. Returns to lower secondary and primary education decreased, whereas returns to higher education either increased or remained stable.

Portugal faced a severe economic crisis in the first half of the 1980s and major economic changes during

the second half. According to Hartog, Pereira and Vieira (2001), returns to education in Portugal remained largely unchanged between 1982 and 1986. Between 1986 and 1992, they increased substantially for both men and women. In contrast to Spain, the increase in returns to education in Portugal was not driven by a reallocation of employment towards skill-intensive sectors. Employment in Portugal shifted after 1986 towards sectors that traditionally employ low-educated workers, such as restaurants and hotels, construction, textiles and services. So why did returns to education in Portugal increase? According to Hartog, Pereira and Vieira (2001), an increase in demand for highly skilled workers within industries may well explain this finding. Portugal joined the European Union in 1986. It hence embarked on a process of modernising its productive structure, particularly through the introduction of new production technologies. This was made possible thanks to the Structural Funds of the EU and specific financial aids. Furthermore, the liberalisation of trade with more developed countries may have enhanced the importation of technologies that require skilled labour.

In France, wage inequality did not increase substantially during the 1980s. It declined until 1984 and increased slightly from 1984 to 1987 (Katz, Loveman and Blanchflower, 1995). The fact that significant relative demand shifts did not result in increases in wage differentials throughout the mid-1980s may be due to French labour market institutions, particularly the negotiated and the legislated minimum wage. Collective bargaining in France mainly takes place at industry level and these industry-level arrangements determine minimum wages for each job category. These negotiated minimums apply to all firms of all sizes throughout the industry and are binding in case they exceed the legislated minimum wage. The legislated minimum wage applies to all sectors.

Similarly to France, the former West Germany did not face any increase in wage inequality during the 1980s (Abraham and Houseman, 1995; Winkelmann, 1996). One possible explanation is that, in contrast to the United States, the growth of the highly educated workforce did not decelerate in Germany. Furthermore, as Abraham and Houseman (1995) point out, the high quality of the German apprenticeship system may have prevented returns to education from increasing. They argue that the high level of education for relatively low-skilled workers facilitates the substitutability of workers with different levels of education and experience. Moreover, German solidaristic wage policies, pursued by German trade unions and which sought to narrow the gap between highly paid and less highly paid workers, may have tended to depress earnings differentials.

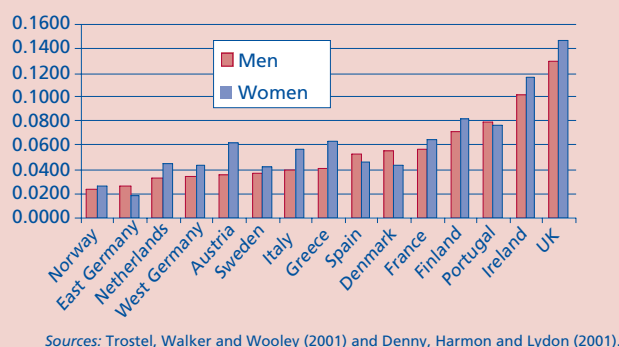
Italy experienced a compression of wage differentials during the 1970s, which according to Erikson and Ichino (1995) came to a halt around 1982–83. The break in the evolution of the wage differentials in 1982–83 coincides with the slowdown in inflation, industrial restructuring, the introduction of an escalator clause in Italian union contracts and the loss of support for unions and their egalitarian pay policies.

In Austria, returns to an additional year of schooling dropped remarkably from 1981 to 1997. The rapid increase in the labour supply of workers with secondary and tertiary education may explain this fall in Austrian returns to education. Fersterer and Winter-Ebmer (1999) provide evidence for this hypothesis. They find that workers, who belonged to education, age and gender groups with the highest increase in supply, faced the lowest growth in wages. In particular, the drop in returns to education was largest for university students, while returns to a vocational school degree or apprenticeship training remained fairly constant.

Returns to education do not vary only over time, but also across countries. Using a common specification across European countries, Harmon, Walker and Westergaard-Nielsen (2001) find that the Scandinavian countries (Norway, Sweden and Denmark) have the lowest returns to an additional year of schooling. Returns are highest in Ireland and the UK, followed by Germany, Portugal and Switzerland. A meta-analysis reveals an average return to an additional year of schooling of around 6.5 % in Europe. It confirms that Scandinavian countries have the lowest returns to schooling, followed by Italy, Greece and the Netherlands, while returns to schooling in the UK and Ireland are indeed higher on average.

Similar evidence is provided by Denny, Harmon and Lydon (2001). They estimate returns to education by OLS using the international social survey programme data 1995. This data set is designed to be consistent across countries. As can be seen in Figure A1.1, they find a large difference in returns to education for men across countries ranging from 2.29 % in Norway to 17.66 % in Northern Ireland. Austria, Germany, the Netherlands and Norway have relatively low returns to schooling for men, while male returns to schooling are highest in Portugal, Ireland and Great Britain. Returns to education for women exceed male returns in the majority of countries. Female returns to education are lowest in the Netherlands (1.81 %), Norway and New Zealand and highest in Great Britain, Ireland and Northern Ireland (16.81 %).

**Figure A1.1: Returns to schooling in selected EU countries**



#### (d) The role of schooling for male–female wage differentials

In most industrialised countries, the gender wage gap has decreased dramatically during the last decade. For a long time, a large part of the gender wage gap had been attributed to differences in schooling between men and women. But differences in average years of schooling among male and female full-time workers have largely disappeared, contributing to a significant decrease in the gender wage gap (Blau and Kahn, 1997, for the United States and Harkness, 1996, for the UK). Not only schooling of women, but also female labour force participation and consequently women's accumulated labour force experience have increased. These changes in experience seem to have been even more important in closing the gender wage gap than the increase in years of education (see, for example, Blau and Kahn, 1997, for the United States). Relative changes in schooling and work experience altogether seem to have narrowed the gender wage gap in the United States by one third to one half between the mid-1970s and late 1980s (O'Neill and Polachek, 1993). But despite dramatic reductions in the male–female wage gap during the last few decades, differences in the earnings of men and women continue to persist.

Differences in the earnings of men and women can arise for a variety of reasons. Differences in schooling, labour force participation rates, work experience, hours worked, job tenure and turnover rates are only the most obvious. Even among equally qualified men and women, a substantial gender wage differential remains. Differences in social roles, parental preferences concerning the level of education or job, financial attractiveness of home versus market work, occupational preferences, tastes for jobs or labour market discrimination have been proposed in order to explain these facts. In what follows, we discuss the different factors that are likely to determine the gender wage gap with a special focus on the role of schooling and 'careers'.

Differences in schooling between full-time working men and women have largely disappeared in many industrialised countries. Today it is not the amount of schooling, but rather differences in what men and women study, as well as differences in aptitudes and achievement scores across subjects through which schooling affects the gender wage gap. The programme for international student assessment (PISA) 2000 of the OECD (OECD, 2001a) finds that while males are likely to underperform in reading, women seem to have a measurable disadvantage in mathematics. Similarly, Brown and Corcoran (1997) conclude for the United States that 12th grade boys score higher on maths achievement tests and lower on reading and vocabulary tests. There exists some evidence for the United States that these differences in aptitudes may translate into earnings differentials. Altonji (1995) and Brown and Corcoran (1997), for example, find that differences in high-school courses play only a modest role in the gender gap among high-school students. But differences in the type of college major (e.g. engineering, physical science, business or law) account for a substantial share of the differential among male and female wages.

A large part of the gender wage gap is generally attributed to the fact that women accumulate a lower amount of experience than men. Women often interrupt their careers, work fewer hours and have a higher propensity to work part-time than men. As a consequence, they may spend a smaller proportion of their working-age time actually working. But it is not only the total amount of experience which matters. Differences in the timing of and the returns to experience account for a sizeable fraction of the gender wage gap. Light and Ureta (1995) show that about 12 % of the raw differential in male–female earnings is due to differences in the timing (i.e. differences in the frequency, duration and placement of non-work spells) of work experience, while 30 % of the gap is due to differences in returns to experience. They further find that career interruptions play a smaller role for women than for men and that women recover more quickly from interrupting their career. This suggests that women may tend to work in occupations that allow them to restore their skills faster, while men may have career interruptions for reasons that are more negatively related to productivity.

Fewer working hours and fewer years in the labour market lead according to the standard human capital theory to less investment in general human capital. Furthermore, women have traditionally higher turnover rates than men. Expected separation from the current job may discourage investment in employer-specific human capital on the part of the women and the employer.



A woman may decide not to invest in employer-specific human capital, as she knows that she is going to interrupt her career soon. The same holds true for employers. Under imperfect information, the employer may discriminate against the woman in terms of training opportunities, if he assumes that she is likely to interrupt her career in the near future, for example because she is of childbearing age.

But women do not only have higher turnover rates. It also seems that the reasons underlying the decision to quit a job vary systematically among men and women. Findings by Sicherman (1996) suggest that women take short-run considerations into account when changing jobs, while men place more importance on long-run career considerations. Sicherman (1996), for example, finds for the United States that 12 % of women and 4 % of men left their job due to a change of residence, which is consistent with the idea that women put more weight on having a job close to their home. Not only proximity to home but also working hours seem to be a job attribute which is relatively more important to women. Empirical evidence suggests that it is rather hours than wages that play a role in the job choice of women and that job mobility of women is strongly linked to changes in hours (Altonji and Paxson, 1992).

Differences in job characteristics such as occupation, industry, unionisation and job-related amenities further contribute sizeably to the male–female wage gap. Blau and Kahn (1997) show that the unexplained part of male–female wage regressions reduced from 22 % to 13 % in 1988 once industry, occupation and collective bargaining variables were included.

Going beyond occupations, there has been a growing amount of research on the impact of part-time and temporary work on wages. Women are heavily over-represented in part-time and temporary jobs. These jobs pay typically less than full-time, permanent jobs. Whether a greater relative fraction of women actually prefer part-time or temporary jobs or whether this behaviour is due to labour market constraints is far from clear. Some evidence exists that a part of the negative effect of part-time work on female wages may be due to selection. Blank (1990), for example, finds that controlling for women's selection significantly reduces the negative effect of part-time work on women's wages. This is also consistent with the findings of Harkness (1996), who shows that, while the wage gap has been closing for full-time working women over the last few decades, the relative earnings position of women working part-time has changed little. But while the qualification gap among male and female full-time workers has disappeared completely for younger workers, part-

time working women continue to be less qualified than full-time working men and women.

Men and women do not earn the same. Differences in the subjects they study and the occupations they choose, as well as differences in work experience, play an important role in explaining the gender wage gap. Lifetime work expectations and career considerations are likely to affect female wages considerably. But even among equally qualified men and women, the gender differentials persist. Discrimination has often been proposed as a means for explaining the unexplained part of the gender wage differential. An alternative explanation is that women have different preferences, which translates into different career choices. The question of how much of the gender wage differential is due to differential choices by women and how much can be ascribed to discriminatory barriers in the labour market is difficult to address. It is not even clear in the first place if the two theories are likely to interact rather than be separated, as past labour market discrimination may have induced women to develop a certain set of preferences, which reflects itself in present choices. The distinction between choice and constraint as determinants of the gender wage gap thus remains difficult and controversial.

### (e) Technological change

An econometrician, who wants to estimate the effect of technological change on human capital and employment, encounters several econometric problems. The first is how to measure technology. Often researchers try to address this problem by repeating their estimation with different measures of technologies. This allows them to check that their results are not susceptible to a specific technology measure. The simplest approach to measuring technology is the use of time trends. Unfortunately, time trends are likely to capture much more than solely technological change, such as changes in demand conditions or prices. As a consequence, evidence on the effects of technological change based on this measure should be treated with care.

A prime candidate for the measurement of technology is R & D expenditures. This information is available at the firm level for many countries and different periods. Furthermore, it has the advantage that it is comparable across countries and time. The major disadvantage of using R & D is that the data usually refer to the industry in which the innovation originates, not where it is actually used. Moreover, in most European countries, firms are not obliged to disclose the amount of R & D expenditure in their company accounts. While

R & D measures the input to knowledge, patents measure its output. Using patents as a measure of technology involves the complication that many of them are of very low value. Taking this into account by weighting the different patents according to their value is not straightforward. Furthermore, the likelihood of an innovation being patented has differed historically across industries. The advantage of patent data is that they measure the direct use of innovations. During the 1980s, the use of computers (and computer-based resources) at the workplace grew enormously. As a consequence, computers may be the most concrete example of technological change during the 1980s and a good proxy for the rate of technological change at the workplace. The advantage of using a technology measure based on investment in computers lies in the fact that it captures the use and not the production of an innovation.

The last few decades have witnessed major changes in technologies, such as the rapid spread of computers at our workplaces, the expansion of computer-assisted production techniques and robots and the more intensive use of the Internet. How do these changes affect the relative demand for skilled workers? Basically two hypotheses exist, which try to explain the relation between the relative demand for skilled workers and technological change. The first hypothesis relates technological change and demand for skilled workers. If highly educated workers have a relative advantage in adjusting to and implementing new technologies, then the spread of these new technologies is likely to increase the demand for skilled workers relative to unskilled workers. This means that, in a period of technological change, the productivity of highly educated workers increases relative to less educated workers, due to the fact the highly educated workers are more able to adjust to a changing environment. Hence, times of rapid technological change should also be associated with an increased demand for skill and may lead to higher returns to education. Furthermore, industries characterised by high rates of innovations should have a higher demand for highly educated workers. Bartel and Lichtenberg (1991) shed some light on this issue. They find that the relative demand for educated workers declines as the age of the plant and particularly of equipment increases. This is especially the case in R & D-intensive industries.

The second hypothesis claims the technological change is skill biased. New technologies mainly replace labour-intensive tasks and are likely to complement skilled workers. Thus, the transition from an old to a new technology results in permanent changes in the equilibrium share of skilled labour, holding output and

relative prices constant. If the demand for skilled workers outstrips supply, then returns to education increase. Clear evidence exists at the industry level that almost all industries started to employ educated workers during the 1970s and 1980s and that industries that were more computerised increased their demand for college-educated workers at a faster rate (e.g. Berman, Bound and Griliches, 1994; Autor, Katz and Krueger, 1998; Machin and Van Reenen, 1998). Machin and Van Reenen (1998) use data of the manufacturing sector in Denmark, France, Germany, Japan, Sweden and the UK. Using R & D intensity as a measure of technology, they provide evidence for skill bias across all these countries. Berman, Bound and Griliches (1994) and Autor, Katz and Krueger (1998) model changes in workforce skill as a function of changes in industry capital intensity and industry-level investment in computer equipment. Their findings reveal a strong positive correlation between the level of computer investment and changes in the skill of workers in the industry.

A positive correlation between the level of computer investment and demand for skilled workers does not necessarily mean that computer investment causes an increase in the demand for skills, since industries that are highly computerised may demand more skilled workers for other reasons as well. Using plant-level data, Doms, Dunne and Troske (1997) also come to the conclusion that a higher proportion of college-educated workers are employed in technologically advanced plants, when using cross-sectional data. The longitudinal analysis, however, reveals that plants that adopt new factory automation technologies have a higher proportion of skilled workers before and after the adoption of the new technologies. They conclude that the correlation between skill upgrading and the adoption of new technologies is largely due to the fact that plants with a high-wage workforce are more likely to adopt new technologies. The authors, however, emphasise that the type of technology they use is directly used in the production of manufactured goods, whereas computer investment is a main tool for white-collar workers. When they use computer investment as an alternative measure of technology, they find a positive correlation with the growth of skilled workers even in the longitudinal data. This leads them to conclude that the effect of new technologies on the structure of the workforce depends critically on which type of technology is adopted.

Industry-level studies may be subject to serious aggregation bias. Hence, the fact that even firm-level studies seem to support the existence of skill-biased technological change considerably strengthens the evidence. Using a data set on British plant, Haskel and Heden (1999) find evidence that computers positively



affect the growth of skill intensity. Duguet and Greenan (1997) use an innovation survey for a panel of French manufacturing firms from 1986 to 1991 and come to a similar conclusion. They argue that skill bias arises mainly from the introduction of new products. For Spain, Aguirregabiria and Alonso-Borrega (1997) find that the introduction of technological capital, defined as 'successful innovations generated externally to the firm', has a strong negative effect on blue-collar workers. However, they find no robust effect of R & D.

While evidence exists that technological change affects the relative demand for skilled workers, only a few studies try to understand the mechanisms through which technological change operates. Unobserved factors play a large role in the analysis of technological change and demand for skills. Some conjecture (Dunne, Haltiwanger and Troske, 1996; Machin and Van Reenen, 1998) that organisational change might well be one of them. In most industrialised countries, there has been a trend towards less hierarchy and more flexible organisational forms. More autonomy and responsibility are given to the workers and often they are performing a wider range of tasks. Caroli and Van Reenen (1999) go even further and claim that lack of necessary organisational structures that facilitated the introduction of new technologies may to some extent explain the so-called 'productivity paradox'. This states that huge investments in computers often fail to result in significant increases in productivity. Caroli and Van Reenen (1999) use a panel of British and French establishments in order to investigate whether organisational changes such as the decentralisation of authority, delayering of managerial functions and increased multitasking affect the skill composition of firms. They find that organisational changes tend to reduce the demand for unskilled workers and lead to greater increases in productivity in establishments with larger initial skill endowments. They conclude that the widespread introduction of new organisational forms may be important in explaining the declining demand for less skilled workers.

In contrast to the studies on technology and demand for skilled workers, most of the studies that try to analyse the relation between technological change and wages use individual data. The rise in wage inequality in the United States and the widespread notion that technological change may be the driving force behind it triggered a large amount of studies on this subject. Mincer (1993a and b), using data from 1963 to 1987, shows that relative earnings of college graduates increased with R & D intensity. Similarly, Allen (2001) provides evidence that changes in innovative activities as measured by R & D intensity and the use of high-tech capital play an important role in explaining changes in

the wage structure. He finds that increases in the return to schooling between 1979 and 1989 were most pronounced in industries with a greater R & D intensity and more high-tech capital. Krueger (1993) argues that computers change the structure of wages and shows that workers who use computers are paid more. The effect of computer use on wages is greater for educated workers.

A positive relation between returns to education and computer use (or other technologies) does not necessarily mean that it is technology that drives up the wages of skilled workers. A large body of evidence exists demonstrating that workers with the highest ability and hence the highest wages are given the best technologies to use. This means that it is rather selection and not the increase in productivity that explains the computer wage premium. DiNardo and Pischke (1997), for example, find a positive correlation between wages and computer use in German data, which is similar to the finding of Krueger (1993). However, they show that the correlation between wages and pencil use is equally robust, which is a point in favour of the selection hypothesis. Likewise, Entorf and Kramarz (1998) emphasise that in France the cross-sectional association between wages and computer use disappears once they control for unobserved individual characteristics. One should thus be careful in interpreting the computer-wage correlation as the causal effect of technical change on wages.

Several studies that use firm-level data find a strong positive relation between technology and interindustry wages. It is not clear, however, whether this effect arises because of sorting. Bartel and Sicherman (1999) address this issue by using individual-level data in order to explain differences in interindustry wages. They conclude that sorting is the dominant explanation for higher wages in industries that are subject to faster technological change. Similarly, Doms, Dunne and Troske (1997) find that the positive effect on wages disappears once they account for individual fixed effects. Chennels and Van Reenen (1997) show that the effect of technology on wages disappears once they use industry-level measures of technological opportunity as an instrument for the adoption of new microelectronic technologies at the plant level.

To understand the effect of technological change on employment, assume that a firm decides to implement a computer-assisted production process. The implementation of this new process allows the firm to save on labour, which means that it can produce the same amount of output as before with a lower level of employment. This initial drop in employment is

accompanied by a cost reduction, which may be reflected in a decrease in prices. The latter may translate into an increase in the output of the firm, inducing employment to increase. Whether employment is higher before or after the adoption of the new technology depends on a variety of factors. The positive employment effect is smaller if the firm has some degree of market power and passes only part of the cost reduction on in the form of lower prices. Economies of scale may magnify the positive employment effect. If consumers react strongly to changes in prices, then the positive employment effect is likely to be large. Also, product innovations as opposed to process innovations have generally a stronger output expansion effect and hence are more likely to affect employment positively. Summarising, the effect of technological change on the level of employment is a priori far from clear.

Cross-industry studies on the relationship between employment and technology have been relatively scarce. Analysing the OECD STAN/Anberd database on manufacturing, Blechinger, Kleinknecht, Licht and Pfeiffer (1998) show that industries with higher R & D intensity expanded more quickly. Firm-level studies provide a wide variety of results from different countries. It appears that product innovation has a positive effect on employment growth (e.g. Entorf and Pohlmeier, 1990, for German firms). Evidence concerning process innovations is rather mixed. Some studies find positive effects (e.g. Blanchflower and Burgess, 1998, for the UK and Australia and Blechinger et al., 1998, for Dutch firms). Greenan and Guelllec (2000) conclude for France that

process innovations have a strong positive effect at the firm level, but that this effect disappears at the industry level. They find the opposite for product innovations. Note, however, that firms may introduce new technology when they expect demand conditions to improve, which may lead to an upward bias in the coefficient on the measure of technology. Finally, Entorf, Gollac and Kramarz (1999) show that computer users are protected from job losses in the short run, that is as long as bad business conditions do not last too long. But also here the question arises as to whether it is not rather selection, which determines not only wage gains but also job losses.

This review of recent studies on technology, demand for education, wages and employment reveals a strong positive correlation between technology and the relative demand for skilled workers for different time periods and across countries. This finding seems to be robust and suggests that technology is on average skill biased. There also exists some evidence of a positive correlation between wages and large technological innovations. However, measures based on the diffusion of technology, such as computer use, provide no evidence of the existence of a causal effect of technology on wages. Similarly, the positive relation between interindustry wages and technology seems to be largely due to sorting. Evidence on total employment is mixed. Product (process) innovation seems to be positively (negatively) associated with employment. Hence, the only definite conclusion we are able to draw is that the recent technological change was on average skill biased.

## 2. Cross-country data on human capital <sup>(34)</sup>

Most governments gather information on a number of educational indicators through population censuses, labour force surveys and specialised surveys. Various international organisations collect these data and compile comparative statistics that provide easily accessible and (supposedly) homogeneous information for a large number of countries. Perhaps the most comprehensive regular source of international educational statistics is Unesco's statistical yearbook. This publication provides reasonably complete yearly time series on school enrolment rates by level of education for most countries in the world and contains some data on the educational attainment of the adult population, government expenditures on education, teacher/pupil ratios and other variables of interest. Other Unesco publications contain additional information on educational stocks and flows and some convenient compilations. Other useful sources

include the UN's *Demographic yearbook*, which also reports educational attainment levels by age group and the IMF's *Government finance statistics*, which provides data on public expenditures on education. Finally, the OECD also compiles educational statistics both for its member States (e.g. OECD, 2000) and occasionally for larger groups of countries.

### (a) Data on schooling

The Unesco enrolment series has been used in a large number of empirical studies of the link between education and productivity. In many cases, this choice reflects the easy availability and broad coverage of these data rather than their theoretical suitability for the purpose of the study. Enrolment rates can probably

<sup>(34)</sup> This section is partly based on de la Fuente and Doménech (2000).

be considered an acceptable, although imperfect, proxy for the flow of educational investment. On the other hand, these variables are not necessarily good indicators of the existing stock of human capital since average educational attainment (which is often the more interesting variable from a theoretical point of view) responds to investment flows only gradually and with a very considerable lag.

In an attempt to remedy these shortcomings, a number of researchers have constructed data sets that attempt to measure directly the educational stock embodied in the population or labour force of large samples of countries. One of the earliest attempts in this direction was made by Psacharopoulos and Arriagada (P&A, 1986) who, drawing on earlier work by Kaneko (1986), report data on the educational composition of the labour force in 99 countries and provide estimates of the average years of schooling. In most cases, however, P&A provide only one observation per country.

More recently, there have been various attempts to construct more complete data sets on educational attainment that provide broader temporal coverage and can therefore be used in growth accounting and other empirical exercises. The existing data sets on educational attainment have been constructed by combining the available data on attainment levels with the Unesco enrolment figures to obtain series of average years of schooling and the educational composition of the population or labour force. Enrolment data are transformed into attainment figures through a perpetual inventory method or some short-cut procedure that attempts to approximate it.

Most of the studies in the macroeconomic literature we review in this report rely on one of the following databases.

- **Kyriacou (1991)** provides estimates of the average years of schooling of the labour force (*YS*) for a sample of 111 countries. His data cover the period 1965–85 at five-year intervals. He uses Unesco data and P&A's attainment figures to estimate an equation linking *YS* to lagged enrolment rates. This equation is then used to construct an estimate of *YS* for other years and countries.
- **Lau, Jamison and Louat (1991) and Lau, Bhalla and Louat (1991)**. These studies use a perpetual inventory method and annual data on enrolment rates to con-

struct estimates of attainment levels for the working-age population. Their perpetual inventory method uses age-specific survival rates constructed for representative countries in each region but does not seem to correct enrolment rates for dropouts or repeaters. 'Early' school enrolment rates are estimates constructed through backward extrapolation of post-1960 figures. They do not use or benchmark against available census figures.

- **Barro and Lee (B&L, 1993)** construct education indicators combining census data and enrolment rates. To estimate attainment levels in years for which census data are not available, they use a combination of interpolation between available census observations (where possible) and a perpetual inventory method that can be used to estimate changes from nearby (either forward or backward) benchmark observations. Their version of the perpetual inventory method makes use of data on gross enrolments<sup>(35)</sup> and the age composition of the population (to estimate survival rates). The data set contains observations for 129 countries and covers the period 1960–85 at five-year intervals. Besides the average years of education of the population over 25, Barro and Lee report information on the fraction of the (male and female) population that has reached and completed each educational level. In a more recent paper (B&L, 1996), the same authors present an update of their previous work. The revised database, which is constructed following the same procedure as the previous one (except for the use of net rather than gross enrolment rates), extends the attainment series up to 1990, provides data for the population over 15 years of age and incorporates some new information on quality indicators such as the pupil/teacher ratio, public educational expenditures per student and the length of the school year. Some further extensions, refinements and updates of this database have been made available by the authors in recent years and are discussed in Barro and Lee (2000) and Lee and Barro (2001).
- **Nehru, Swanson and Dubey (NSD, 1995)** follow roughly the same procedure as Lau, Jamison and Louat (1991) but introduce several improvements. The first is that Nehru et al. collect a fair amount of enrolment data prior to 1960 and do not therefore need to rely as much on the backward extrapolation of enrolment rates. Secondly, they make some adjustment for grade repetition and dropouts using the limited information available on these variables.

