THE DRIVING FORCES OF ECONOMIC GROWTH:
PANEL DATA EVIDENCE FOR THE OECD COUNTRIES

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INTRODUCTION

The past decade has witnessed a renewed interest in the main factors driving economic growth in the OECD countries. A few countries – including the United States, the technology leader – have experienced an acceleration in growth of GDP per capita, but other major economies have lagged behind, raising questions as to the role of technological progress as well as policy and institutions. This paper aims at shedding some light on these issues by presenting evidence on the long-term links between policy settings, institutions and economic growth in OECD countries while controlling for underlying differences in technological progress. In particular, the focus is two-fold: first, on the possible influences of human capital, research and development activity, macroeconomic and structural policy settings, trade policy and financial market conditions on economic efficiency; second, on the effects of many of the same factors on the accumulation of physical capital.

While empirical studies support the relevance of these factors for economic growth, this literature often relies on a large set of countries, including many non-OECD economies and, once constrained to the OECD sample, results are often unsatisfactory (Temple, 1999). The cross-country variability in both growth patterns and potential explanatory variables is much smaller if one focuses on the OECD sub-sample. Hence, data quality and the estimation approach assume an even more crucial role in the empirical analysis. We tackle both issues by using harmonised OECD data and a novel econometric approach that reconciles growth model assumptions with available data.

As in a number of recent studies, we use pooled cross-country time-series data in order to explain both cross-country differences in growth performance as well as the evolution of performance over time in each country. In addition, our econometric technique allows short-term adjustments and convergence speeds to vary across countries while imposing (and testing) restrictions only on long-run coefficients (*i.e.* those related to the production function). To anticipate the main results of this study, we find the accumulation of physical as well as human capital to be the main drivers of economic growth. In addition, R&D activity, a sound macroeconomic environment, trade openness and well-developed financial markets contribute to raise living standard in OECD countries. Some of the same factors

that operate "directly" on growth also influence it indirectly *via* the mobilisation of resources for fixed investment.

The paper is organised as follows. In the first section, we briefly introduce the policies and institutional dimensions that are considered in the empirical investigation of the sources of economic growth. The section focuses on the transmission mechanisms linking policy to growth as well as on cross-country differences in policy settings and their evolution over time. The institutional and policy variables considered have three basic characteristics: *i*) they are largely macroeconomic in nature; *ii*) they yield testable implications for economic growth; and *iii*) they can be evaluated using available data across countries and over time. In the second section we introduce the estimated growth equation and discuss the econometric approach used in the regressions. The third section presents the econometric results. The estimated coefficients from the growth regressions are also used in the fourth section to assess the role of different policy settings in the evolution of growth both over time and across the OECD countries. The final section concludes.

THE DETERMINANTS OF ECONOMIC GROWTH

The literature on economic growth is vast and policy-oriented studies, in particular, have flourished in the past decade (see Temple, 1999 and Ahn and Hemmings, 2000 for surveys). Yet, there is little agreement on the exact mechanisms linking policy settings to growth. For example, if one assumes, consistent with the traditional neo-classical growth model, diminishing returns to reproducible factors and exogenous saving rates, population growth and technological progress, then policies have no role in shaping long-term economic growth. Under these circumstances, richer countries grow at a slower rate than poorer countries adjusted for demographic differences. However, evidence of this process of *unconditional* convergence has weakened, at least amongst the OECD countries, in the most recent decades (Figure 1).[1] Thus, the concept of convergence can only be reconciled with the data if one moves to *conditional* convergence; that is to say, a relation between growth rate and initial conditions after controlling for other variables.

Relaxing the hypothesis of exogenous saving and capital formation gives room for policy to affect growth in the short and medium-term via an impact on saving and the level and composition of investment. Indeed, a number of studies suggest that policy and institutions affect the *level* of economic efficiency with which resources are allocated in the economy. Nevertheless, whether through its effect on investment or on the level of economic efficiency, a one-time change in policy leads only to a transitory change in output growth in such models. When the capital stock and output have risen to levels at which the new rate of gross

Figure 1. **Comparison of GDP per capita growth rates and initial conditions over four decades**
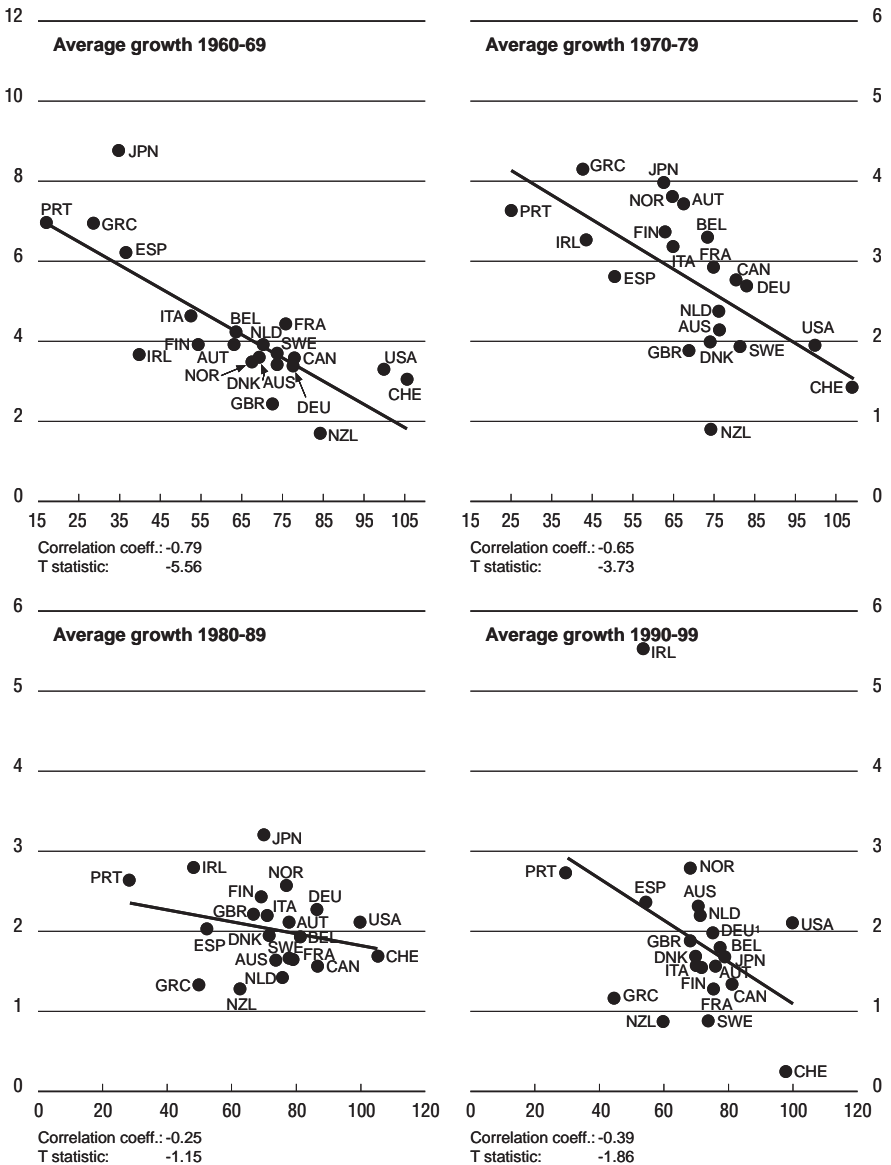
Note: GDP per capita is based on the OECD 1993 purchasing power parities estimates, average growth rates are based on H-P cyclically-adjusted real GDP volumes. Horizontal axis show the PPP level of GDP per capita (USA = 100).
1. 1991-1999 period.
Source: OECD.

investment is only sufficient to maintain a constant capital/labour ratio plus an amount to cover physical depreciation, growth reverts back to the steady state rate. In other words, any policy change will affect output growth only in the short to medium-term by shifting the growth path, although the *underlying rate of growth* remains determined by exogenous population growth and technical progress (that are potentially different across countries).