<sup>(35)</sup> The gross enrolment rate is defined as the ratio between the total number of students enrolled in a given educational level and the size of the population which, according to its age, 'should' be enrolled in the course. The net enrolment rate is defined in an analogous manner but counting only those students who belong to the relevant age group. Hence, older students (typically repeaters) are excluded in this second case.

We can divide these studies into two groups according to whether they make use of both census attainment data and enrolment series or only the latter. The first set of papers (Kyriacou and Barro and Lee) relies on census figures where available and then uses enrolment data to fill in the missing values. Kyriacou uses a simple regression of educational stocks on lagged flows to estimate the unavailable levels of schooling. This procedure is valid only when the relationship between these two variables is stable over time and across countries, which seems unlikely although it may not be a bad rough approximation, particularly within groups of countries with similar population age structures. In principle, Barro and Lee's procedure should be superior to Kyriacou's because it makes use of more information and does not rely on such strong implicit assumptions. In addition, these authors also choose their method for filling in missing observations on the basis of an accuracy test based on a sample of 30 countries for which relatively complete census data are available.

The second group of papers (Louat et al. and Nehru et al.) uses only enrolment data to construct time series of educational attainment. The version of the perpetual inventory method used in these studies is a bit more sophisticated than the one in the first version of Barro and Lee, particularly in the case of Nehru et al. <sup>(36)</sup>. On the other hand, these studies completely ignore census data on attainment levels. To justify this decision, Nehru et al. observe that census publications typically do not report the actual years of schooling of individuals (only whether or not they have completed a certain level of education and/or whether they have started it) and often provide information only for the population aged 25 and over. As a result, there will be some arbitrariness in estimates of average years of schooling based on these data and the omission of the younger segments of the population may bias the results, particularly in least developed countries (LDCs), where this age group is typically very large and much more educated than older cohorts. While this is certainly true and may call for some adjustment of the census figures on the basis of other sources, in our opinion it hardly justifies discarding the only direct information available on the variables of interest.

Methodological differences across different studies would be of relatively little concern if they all gave a

consistent and reasonable picture of educational attainment levels across countries and of their evolution over time. Unfortunately, this is not the case. Different sources show very significant discrepancies in terms of the relative positions of many countries and practically all of them display implausible estimates or time profiles for at least some countries. Although the various studies generally coincide when comparisons are made across broad regions (e.g. the OECD versus LDCs in various geographical areas), the discrepancies are very important when we focus on the group of industrialised countries. Another cause for concern is that existing estimates often display extremely large changes in attainment levels over periods as short as five years (particularly at the secondary and tertiary levels).

To a large extent, these problems have their origin in the deficiencies in the underlying primary data. As Behrman and Rosenzweig (1994) have noted, there are good reasons to worry about the accuracy and consistency of Unesco's data on both attainment levels and enrolment rates. De la Fuente and Doménech (2000), after reviewing the available data for OECD countries, argue that the problems noted above can be traced back to shortcomings in the primary statistics, which do not seem to be consistent, across countries or over time, in their treatment of vocational and technical training and other courses of study <sup>(37)</sup>, and reflect at times the number of people who have started a certain level of education and, at others, those who have completed it. They conclude that — despite the fact that the contributions they review represent a significant advance in this area — the available data on human capital stocks are still of dubious quality.

Concerns about poor data quality and its implications for empirical estimates of the growth effects of human capital have motivated some recent studies that attempt to improve the signal to noise ratio in the schooling series by exploiting additional sources of information and introducing various corrections. De la Fuente and Doménech (D&D, 2000) restrict their work to a sample of 21 OECD countries for which they construct new educational attainment series covering the period 1960–90 at quinquennial intervals. They focus on cleaning up the available census and survey data rather than on perfecting the fill-in procedure. After collecting all the information they could find on educational

<sup>(36)</sup> Differences across these studies have to do with the correction of enrolment rates for dropouts and repeaters and with the estimation of survival probabilities. Later versions of Barro and Lee have improved the treatment of these issues.

<sup>(37)</sup> Steedman (1996) documents the existence of important inconsistencies in the way educational data are collected in different countries and argues that this problem can significantly distort the measurement of educational levels. She notes, for example, that countries differ in the extent to which they report qualifications not issued directly (or at least recognised) by the State and that practices differ as to the classification of courses which may be considered borderline between different ISCED levels. The stringency of the requirements for the granting of various completion degrees also seems to vary significantly across countries.

attainment in OECD countries, both from international publications and from national sources, they use a heuristic approach to try to reconstruct a plausible time profile of attainment in each country, eliminating sharp breaks in the series that can only arise from changes in data collection criteria. Their approach involves using judgment to choose among alternative census or survey estimates when several are available and, at times, requires reinterpreting some of the data from international compilations as referring to somewhat broader or narrower schooling categories than the reported one. Missing data points lying between available census observations are filled in by simple linear interpolation. Missing observations prior to the first census observation are estimated, whenever possible, by backward extrapolations that make use of census information on attainment levels by age group. A revised version of this data set (D&D, 2001) also incorporates information provided by national statistical offices in response to a request for assistance channelled through the OECD.

Cohen and Soto (C&S, 2001) follow a roughly similar approach to construct a schooling data set for a much larger sample of 95 countries at 10-year intervals covering the period 1960–2000. They collect census and survey data from Unesco, the OECD's in-house educational database, and the web sites of national statistical agencies, and exploit to the largest extent possible the available information on attainment levels by age group to fill in missing cells through forward and backward extrapolations. Remaining gaps in the data are filled using enrolment rates from Unesco and other sources.

### *Estimates of reliability ratios for different data sets*

Tables A2.1 and A2.2 report estimates of reliability ratios for some of the data sets we discussed in the previous section. Following the methodology proposed by Krueger and Lindahl (2001) and briefly reviewed in Section 3(b)(iii) of the main report, we estimate the reliability ratio  $r_k$  of a given series of average years of schooling (say  $YS_k$ ) by using  $YS_k$  to try to explain alternative estimates of the same variable ( $YS_j$  with  $j \neq k$ ). Hence, the figure reported in the tables below for data set  $k$  is the average value of the slope coefficient in a series of regressions of the form

$$YS_j = c + r_{kj} YS_k$$

where  $j$  denotes the 'reference' data set and varies over the last available version of all data sets different from  $k$ . The reliability ratio of Barro and Lee's (2000) data set, for instance, is estimated by including these authors' estimate of average years of schooling as the explanatory variable in a set of regressions where the reference (dependent) variables are the average years of schooling estimated by Kyriacou (1991), NSD (1995) and Cohen and Soto (2001). Other versions of the Barro and Lee data set, however, are not used as a reference, because the correlation of measurement errors across the same family of estimates is almost certainly very high and this would artificially inflate the estimated reliability ratio.

The exercise we have just described is repeated for several transformations of average years of schooling and for two different samples (OECD and all available countries, including the OECD). In particular, we estimate reliability ratios for years of schooling measured in levels ( $YS_{it}$ ) and in logs ( $ys_{it}$ ), for average annual changes in both levels and logs measured across successive (quinquennial or decennial) observations ( $\Delta YS_{it}$  and  $\Delta ys_{it}$ ), for log years of schooling measured in deviations from their country means ( $ys_{it} - ys_i$ ) and for average annual log changes computed over the period 1965–85<sup>(38)</sup> ( $\Delta ys_i$ ). Notice that  $\Delta ys_{it}$  corresponds to annual growth rates and  $ys_{it} - ys_i$  is the 'within' transformation often used to remove fixed effects. The last row of each table shows average values of the reliability ratio for each type of data transformation (taken across different data sets), and the last column displays the average reliability ratio of each data set (taken over different data transformations). In each table, the different data sets are arranged by decreasing average reliability ratios.

A comparison of Tables A2.1 and A2.2 shows that the estimated reliability ratios are lower for the OECD than for the full sample (of up to 110 countries). This is likely to be misleading. The number of available primary sources that can be drawn upon to construct estimates of educational attainment is probably higher in developed than in underdeveloped countries. As a result, the variation across data sets is likely to be smaller in LDCs, and this will tend to raise the estimated reliability ratio. To a large extent, however, the larger ratios obtained for the full sample will simply reflect a higher correlation of errors across data sets (i.e. an upward bias in the estimated reliability ratio). Hence, the results in Table A2.1 are probably a better measure of the amount of measurement error in existing schooling data sets.

<sup>(38)</sup> This is the longest period over which all the available schooling series overlap.



**Table A2.1: Average reliability ratios, OECD-21 subsample**

	$YS_{it}$	$ys_{it}$	$\Delta YS_{it}$	$\Delta ys_{it}$	$ys_{it} - ys_j$	$\Delta ys_j$	Average
<i>D&amp;D (2001)</i>	0.623	0.716	0.376	0.736	0.894	0.898	0.707
<i>C&amp;S (2001)</i>	0.619	0.709	0.203	0.595	0.776	0.796	0.616
<i>D&amp;D (2000)</i>	0.638	0.727	0.058	0.457	0.873	0.642	0.566
<i>B&amp;L (2000)</i>	0.646	0.595	0.027	0.08	0.679	0.502	0.421
<i>Kyr. (1991)</i>	0.743	0.831	0.020	0.066	0.446	0.243	0.391
<i>NSD (1995)</i>	0.301	0.528	0.059	0.224	0.858	0.277	0.375
<i>B&amp;L (1996)</i>	0.558	0.488	0.026	0.052	0.628	0.357	0.351
<i>B&amp;L (1993)</i>	0.530	0.428	0.018	0.014	0.403	0.318	0.285
<i>Average</i>	0.582	0.628	0.098	0.278	0.695	0.504	0.464

Note: This subsample comprises the 21 OECD countries for which de la Fuente and Doménech have compiled data.

**Table A2.2: Average reliability ratios, all available countries**

	$YS_{it}$	$ys_{it}$	$\Delta YS_{it}$	$\Delta ys_{it}$	$ys_{it} - ys_j$	$\Delta ys_j$	Average
<i>C&amp;S (2001)</i>	0.788	0.919	0.396	0.848	0.958	0.950	0.810
<i>NSD (1995)</i>	0.877	0.920	0.296	0.634	0.834	0.668	0.705
<i>Kyr. (1991)</i>	0.981	1.000	0.092	0.436	0.754	0.693	0.659
<i>B&amp;L (2000)</i>	0.910	0.781	0.145	0.299	0.823	0.752	0.618
<i>B&amp;L (1996)</i>	0.900	0.777	0.117	0.259	0.812	0.709	0.596
<i>B&amp;L (1993)</i>	0.897	0.788	0.129	0.256	0.704	0.563	0.556
<i>Average</i>	0.892	0.864	0.196	0.455	0.814	0.723	0.657

**Notes:**

- The regressions used to estimate the reliability ratios are estimated using all the common observations for each pair of data sets over a sample of 110 countries for which at least two independent estimates are available.
- Data are reported at five-year intervals except by Cohen and Soto who do it at 10-year intervals. To compute reliability ratios for  $\Delta YS_{it}$  and  $\Delta ys_{it}$  in the case of Cohen and Soto, we attribute the observed annualised change or growth rate in H over the entire decade to both of its quinquennia.
- While the true reliability ratio must lie between zero and one, a few of the coefficients of the pairwise regressions are either negative or greater than one. To compute the averages reported in the table, we ignore these values, i.e. assign a value of zero to negative estimates and a value of one to estimates greater than this number.
- The version we use of Barro and Lee (1993) is actually taken from Barro and Lee (1994b). We do not know if the two data sets are identical or if there are minor differences between them.

The overall average value of the reliability ratio in the OECD subsample is 0.464. This suggests that the estimated coefficient of schooling in growth equations is likely to suffer from a substantial downward bias, even without taking into account the further loss of signal that arises when additional regressors are included in these equations. The bias will tend to be smaller for estimates obtained using the data in levels or logs, even when fixed effects are included, but is likely to be extremely large in specifications that use data differenced over relatively short periods. The average reliability ratio is only 0.278 for the data in quinquennial log differences, and 0.098 for level differences taken at the same frequency.

Our results also indicate that the importance of measurement error varies significantly across data sets,

although their precise ranking depends on the data transformation that is chosen. Two of the data sets most widely used in cross-country empirical work, those by Kyriacou (1991) and Barro and Lee (various years), perform relatively well when the data are used in levels, but contain very little signal when the data are differenced. Recent efforts to increase the signal to noise ratio by de la Fuente and Doménech (2001a) and Cohen and Soto (2001) seem to have been at least partially successful, but even in these cases the potential estimation bias remains large.

**(b) Direct measures of skills and achievement**

It is clear that average years of schooling can be at best an imperfect proxy for the average stock of human capital of the population. The level of skill will vary



across countries with similar levels of school attainment if there are differences among them in the quality of their education systems or in the extent to which skills

are built up or maintained through other channels, such as various types of post-school training and on-the-job learning.

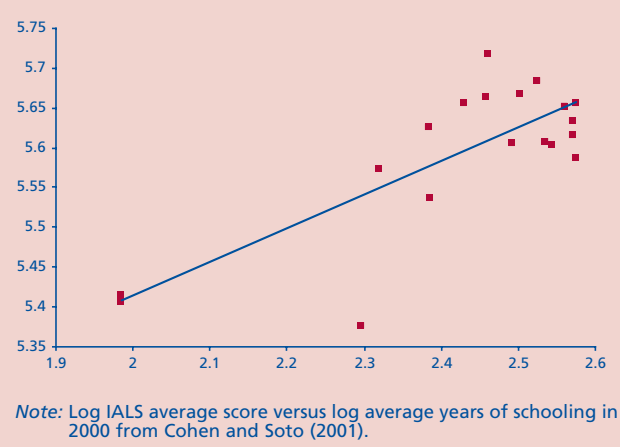
**Table A2.3: International achievement and literacy tests**

<i>Years of data collection</i>	<i>Conducted by</i>	<i>Subjects</i>	<i>Number of countries</i>	<i>Population tested</i>
1964	IEA	mathematics	13	13, final sec.
1970–72	IEA	science	19	10, 14, final sec.
		reading	15	10, 14, final sec.
1982–83	IEA	mathematics	20	13, final sec.
1984	IEA	science	24	10, 14, final sec.
1988	IAEP	mathematics	6	13
		science	6	13
1991	IEA	reading	31	9, 14
1990–91	IAEP	mathematics	20	9, 13
		science	20	9, 13
1993–98	IEA (TIMSS)	mathematics	41	9, 13, final sec
		science	41	9, 13, final sec.
1994–1998	OECD (IALS)	reading and quantitative literacy	23	16–65
2000	OECD (PISA)	reading, mathematical and scientific literacy	32	15

– Key: IEA = International Association for the Evaluation of Educational Achievement; IAEP = International Assessment of Educational Progress; IALS = international adult literacy survey; PISA = programme for international student assessment; final sec. = final year of secondary schooling.  
– Source: Updated from Lee and Barro (2001).

While the available information is much scarcer than for formal school attainment, student scores in standardised international achievement tests and some recent literacy studies provide some data on the quality of educational outputs and on the skill level of the population that can be a useful complement to the schooling data reviewed above. Table A2.3 summarises the standardised tests in mathematics, science and reading that have been administered by different international organisations at various times, as well as two recent literacy studies sponsored by the OECD (known as PISA and the IALS). This last group of studies is of particular interest because the studies specifically attempt to measure the extent to which respondents have developed basic skills that will be essential both at work and in everyday life rather than their mastery of a standard curriculum. These skills include the ability to understand and use information and apply simple mathematical techniques and basic scientific knowledge to the solution of practical problems.

**Figure A2.1: Literacy skills versus average schooling**



The IALS (international adult literacy survey) study is the only available one that focuses on the entire population of working age rather than on young subjects currently enrolled in school. Hence, it probably provides the best available data for testing the hypothesis,

implicit in most of the empirical work we survey below, that educational attainment can be used as a proxy for the stock of human capital because many of the skills that are relevant in production are probably acquired in school. Figure A2.1 shows the relationship between average national literacy scores (after averaging over the three types of skills measured in the study) and average years of schooling in 2000 (taken from Cohen and Soto, 2001), with both variables measured in logs. When we use average schooling to try to explain literacy scores in a simple regression, the estimated slope coefficient is 0.423, with a  $t$  ratio of 3.83, and the  $R^2$  of the regression is 0.494. Hence, educational attainment alone explains half of the observed variation in literacy

scores, suggesting that average schooling is indeed a useful proxy for skills, but a far from perfect one. If we interpret the coefficient of this regression as a reliability ratio (with schooling as a noisy measure of skill levels), its estimated value reinforces the standard concern in the literature that measurement error will lead to the underestimation of the impact of human capital on productivity. Or, to put it differently, it seems likely that we can learn something useful by examining the correlation between school attainment and growth, but it is almost certain that in order to get a better picture of the importance of human capital we need to find ways to control also for the quality of education and for other ways in which skills can be acquired.

### 3. Results of macroeconomic studies on human capital and growth

This section reviews the main empirical studies that have attempted to measure the contribution of human capital accumulation to economic growth<sup>(39)</sup>. We organise the discussion of the bulk of the literature around groups of studies defined in terms of their econometric specification, distinguishing between papers that estimate production function-based specifications and those based on convergence equations and, within the latter group, between those based on ad hoc specifications and those that have estimated structural equations along the lines of Mankiw, Romer and Weil (1992). We consider in a separate section some recent studies that have focused on data quality and measurement error. As noted in the text, practically all of these studies use some schooling indicator (either enrolment rates or average years of schooling) as a proxy for human capital. There are also a small number of studies that explore the growth effects of more direct measures of educational or labour force quality based on internationally comparable achievement tests. These are discussed separately.

For easy reference, Box A3.1 summarises the notation used in the numerous tables that appear below. Wherever possible, we report the estimated values of structural parameters (i.e. the coefficients of the production and technical progress functions) which are denoted by the same symbols as in Box 2 in the main text. Otherwise, the tables show the relevant regressor. Standard explanatory variables include the rates of investment in physical and human capital ( $sk$  and  $sh$ ), initial income per capita or per worker ( $Q$ ) and years of schooling ( $YS$ ). In the last two cases, lower case letters

are used to denote logarithms and the symbol  $D$  to denote annual changes.

#### (a) Ad hoc growth equations

A simple way to explore the connection between human capital and growth is to introduce some indicator of human capital in a convergence equation in which the growth rate of real output over a given period is explained in terms of the initial level of income per capita and other variables motivated by informal theoretical considerations. This approach has been followed with generally encouraging results in a large number of papers in the literature using (mostly cross-section) data for the post-World War II period.

The results of some of the earlier studies in the literature are summarised in Table A3.1. The explanatory variables used in the regressions include the initial level of per capita income ( $Q_0$ ), different indices of human capital at the beginning of the period ( $H_0$ ), and the rates of investment ( $s_k$ ) and population (or labour force) growth ( $n$ ). Landau (1983, 1986), Baumol, Batey Blackman and Wolf (1989) and Barro (1991) find that the coefficient of initial human capital is positive and highly significant. Baumol et al. observe that the inclusion of a proxy for education is enough to 'set things right' in a convergence equation in which, when the only explanatory variable is initial income, the neo-classical prediction that poorer countries tend to grow faster than rich ones seems to fail.

<sup>(39)</sup> This section is based on de la Fuente (2002).

### Box A3.1: Notation used in the tables

As noted in the main text, most structural analyses of the determinants of economic growth are based on a Cobb-Douglas aggregate production function of the form

$$(1) Y_{it} = A_{it} K_{it}^{\alpha_k} H_{it}^{\alpha_h} L_{it}^{\alpha_l}$$

where  $Y_{it}$  denotes the aggregate output of country  $i$  at time  $t$ ,  $L_{it}$  is the level of employment,  $K_{it}$  the stock of physical capital,  $H_{it}$  the average stock of human capital per worker, and  $A_{it}$  an index of technical efficiency or total factor productivity (TFP). In most applications,  $H$  is typically replaced by years of schooling ( $YS$ ) or by an exponential function of it,  $H = \exp(\theta YS)$ .

The tables shown below respect this notation for the different inputs of the production function and for the relevant output elasticities,  $\alpha_i$  (with  $i = k, h, l$  or  $ys$ ). On occasion, the production function also includes as an argument the stock of R & D capital, whose elasticity will be denoted by  $\alpha_{R \& D}$ . The symbol  $\rho$  will denote the coefficient of  $YS$  measured in levels in an otherwise standard Cobb-Douglas production function (this is the Mincerian specification discussed in Box 2 in the text), or the result of dividing  $\alpha_{ys}$  by average  $YS$  in the sample when a standard Cobb-Douglas is estimated with  $YS$  in logs. In both cases, this parameter measures the percentage increase in output that would follow from a unit increase in  $YS$  and  $\alpha_{ys}$  the elasticity of output with respect to years of schooling.

Barro (1991) estimates two different versions of the convergence equation in a first attempt to identify the channels through which education affects growth. In the first, he does not control for fertility or the investment rate, while in the second equation he includes both of these variables. As can be seen in the table, the human capital indicators lose part of their significance and have smaller coefficients in the second equation. This suggests that an important part of the effect of education on growth is channelled through a reduction in the fertility rate (education increases the opportunity cost of female time) and an increase in the investment coefficient (human and physical capital are complementary inputs). The results of two auxiliary regressions in which fertility and the investment rate are the dependent variables tend to confirm these results, for they

As in Box 2, lower case letters will be used for factor stocks measured in logarithms, and the symbol  $\Delta$  will indicate the average annual change in the relevant variable. Hence,  $YS$  is years of schooling in levels,  $ys$  the same variable in logarithms,  $\Delta YS$  the average annual increase in years of schooling over the relevant period, and  $\Delta ys$  the average annual increase in the logarithm of the same variable, which is approximately equal to the annual percentage change in the original variable measured in levels. Similarly,  $\Delta \alpha$  will stand for the rate of technical progress.

We will use  $Q = Y/L$  to stand for output per capita or per worker. The symbol  $s_i$  will denote the fraction of GDP invested in type- $i$  capital or, in the case for human capital, some proxy for this variable typically based on school enrolments. The symbol  $\gamma_i$  will be used for the coefficients of the technical progress function, except for the rate of technological diffusion, which will be denoted by  $\lambda$ , as in

$$(2) \Delta a_{it} = \gamma_{io} + \lambda b_{it} + \gamma_{ys} YS_{it} + \gamma_{bh} YS_{it} b_{it} + \gamma_r R\&D_{it}$$

where  $b$  stands for the gap with the world technological frontier. The parameter  $\beta$  will be interpreted as the rate of convergence and is typically the coefficient of initial income per capita in a convergence equation.

show that high-school enrolments are associated with high investment shares and low fertility rates<sup>(40)</sup>.

In the papers cited so far, the introduction of human capital variables is justified mainly by their possible impact on the rate of innovation and technology adoption. In principle, the best variable to capture such effects would be some indicator of the average educational attainment of the labour force. However, the lack of comparable data for a sufficient number of countries forces the three authors to use flow variables (enrolment rates) as proxies for the relevant stock variables<sup>(41)</sup>. Although all of them take the precaution of using lagged enrolment rates, these could be highly correlated with investment in human capital over the sample

<sup>(40)</sup> Barro and Lee (1994a) provide a more detailed analysis of the relationship between education and fertility. Benhabib and Spiegel (1994) also find that education has a positive effect on investment.

<sup>(41)</sup> Landau (1983, 1986) uses a weighted average of the primary, secondary and university enrolment rates. Baumol et al. (1989) re-estimate the same equation with each of these variables and find that secondary schooling yields the best results. They argue that this is the preferable variable from a theoretical point of view, since it should be the best proxy for the technological absorption capacity of a broad segment of the population. Barro (1991) includes the primary and secondary enrolment rates as separate explanatory variables.

period. Hence, the results of these studies do not allow us to discriminate clearly between level and rate effects. The work of Kyriacou (1991), however, provides more direct evidence of the importance of the second type of effects. Using a procedure described in Section 2(a) of

this appendix, this author constructs an estimate of the average stock of human capital (the average years of schooling of the labour force,  $YS$ ) which he then includes in convergence regressions with results qualitatively similar to those we have just discussed <sup>(42)</sup>.

**Table A3.1: Human capital in ad hoc convergence equations**

Source	$Q_0$	$H_0$	$s_k$	$n$		Other variables	Sample
[1] Landau (1983)	-0.0021 (6.18)	0.026 (7.64)			N = 96 R <sup>2</sup> = 0.82	<i>GCONS</i> (-). <i>POP</i> (0). <i>CLIM</i> (Y)	1961–76 96 countries
[2] Landau (1986)	-0.311 (4.80)	0.032 (4.87)	0.059 (1.37)	-0.262 (1.35)	N = 151 R <sup>2</sup> = 0.714	<i>POP</i> (0). <i>GCONS</i> (-). <i>GINV</i> (0). <i>GED</i> (0). <i>T</i> (0). <i>INF</i> (-). <i>OIL</i> (+). <i>DP</i> (-)	1960–80 65 countries
[3] Baumol et al. (1989)	0.622 (1.72)				N = 103 R <sup>2</sup> = 0.029		1960–81 103 countries
	-1.47 (2.47)	1.615 (*) (5.00)			N = 103 R <sup>2</sup> = 0.227		
[4] Barro (1991)	-0.0075 (6.25)	0.0305 (*) (3.86)			N = 98 R <sup>2</sup> = 0.56	<i>GCONS</i> (-). <i>DISTOR</i> (-). <i>REV</i> (-). <i>ASSAS</i> (-)	1960–85 98 countries
		0.025 (**) (4.46)					
	-0.0077 (8.56)	0.01 (*) (1.15)	0.064 (2.00)	-0.004 (3.07)	N = 98 R <sup>2</sup> = 0.62	<i>GCONS</i> (-). <i>DISTOR</i> (-). <i>REV</i> (-). <i>ASSAS</i> (-)	
		0.0118 (**) (2.07)					
[5] Kyriacou (1991)	-0.009 (2.43)	0.0062 (4.09)			N = 89 R <sup>2</sup> = 0.17		1970–85 89 countries

**Notes:**

- t statistics are shown in parentheses below each coefficient.
- N is the number of observations in the sample.
- The dependent variable is the average growth rate of real per capita income during the sample period.
- Definition of  $H_0$ : (\*) = secondary enrolment rate; (\*\*) = primary enrolment rate. Landau uses a weighted average of three enrolment rates (primary, secondary and university), and Kyriacou an estimate of the average number of years of schooling of the population.
- Other variables: *GCONS* = public consumption/GDP; *POP* = total population; *CLIM* = climate zone dummy; *T* = trend; *GINV* = public investment/PIB; *GED* = public expenditure in education/GDP; *INF* = inflation rate; *OIL* = dummy for oil producers; *DP* = distance to the closest harbour; *DISTOR* = Barro's index of distortions affecting the price of capital goods; *REV* = number of coups and revolutions; *ASSAS* = number of political assassinations.
- (+) and (-) indicate a significant coefficient of the corresponding sign; (Y) denotes significance, and (0) lack of it.
- Landau (1986) uses pooled data with four-year subintervals; the rest of the regressions use cross-section data by countries.