Another class of growth models relaxes the assumption of diminishing returns to reproducible factors. Some authors add human to physical capital to derive a concept of "broad" capital characterised by constant or even increasing returns to scale (*e.g.* Lucas, 1988; Rebelo, 1991). Others introduce externalities to the accumulation of physical capital whereby private returns to scale may be diminishing, but social returns can be constant or increasing – due to either learning by doing (*e.g.* Romer, 1986; Young, 1991) or R&D (*e.g.* Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992). With constant (or increasing) returns to ("broad") capital, the long-term rate of growth becomes endogenous, in the sense that it depends on investment decisions which, in turn, could be influenced by policy and institutions. Some of these endogenous growth models imply "conditional" convergence, while others do not, depending on assumptions about the specification of the production function and the evolution of broad capital accumulation (see Barro and Sala-i-Martin, 1995; Durlauf and Quah, 1999 for reviews).

Only empirical observation can provide evidence on which view of the link between policy and growth is most relevant, but results of such studies are often ambiguous. Aggregate analyses, such as the one we present in this paper, can only shed some light, while microeconomic evidence is needed to better assess the links between capital accumulation and technological progress. Bearing this in mind, we look at the influence of policy and institutions on GDP per capita by estimating a growth equation and an investment equation. The GDP per capita growth equation aims at identifying the effect on output of a policy variable over and above its potential impact on investment, while the investment equation is intended to identify the possible impact of the policy variable on the level of investment. The remainder of this section presents the different variables considered in our analysis.

Basic determinants of growth: the accumulation of physical and human capital

T*he accumulation of physical capital*

The rate of accumulation of physical capital is one of the main factors determining the level of real output per capita although, as stressed above, its effects could be more or less permanent depending on the extent to which technological

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innovation is embodied in new capital. Whatever the transition mechanism from capital accumulation to growth, the significant differences in the investment rate across countries and over time point to it as a possible source of cross-country differences in output per capita. In particular, long-run averages of business-sector investment rates range from around 10 per cent to over 20 per cent of GDP. Furthermore, major shifts in investment rates within countries are not uncommon, a notable example being the rapid rise in the US investment rate in recent years.

In the empirical analysis, we consider the accumulation of physical capital by private agents (proxied by the share of business investment in GDP). Public-sector investment is also considered in extended growth equations to assess its independent impact on output, as suggested by Aschauer (1989), as well as its potential effect on the estimated coefficient of the business-sector investment rate.

Human capital

Recent studies on growth also assume that formal skills and experience embodied in the labour force represent a form of (human) capital. On the one hand, it could be argued that human capital is subject to some kind of diminishing returns so that a more highly trained and skilled workforce would enjoy higher levels of income in the long term, but not necessarily permanently higher growth rates of income. On the other hand, investment in human capital (*e.g.* expenditures on education and training) could have a more permanent impact on the growth process if high skills and training go hand-in-hand with more intensive research and development and a faster rate of technological progress, or if the adoption of new technologies is facilitated by a highly skilled workforce.[2] As in the case of physical capital, only empirical evidence can shed some light on social returns to investment in human capital and, thus, help in discriminating amongst competing theories.

In this study, human capital is measured by estimates of the average number of years of formal education among the working-age population, based on figures on educational attainment and assumptions about how many years of education a particular level of attainment represents. These indicators are admittedly only crude and somewhat narrow proxies, taking little account of quality aspects of formal education or other important dimensions of human capital. Nonetheless, estimates of the average years of schooling amongst the working-age population suggest that, despite some convergence over time, there remain significant differences between countries as to the level of educational attainment. In 1970, the average length of formal education of the working age population ranged from 5.7 years (Spain) to 11.6 years (United States), whilst the most recent observations still indicate a range from 7.7 to 13.6 years (Portugal and Germany, respectively) (Figure 2). The figure also indicates that increases in average length of education

Figure 2. **Average years of education[1] of the working-age population in OECD countries**

1970 and 1998
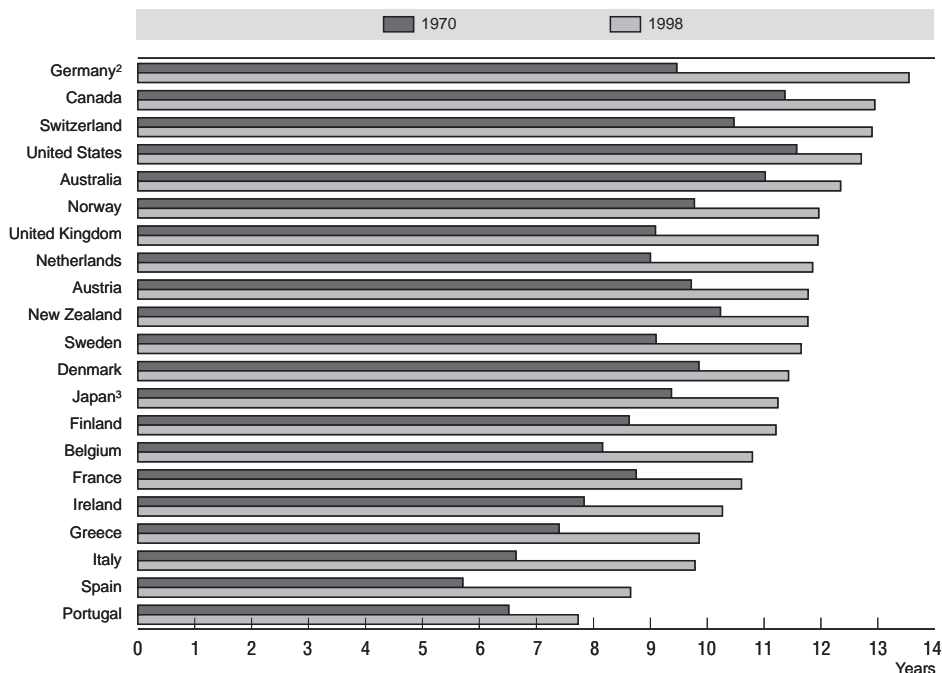
1. Average number of years of education in the population aged 15-64 years, based on data on level of education attained and assumptions about the number of years of education implied by different levels of education attainment.
2. Western Germany in 1970.
3. 1990 instead of 1998 for Japan.
Source: OECD.

range from less than half a year on average per decade (*e.g.* the United States) to more than one year on average per decade (*e.g.* Germany and Italy, the latter from a relatively low level).

Research and development

Expenditure on research and development (R&D) can be considered as an investment in knowledge that translates into new technologies as well as more efficient ways of using existing resources of physical and human capital. Indeed, in the case of R&D, there seems to be stronger consensus that it may have a persis-

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tent effect on growth, that is, higher R&D expenditure would, *ceteris paribus*, be associated with permanently higher growth rates.

The amount of resources that are devoted to R&D can be influenced by government intervention. In particular, the potential benefits from new ideas may not be fully appropriated by the innovators themselves due to spillover effects, which imply that without policy intervention the private sector would likely engage in less R&D than what could be socially optimal. This can justify some government involvement in R&D, both through direct provision and funding, but also through indirect measures such as tax incentives and protection of intellectual property rights to encourage private-sector R&D (see Nadiri, 1993 and Cameron, 1998, for reviews).

Overall expenditure on R&D as a share of GDP has risen since the 1980s in most countries (Figure 3), mainly reflecting increases in R&D activity in the business sector that accounts for the majority of expenditure in this area in most OECD countries. Indeed, the share of publicly financed R&D has declined over the past decade in most countries as a result of reductions in military R&D budgets.

Several issues have to be considered in assessing the role of R&D on growth. First, the relationship between public and private R&D could be one of complementarity or substitution. Second, public-sector R&D is often directed at making improvements in areas not directly related to growth, such as defence and medical research, and any impact on output growth could be diffused and slow to come about (see OECD, 1998). These considerations suggest that any quantitative analysis of growth must take R&D activity into account as an additional form of investment and differentiate between various types of R&D expenditures. Given data availability, we consider total R&D expenditure (as a share of GDP) and its components, public and business sector R&D expenditure.

Macroeconomic policy setting and growth

In the context of growth studies, three issues have generally been considered with respect to macroeconomic policy settings: the benefits of establishing and maintaining low inflation, the impact of government deficits on private investment, and the possibility of negative impacts on growth stemming from a too-large government sector (with associated high tax pressure to finance high government expenditure).