Table A3.2 shows some of the results of several more recent studies by Barro and various co-authors using a pooled data set with two or three observations per country based (mostly) on decade-long averages for a large sample of countries. The data come from various versions of Summers and Heston's Penn World Table and Barro and Lee's (1993) schooling data set and

from miscellaneous other sources. The methodology is similar in all the cases: a separate cross-section convergence equation is estimated for each period, imposing the equality of the coefficients across equations and instrumenting some of the regressors with their lagged values in order to mitigate possible endogeneity biases.

<sup>(42)</sup> Actually, the interpretation problem does not disappear completely since Kyriacou's estimate of  $YS$  is a weighted sum of enrolment rates in the relatively recent past.

The results of the different studies are largely consistent with one another and generally supportive of the view that human capital has a positive effect on growth. The log of life expectancy, which can be expected to be a good proxy for the health component of human capital, appears with a positive and highly significant coefficient in all the equations shown in the table<sup>(43)</sup>. The pattern of results for the schooling indicators is, as we will see, more complex but is generally consistent with the existence of some sort of positive growth effect and suggests also that an increase in educational attainment helps to speed up convergence, possibly by facilitating the adoption of foreign technologies.

Barro and Lee (B&L, 1994a) find that the average number of years of male secondary schooling (*male*  $YS_{sec}$ ) enters the equation with a positive and significant coefficient (equation [1]). This variable, moreover, behaves better than the corresponding flow variable as can be seen in equation [2], where the secondary enrolment rate (*SEC.ENR*) is not significant. The number of years of university education ( $YS_{high}$ ), which is added as a regressor in equation [3], is also not significant. Finally, equation [4], which includes both the stock variable and its first difference (*male*  $\Delta YS_{sec}$ ), suggests that male secondary schooling has both level and rate effects. Most of these findings are replicated by Barro and Sala i Martin (B&S, 1995) (see equation [5]). In this study, however, the change in the years of male secondary schooling is not significant. On the other hand, B&S find indications that educational expenditure matters and that human capital contributes to fast convergence. This can be seen in equation [5], where public expenditure in education measured as a fraction of GDP (*GED*) and the interaction term between log initial income per capita and average human capital<sup>(44)</sup> ( $H^*q_0$ ) are significant and display the expected sign. Finally, Barro (1997) confirms the significance of a broader indicator of male schooling (the average years of secondary and higher education, *male*  $YS_{sec+high}$ ) and of the interaction effect between schooling and initial income (see equation [6]).

One problem with these results is that it is difficult to establish whether the positive schooling coefficients should be interpreted as evidence of level or rate effects<sup>(45)</sup>. In part, the problem arises because Barro and

his co-authors do not use a structural specification that can be used to distinguish sharply between these two effects. A second problematic aspect of Barro et al.'s studies has to do with their puzzling results about the growth effects of female schooling. The coefficient of female educational variables is often negative and sometimes significant in B&L (1994) (equations [1] to [4]) and in B&S (equation [5]) and not significantly different from zero with the revised schooling data used in Barro (1997).

In a comment to B&L's (1994a) paper, Stokey (1994) provides a possible explanation for these results on the basis of a combination of measurement error and the existence of a handful of influential and atypical observations (in particular, those corresponding to the so-called east Asian tigers, which are characterised by very high growth rates and display large educational differences across sexes). She suggests dropping the female schooling variable and conjectures that, given its high correlation with male schooling, the coefficient of the latter will fall, casting some doubt on its statistical significance. Lorgelly and Owen (1999) take up Stokey's suggestion and, using the same data, explore the sensitivity of Barro and Lee's results to the omission of the Asian tigers (Hong Kong, Singapore, Taiwan and South Korea) and of female schooling. Their results confirm that omitting the east Asian economies renders both male and female secondary schooling insignificant and that omitting female schooling in the full sample considerably reduces the coefficient of male secondary attainment. When the two schooling variables are combined into a single measure of average years of schooling of the entire population, this variable is only borderline significant. The authors interpret their findings as an indication of the statistical fragility of Barro and Lee's results — an issue which is also raised in a more general context by Levine and Renelt (1992).

Barro (1997) illustrates and discusses a problem to which we return repeatedly below. He notes, in particular, that some of his key results (and, in particular, those pointing to positive growth effects of human capital) tend to break down when the estimation is done in first differences in order to eliminate country-specific effects. This is illustrated in Table A3.3, where the original pooled-data results (using a slightly different speci-

<sup>(43)</sup> Sachs and Warner (1997) also find that this variable enters significantly in a growth regression. In a more recent paper that uses essentially the same methodology and a slightly longer sample, Barro (2000) finds that health-related variables generally display the expected signs but are often not significant. Except for this, the results of this study are very similar to those of previous ones by the same author.

<sup>(44)</sup> See the notes to the table for the definition of  $H$ .

<sup>(45)</sup> Barro and his co-authors tend to interpret the positive coefficient of schooling in terms of the contribution of education to the absorption of technology and the effects of imbalances between the stocks of human and physical capital. For a given initial income, countries with high schooling will tend to grow faster because their stock of physical capital will be low, relative to their stock of human capital, and physical capital can be accumulated more rapidly.

Table A3.2: Results of Barro and various co-authors

	[1]	[2]	[3]	[4]	[5]	[6]
<i>Life expectancy</i>	0.0801 (5.76)	0.0829 (5.28)	0.0806 (5.80)	0.0903 (6.10)	0.076 (5.07)	0.0418 (3.01)
<i>male YS<sub>sec</sub></i>	0.0138 (3.29)	0.0133 (3.09)	0.0136 (3.16)	0.0199 (4.15)	0.0164 (2.83)	
<i>male YS<sub>sec+high</sub></i>						0.0098 (3.92)
<i>male YS<sub>high</sub></i>			0.000 (0.00)		0.053 (1.77)	
<i>H* q<sub>o</sub></i>					-0.209 (2.16)	-0.0052 (3.06)
<i>male ΔYS<sub>sec</sub></i>				0.289 (2.39)	0.0066 (1.02)	
<i>SEC .ENR male</i>		0.0072 (0.62)				
<i>GED</i>					0.205 (1.90)	
<i>female YS<sub>sec</sub></i>	-0.0092 (1.96)	-0.008 (1.60)	-0.0061 (1.22)	-0.0162 (3.00)	-0.0102 (1.44)	
<i>female YS<sub>high</sub></i>			-0.021 (0.88)		-0.071 (1.97)	
<i>female ΔYS<sub>sec</sub></i>				-0.453 (2.35)	-0.0128 (1.54)	
<i>SEC .ENR female</i>		-0.0119 (0.73)				
<i>R<sup>2</sup> (N)</i>	0.56 (85) 0.56 (95)	0.56 (85) 0.56 (93)	0.56 (85) 0.57 (95)	0.58 (85) 0.57 (95)	0.64 (87) 0.53 (96)	0.60 (80) 0.52 (87) 0.47 (84)
<i>Source</i>	B&L (1994)	B&L (1994)	B&L (1994)	B&L (1994)	B&S (1995)	B (1997)

**Notes:**

- t statistics are shown in parentheses below each coefficient.
- *Additional control variables:* All the equations control for the log of initial GDP per capita (-) and for the following variables (see the notes to the previous table): *GCONS* (-), *REV* (-) and *BMP* (-), where the last variable is the black market premium on foreign exchange and government consumption is measured net of education and defence expenditure. All equations except [6] control for the investment ratio, which is always positive and significant in all cases except for equation [5]. Equations [5] and [6] also include the change in the terms of trade (+). Equation [5] includes as regressors the changes in male and female higher schooling, which are not significant. Equation [6] also controls for the log of the fertility rate (-), and index of democracy (+) and its square (-), the inflation rate (-) and dummies for sub-Saharan Africa, Latin America and east Asia, which have the expected signs but are not significant.
- In equations [1] to [5], two separate regressions are estimated for 1965–75 and 1975–85 (hence the two values of R<sup>2</sup> and sample size reported in the table). In equation [6] the procedure is similar but there is a new observation for 1985–90. The equality of the coefficients across equations is (presumably) imposed. Some regressors are instrumented by their own lagged values.
- The human capital indicator *H* that is used to construct the interaction term with initial GDP per capita (*H\*q<sub>o</sub>*) is different in equation [5] and in equation [6]. In the first case, *H* is the average of five human capital indicators: life expectancy and four schooling variables (male and female average years of secondary and higher schooling), all measured in deviations from sample means. In the second, *H* is the years of male secondary and higher schooling.
- Human capital data are from Barro and Lee (1993) and from subsequent revisions of this data set in Barro (1997).
- *Sources:* B&L = Barro and Lee (1994); B&S = Barro and Sala i Martin (1995); B = Barro (1997).

fication from the one shown in Table A3.2) are compared with those obtained with two alternative specifications, a single cross-section in levels with all variables averaged across subperiods, and an equation in first differences. It is interesting to note that, while the results of the cross-section and pooled-data specifications are rather close, at least qualitatively, the use of first differences leads to the loss of significance of the educational variables and actually reverses the sign of their coef-

ficients. Barro argues that the first difference specification has several important drawbacks. The main one is that it wastes all the cross-sectional information in the data (which accounts for most of the variation in the regressors) and therefore gives less precise estimates. In addition, he stresses that estimates obtained with first-differenced data are more likely to suffer from measurement-error bias and are less robust than other estimates to the likely misspecification of the timing of the



impact of the explanatory variables on growth. While admitting concern about the problem raised by the sensitivity of the results to the specification, he argues that implausible 'panel' results such as those given in equation [3] should be heavily discounted.

**Table A3.3: Alternative specifications in Barro (1997)**

	[1]	[2]	[3]
<i>Life expectancy</i>	0.0388 (3.13)	0.0172 (0.93)	-0.0820 (2.15)
<i>YS<sub>sec+high</sub></i>	0.0123 (5.35)	0.0141 (4.70)	-0.0032 (0.71)
<i>H* q<sub>o</sub></i>	-0.0070 (4.67)	-0.0077 (4.05)	0.0052 (1.49)
<i>Specification</i>	pooled	cross-section	first differences

Note: *t* statistics are shown in parentheses below each coefficient. All equations control for the same additional variables as equation [6] in Table A3.2 except for the regional dummies. Equations [1] and [3] are estimated using a SUR technique without instrumenting some of the regressors and equation [2] is estimated by OLS.

## (b) Results from structural convergence equations

Many recent studies of growth and convergence have made use of the structural convergence equations derived by Mankiw, Romer and Weil (MRW, 1992) from a log-linear approximation to an extended Solow model. In this section, we review the results of a number of these studies, starting with MRW's very influential paper. As will be seen, the pattern of results on human capital is very similar to the one we found in the previous section. Cross-section and pooled estimates generally yield positive results that are consistent with the existence of sizeable level effects. On the other hand, fixed effects and first-difference specifications that rely on the time-series variation in the data often produce insignificant or even negative estimates of the coefficient of human capital in the aggregate production function. As is emphasised in a later section, a possible explanation for these negative findings is related to the weak signal content of differenced schooling data.

Mankiw, Romer and Weil (1992) use cross-sectional data for the period 1960–85 to estimate a structural convergence equation of the form <sup>(46)</sup>

(A3.1)

$$q_{it} - q_{io} = \Gamma + (1 - e^{-\beta T}) \left( \frac{\alpha_k}{1 - \alpha_k - \alpha_h} \ln \frac{s_{ki}}{\delta + g + n_i} + \frac{\alpha_h}{1 - \alpha_k - \alpha_h} \ln \frac{s_{hi}}{\delta + g + n_i} - q_{io} \right)$$

where  $q_{it}$  is log output per capita (using as denominator the working-age population) in country  $i$  at time  $T$ ,  $s_k$  and  $s_h$  the average rates of investment in physical and human capital over the relevant period,  $\delta$  the rate of depreciation, which is assumed to be the same for both types of capital,  $g$  and  $n$  the rates of technical progress and (working-age) population growth. The parameters  $\alpha_k$  and  $\alpha_h$  are the coefficients of physical and human capital in a Cobb-Douglas aggregate production function, and  $\beta$  the convergence parameter that measures the speed at which the economy approaches the steady state or long-run equilibrium determined by the observed investment rates. MRW assume  $g = 0.02$  and  $\delta = 0.03$  and use as their proxy for the rate of investment in human capital ( $s_h$ ) the fraction of the working-age population enrolled in secondary schooling. Implicitly, they also assume a common level of technical efficiency for all countries or, at least, that cross-country differences in TFP can be safely thrown into the error term. Hence, they treat the term  $\Gamma$  in equation (A3.1) as a constant even though the underlying theoretical model suggests that it should vary across countries with differences in initial levels in TFP.

Columns [1] and [2] of Table A3.4 show MRW's results, including the implied values of the coefficients of the production function and the rate of convergence, for two different samples: one formed by 75 countries, and a second comprising the 22 OECD countries with a population above 1 million. The estimated production function coefficients are in general significant and have the expected sign. Their values, moreover, seem quite reasonable when judged from the a priori expectation that they should reflect the shares of the different factors in national income. According to the estimated model, capital's share in national income would be around 40%. Of the remainder, which is labour's share, almost half would be the return on human capital, whose estimated elasticity ( $\alpha_h$ ) is 0.23.

MRW's paper was extremely influential because its appealing results seemed to indicate that a simple extension of the standard neoclassical model provided a satisfactory description of the process of growth and of the evolution of the regional (or national) income distribution <sup>(47)</sup>. The only change required, relative to the more traditional models, was the broadening of the relevant concept of capital in order to include the accumulated investment in education.

<sup>(46)</sup> See Box 2 in Section 3(b) of the main report.  
<sup>(47)</sup> See also Mankiw (1995).

Because of its popularity, MRW's paper provided the starting point for a large number of empirical studies that attempted to extend the original model in various directions, to test the robustness of its results or to improve the quality of the estimation through the use of better data or more adequate econometric techniques. Columns [3] to [8] of Table A3.4 summarise the results of a group of such studies that, making use of cross-section or pooled data, largely corroborated MRW's results and established their robustness to reasonable extensions of the underlying model. Lichtenberg (1992) and Nonneman and Vanhoudt (N&V, 1996) consider a further augmentation of the Solow model in which R & D capital is treated in the same way as physical and human capital. De la Fuente (1998) further controls for government spending, labour market indicators and technological diffusion, and considers a broader measure of human capital investment that takes into account university as well as secondary schooling. In the same line, Vasudeva and Chien (1997) replicate MRW's and N&V's estimates using as a proxy for educational investment a weighted average of the

primary, secondary and university enrolment rates (with weights of 0.2, 0.3 and 0.5 respectively). As can be seen in the table, the results are generally quite satisfactory. Human capital only fails to be significant at conventional levels in N&V (column [6]) and (if we consider the coefficient of  $\ln s_h$  rather than the corresponding parameter of the production function) in MRW's OECD subsample (column [2]). Using essentially the same data and the exact same sample, N&V show, however, that results improve considerably when a broader measure of educational investment is used.

On the other hand, a second set of studies stemming from MRW's paper have shown that these authors' results are not robust along a number of dimensions. Temple (1998a) shows that MRW's results are largely driven by a few influential observations. To identify outliers, Temple first estimates the model by a robust estimation technique (least-trimmed squares, due to Rousseeuw, 1984) that fits the model to the half of the sample that provides the best fit, uses the results to identify as outliers those countries with the greatest

**Table A3.4: Cross-section and pooled-data specifications of the MRW model**

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
$\beta$	0.0186 (9.79)	0.0206 (10.30)	0.024	0.017 (17.99)	0.021 (4.20)	0.029	0.033	0.034 (5.25)
$\alpha_k$	0.44 (6.29)	0.38 (2.92)		0.474 (10.09)	0.354 (4.12)	0.35		0.301 (5.07)
$\alpha_h$	0.23 (3.83)	0.23 (2.09)		0.236 (4.21)	0.259 (3.65)	0.148		0.204 (3.74)
$\alpha_{R\&D}$					0.066 [(2.54)]	0.084		0.060 (2.22)
$\ln s_k$	0.506 (5.33)	0.396 (2.61)	0.550 (2.90)			0.413 (2.65)	0.491 (3.61)	
$\ln s_h$	0.266 (3.33)	0.236 (1.67)	0.621 (3.37)			0.175 (1.55)	0.558 (3.60)	
$\ln s_{R\&D}$						0.098 (1.78)	0.099 (2.25)	
<i>Specification</i>	cross-section 1960–85	cross-section 1960–85	cross-section 1960–85	cross-section 1960–85	cross-section 1960–85	cross-section 1960–85	cross-section 1960–85	pooled 1965–95
<i>Sample</i>	75 countries	22 OECD	22 OECD	53 countries	53 countries	22 OECD	22 OECD	19 OECD
<i>Source</i>	MRW	MRW	V&C	Licht.	Licht.	N&V	V&C	dF

**Notes:**

- *t* statistics are shown in parentheses below each coefficient. For ease of comparison, we have calculated some of them using the originally reported standard errors. These calculations may not be entirely accurate due to rounding error.
- Some authors estimate the coefficients of the production function directly; others infer them from the coefficients of the  $\ln s_i$  terms and others report only the latter.
- dF also controls for the share of government spending in GDP and changes in the unemployment and labour force participation rates and includes a dummy for technological laggards and the interaction of this variable with a trend. In this paper, the convergence equation is estimated using pooled data with averages over five-year periods and the proxy for  $s_h$  is total secondary enrolment as a fraction of the labour force, averaged over the current and previous five-year subperiods.
- Sources: MRW = Mankiw, Romer and Weil (1992); V&C = Vasudeva and Chien (1997); Licht. = Lichtenberg (1992); N&V = Nonneman and Vanhoudt (1996); dF = de la Fuente (1998).

**Table A3.5: Various specifications of the MRW model**

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
$\beta$	0.0186 (9.79)	0.014	0.0206 (10.30)	0.015	0.0142 (7.45)	0.014	0.047	
$\alpha_k$	(6.29)	0.44	(2.92)	0.38	(6.86)	0.48	(5.57)	0.468
$\alpha_n$	0.23 (3.83)		0.23 (2.09)		0.23 (4.60)		-0.121 (1.53)	
$\ln s_k$	0.506 (5.33)	0.66 (5.50)	0.396 (2.61)	0.13 (0.65)	0.500 (9.62)	0.59 (6.56)		
$\ln s_n$	0.266 (3.33)	0.00 (0.00)	0.236 (1.67)	0.13 (0.76)	0.238 (3.97)	-0.01 (0.17)		0.00 (0.08)
<i>Specification</i>	cross-section 1960–85	cross-section 1960–85	cross-section 1960–85	cross-section 1960–85	cross-section 1960–85	cross-section 1960–85	differences	cross-section 1960–85
<i>Sample Source</i>	75 countries MRW (1992)	69 OECD Temple (1998a)	22 OECD MRW (1992)	21 OECD Temple (1998a)	98 countries MRW (1992)	92 countries Temple (1998a)	98 countries H&M (1998)	58 LDCs Temple (1998b)

**Notes:**

- t statistics are shown in parentheses below each coefficient (calculated using the originally reported standard errors).
- Equations [2] and [6] from Temple (1998a) include dummies for Africa (-, -), Latin America (0, 0), east Asia (0, +) and the industrial countries (0, 0).
- The countries considered atypical by Temple (1998a) and excluded from the original samples of MRW are Japan in the OECD sample (equation [4]); Argentina, Cameroon, Chile, Hong Kong, India and Zambia in the intermediate sample (equation [2]) and Chad, Chile, Hong Kong, Mauritania, Somalia and Zambia in the broader sample (equation [6]).
- Equation [8] controls for investment in equipment (+) and structures (+) and includes dummies for Latin America (0), Africa (-) and east Asia (+). The schooling variable is also non-significant in other samples, especially when regional dummies are included.

**Table A3.6: Jones (1996)**

	[1]	[2]	[3]	[4]	[5]	[6]
$\ln s_k$	0.425 (2.85)	0.437 (2.60)	0.394 (4.15)	0.506 (3.95)	0.377 (2.73)	0.353 (3.72)
$ys$	1.032 (5.61)	0.500 (3.65)	-0.050 (0.39)			
$YS$				0.191 (6.16)	0.189 (6.10)	0.159 (2.48)
<i>Implied <math>\alpha_k</math></i>	0.298 (4.08)	0.304 (3.75)	0.282 (5.76)	0.336 (6.00)	0.274 (3.75)	0.261 (5.02)
<i>Implied <math>\alpha_{YS}</math></i>	0.724	0.348	-0.036			
<i>Implied <math>\rho</math></i>				0.127	0.137	0.118
$R^2$	0.668	0.522	0.141	0.678	0.571	0.205
<i>Specification</i>	levels	levels	differences	levels	levels	differences
<i>Year</i>	1960	1990	1960–90	1960	1990	1960–90

**Notes:**

- Summers and Heston (1991) data for 78 countries. Years of schooling are from Barro and Lee (1993).
- t statistics are shown in parentheses below each coefficient.
- The rates of investment rate ( $s_k$ ) and population growth ( $n$ ) are averages over relatively short periods around the year whose output level is taken.

residuals, and then re-estimates the model by OLS after excluding outliers. His results for the three samples considered by MRW are shown in Table A3.5 (equations [2], [4] and [6]) next to MRW's original results (equations [1], [3] and [5]) that are reproduced here for convenience. In all cases, he finds that the exclusion of a few outliers (listed in the notes to the table) renders the coefficient of human capital insignificant. The same author (Temple, 1998b) also finds that schooling is not significant in a variety of samples in an extension of MRW's model in which investment in physical capital is disaggregated into its equipment and structures components following De Long and Summers (1991) (see equation [8] in Table A3.7).

Hamilton and Monteagudo (1998) find that MRW's schooling indicator also loses its significance when their model is used to try to explain changes in growth performance across decades. They essentially re-estimate MRW's model in first differences (calculated as the difference between average values for 1960–70 and 1975–85) with the results shown in equation [7] in Table A3.5: while the coefficient of investment in physical capital is very similar to the original estimate (equation [5]), the point estimate of the schooling variable is actually negative.

A study by Jones (1996) reaches rather more optimistic conclusions regarding the contribution of schooling to productivity using a Mincerian specification. Starting from a different theoretical model (that emphasises the role of ideas and technological diffusion), this author derives a steady state equation that is identical to the one implied by MRW's model when the stock of human capital  $H$  is an exponential function of the average years of schooling,  $YS$ . Assuming that countries have reached their steady states, Jones derives an expression that relates (the log) of per capita income,  $q_{it}$ , to the rate of investment in physical capital ( $s_{kit}$ ), average years of schooling ( $YS$ ) and log TFP ( $a$ ). When we interpret it as coming from MRW's model, this equation can be written as follows:

$$(A3.2) \quad q_{it} = \ln \left( \frac{s_{kit}}{\delta + g + n_{it}} \right)^{\frac{\alpha_k}{1 - \alpha_k}} + \frac{\rho}{1 - \alpha_k} YS_{it}.$$

Jones estimates this equation and its standard (non-Mincerian) MRW counterpart (with  $\frac{\alpha_h}{1 - \alpha_k} y_{it}$  replacing the last term in equation (A3.2)) using data in levels for 1960 and 1990 (without controlling for possible differences in TFP levels,  $a_{it}$ ), and with the variables measured in differences across these two years. As can be

seen in Table A3.6, the results vary dramatically depending on the specification chosen for the schooling variable. When years of schooling enter the equation in logs (equations [1] to [3]), the results are similar to those obtained by Hamilton and Monteagudo (1998): the coefficient of the human capital variable (which is positive and significant in the cross-section) becomes negative in the differenced specification. When  $YS$  is entered in levels, by contrast, the human capital coefficient is always positive and significant, and the estimated value of the returns to schooling parameter ( $\rho$ ) is slightly above 10 %, which is above the average of the available microeconomic estimates when these are properly adjusted<sup>(48)</sup>.

### Panel data specifications

The doubts about the growth effects of educational investment that were first motivated by the apparent statistical fragility of some earlier results have been reinforced in recent years by a set of papers which have approached the empirical analysis of convergence from a panel data perspective. Knight, Loayza and Villanueva (KLV, 1993), Islam (1995) and Caselli, Esquivel and Lefort (CEL, 1996) re-estimate the MRW model introducing various fixed effects specifications to pick up possible cross-country differences in levels of TFP. In addition, CEL use an instrumental variables technique to allow for the likely endogeneity of some of the regressors. The results of all three papers indicate that panel estimates of the MRW model which rely heavily on the time-series variation of the data generally yield insignificant or negative coefficients for human capital.

This finding is illustrated in Table A3.7, which summarises some of the key results of these studies. Islam uses a variant of the MRW model in which the growth rate of output per worker appears as a function of the log of the stock of human capital, which is proxied by current average years of schooling from Barro and Lee (1993), rather than as a function of school enrolments. CEL, on the other hand, deviate in this respect from MRW only in that they use the secondary enrolment ratio as a proxy for the investment rate in human capital, and KLV use the same schooling variable as MRW. In spite of these differences in the choice of regressors, and additional differences in the way the fixed effects model is implemented, the results are broadly similar. The estimated coefficient of human capital in the production function is positive and sometimes significant in either cross-section or pooled-data specifications, but becomes negative and often significant when fixed

<sup>(48)</sup> Psacharopoulos (1994) reports an average microeconomic estimate of the return to schooling of 10.1 % for a large sample of countries. The adjustment required to make this figure comparable to macroeconomic estimates brings it down to 6.7 %.

**Table A3.7: Panel estimates of the MRW model**

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
$\beta$			0.0069 (2.76)	0.0375 (4.03)	0.0162 (2.95)	0.0913 (5.71)	0.0107 (3.96)	0.0679 (3.30)
$\alpha_k$			0.8013 (15.01)	0.5224 (8.14)	0.6016 (5.93)	0.2074 (1.97)	0.496 (6.44)	0.491 (4.31)
$\alpha_h$			0.0544 (0.53)	-0.199 (1.81)	0.0174 (0.10)	-0.045 (0.31)	0.18 (3.33)	-0.259 (2.09)
$\ln s_k$	0.105 (10.16)	0.023 (1.61)						
$\ln s_h$	-0.111 (13.26)	-0.065 (5.09)						
Specification	fixed effects	fixed effects	pooled OLS	fixed effects	pooled OLS	fixed effects	pooled OLS	fixed effects and IV
Sample	75 LDCs	96 countries	79 countries	79 countries	22 OECD	22 OECD	97 countries	97 countries
Source	KLV	KLV	Islam	Islam	Islam	Islam	CEL	CEL

Note: Panel data from Summers and Heston's PWT for 1960–85 with five-year subperiods. *t* statistics are shown in parentheses below each coefficient (in the case of CEL and Islam, they are calculated using the originally reported standard errors).

country effects are added to the equation. KLV also report that the coefficient of schooling is positive and highly significant when only its average value for each country is used in the regression.