Inflation and growth

The usual arguments for lower and more stable inflation rates include reduced uncertainty in the economy and enhanced efficiency of the price mechanism. A reduction in the level of inflation could have an overall effect on the level of capital accumulation in cases of tax distortions (*e.g.* nominally-denominated

Figure 3. **Expenditure on R&D in the OECD countries**

1980s and 1990s
Total expenditure on R&D as a percentage of GDP

Legend: ■ Business-enterprise expenditure on R&D   □ Non-business-enterprise expenditure on R&D
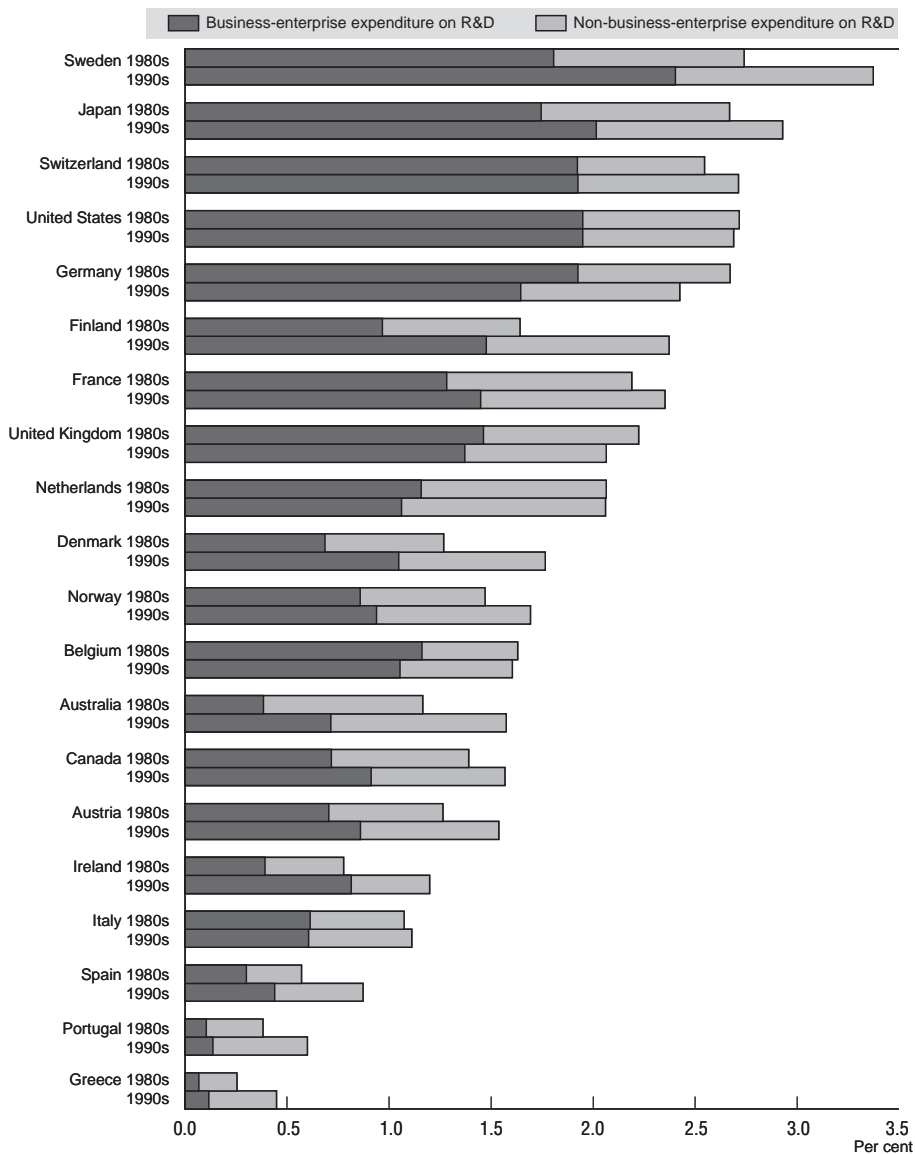
Source: OECD.

allowances) or when investment decisions are made with a long-run perspective (*e.g.* shift in technologies). Moreover, uncertainty related to higher volatility in inflation could discourage firms from investing in projects that have high returns, but also a higher inherent degree of risk.[3]

Evidence on the relationship between inflation and growth is somewhat mixed: while there is evidence that investment suffers in cases of high inflation, the relation is less clear in cases of moderate or low inflation (see *e.g.* Edey, 1994; Bruno and Easterly, 1998). Moreover, to the extent uncertainty is the link to investment and growth, it would suggest a focus on variation in inflation. However, given the correlation between level and variability of inflation, the two effects could be difficult to distinguish.