It is interesting to note that the reaction of the authors to their findings regarding human capital is quite different. KLV argue that, because of the long time lags involved, it makes little sense to use quinquennial enrolment rates as a proxy for the relevant investment in human capital, and advocate disregarding the time-series variation in this variable in the estimation (which, as we noted above, yields positive schooling coefficients). Islam (1995) tries to rescue human capital as a determinant of the level of technological development (which is presumably what is being captured by the country dummies) by observing that the fixed effects are highly correlated with standard measures of educational achievement. The argument, however, merely sidesteps the problem: we know that human capital variables work well with cross-sectional data, but if they really had an effect on the level of technical efficiency, they should be significant when entered into the panel equation. Finally, CEL (1996) seem quite willing to take their negative findings at face value.

### (c) Production function estimates and related specifications

A third group of papers has examined the growth effects of human capital through the estimation of

aggregate production functions and related specifications. As far as we know, the earliest studies in this branch of the literature are due to Kyriacou (1991) and Benhabib and Spiegel (B&S, 1994), who estimate a Cobb-Douglas production function using a single cross-section of growth rates computed over a long period and Kyriacou's (1991) schooling data set. Pritchett (1999) undertakes a similar exercise after constructing a 'Mincerian' stock of human capital using microeconomic estimates of the returns to schooling parameter and data from both Barro and Lee (1993) and Nehru, Swanson and Dubey (NSD, 1995). Finally, Temple (1999, 2001b) uses B&S's and Pritchett's data to examine the robustness of their results to outliers and to some changes in the specification.

The key results of these studies are summarised in Table A3.8. The coefficient of the human capital variable ( $\alpha_h$  or  $\alpha_{ys}$ ) is either non-significant or negative in the basic specifications used in the three earlier studies (equations [1] to [4]). The authors also show that this result is robust to a number of changes in the specification, such as the inclusion of regional dummies or initial income per capita to control for a technological catch-up effect.

Kyriacou (1991) also tests for threshold effects and various non-linearities with generally negative results. Pritchett (1999) argues that the results do not seem to be due to measurement error in human capital, as they remain essentially unchanged when the estimation is repeated using the NSD schooling data to construct



an instrument for his (Barro and Lee based) human capital stock (equation [5]). On a somewhat more positive note, Temple (1999, 2001) finds that the elimination of outliers generates a positive and significant human capital coefficient <sup>(49)</sup> (equation [6], but notice that this requires the elimination of 14 of 78 countries), and that the Mincerian (log-level rather than log-log) specification produces better results than the Cobb-Douglas when the Barro and Lee (1993) data are used (but not with Kyriacou's data, see equations [7] and [8]). Even in this case, however, the schooling variable becomes only borderline significant when regional dummies are added to the equation (equation [9]).

#### Rate effects and interaction with technological diffusion

The results of the production function studies we have just reviewed are largely consistent with the hypothesis that the stock of human capital does not enter the production function as a productive input (i.e. that there are no level effects). Some of these papers, however, find rather clear indications that the level of

education is an important determinant of the rate of technological progress. This positive rate effect, moreover, seems to work at least in part through the role of education in facilitating the absorption of foreign technologies.

Following the work of Nelson and Phelps (1966) and Romer (1989), Kyriacou (1991) argues that the level of education (rather than its first difference) should be included in a growth equation as a determinant of the rate of technological progress. This hypothesis leads to equations [1] and [2] in Table A3.9, where he introduces the log of average years of schooling ( $y_s$ ) or the level of the same variable ( $YS$ ) and its square to try to capture rate effects with encouraging results, particularly in the second case.

Benhabib and Spiegel (B&S, 1994) follow a similar route and extend the model to allow for technological diffusion and rate effects from human capital. In equation [3], they add the log of the stock of human capital ( $ys$ ) to capture rate effects and the log of initial income per capita income ( $q_0$ ), interpreted as a proxy for the

**Table A3.8: Aggregate production functions with human capital**

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
$\alpha_k$	0.449 (5.05)	0.457 (5.38)	0.524 (12.8)	0.501 (15.4)	0.460 (10.18)	0.553 (13.16)	0.432 (5.08)	0.490 (8.18)	0.462 (5.97)
$\alpha_l$	0.261 (0.90)	0.209 (1.01)				0.241 (2.15)	0.266 (1.38)		
$\alpha_h/\alpha_{ys}$	-0.152 (1.68)	0.063 (0.80)	-0.049 (1.07)	-0.104 (2.07)	-0.120 (1.42)	0.165 (4.00)			
$\rho$							0.015 (0.52)	0.080 (2.56)	0.062 (1.76)
Notes					IV				reg. dum.
<i>N</i>	87	78	91	79	70	64	78	91	91
<i>Period</i>	1970–85	1965–85	1960–87	1960–87	1960–87	1960–85	1960–85	1960–87	1960–87
<i>H data</i>	Kyr.	Kyr.	B&L	NSD	B&L, NSD	Kyr.	Kyr.	B&L	B&L
<i>Source</i>	Kyr.	B&S	Prit.	Prit.	Prit.	T99	T01	T01	T01

**Notes:**

- $t$  statistics are shown in parentheses below each coefficient (some of them are computed using the originally reported standard errors).  $N$  is the number of observations (countries) in the sample.
- $\rho$  is the coefficient obtained from a Mincerian specification, where the regressor is the change in the years of schooling rather than the change in their logarithm. In the case of Pritchett, a Mincerian estimate of the stock of human capital (based on an exponential function of the years of schooling and an outside estimate of the relevant coefficient) is inserted into a standard Cobb-Douglas production function and  $\alpha_h$  is the elasticity of this function. Constant returns to scale are imposed when the coefficient of labour ( $\alpha_l$ ) is not shown.
- Cross-sectional data and estimation in long differences or average growth rates by OLS except in equation [5] where instrumental variables are used. Equation [9] includes regional dummies (presumably for Africa, Latin America, east Asia and developed countries, although the author does not say it explicitly).
- For Kyriacou and Benhabib and Spiegel, the dependent variable is the log change in total output during the sample period; in Pritchett, it is the growth rate of output per worker. Pritchett uses least-squares logarithmic growth rates of output and factor stocks.
- Capital stocks are obtained by accumulating investment flows.
- Sources: Kyr. = Kyriacou (1991); B&S = Benhabib and Spiegel (1994); Prit. = Pritchett (1999); T99 = Temple (1999) and T01 = Temple (2001b).
- Sources of human capital data: Kyr. = Kyriacou (1991); B&L = Barro and Lee (1993) and NSD = Nehru, Swanson and Dubey (1995).

<sup>(49)</sup> Temple (1999) follows essentially the same procedure as a previous paper by the same author that we have already commented upon (Temple, 1998a). He uses large residuals from LTS estimates to identify influential observations and deletes them before re-estimating the equation by OLS.

**Table A3.9: Rate effects in aggregate production functions with human capital**

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
$\alpha_k$	0.435 (4.88)	0.417 (6.24)	0.479 (5.10)	0.4723 (6.59)	0.5005 (6.49)	0.5076 (5.38)	0.5517 (4.50)	0.5233 (3.66)
$\alpha_l$	0.176 (0.58)	0.387 (1.49)	0.391 (2.01)	0.188 (1.15)	0.2045 (1.31)	0.1720 (0.74)	0.5389 (1.39)	0.2901 (0.57)
$\alpha_{YS}$	0.018 (0.12)	0.0359 (0.34)						
$q_o$			-0.235 (5.11)					
$YS$		0.0101 (3.25)		-0.00136 (0.09)	0.0021 (0.14)	0.0439 (1.96)	-0.0003 (0.01)	-0.0736 (1.26)
$YS^2$		-0.001 (3.07)						
$ys$	0.0068 (1.79)		0.167 (3.09)					
$YS*(Q_i/Q)$				0.0011 (5.50)	0.0007 (2.33)	0.0003 (0.33)	-0.0001 (0.11)	0.0012 (4.00)
$Q_i/Q$					0.0014	(1.40)		
<i>Notes</i>						rich	middle	poor
<i>N</i>	87	87	78	78	78	26	26	26
<i>Source</i>	Kyr.	Kyr.	B&S	B&S	B&S	B&S	B&S	B&S

**Notes:**

- The human capital variable used in all the equations is the average number of years of schooling from Kyriacou (1991). The sample period is 1970–85 in Kyriacou and 1965–85 in Benhabib and Spiegel (1994).
- Equation [3] includes continent dummies for Latin America and Africa; equation [2] includes dummies for oil producers, mixed economies and Latin America, as well as an index of political instability.

initial level of technical efficiency, to control for a technological catch-up effect. Both variables are significant and have the expected signs.

Starting from this last specification, B&S try to characterise more precisely the channels through which human capital contributes to technological progress. For this purpose, they estimate a 'more structural' model in which they include as regressors, in addition to the average years of schooling,  $YS$ , (which should capture human capital's contribution to domestic innovation), the ratio  $(Q_i/Q)$  between output per worker in the leading country and that in each member of the sample (as a proxy for technological backwardness), and the product of these two variables to capture interaction effects. The results for the complete sample (equations [4] and [5] in Table A3.9) suggest that human capital's effect on growth works mostly through its contribution to technological diffusion and absorption as signalled by the fact that only the interaction term is significant. The results, however, change with the level of development. When the same equation is re-estimated separately for each of three subsamples, the catch-up effect dominates

in the poorest countries (equation [8]), while the contribution to domestic innovation is more important in the richer group (equation [6]). Neither of these variables is significant in the case of the middle-income subsample (equation [7]).

A more recent study that also finds evidence of rate effects in a more complete model is by Engelbrecht (1997). This paper investigates the connection between education and technical progress using an extension of the model estimated by Coe and Helpman (1995). These authors examine the relationship between (estimated) total factor productivity (TFP) and domestic and foreign R & D investment. For each country in a sample of 21 developed economies, an estimate of the domestic stock of technological capital ( $R^d$ ) is constructed by accumulating past R & D expenditures. To allow for cross-country spillovers, the level of domestic TFP is also allowed to be a function of the stock of foreign R & D capital ( $R^f$ ), defined as an average of the domestic stocks of a country's trading partners weighted by the share of each country in total domestic imports.

**Table A3.10: Engelbrecht (1997)**

	[1]	[2]	[3]	[4]
$\Delta \ln R^d$	0.072 (5.29)	0.098 (6.83)	0.098 (6.70)	0.105 (7.15)
$\Delta G7 * \ln R^d$	0.17 (5.54)	0.175 (5.01)	0.163 (4.77)	0.166 (4.86)
$\Delta m \ln R^f$	0.198 (3.93)	0.303 (5.75)	0.249 (4.56)	0.249 (4.72)
$\Delta ys$	0.136 (3.89)			
$ys^{(*)}$		-0.007 (0.42)	0.141 (2.93)	0.128 (2.71)
$ys * \ln Q_i/Q_{us}$			0.127 (3.34)	0.107 (2.82)
$\ln Q_i/Q_{us}$				-0.260 (4.51)

**Notes:**

- Annual panel data for the period 1970–85. Annual data on years of schooling are constructed by interpolating between quinquennial observations from Barro and Lee (1993). *t* statistics are shown in parentheses below each coefficient.
- G7 = dummy variable = 1 for the G7 countries; *m* is the share of imports in GDP.
- Equations [2] to [4] include both period and country dummies.
- (\*) Notice that the coefficient of *ys* is not really an estimate of  $\gamma_h$  as we have defined it. To recover the latter parameter (which measures the contribution of *YS* to TFP growth (rather than that of its logarithm), we have to divide the relevant coefficient in the table by the value of *YS*).

Drawing on Benhabib and Spiegel (1994), Engelbrecht (1997) extends Coe and Helpman's model to allow the rate of TFP growth to be a function of the log of average schooling or its growth rate and of the technological gap with the leading country, proxied by the ratio of each country's real per capita GDP to that of the United States ( $Q_i/Q_{us}$ ). The resulting model is estimated using Coe and Helpman's data together with Barro and Lee's (1993) series on average years of schooling.

The results of the exercise are summarised in Table A3.10. Since the dependent variable is the growth rate of total factor productivity, the explanatory variables enter in log differences when we are looking for a level effect and in logs when it is expected that they will have a direct effect on the rate of technical progress. The coefficients on the domestic and foreign stocks of R & D, and the interaction between home R & D and size (prox-

ied by a dummy variable for the G7 economies) confirm Coe and Helpman's results about the impact of research expenditures, the importance of trade as a vehicle for technological diffusion and the existence of scale effects in innovation. The coefficients of the human capital indicators are consistent with the existence of both level (equation [1]) and rate effects, although the two hypotheses are not tested simultaneously (presumably because a high correlation between *ys* and its first difference would generate multicollinearity problems). It is interesting to note, however, that rate effects (a significant positive coefficient for *ys*) appear only when we introduce a catch-up term and its interaction with the schooling indicator <sup>(50)</sup>.

**(d) Data quality and measurement error**

A number of recent papers argue that the negative results found in the earlier literature can be attributed to low data quality and the resulting measurement error bias (see the main text for a discussion). Krueger and Lindahl (K&L, 2001) argue that Benhabib and Spiegel's (B&S, 1994) widely cited failure to find significant level effects can be attributed to the almost complete lack of signal in the schooling variable they use. According to K&L's estimates, the simple reliability ratio for the relevant regressor (which is the average growth rate of Kyriacou's years of schooling over the entire sample period) is only 0.195. Since the  $R^2$  of a regression of this variable on the remaining explanatory variables of B&S's model is about the same size, the expected value of the human capital coefficient in the absence of a correction for measurement error is zero regardless of its true value. A similar argument, combined with available estimates of reliability ratios for the data sets used in the prior literature (see Section 2(a) of this appendix) suggests that many previous estimates of the coefficients of interest may be similarly flawed.

De la Fuente and Doménech (D&D, 2000, 2001a), Cohen and Soto (C&S, 2001) and Bassanini and Scarpetta (2001) find clear evidence of sizeable and significant level effects using newly constructed data sets which appear to have higher signal to noise ratios than those used in the earlier literature (see Section 2(a) of this appendix). De la Fuente and Doménech estimate several production function specifications that allow for level

<sup>(50)</sup> It is interesting to note that the sign of the interaction term between human capital and the relative productivity variable used as a proxy for technological backwardness is the opposite to that in Benhabib and Spiegel (B&S, 1994). Notice that the latter variable is constructed in different ways in the two studies, with own productivity in the numerator in one case and in the denominator in the other. Hence, B&S's results (equation [5] in Table A3.9) imply that rate effects from human capital are higher in technologically backward countries, whereas Engelbrecht (equation [5] in Table A3.10) finds that they will be larger in more advanced countries. Notice, however, that the samples are different. Engelbrecht's sample is presumably a subset of Benhabib and Spiegel's rich-country subsample, where the interaction term is not significant.

effects using pooled data at quinquennial intervals for a sample of OECD countries. They examine the sensitivity of the results to the quality of the human capital data by re-estimating several specifications with three different data sets: their own, and those constructed by Barro and Lee (1996) and Nehru, Swanson and Dubey (1995). Table A3.11 shows the results obtained with their preferred specification, which incorporates a technical progress function allowing for technological diffusion and for permanent TFP differences across countries. The pattern of results that emerges for the different human capital data sets is consistent with the authors' hypothesis about the importance of educational data quality for growth estimates. The human capital variable is significant and displays a reasonable coefficient with their data (D&D, 2000, equation [3]), but not with the, NSD or B&L series (equations [1] and [2]), which actually produce negative human capital coefficients. Moreover, the coefficients of the stocks of physical and human capital estimated with the D&D data are quite plausible, with  $\alpha_k$  only slightly above capital's share in national income (which is 0.35 in their sample) and  $\alpha_{YS}$  close to one third. Equation [4] is taken from an update of de la Fuente and Doménech (2000) that uses the revised data set described in de la Fuente and Doménech (2001b). This further revision of the data increases the coefficient of the schooling variable by over one third.

In a background study for the OECD growth project (OECD, 2001b), Bassanini and Scarpetta (2001) use D&D's (2001) updated schooling series and in-house OECD data to extend the sample period (from 1971) until 1998 and interpolate the schooling series to obtain annual observations for a sample of OECD countries. These authors estimate a convergence equation à la MRW (written in terms of the stock of human capital rather than the investment rate) which includes fixed effects and is embedded into an error-correction model that allows for short-term deviations from the equilibrium path described by the underlying growth model. Their specification permits short-run coefficients and the convergence parameter to differ across countries but imposes (as is usually done in the literature) a common value of the coefficients of the production function. The estimated level effects are highly significant and much larger than those found by D&D (2000). The parameter values obtained in the preferred specification are  $\alpha_k = 0.13$  and  $\alpha_{YS} = 0.82$ , whereas removing Finland from the sample yields  $\alpha_k = 0.19$  and  $\alpha_{YS} = 0.41$ . The authors settle for an intermediate 'best-guess' estimate of around 0.60 for  $\alpha_{YS}$ , which (since the average years of schooling in the sample is a little over 10) implies a gross Mincerian return to schooling of about 6 %.

Cohen and Soto (2001) construct a new data set for a sample of 95 countries which they use to estimate two alternative 'Mincerian' specifications, finding evidence of sizeable level effects. The first (equations [1] and [2] in Table A3.12) is an MRW-style steady state equation linking income per capita to the rate of investment in physical capital ( $s_k$ ) and school attainment in levels,  $YS$ . The (lagged) urbanisation rate and continental dummies are used to proxy for differences in TFP levels in this equation. The second specification (equations [3] to [5]) relates the growth rate of income per capita to the average annual change in average years of schooling,  $\Delta YS$ . The equation includes an LDC dummy and controls for the urbanisation rate but not for investment in physical capital. The coefficient of years of schooling in the steady state equation (which will be an estimate of  $\rho/(1 - \alpha_k)$ ) is 0.085 when the equation is estimated by OLS and rises to 0.100 when schooling is instrumented to mitigate any potential endogeneity problems. These estimates imply that the gross return to schooling lies between 5.7 and 6.7 %. The estimated coefficient of  $\Delta YS$  in the growth equation is also consistent with this range of values<sup>(51)</sup> when Cohen and Soto's own data set

**Table A3.11: Results of D&D with different human capital data sets**

	[1]	[2]	[3]	[4]
<i>Schooling data</i>	<i>NSD</i>	<i>B&amp;L</i>	<i>D&amp;D 2000</i>	<i>D&amp;D 2001</i>
$\alpha_k$	0.510 (8.30)	0.409 (6.12)	0.373 (7.15)	0.345 (6.83)
$\alpha_{YS}$	-0.148 (2.62)	-0.057 (0.88)	0.271 (2.53)	0.394 (4.57)
$\lambda$	0.100 (6.98)	0.063 (8.27)	0.068 (6.34)	0.074 (7.07)
<i>adj. R<sup>2</sup></i>	0.840	0.811	0.809	0.828

Note: White's heteroscedasticity-consistent  $t$  ratios are shown in parentheses. Only significant country dummies are left in the reported equation. The parameter  $\lambda$  is the coefficient of the technological gap with the United States and measures the speed of technological diffusion. Aside from the schooling variable, the data used to estimate equation [4] are slightly different from the data used in the previous equations because they incorporate the latest revision of the OECD's national accounts series. The sample period is 1960–90, except for the NSD data, which only extend to 1985.

<sup>(51)</sup> The structural interpretation of the coefficient of  $\Delta YS$  in the growth equations is made difficult by the failure to control for the accumulation of physical capital ( $K$ ). If there is perfect capital mobility across countries, so that  $K$  adjusts instantaneously and optimally to changes in  $YS$ , as we have assumed at the individual level to derive the correction factor for microeconomic estimates, the coefficient of  $\Delta YS$  in equations [3] to [5] will also be an estimate of  $\rho/(1 - \alpha_k)$  and can therefore be directly compared to the coefficient of  $YS$  in the steady state equations.

Table A3.12: Cohen and Soto (2001)

	[1]	[2]	[3]	[4]	[5]
$\ln s_k$	0.46 (5.7)	0.41 (2.00)			
$YS$	0.085 (4.0)	0.100 (2.06)			0.00078 (0.76)
$\Delta YS$			0.0845 (2.51)	0.028 (1.45)	0.0864 (2.56)
<i>Urban</i>	0.011 (5.3)	0.010 (2.55)	-0.00019 (2.3)	-0.00015 (1.6)	-0.00024 (2.3)
<i>Poor</i>			-0.0104 (2.80)	-0.0090 (2.31)	-0.0080 (1.60)
$R^2$	0.83	0.83	0.20	0.21	0.21
<i>Schooling data</i>	C&S	C&S	C&S	B&L (2000)	C&S
<i>Notes</i>	OLS levels	IV levels	OLS growth rates	OLS growth rates	OLS growth rates

is used (see equation [3]), but drops sharply when the estimation is repeated with Barro and Lee's (2000) data set (equation [4]).

The one discouraging feature of the studies reviewed in this section is that they generally do not find clear evidence of rate effects. The coefficient of years of schooling in Cohen and Soto's growth equation, which would be an estimate of  $\gamma_n$ , is positive but extremely small and not significantly different from zero (see equation [5] in Table A3.12). Similarly, the introduction of  $ys$  in D&D's growth equation yields a positive but small and insignificant coefficient and sharply reduces the precision of the estimate of the level effect ( $\alpha_{ys}$ ) — a pattern which suggests that the simultaneous introduction of the level and the growth rate of schooling in the same equation can give rise to serious collinearity problems that make it difficult to untangle level and rate effects. Krueger and Lindahl (K&L, 2001), finally, also report some adverse results in this respect. They find that rate effects tend to be positive and significant in standard specifications that constrain the relevant parameter to be equal across countries, but that relaxing this assumption generates insignificant coefficients except for countries with very low levels of education.

### (e) Educational quality and test scores

All the studies we have reviewed until now use enrolment rates or years of schooling as proxies for investment in human capital or for the stock of this factor. An obvious limitation of these indicators is that they

measure only the quantity of schooling. But since workers with the same number of years of schooling may have very different skills across countries depending, among other things, on the quality of national education systems, one would ideally like to complement the standard schooling indicators with some measure of quality. In this section, we review some studies that have tried to do this by using data on educational expenditures and other possible determinants of school quality and/or direct measures of skills such as scores in standardised international achievement tests. Some of these papers also analyse, with conflicting results, the impact of educational expenditures on student achievement.

Dessus (1999) argues that the impact on productivity of an additional year of schooling should vary across countries depending on the quality of the education system. He uses quinquennial data covering the period 1960–90 for a sample of 83 countries to estimate a variant of the MRW model (written in terms of the stock of human capital) with fixed country effects and a varying parameter specification that makes the coefficient of human capital ( $\alpha_{ys}$ ) a function of some indicator ( $QS_i$ ) of the average quality of schooling,

$$\alpha_{ys_i} = \alpha_{ys_0} + \eta QS_i$$

While the results of the study are not very sharp, they are generally supportive of the view that human capital elasticities do indeed differ across countries and are responsive to expenditure variables. As can be seen in Table A3.13, the share of educational expenditure in GDP ( $SEDU$ ) and the average number of students per teacher in primary school ( $PT1$ ) are significant



Table A3.13: Dessus (1999)

	[1]	[2]	[3]	[4]
$q_0$	-0.444 (5.45)	-0.439 (5.26)	-0.457 (5.31)	-0.459 (5.53)
$\ln s_k$	0.214 (4.62)	0.209 (4.43)	0.211 (3.84)	0.220 (4.49)
<i>h. capital param:</i>				
$\alpha_{Y_{50}}$	-0.175 (1.57)	0.714 (3.05)	-0.133 (0.45)	-0.351 (0.05)
$Y_{S_0}$	0.080 (2.96)			
$PT1$		-0.018 (2.76)		
$PT2$			0.013 (0.86)	
$SEDU$				0.111 (2.08)

Note: *t* statistics are shown in parentheses below each coefficient. The varying parameter model is estimated using the specification proposed by Amemya (1978). Average years of schooling are taken from Barro and Lee (1993) and the other educational indicators from Unesco. Notice that there is no temporal variation in the quality indicators, which are defined as averages over the sample period.

and have the expected sign when included alone in the varying parameter specification, but the secondary pupil to teacher ratio ( $PT2$ ) has the wrong sign and is not significant. Dessus also finds that the human capital coefficient increases with average schooling measured at the beginning of the sample period ( $Y_{S_0}$ ). This result may be interpreted as an indication of the importance of intergenerational externalities (children benefit from having educated parents, through learning at home and greater motivation) and may generate threshold effects as argued by Azariadis and Drazen (1990).

Some studies have examined the correlation between growth performance and standardised achievement measures. A paper by Lee and Lee (1995) obtains some suggestive results with data on average national scores in tests administered by the International Association for the Evaluation of Educational Achievement (IEA) in the early 1970s. Using science scores as their proxy for initial human capital, these authors estimate a series of simple cross-section convergence regressions for a sample of 17 (developed

Table A3.14: Results of Lee and Lee (1995)

	[1]	[2]	[3]
$Q_0$	-0.0016 (4.00)	-0.0019 (2.11)	-0.0009 (0.64)
$SCORE$	0.0018 (4.50)	0.0016 (2.29)	0.0027 (4.50)
$PR.ENROL$		0.0008 (0.03)	
$SEC.ENROL$		0.0128 (0.40)	
$YS$			-0.0042 (1.91)
$R^2$	0.572	0.507	0.640

Note: *t* statistics are shown in parentheses below each coefficient.  $YS$  seems to be taken from some version of the Barro and Lee data set, but the authors do not say it explicitly.

and underdeveloped) countries with the results shown in Table A3.14. As usual, the dependent variable is the growth rate of GDP per worker (between 1970 and 1985) and the conditioning variables include the initial level (not log) of GDP per worker ( $Q_0$ ) and one or several schooling indicators. It is interesting to note that the partial correlation between test scores ( $SCORE$ ) and growth is positive and significant even when we control for alternative human capital indicators such as the primary or secondary enrolment rates ( $PR.ENROL$  or  $SEC.ENROL$ ) or the average years of schooling of the adult population ( $YS$ ) and that all these variables tend to lose their significance when  $SCORE$  is included as a regressor. Barro (1998, 2000) confirms Lee and Lee's findings on the significance of test scores but finds that, in some but not all specifications, years of schooling continue to be significant when both variables are entered simultaneously in the growth equation.

A more thorough attempt along similar lines is made by Hanushek and Kimko (H&K, 2000). These authors construct an indicator of labour force quality for a sample of 31 countries using their scores in a number of international achievement tests in mathematics and science<sup>(52)</sup>. This indicator is then included as a regressor in a growth equation with results that are qualitatively similar to those of Lee and Lee (1995). H&K, moreover, conduct extensive robustness checks and provide fairly convincing evidence that the observed correlation

<sup>(52)</sup> The authors use the results of six such tests that were conducted between 1965 and 1991 (four by the IEA and two by the IAEP (International Assessment of Educational Progress)). The countries for which direct score data are available are: Australia, Belgium, Brazil, Canada, Chile, China, Finland, France, West Germany, Hong Kong, Hungary, India, Iran, Ireland, Israel, Italy, Japan, Jordan, Luxembourg, Mozambique, the Netherlands, New Zealand, Nigeria, Norway, the Philippines, Poland, Portugal, Singapore, South Korea, Swaziland, Sweden, Switzerland, Taiwan, Thailand, the United Kingdom, the United States and the former USSR. Some of these are excluded from the sample used in the growth equations due to lack of other relevant variables.

Table A3.15: Hanushek and Kimko (2000)

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
$Q_0$	-0.609 (3.27)	-0.472 (4.92)	-0.460 (4.47)	-0.270 (3.14)	-0.382 (4.72)	-0.370 (4.40)	-0.393 (4.14)	-0.368 (3.87)
$YS$	0.548 (2.62)	0.103 (0.82)	0.100 (0.68)	0.085 (0.75)	0.127 (1.43)	0.120 (1.25)	0.070 (0.67)	0.065 (0.56)
$QL1$		0.134 (5.83)		0.091 (3.96)	0.108 (5.14)		0.112 (5.60)	
$QL2$			0.104 (6.93)			0.094 (5.88)		0.100 (6.67)
$PT1$							0.001 (0.04)	0.006 (0.25)
$PT2$							-0.038 (0.86)	-0.038 (0.84)
$SEDU$							7.388 (0.46)	3.968 (0.26)
$R^2$	0.33	0.73	0.68	0.40	0.41	0.41	0.42	0.42
$N$	31	31	31	25	78	80	76	78

**Notes:**

- $t$  statistics are shown in parentheses below each coefficient.  $N$  is the number of observations (countries).
- The dependent variable is the average annual growth rate of real per capita GDP between 1960 and 1990.
- Initial income is in levels, not in logs.  $YS$  is average years of schooling from Barro and Lee (using a 1994 update of their 1993 paper); this variable enters the equation as the average of the quinquennial observations for each country between 1960 and 1985.
- Equation [4] excludes Hong Kong, Japan, Singapore, South Korea, Taiwan, and Thailand.
- $PT1$  and  $PT2$  are the pupil to teacher ratios in primary and secondary education and  $SEDU$  the share of educational expenditure in GDP.

between test scores and growth reflects, at least in part, a causal relationship.

To approximate the average quality of the stock of workers (rather than that of current students), H&K combine all the test scores available for each country into a single cross-section indicator that is constructed as a weighted average of the standardised values of such scores. They use two alternative standardisation procedures to produce two different (but highly correlated) measures of labour force quality that they denote by  $QL1$  and  $QL2$ . In the first case ( $QL1$ ), the average world score in each year (measured by the percentage of correct answers) is normalised to 50. This procedure implicitly assumes that average performance does not vary over time. In the second case, they allow average performance to drift over time reflecting average US scores in a different but comparable set of national tests. Finally, H&K enlarge their original sample (to around 80 countries) by estimating the values of their quality measures in a number of other countries using an auxiliary equation that is estimated with the original sample. This equation links their quality indicators to

the primary enrolment rate, the average years of schooling of the adult population, the share of educational expenditures in GDP, the rate of population growth and regional dummies for Asia, Latin America and Africa <sup>(53)</sup>.

Labour force quality indicators are then entered into cross-section growth regressions that control for initial real income per capita,  $Q_0$  (measured in levels, not in logs) and by Barro and Lee's (1993) measure of average years of schooling of the adult population ( $YS$ ). As can be seen in Table A3.15, the quality variables display the expected positive sign, are highly significant, and tend to drive out other educational indicators, including average years of schooling, which is only significant when the quality variable is omitted. This result holds for both quality indicators in the original and in the enlarged samples (equations [2] and [3] versus [5] and [6]), and are robust to the omission of east Asian countries (equation [4]), which might conceivably generate a spurious correlation between growth and test scores because of their excellent performance on both accounts. H&K's indicators, moreover, seem to be better

<sup>(53)</sup> The estimated contribution of these variables to labour force quality is positive and significant in the cases of primary enrolments and average schooling, negative and significant for the rate of population growth, and positive but not significant for educational expenditures.

measures of schooling quality than pupil to teacher ratios in primary and secondary schooling (*PT1* and *PT2*) or the share of educational expenditure in GDP (*SEDU*). In fact, these variables are not significant in the growth equation even without controlling for test scores. Finally, the authors also report that their findings are not sensitive, qualitatively or quantitatively, to the inclusion of additional variables such as the share of government consumption in GDP, the investment ratio, a measure of openness to international trade and indices of political instability.

Hanushek and Kimko provide fairly convincing evidence that their results are not, at least in qualitative terms, driven by reverse causation or by omitted variables bias and can therefore be interpreted as evidence of a causal relationship running from the quality of education to growth. They base this conclusion on two separate pieces of evidence. The first is their finding (discussed further below) that various measures of resource input into the school system do not seem to be positively correlated with test scores. It is conceivable, they argue, that growth may feed back into higher educational quality through increased school funding, thereby generating an upward bias in the coefficient of quality in growth regressions. But since funding seems to have no measurable effect on quality, a crucial link in the chain is broken and it is unlikely that the results are driven by reverse causation.

The second piece of evidence is obtained through the estimation of a Mincerian wage equation for a sample of immigrants into the United States. H&K find that the quality of schooling in the country of origin enters the equation with a positive and significant coefficient (after controlling in the usual way for years of schooling and experience) but only in the case of those workers who migrated after completing their education abroad, and not for those who completed their schooling in the United States. The authors interpret this finding as an indication that their quality variables are not simply proxies for relevant country characteristics that are omitted in the growth equation, or even for cultural or family factors that may persist after migration. They note, however, that the microeconomic estimates obtained with immigrant data seem to imply much smaller productivity effects than their macroeconomic growth equation results, and that this suggests that the latter set of estimates may be picking up something more than direct productivity effects.

### *Can quality be purchased?*

The results we have reviewed in this section suggest that educational quality may be just as important as quantity as a determinant of productivity, if not more so.

This raises the obvious policy question of what may be done to improve the quality of education systems. In addition to teaching techniques and curriculum design, a plausible hypothesis is that quality will tend to rise with educational expenditure, as more resources are likely to translate into more and better teachers and into improved facilities.

The evidence on this issue, which comes mostly from microeconomic studies, is conflictual (see, for instance, Hanushek, 1986, and Card and Krueger, 1996a). At the macroeconomic level, we are aware only of two studies that have dealt with the subject and they too reach conflicting results. As noted above, Hanushek and Kimko (H&K, 2000) conclude that standard measures of school resources do not have a perceptible effect on the quality of schooling as measured by achievement tests. Lee and Barro (2001), on the other hand, find a positive correlation between test results and some expenditure variables.

The results of both studies are summarised in Table A3.16. Both sets of authors find that the average attainment of the adult population (*YS*) has a positive impact on school performance. This result, which is consistent with Dessus's (1999) findings, is suggestive of a strong family influence on school outcomes. In the same line, Lee and Barro (2001) also find that income per capita (*q*), which they interpret as a proxy for parents' income has a strong positive effect on test scores, and H&K report that test scores tend to be lower in countries with greater rates of population growth (*GPOP*), as suggested by theoretical models emphasising the trade-off between the quantity and quality of children.

Turning to measures of school inputs, H&K (2000) find that the primary school pupil to teacher ratio (*PT1*) and two measures of educational expenditure (total expenditure in education as a fraction of GDP (*SEDU*) and a measure of expenditure per student (*exp/pupil*)) display the 'wrong' sign in the test score regression. Lee and Barro (2001), by contrast, conclude that smaller class sizes tend to be associated with better performance (i.e. obtain a significant negative coefficient for *PT1*) and detect some indications of a positive effect of primary school salaries ( $W_{teacher}$ ) which presumably operates through the quality and motivation of the teaching staff. It is interesting to note that expenditure levels per se (*exp/pupil*) are only weakly positively correlated with performance (see equation [5]), and that this correlation disappears when we control for class size and teacher salaries (equation [6]). This suggests that expenditures that do not affect the quantity and quality of teachers are much less important for performance than these two items. These results are generally robust to the inclusion of an Asian dummy (which turns out to be

**Table A3.16: Hanushek and Kimko (2000) versus Lee and Barro (2001) dependent variable = test scores**

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
<i>q</i>				3.19 (3.00)	4.16 (4.23)	3.41 (3.20)	3.39 (3.42)	3.53 (0.42)
<i>YS</i>	2.04 (2.49)	1.62 (2.13)	1.54 (2.41)	1.33 (4.93)	1.33 (4.94)	1.35 (4.90)	1.17 (4.67)	5.02 (1.96)
<i>GPOP</i>	-4.65 (2.77)	-4.60 (3.38)	-2.64 (1.35)					
<i>PT1</i>			0.066 (0.41)	-0.15 (2.44)		-0.22 (2.54)	-0.19 (3.20)	-0.76 (1.70)
<i>SEDU</i>		-165.9 (1.83)						
<i>exp/pupil</i>	-0.69 (3.63)				1.06 (1.46)	-1.34 (1.13)		5.86 (0.86)
<i>W<sub>teacher</sub></i>				1.62 (1.81)		2.88 (2.09)	1.92 (2.28)	7.69 (1.80)
<i>Schoolday</i>				0.01 (0.46)		0.003 (0.14)	-0.02 (0.89)	
<i>Asia</i>							3.67 (3.71)	
<i>N</i>	69	67	70	214	214	214	214	197
<i>Source</i>	H&K	H&K	H&K	L&B	L&B	L&B	L&B	L&B

**Notes:**

- *t* statistics are shown in parentheses below each coefficient. *N* is the number of observations.
- *YS* is average years of total schooling of the adult population in H&K and average years of primary schooling in L&B; *exp/pupil* is current public expenditure per student and is measured in levels in H&K and in logs in L&B; *W<sub>teacher</sub>* is measured in logarithms and *schoolday* refers to its length in hours.
- Equation [8] includes country fixed effects.

positive and highly significant, see equation [7]) and of fixed country effects (equation [8]).

### (f) A plausible range of parameter estimates

In this section, we try to extract from the preceding review of the literature a plausible range for the values of the parameters that describe the relationship between human capital and the level and growth rate of productivity. The coefficients of interest are two alternative measures of level effects and one measure of rate effects. The level parameters are the elasticity of output with respect to average schooling,  $\alpha_{ys}$ , and the Mincerian 'gross return' to schooling,  $\rho$ , that measures the percentage increase in output resulting from a one-year increase in average attainment. As the reader will recall (see Box 2 in the main text),  $\rho$  can be obtained by dividing  $\alpha_{ys}$  by average attainment in years, and vice versa. The rate effects parameter is the coefficient of *YS*

in the technical progress function,  $\gamma_{ys}$ , and measures the contribution of an additional year of schooling to the rate of TFP growth holding other things (and, in particular, the gap with the world technological frontier) constant.

The first block of Table A3.17 shows a number of selected coefficient estimates taken from the empirical literature reviewed in previous sections. The first row of the table gives the source of the estimate, the second shows the specific form in which years of schooling enter the equation<sup>(54)</sup>, the third and fourth rows display the estimated value of the 'raw' regression coefficient and the associated *t* statistics, and the fifth row lists the source of the schooling data. To facilitate the comparability of the coefficients and their interpretation, we have selected only estimates obtained using data on average years of schooling (rather than enrolment rates). We have focused mostly on recent studies that make use of the latest available data sets and use

<sup>(54)</sup> The notation is the standard one in this report: *YS* denotes years of schooling, *ys* the log of this variable and  $\Delta ys$  its annual growth rate, computed as the average annual log change over the relevant period.

specifications that produce 'respectable' signal to noise ratios for the OECD data set. Implicitly, then, we are accepting Krueger and Lindahl's (2001) argument that failure to find significant productivity effects is most likely due to poor data, and not taking into account the negative findings of some of the studies we have reviewed.

The second block of the table shows the values of  $\alpha_{YS}$  and  $\rho$  implied by the original coefficients when these are interpreted as capturing level effects only. In most cases, the values of these parameters are not given directly by the estimated coefficients displayed in the first block of the table but can be recovered from them using either the explicit structural model that underlies the estimated equation, or a model that generates the same reduced-form specification. For instance, Jones (1996) interprets the coefficient of YS in the steady state equation which he estimates as capturing rate effects in a world with technological diffusion. We do something similar below, but for now we interpret his coefficient within the framework of a Mincerian MRW model (which yields exactly the same steady state specification) as capturing a level effect. In the case of Barro (2000), the estimated convergence equation is not explicitly derived from a structural model, but it can be interpreted as such because the functional form is similar to the one that would be implied by the same Mincerian MRW model when we allow for transitional dynamics<sup>(55)</sup>. To recover the values of  $\alpha_{YS}$  and  $\rho$ , we typically need an estimate of  $\alpha_k$ . When possible, this is taken from the original equation (as in Jones, 1996, or in Bassanini and Scarpetta, 2001); otherwise, a value of 0.333 is assumed for this parameter.

The calculations we have just sketched will produce an estimate of  $\alpha_{YS}$  when the underlying production function is Cobb-Douglas in years of schooling (i.e. when we assume that  $H = YS$ ), and an estimate of  $\rho = \theta\alpha_h$  when a Mincerian specification (with  $H = \exp(\theta YS)$ ) is adopted. To compute  $\rho$  given  $\alpha_{YS}$ , we divide the latter parameter by 10.64, which is the average years of schooling in 1990 in a sample of OECD countries using D&D's (2001b) data set<sup>(56)</sup>. The reverse procedure is used to compute  $\alpha_{YS}$  given the value of  $\rho$ .

The values of the auxiliary parameters used in these computations are shown in the last block of the table.

The third block of the table shows the effects on parameter estimates of correcting for measurement error using the appropriate reliability ratios taken from Tables A2.1 and A2.2 above. Notice that the correction is only a partial one because it ignores the increase in the attenuation bias that will result from the introduction of additional regressors when these are correlated with schooling (see Section 2(b)(iii) of the main report). The corrected estimates of the raw coefficients are obtained by dividing their original values (in the first block of the table) by the reliability ratios shown in the first row of the third block. The implied values of  $\alpha_{YS}$  and  $\rho$  are then recovered in the manner explained above, working with the corrected raw coefficients.

The range of parameter values obtained in this manner is very broad. Estimates of the Mincerian return to schooling in OECD countries ( $\rho$ ) range from 3.7 % (using D&D's uncorrected estimates) to 13.1 % (using Jones's estimates corrected for measurement error). The higher values in this range appear extremely implausible when we interpret them as estimates of direct level effects. After correcting for measurement error, three of the five studies imply values of  $\alpha_{YS}$  greater than one, i.e. increasing returns to schooling alone.

We interpret these findings as an indication that, as may be expected from our previous discussion about the difficulty of empirically separating level and rate effects, the coefficient estimates shown in Table A3.17 are picking up both of them. To get some feeling for the likely size of the rate effects, we take as given the values of the level parameters implied by D&D's estimates (corrected for measurement error) and solve for the value of the rate effects coefficient,  $\gamma_{YS}$ , that is consistent with the raw coefficient of schooling. To do this, we reinterpret the reported raw coefficients within the framework of an enlarged model with rate effects and technological diffusion. In this context, and under the further assumption that countries are reasonably close to their 'technological steady states' relative to the world

<sup>(55)</sup> Within this model, the coefficient of years of schooling will provide an estimate of  $\beta \frac{\rho}{1 - \alpha_k}$ , where  $\beta$  (the rate of convergence) is the coefficient of log initial income

per capita. Barro's equation includes both this variable and its square, but the author reports that the average rate of convergence in the sample is 2.5 %. This is the value of  $\beta$  which we use in our calculations and is shown in the last block of the table. Barro's equation controls for investment in physical capital, but the investment ratio does not enter the equation in a way that permits us to recover an estimate of  $\alpha_k$ . Hence, we assume a value of 1/3 for this parameter.

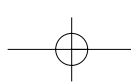
<sup>(56)</sup> Hence, the values of  $\rho$  given in Table A3.17 refer to this sample and are therefore different from those used in the rate of return calculations in the main report, which correspond to a subset of the OECD sample comprising 14 Member States of the EU.



Table A3.17: Selected estimates, corrections for measurement-error bias and tentative estimates of rate effects

1. Original coefficient estimates					
<i>Source</i>	<i>D&amp;D update</i>	<i>C&amp;S (2001)</i>	<i>Bas&amp;Scarp</i>	<i>Barro (2000)</i>	<i>Jones (1996)</i>
<i>Regressor</i>	$\Delta ys$	YS	ys	YS(*)	YS
<i>Raw coefficient</i>	0.394	0.085	0.95	0.0044	0.159
<i>(t)</i>	(4.57)	(4.00)	(3.96)	(2.44)	(2.48)
<i>Data from</i>	D&D (2001)	C&S (2001)	D&D (2001)	B&L (2000)	B&L (1993)
2. Implied values of the level parameters					
<i>Coefficient interpreted as</i>	$\alpha_{ys}$	$\frac{\rho}{1 - \alpha_k}$	$\frac{\alpha_{ys}}{1 - \alpha_k}$	$\beta \frac{\rho}{1 - \alpha_k}$	$\frac{\rho}{1 - \alpha_k}$
<i>Implied <math>\rho</math></i>	<b>3.70 %</b>	5.67 %	7.76 %	11.73 %	11.75 %
<i>Implied <math>\alpha_{ys}</math></i>	0.394	0.603	0.826	1.248	1.250
3. Level parameters after correcting for measurement error					
<i>Reliability ratio</i>	0.736	0.788	0.716	0.910	0.897
<i>Corrected coefficient</i>	0.535	0.108	1.327	0.005	0.177
<i>Implied <math>\rho</math></i>	<b>5.03 %</b>	7.19 %	10.84 %	12.89 %	13.10 %
<i>Implied <math>\alpha_{ys}</math></i>	0.535	0.765	1.154	1.372	1.394
4. Implied value of $\gamma_h$ under the assumption that $\alpha_{ys} = 0.535/\rho = 5.03\%$					
<i>Corrected coefficient interpreted as</i>	$\frac{\rho}{1 - \alpha_k} + \frac{\gamma_{ys}}{\lambda} \frac{\alpha_{ys}}{1 - \alpha_k} + \frac{\gamma_{ys}}{\lambda} \frac{\beta\rho}{1 - \alpha_k} + \frac{\rho}{1 - \alpha_k} + \frac{\gamma_{ys}}{\lambda} \frac{\beta\gamma_y}{\lambda}$				
<i>Implied <math>\gamma_{ys}</math></i>	0.00 %	0.24 %	0.49 %	0.87 %	0.81 %
5. Other parameter values used in the calculations					
<i>Average YS</i>	10.64	10.64	10.64	10.64	10.64
$\lambda$	0.074	0.074	0.074	0.074	0.074
$\alpha_k$	0.333	0.130	0.333	0.261	
$\beta$			0.025		

(\*) The regressor is some transformation of the average years of total schooling of the adult population, except in Barro (2000), where it is the average years of secondary and higher schooling of the adult male population.



frontier, the coefficient of the schooling variables will reflect both the standard level effect and an additional term of the form  $\gamma_{YS}\lambda$ , where  $\lambda$  is the rate of technolog-

ical diffusion<sup>(57)</sup>. The fourth block of the table shows the results of this calculation, which uses the value of  $\lambda$  estimated by de la Fuente and Doménech.

## 4. Selected educational indicators for the EU and other countries of interest

Tables A4.1 to A4.12 collect a number of human capital indicators for the EU and other countries of interest. Each table is divided into four blocks. The first gives values for EU members (EU-14), typically with the exception of Luxembourg for which data are often not available. The second refers to a group of seven advanced OECD economies that serve as a useful reference to gauge the EU's position relative to its most direct competitors. The third gives the data available for countries that are currently candidates for accession to the EU. The coverage for the last group varies across tables and is often restricted to countries in this group that are also members of the OECD. The fourth block of each table, finally, displays average values for different subsamples and other statistics of interest.

The values in the tables are always given in relative terms, taking as a reference the average value of each variable taken over the available observations for the group of 21 OECD countries that are listed in the first two blocks. This average value, which is denoted by *avge. OECD-21* or *avge. 21* in the tables, is normalised to 100. The original variables can be recovered by multiplying the average value for the reference group (which is listed under *avge. OECD in levels*) by the relative values given in the table.

Tables A4.1 to A4.4 contain various measures of the educational attainment of the adult population (i.e. of the quantity of human capital) in selected years between 1960 and 2000. As has been emphasised else-

where in this report, there are significant discrepancies across sources that introduce a considerable amount of uncertainty in cross-country comparisons. Nonetheless, it seems clear that south European countries (Greece, Italy, Spain and especially Portugal) have significantly lower attainment levels than the rest of the Union, and that the Nordic countries and Germany occupy the first positions of the EU ranking by school attainment. In terms of average years of schooling (YS), the average EU country was around 10 percentage points below the OECD average in 1960. This educational gap had been reduced by only 2.5 percentage points by 1990 and perhaps by 1 additional point by 2000. (See Tables A4.1 and A4.2.) Projections based on current enrolment rates, however, suggest that EU attainment will gradually converge to the OECD average in the future provided current conditions remain unchanged (see the last two columns of Table A4.2).

The dispersion of relative national attainment levels within the EU has declined significantly during the period we are considering and can be expected to continue to do so in the foreseeable future. This convergence process is illustrated in Table A4.3, which shows the standard deviation of normalised years of schooling according to various sources in selected years and the same dispersion indicator for the OECD and World Bank projections based on current enrolment rates. Between 1960 and 1990, this indicator of educational inequality fell by almost 30 % (when we work with an average across the three available sources of data on years of

(57) The details of the required calculations are as follows. Let  $x$  be the relevant 'raw coefficient' corrected for measurement error and assume for concreteness that we are interpreting this coefficient as

$$x = \frac{\rho}{1 - \alpha_k} + \frac{\gamma_{YS}}{\lambda}$$

Given the assumed values of  $\lambda$ ,  $\rho$  and  $\alpha_k$ , we can solve for  $\gamma_{YS}$  as

$$\gamma_{YS} = \lambda \left( x - \frac{\rho}{1 - \alpha_k} \right)$$

In the case of Bassanini and Scarpetta (2001), an additional step is necessary. Since these authors use years of schooling in logs rather than in levels (i.e.  $ys = \ln YS$ ), the calculation just described will yield an estimate of the change in the rate of technical progress ( $g$ ) induced by a unit increase in log schooling, i.e. of  $\frac{\partial g}{\partial \ln YS}$  rather than of  $\gamma_{YS}$

which is defined as  $\frac{\partial g}{\partial YS}$ . To recover the parameter of interest, notice that

$$\frac{\partial g}{\partial YS} = \frac{\partial g}{\partial \ln YS} \frac{d \ln YS}{d YS} = \frac{\partial g}{\partial \ln YS} \frac{1}{YS}$$

so we have to divide the result of the first calculation by average years of schooling to recover  $\gamma_{YS}$ .

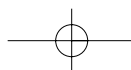


Table A4.1: Average years of schooling (YS) in 1960 and 1990

Source Year	D&D01 1960	C&S 1960	B&L00 1960	Average 1960	D&D01 1990	C&S 1990	B&L00 1990	Average 1990
West Germany	118.5	117.9	123.6	120.0	121.7	120.9	102.1	114.9
Denmark	129.0	112.5	133.6	125.0	110.2	105.6	114.2	110.0
Sweden	96.2	107.5	114.2	106.0	99.8	110.2	107.9	105.9
UK	102.5	112.9	114.5	110.0	98.9	112.4	98.5	103.2
Finland	91.5	84.9	80.2	85.5	103.1	98.2	106.8	102.7
Austria	107.7	102.6	100.2	103.5	106.3	100.1	92.6	99.7
Netherlands	97.0	103.3	78.7	93.0	102.9	98.1	97.0	99.3
Belgium	92.5	91.6	111.4	98.5	94.7	91.8	95.0	93.8
France	97.3	83.4	86.3	89.0	98.2	94.8	85.2	92.7
Ireland	88.0	89.8	96.3	91.4	88.4	87.2	95.8	90.5
Greece	66.5	73.6	69.3	69.8	74.3	79.7	86.3	80.1
Italy	64.7	72.1	68.1	68.3	75.6	83.3	69.4	76.1
Spain	59.5	71.7	54.3	61.8	66.7	77.2	68.6	70.9
Portugal	52.3	39.0	29.0	40.1	60.2	54.1	48.8	54.4
United States	126.3	126.1	129.3	127.2	119.1	115.5	135.2	123.3
Australia	117.7	121.7	140.8	126.7	121.1	116.8	114.1	117.3
Canada	124.1	112.9	125.0	120.6	119.7	113.1	118.3	117.1
Switzerland	124.8	135.8	109.0	123.2	114.9	118.6	111.8	115.1
New Zealand	125.1	111.3	142.7	126.4	113.8	100.8	126.0	113.6
Norway	115.8	112.1	91.2	106.4	104.4	112.7	122.3	113.1
Japan	103.1	117.4	102.6	107.7	105.6	109.2	103.9	106.2
Poland			100.62				108.2	
Latvia							107.52	
Czech Republic							105.83	
Lithuania							104.81	
Bulgaria		90.44	90.77			96.9	104.36	
Romania		89.45	79.57			91.5	104.14	
Estonia							103.35	
Slovakia							102.22	
Hungary		93.78	99.27			99.46	98.16	
Cyprus		68.51	64.04			81.16	94.78	
Slovenia							78.22	
Malta			84.2				76.3	
Turkey		26.51	29.86			57.19	44.52	
Former Czechoslovakia			107.34					
East Germany			131.37				114.62	
avge. 21 in years	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
avge. EU-14	8.36	8.07	6.70		10.64	10.93	8.87	
avge. cand.s	90.22	90.20	89.97	90.13	92.95	93.81	90.60	92.45
		73.74	81.96			85.24	94.80	

## Notes:

- The data refer to the population aged 25 and over in D&D and B&L, and to the population between 15 and 64 in C&S.
- The average values given in the fourth and eighth columns of the table are simple averages across sources of the normalised values for each year.
- The average for the candidate countries (*avge. cand.s*) does not include East Germany.
- Sources: D&D01 = de la Fuente and Doménech (2001); C&S = Cohen and Soto (2001); and B&L00 = Barro and Lee (2000).

**Table A4.2: Average years of schooling (YS) in 2000 and expected years of schooling based on current enrolment rates**

	YS (C&S, 2001)	YS (B&L, 2000)	YS expected (OECD)	YS expected (WB)
Sweden	101.75	119.13	117.00	93.21
Finland	101.40	106.33	105.48	102.86
Denmark	105.92	105.81	102.02	96.43
Germany (*)	112.43	102.24	99.14	102.86
UK	113.90	98.05	108.93	106.07
Netherlands	98.45	96.89	98.56	102.86
Ireland	88.29	94.59	92.22	90.00
Austria	99.23	92.28	92.22	93.21
Belgium	94.11	91.55	106.63	109.29
Greece	85.95	89.24	89.91	90.00
France	93.15	87.77	95.10	99.64
Spain	82.48	76.03	99.71	
Italy	89.68	73.40	91.07	
Portugal	63.20	51.49	96.83	93.21
United States	109.65	128.46	99.14	102.86
Norway	108.35	124.37	103.17	99.64
New Zealand	104.96	120.80	99.14	106.07
Canada	113.47	119.86	95.10	109.29
Australia	113.64	110.84	114.70	109.29
Switzerland	110.52	108.95	93.95	93.21
Japan	109.48	101.93		
Poland		103.82	92.22	83.57
Bulgaria	91.94	102.14		77.14
Latvia (**)		100.04		80.36
Romania	86.82	99.73		77.14
Czech Republic		99.20	87.03	83.57
Lithuania (**)		97.52		
Slovakia		96.37		
Estonia (**)		96.16		80.36
Hungary	94.37	92.38	92.22	83.57
Cyprus	77.01	91.97		
Malta		79.38		
Slovenia		77.07		
Turkey	54.26	50.33	61.10	64.29
avge. OECD-21	100.00	100.00	100.00	100.00
in levels	11.52	9.54	17.35	15.56
avge. EU-14	95.00	91.77	99.63	98.30
avge. cands	80.88	91.24	83.14	78.75

Notes:

– Average years of schooling of the adult population (YS) in 2000 from Barro and Lee (2000) and Cohen and Soto (2001), and expected years of schooling in the future on the basis of currently observed enrolment rates as calculated by the World Bank (WB) for the 2000/01 *World development report* and by the OECD in the 2001 edition of *Education at a glance*. Both estimates of 'school expectancy' are constructed essentially by adding up across successive school grades (excluding pre-primary education) the enrolment rates observed in the late 1990s.

(\*) In Cohen and Soto, Germany is West Germany.

(\*\*) In the case of the Baltic countries the Barro and Lee data refer to 1990.

**Table A4.3: Standard deviation of normalised years of schooling in EU-14**

	<i>D&amp;D</i>	<i>C&amp;S</i>	<i>B&amp;L</i>	<i>Average</i>	<i>WB</i>	<i>OECD</i>
<i>1960</i>	21.55	20.78	27.98	22.73		
<i>1990</i>	17.00	16.42	17.17	16.16		
<i>2000</i>		12.60	15.97			
<i>Future</i>					6.22	7.49
<i>%D 1960–90</i>	-21.1	-21.0	-38.6	-28.9		
<i>%D 1990–2000</i>		-23.2	-7.0			

Note: Standard deviation of normalised years of schooling and expected future years of schooling from Tables A4.1 and A4.2.

**Table A4.4: Upper secondary attainment by age group in 1999**

	<i>Ages 25–64</i>	<i>Ages 25–34</i>	<i>Ages 35–44</i>	<i>Ages 45–54</i>	<i>Ages 55–64</i>
<i>Germany</i>	124.19	112.30	121.62	132.84	147.43
<i>Denmark</i>	121.72	114.98	114.26	128.62	141.19
<i>Sweden</i>	117.10	114.74	116.56	120.24	123.86
<i>Austria</i>	112.89	109.65	111.78	113.15	118.53
<i>Finland</i>	109.32	112.83	117.26	108.80	93.87
<i>France</i>	94.59	100.68	93.48	92.23	84.98
<i>UK</i>	94.32	86.89	91.11	97.40	107.96
<i>Belgium</i>	87.71	96.23	87.52	81.58	72.32
<i>Ireland</i>	78.43	87.93	80.82	66.24	62.37
<i>Greece</i>	76.34	93.81	83.47	69.27	49.51
<i>Italy</i>	64.57	73.10	71.40	59.95	43.05
<i>Spain</i>	53.70	71.87	58.56	40.65	27.26
<i>Portugal</i>	32.48	40.18	30.45	25.10	22.79
<i>Netherlands</i>					
<i>United States</i>	132.87	115.67	126.32	144.14	164.28
<i>Norway</i>	129.32	123.81	127.73	128.65	138.47
<i>Switzerland</i>	124.93	117.01	120.27	129.07	145.40
<i>Japan</i>	123.72	122.67	132.21	128.12	120.44
<i>Canada</i>	121.52	114.89	119.15	127.66	125.97
<i>New Zealand</i>	112.55	104.53	111.13	116.47	121.29
<i>Australia</i>	87.73	86.23	84.89	89.81	89.04
<i>Czech Republic</i>	131.53	121.98	128.08	137.88	151.73
<i>Hungary</i>	103.01	105.00	109.33	114.36	73.83
<i>Poland</i>	82.54	81.73	84.65	86.48	74.89
<i>Turkey</i>	33.93	34.54	32.71	29.86	23.88
<i>avge. OECD-21</i>	100.00	100.00	100.00	100.00	100.00
<i>in levels</i>	65.42	75.86	69.70	61.29	49.41
<i>avge. EU-14</i>	89.80	93.48	90.64	87.39	84.24
<i>avge. cands</i>	73.16	73.76	75.57	76.90	57.53
<i>SD OECD-21</i>	27.10	20.45	25.79	32.66	41.08
<i>SD EU-14</i>	26.95	21.05	25.62	32.48	40.37

**Notes:**

- *Definition:* Percentage of the population that has attained at least upper secondary education by age group.
- *SD* is the standard deviation of attainment and is computed with the normalised data.
- The data refer to 1998 in the cases of Austria, Ireland, Norway and Poland.
- *Source:* *Education at a glance*, 2001.



schooling). The 1990s saw a further reduction in this variable, although the two available sources imply very different convergence rates, and existing projections suggest that, under current conditions, the level of educational inequality within the EU should fall to about half its current level within a generation. Educational convergence is also apparent in the data on upper secondary attainment by age group contained in Table A4.4: the dispersion of the normalised values of this indicator is 50 % lower in the 25–34 age group than in the 55–64 age group.

The attainment data available for the countries that are currently candidates for accession to the EU (henceforth the candidate countries) are limited and somewhat hard to assess. Barro and Lee (2000) is the only data set that provides estimates of average years of schooling for all the countries in this group. According to these authors, average attainment in the candidate countries (*avge. cand.* in Tables A4.1 and A4.2) was 4 percentage points above the EU-14 level in 1990 and approximately equal to the EU-14 average in 2000, with all candidate countries except Malta, Slovenia and Turkey above mean EU-14 attainment in this year. These figures, however, may significantly overestimate attainment levels in the candidate countries. Cohen and Soto's estimates of schooling in 2000 are significantly lower than Barro and Lee's for two of the three formerly socialist countries for which these authors supply data. A recent study for the European Commission (EIC, 2001) also suggests that attainment statistics tend to overstate the human capital stocks of east European countries because a large share of secondary-level qualifications were obtained in vocational schools that typically offered short courses with deficient curricula. The rapid decline in attendance to these schools may be partly responsible for the apparent fall in (relative) enrolment rates that these countries seem to have experienced over the recent period of turmoil caused by the crisis and eventual demise of their communist regimes. This decline is apparent in Table A4.4, where we see that secondary attainment rates in socialist countries decline as we move to younger cohorts, following the opposite pattern than the rest of the sample, and in Table A4.2, where projections based on current enrolment rates suggest that the relative attainment levels of formerly socialist countries are likely to deteriorate rapidly in the future.

Tables A4.5 to A4.8 contain various indicators of educational expenditure and school resource input in recent years. The source for Tables A4.5 and A4.6 is the 2001 edition of the OECD's *Education at a glance*, which provides information for our OECD sample and for four candidate countries (the Czech Republic, Hungary, Poland and Turkey). Some additional information for other candidate countries is provided in Tables A4.7 and A4.8, which are taken respectively from the World Bank and from Barro and Lee's (2000) data set. As in the case of attainment estimates, there are worrisome discrepancies across data sources that make it necessary to interpret international comparisons with great caution<sup>(58)</sup>. On the whole, however, the OECD data (Tables A4.5 and A4.6) suggest that the EU is only slightly below the OECD average in terms of most indicators of educational expenditure and slightly above this average in terms of direct measures of school input (teachers per pupil and hours of instruction per year). The exceptions to this rule occur at the tertiary level, where both normalised expenditure and the number of teachers per student (the inverse of the pupil to teacher ratio shown in Table A4.6) are significantly below the OECD average. The other peculiarity of the EU is that private expenditure in education is generally lower than in the rest of the OECD sample. A comparison of the OECD data with the World Bank's expenditure indicators (which consider only public spending) suggests that the relatively low level of EU spending per student at the tertiary level is due mostly to low private expenditures (i.e. to low tuition fees at universities).

Within the EU, there are very significant differences across countries in terms of the various resource indicators. The ratio between the highest and the lowest value of each indicator within this sample (*max/min EU*), which is given in the last row of Tables A4.5 and A4.6, is always above 1.5 and often above 2.0. If we measure expenditure per student as a fraction of output per employed worker (which is probably a better reference than GDP per capita as a way to correct expenditure for differences in purchasing power), Austria, Sweden and Denmark have the highest expenditure levels and Ireland the lowest. At the tertiary level, expenditure so normalised is particularly low in Spain, Italy, Belgium and Greece. Pupil to teacher ratios and hours of instruction vary considerably less than expenditures per student, but even here the differences across countries are quite significant.

<sup>(58)</sup> Many of these indicators are not strictly comparable across sources, but they should in principle capture similar things. The coefficient of correlation among similar OECD and World Bank indicators, computed over common observations and normalised by the OECD-21 average, is as follows: public expenditure in education as a percentage of some measure of national income (0.322), expenditure per student as a percentage of income per capita (0.756 at the primary level, 0.457 at the secondary level and 0.452 at the tertiary level) and pupil to teacher ratio at the primary level (0.888).

Table A4.5: Indicators of expenditure in education in 1998 (OECD)

	GEDUps/GDPpc			GEDUps/GDPpew			GEDU/GDP		
	Primary	Secondary	Tertiary	Primary	Secondary	Tertiary	Public	Private	Total
<i>Austria</i>	130.13	130.90	112.71	142.86	144.24	121.80	115.84	62.88	112.34
<i>Sweden</i>	129.22	97.77	142.65	129.97	98.70	141.23	96.30		87.75
<i>Denmark</i>	132.76	106.43	88.07	150.41	121.02	98.22	131.93	59.17	126.62
<i>Portugal</i>	106.93	110.56		107.62	111.68		111.32		101.06
<i>Italy</i>	129.06	110.21	66.94	101.52	87.02	51.83	113.83	59.50	110.14
<i>France</i>	89.82	118.19	80.58	78.22	103.31	69.08	84.30	197.41	97.98
<i>UK</i>	79.93	93.86	108.46	82.45	97.18	110.14	66.65	217.58	84.04
<i>Germany</i>	78.01	102.51	97.55	79.89	105.38	98.34	83.39	66.66	83.16
<i>Finland</i>	107.82	88.74	79.27	103.63	85.61	75.00	93.30	31.86	88.47
<i>Spain</i>	97.08	102.75	69.72	72.87	77.41	51.51	86.90	19.45	81.31
<i>Netherlands</i>	77.81	81.28	102.71	73.31	76.86	95.26	117.10		
<i>Belgium</i>	80.95	94.54	63.63	68.45	80.24	52.96	107.85	13.59	99.79
<i>Greece</i>	83.63	86.77	68.37	69.44	72.32	55.89	86.02	140.79	93.49
<i>Ireland</i>	61.18	65.54	88.46	56.19	60.42	79.98	127.57	30.05	119.53
<i>New Zealand</i>							89.99	45.71	86.94
<i>Canada</i>			136.32			140.37	83.95	186.02	96.44
<i>Switzerland</i>	119.74	129.30	142.77	145.13	157.30	170.34	106.20	111.44	108.75
<i>United States</i>	94.77	91.01	144.64	103.15	99.42	154.97	68.74	192.78	83.33
<i>Norway</i>	111.48	106.21	98.40	126.62	121.08	110.01	131.17	21.14	121.85
<i>Japan</i>	106.54	92.42	96.51	122.80	106.92	109.49	104.24	77.98	103.39
<i>Australia</i>	83.14	91.00	112.24	85.48	93.90	113.59	93.40	265.98	113.61
<i>Hungary</i>	98.69	77.31	124.17				78.87	98.20	82.41
<i>Poland</i>	92.52	66.46	122.74				86.32	96.62	89.04
<i>Czech Rep.</i>	64.31	93.00	101.71				103.56		
<i>Turkey</i>							56.91	89.19	61.43
<i>avge. 21</i>	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
<i>in levels</i>	19.76	26.44	42.44	8.83	11.77	19.26	5.16	0.61	5.66
<i>avge. EU-14</i>	98.88	99.29	89.93	94.06	94.38	84.71	100.82	78.72	98.04
<i>avge. cand</i>	85.17	78.92	116.21				81.41	94.67	77.63
<i>max/min EU</i>	2.17	2.00	2.24	2.68	2.39	2.74	1.98	16.01	1.56

**Definitions:**

– *GEDUps/GDPpc* = expenditure per student relative to GDP per capita (expenditure on public and private educational institutions per student, measured as full-time equivalent).

– *GEDUps/GDPpew* = expenditure per student relative to GDP per employed worker. It is obtained by multiplying the previous variable by the ratio of employment to the total population using data for 1998 from an updated version of Doménech and Bosca (1996).

– *GEDU/GDP* = direct and indirect expenditure on educational institutions from public and private sources as a fraction of GDP.

**Notes:**

– Countries are ranked within each group by the average value of all the normalised indicators shown in the table.

– For expenditure per student as a fraction of GDP per capita or per employed worker, the data refer to public institutions only in Austria, Hungary, Italy, Norway and Portugal, and to public and government-dependent private institutions only in Belgium and Greece.

– For *GEDU/GDP*, public subsidies to households are included in private rather than public expenditure in Austria, Greece, New Zealand, Norway and Poland.

– Source: *Education at a glance*, 2001.

Table A4.6: Other indicators of school resource input in 1999 (OECD)

	Pupil to teacher ratios				Hours of instruction per year			
	Primary	Secondary	Tertiary	Average	Age 12	Age 13	Age 14	Average
Denmark	63.23	90.67		76.95	93.62	94.43	96.76	94.94
Sweden	79.58	106.27	59.12	81.66	82.54	77.70	77.05	79.10
Austria	86.57	71.80	93.32	83.90	111.68	121.32	129.92	120.97
Belgium (Fl.)	83.34	64.48	113.09	86.97		100.73	99.88	100.30
Spain	92.52	94.28	102.56	96.45	88.49	91.28	90.52	90.10
Italy	67.89	75.15	154.55	99.20	123.15	115.94	114.97	118.02
Netherlands	99.67	129.69	74.81	101.39	118.88	111.92	110.98	113.93
Finland	104.36	99.28		101.82	76.23	89.71	88.95	84.97
Germany	126.02	111.37	76.60	104.66	96.29	96.63	95.82	96.25
France	117.54	93.87	105.17	105.53	93.73	102.72	101.86	99.44
Greece	81.08	78.03	162.25	107.12	115.46	108.70	107.79	110.65
Ireland	129.57	107.23	107.72	114.84	104.23	98.12	97.30	99.88
UK	134.47	107.71	115.22	119.13	108.11	101.77	100.92	103.60
Portugal					103.65	97.58	96.76	99.33
Norway	75.47		83.39	79.43	85.76	89.71	88.95	88.14
Switzerland	96.16	90.12		93.14				
Australia	103.73	92.89		98.31		106.28	105.80	106.04
United States	97.34	114.50	87.53	99.79			101.96	101.96
Japan	126.68	113.02	72.04	103.91	97.52	91.81	91.04	93.45
New Zealand	122.92	117.87	92.62	111.14	100.63	103.66	102.79	102.36
Canada	111.85	141.77		126.81				
Hungary	65.22	77.50	75.73	72.82	86.97	94.63	93.83	91.81
Slovakia	117.20	99.90	64.06	93.72				
Czech Republic	140.22	107.77	92.92	113.64	88.92	86.81	92.23	89.32
Turkey	179.73	117.62	133.89	143.75	96.29	90.65	89.89	92.28
avge. 21 in levels	100.00	100.00	100.00		100.00	100.00	100.00	
avge. EU-14	16.70	13.65	16.03		897.25	953.09	961.16	
avge. candS	97.37	94.60	105.86		101.24	100.61	100.68	
max/min EU	125.59	100.70	91.65		90.73	90.70	91.99	
	2.13	2.01	2.74	1.55	1.62	1.56	1.69	1.53

**Definitions:**

– *Pupil to teacher ratio* = ratio of students to teaching staff in public and private institutions; calculations based on full-time equivalents.

*Hours of instruction per year* = total intended instruction time in hours per school year for students aged 12 to 14.

**Notes:**

– The data for Belgium refer to the Flanders region.

– In the case of hours of instruction per year, the value shown in the table for the UK is estimated as the (unweighted) average of the values for England and Scotland.

– Countries sorted by the average pupil to teacher ratio.

– Source: *Education at a glance*, 2001.

Table A4.7: Indicators of educational expenditure and school input in 1997 (World Bank)

	Public GEDU/GNP	GEDUPps/GNIpc			Pupil to teacher ratios
		Primary	Secondary	Tertiary	Primary
Denmark	141.99	136.09	148.14	141.23	67.09
Italy	85.89	114.52	122.37	60.36	73.80
Austria	94.66	111.44	106.06	100.51	80.51
Belgium	54.34	45.19	57.54	49.83	80.51
Portugal	101.67	99.12	92.32	69.76	80.51
Sweden	145.49	151.50	146.42	206.15	80.51
Greece	54.34		64.84	63.50	93.93
Netherlands	89.40	76.01	91.03	134.68	93.93
Spain	87.65	86.28	96.61	50.68	100.64
Germany	84.14			107.63	114.06
Finland	131.47	117.09	118.08	129.84	120.77
France	105.18	81.14	115.07	79.73	127.48
UK	92.90	91.41	88.02	115.89	127.48
Ireland	105.18	70.36	94.03	103.36	147.60
Norway	129.72	157.15	76.43	132.97	46.96
Switzerland	94.66	99.12	124.52	129.27	80.51
Canada	120.95				107.35
United States	94.66	98.09	102.62	70.33	107.35
Australia	94.66	76.52	72.14	84.57	120.77
New Zealand	127.96	91.93	102.19	130.13	120.77
Japan	63.11	97.06	81.58	39.58	127.48
Hungary	80.63	94.49	78.15	89.41	80.51
Latvia	110.43		219.41	93.39	87.22
Slovenia	99.92	103.22	32.20	106.78	93.93
Poland	131.47	90.39	73.42	77.45	100.64
Lithuania	94.66		119.37	119.87	107.35
Bulgaria	56.09	157.66		49.54	114.06
Estonia	126.21		194.94	109.34	114.06
Czech Republic	89.40	84.22	92.32	99.37	120.77
Romania	63.11	104.25	37.79	90.55	134.19
Slovakia	87.65	114.52		87.70	134.19
Turkey	38.56	46.22	39.50	145.50	161.02
avge. OECD-21	100.00	100.00	100.00	100.00	100.00
in levels	5.70	19.47	23.29	35.12	14.90
avge. EU-14	98.16	98.35	103.12	100.94	99.20
avge. cands	88.92	99.37	98.57	97.17	113.45

## Notes:

- Public GEDU/GNP = public educational expenditure as a percentage of GNP in 1997, from the 2000/01 *World development report*.
- GEDUPps/GNIpc = public expenditure per student as a fraction of gross national income per capita. This variable and the primary school pupil to teacher ratio are taken from the World Bank's 2001 *World development indicators*.

Table A4.8: Indicators of educational expenditure and school input in 1990 (Barro and Lee, 2000)

	Pupil to teacher ratios		GEDUPps/GDPpc		Hours per year
	Primary	Secondary	Primary	Secondary	Primary
Sweden	39.02	72.53	241.58	92.65	123.29
Belgium	62.30	56.76	81.38	132.70	
Austria	67.97	66.22	93.58	144.76	98.63
Denmark	72.37	84.36	168.35	114.36	106.85
Italy	72.37	68.59	78.83	106.16	83.84
France	76.78	98.55	61.03	100.37	99.86
Portugal	88.73	81.99	78.83	87.82	100.68
Finland	90.62		103.25	128.84	89.79
Netherlands	108.24	123.78	64.59	109.05	102.74
West Germany	112.02	109.59	61.03	88.30	78.08
Greece	123.34	120.62	47.81	70.93	92.47
UK	124.60	105.64	75.78	125.94	97.60
Spain	138.45	131.66	61.03	66.59	105.31
Ireland	168.03	121.41	62.05	97.95	
Norway	38.39	70.17	180.04	89.27	
Canada	96.28	110.37	114.43	119.19	100.17
Australia	103.84	97.76	100.19	57.90	
New Zealand	113.28	135.60	83.92	69.97	102.74
United States	116.42	112.74	76.80	111.47	117.95
Japan	130.27	131.66	82.90	83.00	
Switzerland	156.70		182.59	102.78	
Hungary	78.66	94.61	106.81	127.87	
Bulgaria	96.91	112.74		195.81	88.15
Poland	102.58	143.49			97.60
Former USSR	106.98				
Romania	107.61	221.54			76.85
Former					
Czechoslovakia	120.83	78.84			84.76
Cyprus	129.01	93.82	65.61	9.65	86.30
Malta	130.27	95.39			112.19
Yugoslavia	142.85	130.87			69.35
Turkey	191.31	188.42	63.07	54.53	89.90
avge. OECD-21	100.00	100.00	100.00	100.00	100.00
in levels	15.89	12.68	19.66	20.72	973.33
avge. EU-14	96.06	95.52	91.37	104.74	98.26
avge. cands	120.70	128.86	78.49	96.97	88.14

Note: GEDUPps/GDPpc = public expenditure per student as a fraction of GDP per capita.



Table A4.9: Average IALS results

	Mean score	5th percentile	95th percentile	Range of scores	% in levels 1 or 2
<i>Sweden</i>	109.88	127.81	107.56	89.63	59.31
<i>Denmark</i>	105.09	127.01	99.02	74.24	76.59
<i>Finland</i>	103.68	115.76	100.45	86.89	86.01
<i>Germany</i>	103.47	124.56	100.27	78.77	90.09
<i>Netherlands</i>	103.23	119.32	98.82	80.66	84.98
<i>Belgium (*)</i>	100.44	95.84	100.37	104.38	95.03
<i>UK</i>	96.35	85.39	100.02	112.98	117.42
<i>Ireland</i>	95.05	88.52	98.51	107.35	123.79
<i>Portugal</i>	81.67	57.96	89.63	117.66	172.65
<i>Norway</i>	106.30	122.59	101.02	81.93	70.16
<i>Canada</i>	100.99	87.03	103.58	118.22	98.24
<i>Australia</i>	99.11	86.91	99.75	111.10	100.77
<i>United States</i>	98.46	79.65	103.35	124.32	108.40
<i>Switzerland (**)</i>	98.40	88.96	97.47	105.00	104.65
<i>New Zealand</i>	97.89	92.68	100.20	106.86	111.91
<i>Czech Republic</i>	103.55	115.61	101.55	89.11	91.01
<i>Hungary</i>	92.97	93.79	95.10	96.26	142.28
<i>Slovenia</i>	85.40	63.93	91.95	116.74	160.88
<i>Poland</i>	83.24	58.51	91.51	120.71	167.43
<i>avge. OECD-21</i>	100.00	100.00	100.00	100.00	100.00
<i>in levels</i>	277.28	169.08	360.12	191.04	43.54
<i>avge. EU-14</i>	99.87	104.69	99.40	94.73	100.65
<i>avge. candS</i>	91.29	82.96	95.03	105.71	140.40
<i>SD all</i>	7.53	22.19	4.25		

## Notes:

- The figures shown in the table are averages of the values corresponding to the three types of literacy assessed in the study (prose, document and quantitative) with weights 0.25, 0.25 and 0.50 respectively.
- For each country, we show the overall mean score and the scores at the 5th and 95th percentiles of the national distribution. Range of scores is the difference between the 95th and 5th percentile scores, and % in levels 1 or 2 refers to the fraction of the population which is classified below level 3, which is considered the minimum required for satisfactory performance in everyday situations.

(\*) Belgian data refer only to the Flanders region.

(\*\*) For Switzerland, we report the unweighted average of the values for the German, French and Italian-speaking populations.

– Source: OECD and Statistics Canada (2000).

Table A4.10: Average PISA results

	Mean score	5th percentile	95th percentile	Range of scores	% in levels 1 or 2
<i>Finland</i>	106.83	115.42	103.03	89.64	57.22
<i>UK</i>	103.92	106.09	104.06	101.87	89.92
<i>Ireland</i>	102.10	105.65	100.32	94.56	79.02
<i>Sweden</i>	101.31	103.74	100.43	96.86	87.19
<i>Austria</i>	101.01	102.85	99.82	96.55	98.09
<i>Belgium</i>	100.12	90.36	100.97	112.43	98.09
<i>France</i>	99.98	101.46	99.56	97.50	100.82
<i>Denmark</i>	98.10	97.56	98.60	99.72	111.72
<i>Spain</i>	96.33	98.74	95.55	92.10	114.44
<i>Germany</i>	95.93	87.65	99.14	111.55	122.62
<i>Italy</i>	94.16	93.89	94.90	95.99	122.62
<i>Greece</i>	91.54	85.96	94.75	104.25	138.96
<i>Portugal</i>	91.39	89.19	93.11	97.34	141.69
<i>Netherlands</i>					
<i>Japan</i>	106.09	112.04	102.11	91.39	76.29
<i>Canada</i>	105.06	111.08	103.03	94.32	73.57
<i>New Zealand</i>	104.71	102.49	105.24	108.22	84.47
<i>Australia</i>	104.41	106.97	103.94	100.67	84.47
<i>Switzerland</i>	99.28	96.76	100.74	105.04	111.72
<i>Norway</i>	99.09	96.83	99.67	102.74	100.82
<i>United States</i>	98.64	95.29	101.04	107.26	106.27
<i>Czech Republic</i>	98.30	97.71	98.98	100.36	114.44
<i>Hungary</i>	95.88	95.14	97.65	100.36	130.79
<i>Poland</i>	94.25	90.36	96.66	103.45	130.79
<i>Latvia</i>	90.70	84.71	94.59	105.28	155.31
<i>avge. OECD-21</i>	100.00	100.00	100.00	100.00	100.00
<i>in levels</i>	506.88	340.29	655.16	314.88	36.70
<i>avge. EU-14</i>	98.67	98.35	98.79	99.26	104.80
<i>avge. candS</i>	94.78	91.98	96.97	102.36	132.83
<i>SD all</i>	4.62	8.20	3.23		

## Notes:

- See the notes to the previous table.
- The figures shown in the table are averages of the values corresponding to the three types of literacy assessed in the study (maths, science and reading) with weights 0.25, 0.25 and 0.50 respectively.
- The % in levels 1 or 2 refers to the reading literacy scale, which is the only one for which this information is supplied.
- Source: OECD (2001a).

Table A4.11: PISA and TIMSS results by subject

	<i>PISA reading</i>	<i>PISA maths</i>	<i>PISA science</i>	<i>PISA average</i>	<i>TIMSS maths</i>	<i>TIMSS science</i>	<i>TIMSS average</i>
<i>Finland</i>	107.57	105.63	106.57	106.83			
<i>UK</i>	103.03	104.25	105.38	103.92	96.68	101.64	99.17
<i>Ireland</i>	103.82	99.12	101.61	102.10	101.50	102.30	101.90
<i>Sweden</i>	101.65	100.50	101.42	101.31	99.95	101.73	100.85
<i>Austria</i>	99.88	101.49	102.80	101.01	103.81	106.10	104.96
<i>Belgium</i>	99.88	102.47	98.25	100.12	105.06	97.07	101.04
<i>France</i>	99.49	101.88	99.04	99.98	103.61	94.70	99.13
<i>Denmark</i>	97.91	101.29	95.28	98.10	96.68	90.89	93.77
<i>Spain</i>	97.12	93.80	97.26	96.33	93.79	98.31	96.06
<i>Germany</i>	95.35	96.56	96.46	95.93	98.03	100.97	99.51
<i>Italy</i>	95.94	90.06	94.68	94.16			
<i>Greece</i>	93.38	88.09	91.31	91.54	93.21	94.51	93.86
<i>Portugal</i>	92.59	89.47	90.92	91.39	87.44	91.27	89.37
<i>Netherlands</i>					104.19	106.49	105.35
<i>Japan</i>	102.84	109.76	108.94	106.09	116.52	108.58	112.52
<i>Canada</i>	105.20	105.03	104.78	105.06	101.50	100.97	101.23
<i>New Zealand</i>	104.22	105.82	104.59	104.71	97.84	99.83	98.84
<i>Australia</i>	104.02	105.03	104.59	104.41	102.07	103.63	102.86
<i>Switzerland</i>	97.32	104.25	98.25	99.28	104.96	99.26	102.09
<i>Norway</i>	99.49	98.33	99.04	99.09	96.87	100.21	98.55
<i>United States</i>	99.29	97.15	98.84	98.64	96.30	101.54	98.93
<i>Czech Republic</i>	96.93	98.14	101.22	98.30	108.62	109.15	108.89
<i>Bulgaria</i>					104.00	107.44	105.73
<i>Slovenia</i>					104.19	106.49	105.35
<i>Hungary</i>	94.56	96.17	98.25	95.88	103.42	105.34	104.39
<i>Slovakia</i>					105.35	103.44	104.39
<i>Latvia</i>	90.23	91.24	91.12	90.70	94.95	92.22	93.58
<i>Romania</i>					92.83	92.41	92.62
<i>Lithuania</i>					91.87	90.51	91.18
<i>Cyprus</i>					91.29	88.04	89.65
<i>Poland</i>	94.37	92.62	95.67	94.25			
<i>avge. OECD-21 in levels</i>	100.00	100.00	100.00	100.00	100.00	100.00	100.00
<i>avge. EU-14</i>	507.60	507.45	504.85	506.88	519.24	525.89	522.57
<i>avge. cand</i> s	99.05	98.05	98.54	98.67	98.66	98.83	98.75
<i>avge. cand</i> s	94.02	94.54	96.56	94.78	99.61	99.45	99.53

## Notes:

- TIMSS: scores are for 13-year-olds. In the cases of the UK and Belgium, reported figures are based on the unweighted average of mean regional scores (for England and Scotland and Flanders and Wallonia respectively).
- Countries ranked by average PISA scores (with weights 0.5 for reading and 0.25 for maths and science), except candidate countries, which are ranked by their average TIMSS score (with equal weights for maths and science).
- Sources: OECD (2001a) and *The Economist* (1997).

Table A4.12: Communications and technology indicators

	<i>Telephone lines</i>	<i>Mobile phones</i>	<i>Personal computers</i>	<i>Internet hosts</i>	<i>R &amp; D personnel</i>
<i>Denmark</i>	120.26	127.91	133.46	130.31	127.14
<i>Sweden</i>	122.81	163.05	127.80	138.36	149.26
<i>Finland</i>	100.95	201.00	123.49	251.31	109.19
<i>Netherlands</i>	108.05	74.85	112.31	106.64	86.57
<i>Germany</i>	103.31	59.74	107.75	42.82	110.44
<i>Belgium</i>	91.11	60.79	101.14	64.65	88.63
<i>Ireland</i>	79.26	90.31	96.08	32.83	90.47
<i>UK</i>	101.49	88.55	93.01	66.29	95.50
<i>Austria</i>	89.47	99.10	82.54	69.87	63.47
<i>France</i>	103.86	66.06	73.49	27.12	103.73
<i>Italy</i>	82.18	124.75	61.32	23.60	51.42
<i>Spain</i>	75.44	62.90	51.21	21.73	50.91
<i>Portugal</i>	75.25	108.58	28.75	18.70	46.11
<i>Greece</i>	95.11	68.17	18.35	15.23	30.16
<i>United States</i>	120.44	89.96	162.18	400.13	143.40
<i>Switzerland</i>	122.99	82.58	149.16	88.49	117.27
<i>Australia</i>	93.29	100.50	145.56	117.01	130.96
<i>Norway</i>	120.26	166.57	132.05	185.52	142.94
<i>Canada</i>	115.52	61.85	116.70	111.41	106.07
<i>New Zealand</i>	87.28	71.34	99.76	145.07	64.88
<i>Japan</i>	91.65	131.43	83.88	42.91	191.50
<i>Slovenia</i>	68.33	29.52	88.73	21.39	87.81
<i>Czech Republic</i>	66.33	33.03	34.41	22.64	47.67
<i>Slovakia</i>	52.11	30.57	23.02	9.89	72.79
<i>Hungary</i>	61.22	36.90	20.83	23.39	42.87
<i>Lithuania</i>	54.66	25.30	19.10	7.10	79.11
<i>Poland</i>	41.54	17.57	15.52	9.75	52.98
<i>Estonia</i>	62.50	59.74	12.17	42.66	78.69
<i>Turkey</i>	46.28	18.62	8.20	2.87	11.35
<i>Romania</i>	29.52	10.19	3.61	2.27	54.11
<i>Bulgaria</i>	59.95	5.27		2.99	68.15
<i>Latvia</i>	55.03	23.90		11.82	40.92
<i>avge. OECD-21</i>	100.00	100.00	100.00	100.00	100.00
<i>in levels</i>	548.81	284.57	282.78	484.83	2 563.38
<i>avge. EU-14</i>	96.33	99.70	86.48	72.10	85.93
<i>avge. cands</i>	54.32	26.42	25.06	14.25	57.86

*Definitions:*

- *Main telephone lines* per 1 000 people in 1998.
- *Number of mobile phones* per 1 000 people in 1998.
- *Personal computers* per 1 000 people in 1998.
- *Internet hosts* per 10 000 people in 2000.
- *R & D personnel* = scientists and engineers employed in R & D per million, most recent year available (ranges between 1987 and 1997).
- *Source:* World Bank, 2000/01 *World development report*.

The available information suggests that the candidate countries as a whole spend less on education than the EU, both as a fraction of national income and on a per student basis. There are, however, large differences across countries in this group and discrepancies across sources that make it difficult to be very precise concerning expenditure patterns in candidate countries. On the whole, it seems clear that expenditure levels are particularly low in Turkey, Romania and Bulgaria, whereas Hungary, the Baltic republics, Slovenia, Poland and the Czech Republic are not far from EU levels at least in terms of some resource indicators.

Tables A4.9 to A4.11 display various indicators of school achievement and labour force quality based on international standardised tests or literacy surveys. Tables A4.9 and A4.10 summarise the results of two recent OECD studies (IALS and PISA) that have already been discussed in Section 2(b) of this appendix. We construct summary measures of national performance in each of these studies by averaging each country's results across the various dimensions of literacy analysed in these surveys. These two tables display the mean national scores, the scores corresponding to the 5th and 95th percentile of each national distribution, the range of scores (defined as the difference between the previous two values) and the percentage of the adult population (in IALS) or the student population (in PISA) that falls below the literacy level (level 3) that is considered necessary for coping with the demands of work and everyday life in advanced societies. Table A4.11 shows average scores by subject in the PISA study and in another recent international study of achievement in maths and science (TIMSS). As usual, all variables are normalised by their average values in our primary sample of 21 OECD countries.

According to most of these indicators, mean EU performance is slightly below the OECD average and significantly above that of the group of candidate countries (except for the TIMSS study, where the last group does slightly better than EU-14 on average). A particularly worrisome finding of the IALS is that a large fraction of the population (43.54 % for OECD-21 and over 60 % in the candidate countries) lacks basic literacy and quantitative skills that are likely to be important both on the job and in everyday life. The corresponding figures for the (reading literacy of the) student population are only somewhat better (36.70 and 48.75 % respectively) according to the PISA study. It is also interesting to note that the cross-country variation in skill levels (as measured by the standard deviation of normalised scores) is much higher at the bottom of the distribution (fifth percentile score) than for mean or top performance levels, and that there is essentially no correlation between mean national performance and the range of scores in the PISA study. This suggests that the quality of the education system is particularly important for disadvantaged individuals, and that the performance of this group can be improved without lowering average standards.

Finally, Table A4.12 collects various indicators of the penetration of ICT technologies and of R & D effort. In terms of these indicators, most candidate countries are lagging well behind the EU which is, in turn, far below US standards. Within the EU, there is a clear divide between the north and the south, with the Scandinavian countries at one end of the scale and Spain, Portugal and Greece at the other, in terms of indices of computer and Internet use and R & D investment.

## 5. Social capital: a survey of the theoretical and empirical literature

The attention paid by economists to social capital has been rapidly increasing in the last decade. The term social capital was rendered popular by the contributions of Coleman (1988, 1990) and Putnam (1993a and b, 1995a and b) and by now the World Bank (2002) has an excellent Internet site with an entire electronic library on the subject. Coleman starts with the consideration that social interaction brings about long-lasting patterns of relations, which constitute a resource available to individual actors. Such a resource may be accumulated or depleted over time and is defined by its productive function: it allows actors to reach goals otherwise not reachable or it diminishes the cost of reaching them.

Thus, it may be thought of as a peculiar form of capital, namely a 'social capital', whose specific characteristic consists of the fact that it is not incorporated into physical goods or into single human beings, as physical and human capital, but rather into social relations: it is an attribute of social structures. Examples of social capital are the level of trust and the information potential incorporated into relations, the existence of civic norms with effective sanctions, and the presence of hierarchical and horizontal relations and organisations.

A critical difference between social capital and other forms of capital, stressed by Coleman, is that it presents

a key aspect of public goods: 'As an attribute of the social structure in which a person is embedded, it is not the private property of any of the persons who benefit from it'. This poses a problem of underinvestment, since 'there will be in society an imbalance between the relative investment in organisations that produce private goods for the market and in organisations (often voluntary associations) from which the benefits are not captured — an imbalance in the sense that if the positive externalities created by such social capital could be internalised, it would come to exist in greater quantity'. Thus, private investment in social capital could fall short of the social optimum; on the other hand, if social capital is accumulated through interaction among individuals, public provision cannot be a solution either. One of the key contributions of social capital, according to Coleman, is to the accumulation of human capital: it is much easier to develop individual skills in a socially rich environment than in a socially poor one. Since human capital accumulation constitutes an engine of growth in advanced economies, social capital appears in a way as a deep root of growth processes.

Putnam (1993a) investigates the link between social capital and economic and political performance in Italy and finds that a great part of the difference in development between southern and northern Italian regions is 'explained' by the different presence of networks of horizontal organisations, which is a historical heritage and constitutes a form of social capital. In particular, he shows that local governments are more efficient where civic engagement is stronger, and argues that civic engagement is strictly related to the presence of horizontal associational networks. In other works (1993b, 1995a and b, 1996, 2000), he extends the analysis of social capital. In particular, applying it to the United States, he argues that the stock of American social capital declined in the late 20th century, mainly due to the disappearance of the 'civic generation', which came of age between the Great Depression and World War II, and to television, that keeps individuals apart from one another. Nevertheless, his latest work also discusses some signs of revival.

Already in these contributions, the authors do not always refer the term social capital to the same thing: Putnam's definition is relatively narrow, whereas Coleman's is broader. The World Bank now defines social capital at the broadest level as 'the norms and networks that enable collective action'. Different authors have proposed still different definitions, so that by now 'social capital' denotes more a whole strand of research than a single concept. Our first step is consequently to review the various theoretical definitions and to provide conceptual clarification. Next, we con-

sider the empirical problem of measuring social capital and its effects. The subsequent step is to analyse the process of social capital accumulation. Finally, we consider some policy implications, with particular attention to Europe.

### (a) What is social capital?

Let us start with a rather general definition of social capital — adapted from the World Bank — as the norms and social relations embedded in the social structure of a group that enable people to coordinate action to achieve desired goals. This definition deserves some comments. Firstly, the group considered might consist of only one individual, at one extreme, as well as of the whole society, at the opposite extreme; correspondingly, we can define social capital at the individual as well as at the aggregate level, and we can choose between focusing on a specific group or on society as a whole. Secondly, social capital consists of norms and social relations, which are attributes of the social structure. They can be reinforced or weakened over time, but at a given point in time they constitute a stock. Thirdly, this stock is 'productive', in the sense that it allows group members to reach their goals. Such goals may concern standard output and income, but may also concern socially provided goods, like status and friendship. Moreover, the goals pursued by one group may be in accordance with or contrary to those of other groups, so that social capital may display both positive and negative externalities (for instance, it may serve cooperative as well as rent-extracting purposes). Fourthly, social capital is both accumulated and displays its effects through social interaction: it is in this way that norms and relations are reinforced or weakened and that coordination among people is achieved. Such coordination may take place at two levels: either within the group members ('bonding social capital'), or with non-members ('bridging social capital'). There is an intrinsic difficulty in the aggregation of social capital, because what is productive for one group may either hurt or benefit a different group: if we collect together groups with a strong 'bonding' social capital, we do not necessarily end up with a high aggregate level of social capital; 'bridging' links play a crucial role. For this reason, it is useful to work both with an individual-level definition of social capital and with a group-level one. In the literature both are present. Let us consider them in turn.

#### (i) Individual social capital

Glaeser, Laibson and Sacerdote (2000) propose to define individual social capital as an individual's social skills, which are partly innate (e.g. being extroverted



and charismatic), but partly cultivated (e.g. popularity), i.e. they are the result of an investment. Social skills enable an individual 'to reap market and non-market returns from interaction with others. As such, individual social capital might be seen as the social component of human capital'. Not all the social skills which are beneficial to an individual are also beneficial to the aggregate outcome of social interaction: for instance, the ability to persuade others that you are trustworthy when you are not generates a negative externality (think, for example, of some sellers of encyclopaedias or of used cars), whereas the ability to induce others to participate in a socially beneficial project generates a positive one. Moreover, the same social skills may sometimes be used to increase aggregate outcome, but sometimes only to increase the slice reaped by their owner, with a possible aggregate loss. This problem makes it difficult to aggregate individual social capital over a whole economy (or even over a group), since one should incorporate 'all of the cross-person externalities generated by the different types of individual social capital'. The consequence is that 'the determinants of social capital at the individual level may not always determine social capital at the society level'. On the other hand, the big advantage of this framework is that it allows studying individual decisions of investment in social capital with standard investment models, which provide predictions that can be confronted with the data. Glaeser, Laibson and Sacerdote perform such an exercise and find that individuals invest in social skills in the same way as they invest in human capital.

Two remarks are in order. On the one hand, Glaeser, Laibson and Sacerdote's definition of social capital does not really fit the definition we have given above, since they focus on individual characteristics and not on traits of the social structure. As they recognise, what they are analysing is the social component of human capital, which, for the sake of clarity, should, perhaps, be kept separated from the concept of social capital. On the other hand, the amount of social skills belonging to an individual is highly correlated with the amount of his or her social connections, an aspect that is more compatible with our definition.

In this spirit, DiPasquale and Glaeser (1999) define individual social capital as an individual's connections to others and argue that it matters much for private provision of local amenities and of local public goods. They also investigate empirically whether homeownership increases investment in local amenities and social capital and find that indeed it does, especially because it reduces individual mobility. We discuss this last point in Section 5(c).

## *(ii) Group social capital*

At the aggregate level, definitions of social capital tend to focus either on the density of trust, which facilitates collective action and reduces 'freeriding' or on networks of civic engagement and of horizontal associations, following Putnam. Although these two aspects overlap to some extent, so that it is often not easy to distinguish between them, they have given rise to two strands of the literature.

### Trust

Although at first sight very intuitive, the notion of trust is hard to define theoretically in a clear-cut way. There is much literature on this topic, but its subtleties are probably not so relevant for an aggregate theory of social capital, especially when it comes to the empirical side. A relevant feature of trusting behaviour seems to be that it exposes an individual to the risk of being worse off, if others behave in a purely selfish way. A key effect is that trusting others may make them more trustworthy. If this happens, the advantages of cooperation may be exploited; if it does not, trusting people may be exploited by non-trustworthy ones.

Paldam and Svendsen (2000) define social capital as 'the density of trust within a group' and notice that 'the group may be extended to the whole society', which is consistent with the definition we gave above. They discuss the link between social capital theories dealing with goodwill (management), credibility (macroeconomic policy), cooperative solutions (game theory) and group norms (anthropology and psychology), and point out three possible, non-mutually-exclusive approaches to social capital: as a factor in a production function, as a factor that reduces transaction costs, and as a determinant of monitoring costs.

Fukuyama (1995a and b) identifies social capital with trust and argues that it determines the industrial structure of an economy. Germany, Japan and the United States, for instance, are high-trust societies, where trust is not restricted to the family, but rather generalised, whereas Taiwan, Hong Kong, Italy and France are examples of low-trust societies. In the former group of countries, it is easy to find giant, professionally managed corporations, because people are better able to cooperate on an enlarged scale, whereas, in the latter group, smaller, family-owned and family-managed firms dominate the industrial structure. In general, Fukuyama argues that the strength of family ties may be detrimental to the emergence of large organisations, and that, where familism is not accompanied by a strong culture of work and education, it may lead to stagnation,

as pointed out, for example, by Banfield (1958). This does not automatically imply that high trust, and hence large companies, are per se better performing or even better for aggregate growth, since what they gain in scale may be lost in flexibility and rapidity of decision-making. The economic success of northern Italy provides a good example.

The theoretical relationship between trust and growth is investigated by Zak and Knack (2001) through a moral hazard model, in which formal and informal institutions determine the amount of monitoring that a principal needs to exercise over an agent. They argue that 'informal sanctions depend on, or are facilitated by, social ties', which can be captured by a notion of social distance, and that monitoring costs and risk aversion may make low-trust societies have lower income and lower investments, and thereby lower growth. Moreover, they add that trust is lower in more heterogeneous societies because a higher social distance among actors weakens informal controls. As a consequence, in such societies, growth may be lower as well: there may be a 'low-trust poverty trap'.

Indeed, one can observe that their model deals more with informal sanctions than with trust: once we consider the incentives induced by such sanctions, we can avoid any reference to trust without conceptually losing anything (in Williamson's, 1993, words, 'calculative trust is a contradiction in terms'). The point is that trust is the complex product of a structure of social relations, of the interactions that take place in it, and of how these shape individual identities and motivations, and finally behaviour. So let us now turn to a more structural point of view.

#### Social norms and networks

As we pointed out above, Putnam defines social capital in terms of networks of civic engagement and of horizontal associations. Norms and associations are a relatively stable attribute of a social structure, and can be thought of as a stock. They arise through social interaction and they shape the way individuals interact with one another, so that social interaction (a flow) is both a source of social capital and the means through which it displays its productive services. If a norm of cooperation or of participation is effective, that behaviour that is in accordance with it will also appear quite stable. This has generated some confusion in the theoretical definition of social capital, since the term sometimes refers to the stock of social norms and networks and sometimes to the specific form of interaction that arises out of it. This has led some authors, for instance Bowles and Gintis (2000), to abandon the term social capital in

favour of something they perceive as more precise. In particular, Bowles and Gintis prefer to speak of community governance, arguing that it is often the case in the literature that the term social capital refers to what groups do rather than to what they own, and such an aspect is better captured by the notion of community governance — as opposed to the governance mechanisms of the State and of the market — than by the notion of social capital. Notice, however, that considering just the community of direct and frequent interactions, expressed by Bowles and Gintis's idea of community governance, is restrictive, since it may overlook the strength of weak ties, stressed, for example, by Granovetter (1973) and by Narayan (1999), and the relevance of generalised trust, as we discussed above.

Aware of such conceptual problems, Fukuyama (1999) proposes to change his previous definition of social capital in terms of trust into the following: 'social capital is an instantiated informal norm that promotes cooperation between two or more individuals'. He argues that 'by this definition, trust, networks, civil society, and the like which have been associated with social capital are all epiphenomenal, arising as a result of social capital but not constituting social capital itself'. One crucial aspect of such definition is the extent of validity of the norms considered (also referred to by Fukuyama as the 'radius of trust, that is, the circle of people among whom cooperative norms are operative'). This leads to a more precise specification of the group (or institution) to which one refers the term social capital.

A second crucial aspect is that cooperation within a certain group may have positive as well as negative external effects on other groups. For instance, the degree of participation in associational activities does not necessarily increase aggregate (society-level) social capital, as hypothesised by Putnam: Olson (1982) emphasises that the purpose of some groups is to exert a distributive pressure, i.e. to seek rents, and that active participation in such groups indeed increases the level of distributive struggle in a society and decreases social capital.

Both these aspects — the extension of the group and the kind of external effects — are captured by Collier (1998). He starts with a definition of social capital in terms of those externality-generating social interactions which are either themselves durable or whose effects are durable, and he carefully distinguishes between the various institutional levels at which social capital may be present: the family, the firm, the government and civil society.

Social capital at the firm level is the easiest to study. As already noticed by Coleman, the internal organisation of a firm is intentionally designed to make profits, so that this is one of the few cases in which social capital is the product of a specific investment and not just the by-product of other activities. Such aspects are widely studied in management and business disciplines, although without any reference to the notion of social capital. Proof of their relevance is the amount of money that firms spend not only to design internal structures, but also to train managers and workers to work in groups: management consultants and labour psychologists are often very well paid to provide such training, evidently because it pays off. Interfirm linkages, typical, for instance, of industrial districts, constitute a second form of firm-level social capital. Signorini (2000) presents a very detailed analysis of the Italian case, which helps in the understanding of how the success of many small Italian firms relies upon external economies that compensate for the scale disadvantage.

Coming to the family, we have noticed above that Fukuyama and Banfield, among others, emphasise the possible contrast between strong family ties and more aggregate levels of social capital. Family is indeed the primary source of narrow trust, i.e. trust in peer or primary groups, but whether or not trust generalises and extends beyond kinship relations depends to a high degree both upon the kind of interaction that takes place in the intermediate structures of civil society, and upon the well functioning of the government, which can provide, for instance, a reliable judicial system.

As we have seen, Putnam emphasises the first aspect, i.e. participation in associational networks at the level of civil society. However, whether trust remains confined within certain groups or generalises beyond their scope depends to a high degree on whether groups form along social cleavages or across them: one needs to look at the specific kind of social participation and not just at the density of associations, although the latter one may be sometimes the best empirical proxy available.

As far as the link between social capital and the well functioning of government is concerned, Narayan (1999) points out it is not univocally of substitution or of complementarity, since when either of them is poor, the other may work as a substitute, but if both of them are rich, they indeed work as complements (he also provides a detailed discussion of the empirical evidence available). The fact that formal institutions (market and State) are not working properly may increase reliance on primary groups — what Rose (1998) claims happened in Russia after the collapse of the Soviet Union, but he

also points out that such reliance on primary groups had previously been fostered by the extreme centralisation and had emerged as a way of defending oneself from invasion by the State. Another interesting example of how government, family and civil society interplay to shape trust, norms and connections (social capital) at the level of some groups, but with troublesome extensions to the whole society, is Gambetta's (1993) analysis of the Sicilian Mafia.

The problem is that social capital tends to exert positive aggregate effects when trust, norms and networks that foster cooperation extend beyond primary, ethnic, linguistic or even income groups and form 'bridges' among different groups. This last point is made with particular strength by Narayan (1999), who observes that the same links that keep together the members of a group may also exclude the non-members, and who displays an analytical framework to study 'bonding' and 'bridging' (i.e. intragroup and intergroup) social capital at the level of civil society, together with its connections to the functioning of the State.

## **(b) Empirical evidence on social capital and aggregate performance**

There is by now wide empirical literature on the effects of social capital on aggregate performance. The World Bank considers a list of 11 broad topics to which social capital is relevant. Here, we analyse only some of them: in particular, we consider empirical evidence on the effects of social capital on growth, trade and migration, finance, government performance, education, crime and violence.

### *(i) Social capital and growth*

Knack and Keefer (1997) examine various possible empirical proxies for social capital, corresponding to the different aspects emphasised by the theoretical literature, and assess their impact on growth. They discuss three main relationships: between trust and civic norms and economic growth; between associational activity and growth; and between trust and civic norms and their determinants, including associational activity and formal institutions. The last relationship is discussed in the next section. The first two are considered here.

Knack and Keefer consider data from the world value survey for 29 market economies between 1981 and 1991. As a proxy for trust (TRUST), they take for each nation the percentage of respondents who answered that most people can be trusted (after deleting the 'don't know' answers), to the following

question: 'Generally speaking, would you say that most people can be trusted, or that you can't be too careful in dealing with people?'. This measure of trust exhibits a high cross-country variance and high serial autocorrelation within each country. To capture the strength of norms of civic cooperation, they construct a variable (CIVIC) on the basis of the answers to various questions about how individuals evaluate some anti-civic behaviour. These two variables are highly positively correlated and both of them are designed to capture generalised trust and cooperative attitudes, rather than social capital at the level of a specific group.

The first main finding of Knack and Keefer is that 'trust and civic cooperation are associated with stronger economic performance'. In particular, they find that one standard deviation change in TRUST is associated with a change in growth of more than half of a standard deviation. This result seems to be quite robust. The second question they address concerns the effects of associational activities, about which, as noticed above, Olson and Putnam have contrasting hypotheses. As a proxy for the density of horizontal networks in a society (GROUPS), they consider the average number of groups cited per respondent when faced with the question of whether they belong to any of a list of groups of 10 kinds. The second main result is that 'associational activity is not correlated with economic performance — contrary to Putnam's (1993) findings across Italian regions'. They also split the data to identify the possibly contrasting effects of 'Putnamesque' and 'Olsonian' groups, i.e. of groups that 'involve interactions that can build trust and cooperative habits' and of groups with redistributive goals, respectively. The results are contrary to what the theory predicts, but, by admission of the authors, they should be regarded as only preliminary. Their relevance is methodological rather than substantial.

Zak and Knack (2001) perform a similar analysis, using the same variable for trust, but with more data. In particular, while Knack and Keefer's investigation concerns 29 OECD countries, Zak and Knack add 12 more countries to the sample. The effect of the larger sample is basically that it reinforces the statistical impact of trust on investments and growth. Moreover, they investigate the impact of formal institutions and social homogeneity, finding that they 'increase growth in part by building trust'.

A related empirical contribution is made by Temple and Johnson (1998), who show that indices of 'social capability' constructed in the early 1960s, adapted from the work of Adelman and Morris (1967), are good predictors of long-run growth for a wide set of developing

countries. In particular, they find that a mass communication index is robustly correlated with growth and argue that this may be due to the fact that 'it captures the social capital of developing countries'. Although these results are striking, it is hard to understand exactly how one should evaluate them, because the social capability index used is quite composite and not so straightforward to interpret, and because it is not very clear how the index of mass communication is related to social capital.

Taken together, this evidence consistently shows that social capital, especially in the form captured by the variable TRUST, has a relevant impact on growth. Glaeser, Laibson, Scheinkman and Soutter (2000) address the question of what exactly TRUST measures. For this purpose, they use two experiments and a survey, and assess that standard questions about trust, such as the one reflected in TRUST, provide a better measure of the level of trustworthiness in a society rather than of trusting behaviour. Nevertheless, they also assess the possibility to gain robust measures of social capital (trust) as an individual-level variable. In particular, measures of past trusting behaviour predict an individual's trust better than abstract questions.

#### *(ii) Social capital and government performance*

Hall and Jones (1999) explain a relevant part of country productivity as due to institutions and government policies (what they call 'social infrastructures'). Since these characteristics are endogenous, they propose a set of instruments. A growing amount of evidence is now showing that the quality of government is positively influenced by social capital. An in-depth investigation of the determinants of government quality is due to La Porta, Lopez-de-Silanes, Shleifer and Vishny (1999). They evaluate empirically the ability of economic, political and cultural theories to explain the observed quality of governments, according to different measures. Broadly speaking, they find that economic theories focusing on efficiency are rejected by the data; political theories focusing on redistribution are highly and robustly supported by the evidence (as instruments for redistributive tendencies they use ethnolinguistic heterogeneity and legal system); and, finally, cultural theories focusing on trust, social norms of tolerance and work ethic cannot be rejected. In particular, as an instrument for such cultural characteristics, they use religion, in the spirit of Weber (1958), and find essentially that 'predominantly Protestant countries have better government than either predominantly Catholic or predominantly Muslim countries'. Such results prove to be robust to many alternative specifications and confirm earlier findings of the same authors.



One of the main functions of governments is to provide public goods. Alesina, Baqir and Easterly (1999) relate spending on public goods to ethnic division at the level of cities, metropolitan areas and urban counties in the United States. Their finding that 'more ethnically diverse jurisdictions in the United States have higher spending and higher deficits/debt per capita, and yet devote lower shares of spending to core public goods like education and roads' is consistent with the idea that 'heterogeneous and polarised societies will value public goods less'.

The relationship between the variables considered in these studies, like ethnolinguistic heterogeneity and religion, and social capital is considered in the next section. Here, in turn, we pass to the analysis of the impact of social capital on education.

#### *(iii) Social capital and education*

One of the possibly most relevant contributions of social capital is to the formation of human capital. This was recognised very early by Coleman (1988), who argued that the same basic individual skills have much better chances of being well cultivated and developed in a socially rich environment than in a socially poor one. Goldin and Katz (1999a), in a study on the development of secondary education in the United States and, in particular, in Iowa, acknowledge that, 'because educational decisions are made primarily at a local level in the United States, the production of human capital depends largely on social capital lodged in small communities'. As a measure of community-level social capital, they use 'the amount of public resources committed to education as a fraction of the total resources of the community, given by income'. It is interesting to see that this 'indicator of educational commitment rose steeply during the 1910s and for most of the 1920s' and then rose again in the 1950s, but it is harder to take it as a direct measure of community-level social capital. However, one further empirical observation supports this interpretation: 'one good reason for building schools in rural America was to stop the drift of the population to the cities', i.e. to save and promote community cohesion. The almost ubiquitous public provision of schooling is consistent with the view that 'public funding was part of an intergenerational loan. According to this view, homogeneous communities, in which people tend to remain and take an active interest in each other, would be more likely to provide intergenerational loans'. Indeed, such communities were present in Iowa, one of the leading states in the development of schooling. In particular, 'smaller towns of Iowa had the highest rates of secondary school attendance', even though a more precise assessment of why this was the case turns out to be difficult.

A relevant problem in empirical analyses of the link between social capital and education is that there is an issue of reverse causation. Goldin and Katz find a strong correlation 'between an index of social capital today (combining measures of associational activities, social trust, and political/civic participation)' and 'the high-school graduation rate in 1928'. They conclude that social capital has a double role of condition for accumulation of human capital and of handmaiden of human capital. The issue of how education determines social capital is also tackled by Helliwell and Putnam (1999), to whom we turn in the next section.

#### *(iv) Social capital and crime*

It is intuitive that social capital, determining the degree of social cohesion, may have a relevant influence on the rates of crime and violence. Coleman (1990) already stresses this point. Glaeser, Sacerdote and Scheinkman (1996) explore this issue. In the face of several possible empirical explanations of the high variance of crime across time and space, they take a sharp interactionist view, assessing that 'positive covariance across agents' decisions about crime is the only explanation for variance in crime rates higher than the variance predicted by differences in local conditions'. Patterns of local interaction thus seem to drive crime to a relevant extent, the more so as far as young people and petty crimes are concerned.

#### *(v) Social capital and financial development*

Guiso, Sapienza and Zingales (2000) investigate the impact of trust on financial development. They argue that 'financing is nothing but an exchange of a sum of money today for a promise to return more money in the future. Whether such an exchange will take place depends not only upon the enforceability of contracts, but also the extent the financier trusts the financee. In fact, financial contracts are trust intensive par excellence. Thus, if trust matters, it should matter most for the development of financial markets'. Their proxy for trust is different from standard survey measures, since they consider participation in elections and blood donation. They use data on Italian regions, which present the advantage of having the same 'legal, administrative, judicial, regulatory and tax system', but at the same time very different levels of social capital, and assess that higher trust increases investment in stocks, access to credit and use of cheques, whereas it reduces investment in cash and resorting to informal credit channels. Moreover, such effects appear to be more relevant where legal enforcement is weak and among less educated people.

### (c) Social capital accumulation

The theoretical and empirical literature considered so far shows that social capital, defined and measured in several ways, matters for a great variety of economic outcomes. This finding raises the questions of how social capital is accumulated and of whether its accumulation may be enhanced by policy intervention. We address the first question in this section and the second in the next.

#### (i) Theory

There is not much theoretical work discussing the determinants of social capital. According to Glaeser, Laibson and Sacerdote (2000), as we noticed above, this lack is due to the fact that most definitions and measures of social capital are aggregate ones, whereas economists are used to thinking of capital accumulation as a result of individual investments. They therefore define social capital in terms of individual social skills, i.e. as the social component of human capital, and apply a standard model of individual investment. Such a model implies that investment in social capital should increase with patience and with the relevance of positive externalities in the return to social capital investment (e.g. individuals invest more in social skills in those occupations where returns to social skills are higher), whereas it decreases when there are higher expected mobility (e.g. homeowners should invest more in social skills), the opportunity cost of time, the rate of depreciation and the degree of community specificity of social capital. Moreover, investment should decrease with age, but, assuming that individual endowment at birth is sufficiently low, the stock of individual social capital should first increase and then decrease with age.

This model is theoretically very clear, but it does not solve the problem of aggregation, so that aggregate determinants of social capital might be quite different from the determinants of investment in individual social skills. In the authors' words, 'understanding the link between individual and aggregate social capital is important, difficult, and best left to future research'.

If we consider group-level definitions of social capital, both in terms of trust and of social networks, the theory of social capital accumulation focuses on the individual problems of whether or not to trust and of whether or not to join a group.

As far as trust is concerned, Alesina and La Ferrara (2000b) admit that 'the theory of what determines trust is sketchy at best'. They consider 'five broad factors influencing how much people trust others: (1) individual

culture, traditions and religion; (2) how long an individual has lived in a community with a stable composition; (3) recent personal history of misfortune; (4) the perception of being part of a discriminated group; (5) several characteristics of the composition of one's community, including its racial and income heterogeneity'. However, they do not display any formal model.

As far as participation in groups and associational activities is concerned, Alesina and La Ferrara (2000a) focus on population heterogeneity and argue that its link with social participation is theoretically ambiguous. On the one hand, heterogeneity could increase the number of associations, since each group would like to have its own. On the other hand, heterogeneity may also increase the likelihood of mixed groups being formed. This, in turn, may reduce participation if individuals prefer to interact with others similar to themselves (e.g. in terms of income, 'race' or ethnicity).

#### (ii) Evidence

Let us now consider the empirical evidence on the accumulation of the different kinds of social capital (individual social skills, trust and social participation) and then on the extent of the decline of social capital assessed by Putnam.

##### Individual social capital

Using data from the general social survey in the United States from 1972 to 1998, Glaeser, Laibson and Sacerdote (2000) find that their theoretical model (discussed above) fits well with the data. In particular, organisation membership has an inverted U-shape over the life cycle; the prediction that expected mobility reduces individual social capital seems to be consistent with the data, although they do not find a good instrument for expected mobility; more social occupations induce higher investment in social skills; the evidence on the impact of homeownership on group membership varies according to the kind of group (for instance, it is low for political groups and high for school services): in general, it seems that homeownership affects social capital more through its effect of reduced mobility than through patrimonial effects, i.e. through incentives due to expected changes in property value; investment in individual social skills might indeed be partly due to the opportunity cost of time, but it is very difficult to find a satisfactory empirical assessment of this relationship; physical distance, unsurprisingly, affects negatively social connections; education and membership in organisations are positively correlated, as predicted by the theory, since patience increases both investment in human capital and in social capital; and, finally, the



empirical evidence they find leaves the authors undecided as to the relevance of interpersonal complementarities.

As a general point, one might notice that most of the empirical proxies used by Glaeser, Laibson and Sacerdote are more related to the rest of the literature on social capital than to their own definition of the social component of human capital. Indeed, they acknowledge that standard measures of individual trust and of organisation membership do not capture in an obvious way what they define as 'social capital'.

As discussed above, DiPasquale and Glaeser (1999) also start with an individual-level definition of social capital, although they stress more an individual's social connections with others. Empirically, they study how homeownership may create incentives to social capital accumulation and to provision of local amenities. This might work either through the fact that such investments increase the value of property or because owning a home reduces mobility and thus increases the time one expects to enjoy the fruits of such investments. They use data from the US general social survey and from the German Socioeconomic Panel. Both in the United States and in Germany, they find a strong correlation between homeownership and measures of civic engagement in one's community (e.g. membership in non-professional organisations, knowing the names of local political representatives, voting in local elections, gardening and church attendance). Such effects are weaker in Germany than in the United States. Moreover, in the United States, a larger fraction of the effect seems to be attributable to increased community tenure. The authors are very careful about policy conclusions, since unobserved omitted variables might play a relevant role (homeowners may be different from renters), and since they do not measure either the positive or the negative externalities linked to homeownership and decreased mobility.

A general conclusion is that individual incentives matter for social capital accumulation, but not in a naive way. Social rewards may provide more effective incentives for social capital accumulation than material ones, a point that hints at the relevance of social capital for 'relational production' besides material production and that should be kept in mind when thinking of policy intervention.

#### Trust

Alesina and La Ferrara (2000b) consider both individual experiences and community characteristics as possible determinants of individual trust. Using data

from the general social survey for the United States from 1974 to 1994, they find that the major causes of low trust are recent traumatic experiences, belonging to a discriminated group, low income, low education, and living in a society with strong 'racial' cleavages or with high income inequality. Religious beliefs and ethnic origins, in contrast, are found not to affect trust significantly.

Glaeser, Laibson and Sacerdote (2000) combine survey and experimental data to identify separately the determinants of trust and trustworthiness. Two of their findings are that a smaller social distance among individuals, for instance due to joint group membership or the same 'race' or nationality, increases both trust and trustworthiness. Moreover, an individual's higher status induces others to behave in a more trustworthy manner towards him or her.

Finally, Knack and Keefer (1997) find that 'trust and norms of civic cooperation are stronger in countries with formal institutions that effectively protect property and contract rights, and in countries that are less polarised along lines of class or ethnicity'.

#### Social participation

Alesina and La Ferrara (2000a) study participation in associational activities like religious groups, sport groups, hobby clubs, unions, etc. (they consider participation in a list of 16 different kinds of groups). They analyse data for metropolitan areas in the United States from 1974 to 1994, mainly from the general social survey. They run a probit regression to explain the probability of social participation, controlling for individual and community characteristics. The key results are striking: social participation is higher where income inequality, 'racial' segmentation and ethnic segmentation are lower. This happens in the north/north-west of the United States, the opposite features appearing in the south/south-east. Moreover, looking at participation in different kinds of groups, the authors find that heterogeneity matters less for participation in groups with a relatively **high degree of excludability** or a **low degree of close interaction** among members. Finally, they find that 'racial' segmentation matters more for individuals more averse to 'racial' mixing.

In more detail, they find that younger cohorts participate less than older ones, providing some support to Putnam's idea of a decline in participation due to the ageing of the 'older civic generation'. Years of schooling have a positive impact on participation. Women participate less than men. Black people participate more. Young children reduce parents' participation. Family

income has a positive effect, 'suggesting that participation is a normal good'. As regards community characteristics, the measures of income inequality and of racial and ethnic segmentation always have a negative impact on participation, controlling for individual variables and for year and state dummies. The authors also perform some sensitivity analyses, which confirm and even strengthen the results: they assess that an increase by one standard deviation in racial segmentation, income inequality and ethnic segmentation reduces the probability of participation by respectively 8, 6 and 6 percentage points; the impact of passing from high-school dropout to high-school graduate or higher is a positive increase of 13 percentage points; moving from a full-time to a part-time job increases the propensity to participate by 4 percentage points; finally, having a child below the age of five reduces it by 3.5 percentage points. Interestingly, the relation between participation and income seems to be increasing but is not linear: it is convex for low levels of income and concave for high levels. Instrumenting for income inequality leaves its effect on participation highly negative and significant.

Helliwell and Putnam (1999) consider both trust and social participation at the same time. They investigate whether and how education determines social capital. They start with the observation that, although average educational levels have risen sharply in the United States in the last half century, the same has not happened to political and social participation. This is somewhat puzzling, because individual education is widely acknowledged to be the best predictor of many forms of political and social engagement. Helliwell and Putnam discuss the theory trying to solve this puzzle and argue that it does not allow a clear conclusion to be reached. Using data from the US general social survey from 1972 to 1996 and from the DDB-Needham lifestyle surveys from 1975 to 1997, they assess that higher average education increases trust and does not reduce participation.

Is there a decline in social capital?

One of the main issues in the theory of social capital is the problem of possible underinvestment. Coleman (1990) raises this issue and Putnam (1995a and b, 2000) documents empirically a decline in American social capital, identifying the main culprits as television and ageing of the 'civic generation' of Americans born between 1910 and 1940. Putnam finds that television is responsible for up to a quarter of the decline in social capital and the ageing of the 'civic generation' up to half of it. However, there is no widespread agreement either on the empirical relevance of such decline or on its causes.

Costa and Kahn (2001) argue that it has been overestimated by Putnam, although some forms of social capital indeed declined in the United States from 1952 to 1998: whereas group membership indeed diminished, the probability of volunteering did not; the largest declines are found in the time devoted to entertainment and visits with friends, relatives and neighbours. Such results are found using probit regressions with a great variety of data sources. Costa and Kahn also show that the decline in the social capital produced outside the home is mainly due to rising community heterogeneity (especially income inequality), whereas the decline in the social capital produced within the home is mainly explained by women's increased labour force participation rate (always controlling for education).

#### (d) Policy

Policy implications are drawn in a sparse and usually very cautious way in the literature on social capital. The World Bank considers the following list of political issues, strictly connected with social capital: crime and violence, trade, education, environment, finance, health, nutrition and population, information technology, poverty and economic development, rural development, urban development and water supply and sanitation. Many of them are more relevant for developing countries than for Europe, but some of them represent hot issues in the current European political debate. Let us briefly examine some of the indications arising from the literature.

##### (i) *Individual social capital*

Those contributions that emphasise individual aspects of social capital make the general point that its accumulation responds to individual incentives, but not in a naive way. One of the difficulties here comes from the fact that intrinsic motivations may be either reinforced or crowded out by an exogenous introduction of incentive schemes. This is especially the case if incentives change the way individuals interpret and frame a situation. For instance, suppose that in a certain situation cooperation is perceived as the appropriate behaviour, in accordance with a social norm, and that we now introduce a fine to sanction defective behaviour; then individuals might abandon the social norm interpretation and embrace a market-based one, according to which defection amounts to purchasing a good (the individual advantage arising from it) at a given price (the fine), without any remorse for bad behaviour: if the monetary cost of the fine is lower than the psychological one perceived by breaking a norm, the incentive

will be counterproductive. Gneezy and Rustichini (2000) provide convincing empirical evidence of this mechanism. A second problem is that, even if incentives to individual investment in social capital were to work well, it is difficult to evaluate the aggregate impact, because one should find a way to measure interpersonal externalities.

### *(ii) Trust*

Policy indications are somewhat easier to draw if one looks at the correlates of generalised trust. In particular, policies that increase the well functioning of the State, the effective protection of property rights, a low degree of inequality in the distribution of income and a low degree of 'racial' heterogeneity create a favourable environment for the development of trust. Whether or not such policies are desirable (in particular, the last two) involves political issues that we do not tackle here.

The positive correlation found by Helliwell and Putnam (1999) between average education and social capital provides an additional rationale, besides the traditional ones, to invest in education even more than we are currently doing. This is especially advisable since, on the one hand, there is a virtuous dynamics between human capital and social capital accumulation, and, on the other hand, trust-enhancing policies may start a multiplier mechanism. Indeed, both the theory and the experimental evidence tell us that a key effect of trust is to induce a higher trustworthiness, which, in turn, allows people to trust without being exploited. The role of policy may then be that of activating such a mechanism, especially in low-trust environments, such as some European regions, which otherwise may remain stuck in a low-trust poverty trap, where low trust and low trustworthiness justify each other.

As we discussed above, trust-enhancing policies have a special relevance, among other things for the purposes of long-run growth and of financial development. What may be added here is that they can play a special

role in the context of the 'new economy', in which we are more and more transacting ideas (e.g. inventions, images, and so on). Unlike physical goods, whose characteristics are observable before the transaction, ideas cannot be revealed *ex ante* (once they are communicated, there is no need to purchase them any more), so that trust comes to play a prominent role. In a well-operating market, reputation mechanisms may probably substitute for trust to a high degree, but in new, emerging markets such an element of stability is absent, so that the level of trust and trustworthiness may determine whether some innovative, idea-intensive activities take off at all — and may in any case substantially reduce their transaction and monitoring costs.

### *(iii) Social participation and networks*

Social participation seems to be less an issue for Europe than for the United States. The general problem in designing participation-enhancing policies is that one cannot, by definition, force voluntary participation. With this caveat in mind, one can think of effective incentive schemes, which are, however, hard to formulate in general terms. Notice that the construction of networks of participation may be crucial at least at three levels. First, family- and community-level participation facilitates human capital accumulation and private provision of local amenities and of local public goods. Second, social participation at the level of civil society generates positive externalities, at least if one focuses attention on 'Putnamesque' groups and on 'bridging' links. In affluent societies, where material needs have reached a high degree of satisfaction and relational needs assume a prominent role, these kinds of participation dynamics may be crucial for individual and social well-being. Finally, cooperation networks among firms may provide at the same time those efficiency and flexibility characteristics that allow a successful adaptation in rapidly changing economies, but this is an area in which direct intervention may have positive as well as distortionary effects, so that it is hard to identify policies recommendable in general.

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**Table A1.1: Instrumental-variable estimates based on institutional features**

<i>Authors</i>	<i>Country</i>	<i>Instrument</i>	<i>Controls</i>	<i>Data</i>	<i>Specification</i>	<i>OLS</i>	<i>Measurement error corrected</i>
Conneely and Uusitalo (1997)	FIN	Living in a university town.	Quadratic in experience.	Administrative earnings and education data 1994. Male veterans.	Without parental education and earnings.	0.085 (0.001)	0.110 (0.0024)
					With parental education and earnings.	0.083 (0.001)	0.098 (0.035)
Brunello and Miniaci (1999)	I	Change in access to college and family background variables.	Age, region, size of town and survey year.	Bank of Italy survey. 1993 and 1995. Men.		0.048 (0.00)	0.057 (0.00)
Harmon and Walker (1995)	UK	Changes in the minimum school leaving age in 1947 and 1973.	Quadratic in age, year, survey and region.	British family expenditure survey 1978–86. Men.		0.061 (0.001)	0.153 (0.015)
Levin and Plug (1999)	NL	Season of birth.	Marital status. Experience and experience squared.	OSA panel survey 1994. Men.		0.036 (0.002)	0.040 (0.029)
Veira (1999)	P	Changes in years of compulsory education in 1956.	Quadratic in age, four region dummies.	Quadros de Pessoal 1986, 1992.	1986 sample: change 1956.	0.075 (0.000)	0.030 (0.020)
					Change 1956.	—	0.051 (0.039)
					1992 sample: change 1956.	0.082 (0.000)	0.035 (0.015)
					Change 1964.	—	0.057 (0.015)
Angrist and Krueger (1991)	US	Quarter or birth interacted with year of birth.	Quadratic in age, race, marital status and urban residence.	1970 census. Men.	1920–29 cohort.	0.070 (0.000)	0.010 (0.033)
				1980 census. Men.	1930–39 cohort.	0.063 (0.000)	0.060 (0.030)
					1940–49 cohort.	0.053 (0.000)	0.078 (0.030)
Card (1999)	US	Indicator for a nearby four-year college in 1966.	Race, experience (endogenous), region, parental education.	NLS young men in 1976. 1966 cohort.	College proximity as instrument. College proximity interacted with family background as instrument.	0.073 (0.004)	0.132 (0.049)
						—	0.097 (0.048)



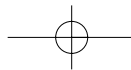
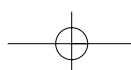
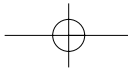


Table A1.3: Estimates using family background variables

Authors	Country	Family background variable	Controls	Data	Specification	OLS		IV
						No Control	control	
Callan and Harmon (1999)	IRL	Parental educational attainment, social class.	Quadratic in age, marital status, urban, Dublin and occupation-specific unemployment rate.	Survey of income distribution, poverty and usage of State services, 1987. Men.		0.074 (0.005)		0.101 (0.013)
Conneely Uusitalo (1997)	FIN	Parent's education.		Administrative earnings and education data 1994.		0.085 (0.001)	0.082 (0.001)	0.114 (0.006)
Dearden (1999a)	UK	Teacher's evaluation of parent's interest in child's education. Father's social class. Education of parents. Number of siblings.	Reading and mathematics ability, region, school type, firm size and local authorities' demographics.	National child development survey. 1991. Men.		0.080 (0.000)	0.048 (0.004)	0.055 (0.005)
Ichino and Winter-Ebmer (1999)	D	Father in World War II, father highly educated, father blue-collar worker, father self-employed.	Basic: quadratic and cubic in age. Extended: father blue-collar worker, father self-employed, father highly educated.	German Socioeconomic Panel 1986.	Extended: father in war father highly educated. Basic: father in war father highly educated.		0.055 (0.005)	0.117 (0.053)
								0.048 (0.014)
Levin and Plug (1999)	NL	Education of mother and father, level of father's occupation, teacher's evaluation of family's social status.	Marital status. Experience and experience squared.	Brabant survey 1983. Men.	Parental education/job level. Social status.	0.029 (0.004)	0.024 (0.004) with IQ test as control.	0.045 (0.010)
				OSA panel survey. 1994. Men.	Parental education/job level.	—		0.027 (0.032)
Ashenfelter and Zimmerman (1997)	US	Brother's or father's education.	Quadratic in age and marital status.	NLS young men.	Brother's education.	0.059 (0.014)	0.052 (0.015)	0.080 (0.027)
				NLS older men.	Father's education.	0.057 (0.009)		0.109 (0.025)
Card (1999)	US	Mother's education.	Cubic in age, race, survey year, region.	General social survey, 1974–96.	Men.	0.073 (0.003)	0.067 (0.003)	0.106 (0.007)
					Women.	0.112 (0.004)		0.113 (0.004)





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