Based on the above discussion, two indicators of inflation are considered in the empirical analysis: the level of inflation and its variability. These indicators are included in the growth equation, which incorporates the investment share, whereby the estimated impact on growth occurs *via* the effects of these variables on overall efficiency and the choice of investment projects. They are also included in the investment equation, which permits testing for an effect of both variables on the level of investment.

Fiscal policy and growth

Fiscal policy settings can affect output and growth in the medium term as well as over the business cycle. In particular, where government deficits finance consumption or transfers, a traditional argument for prudent policy is to reduce the crowding out effects on private sector investment. Also, if fiscal policy is seen as being at odds with monetary policy, the credibility of the latter could be undermined leading to risk premia in interest rates and pressures on exchange rates, with repercussions on capital accumulation.

It has been argued that taxes necessary to finance government spending could also distort incentives, with negative implications for the efficient allocation of resources and hence the level or the growth of output. The main conclusion from the literature is that there may be both a "size" effect of government intervention as well as specific effects stemming from the financing and composition of public expenditure. At a low level, the productive effects of public spending are likely to exceed the social costs of raising funds. However, government expenditure and the required taxes may reach levels where the negative effects on efficiency and hence growth starts dominating. These negative effects may be more evident where the financing relies heavily on more "distortionary" taxes (*e.g.* direct taxes) and where public expenditure focuses on "unproductive" activities.

Between the 1980s and 1990s the "size" of the public sector tended to increase in most OECD countries as did government gross liabilities. More

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recently, public-sector balances have improved significantly. Notwithstanding these important developments, the share of total government expenditure in GDP was still in the range of 40-50 per cent in a number of OECD countries in 1999 (Table 1). Moreover, less than 20 per cent of public expenditure in OECD countries consists of expenditure that could be classified as directly "productive" (*e.g.* schooling, infrastructure and R&D). And in a number of countries, the share of "productive" expenditure declined over the past decade.

In our empirical analysis of both growth and investment, supply-side hypotheses relating government size to growth are tested by looking at both taxation and

Table 1. **Total government outlays and "productive" government spending as a share of total spending in OECD countries, 1985, 1995 and 1999**
Percentage

	A Education		B Transport and communication		C R&D		A + B + C		Share of total government outlays in GDP		
	1985	1995	1985	1995	1985	1995[4]	1985	1995	1985	1995	1999
Australia	14.6	13.2	10.1	8.3	2.1[5]	2.2[4]	26.8	23.6	37.3	35.5	32.3
Austria	9.6	9.5	3.3	2.1	1.2	1.4	14.1	13.0	50.1	52.6	50.7
Belgium	12.7	..	8.7	..	0.9	..	22.3	..	57.3	50.1	47.9
Canada	13.0	..	5.4	..	1.5	..	19.8	..	46.0	46.3	40.2
Denmark	11.3	11.7	4.0	3.0	1.2	1.2	16.4	15.9	56.6[3]	59.0	54.3
France[1]	10.5	10.7	2.9	1.9	2.3	1.8	15.7	14.4	51.8	53.5	52.2
Germany	9.5	7.6	4.3	3.4	2.2	1.8	16.0	12.9	45.6	46.3	45.6
Iceland	13.0	12.3	9.0	7.6	1.6	2.5	23.6	22.4	32.5[7]	36.0	33.4
Ireland[1]	10.6	12.2	4.5	5.0	0.8	0.8	15.9	18.0	46.6	36.4	31.5
Italy	10.0	8.9	7.7	4.6	1.2	1.0	18.8	14.5	50.6	52.3	48.3
Japan	12.8	10.8[4]	..	..	1.8	1.9	..	..	31.6	35.6	38.1
Korea	17.8	18.1	7.1	9.6	..	2.7	..	30.4	17.6	19.1	25.5
Netherlands	9.9	..	..	..	1.8	..	..	..	51.9	47.7	43.2
New Zealand	..	13.3[4]	..	..	..	1.3[1]	..	..	52.6[6]	38.8	40.8
Norway	12.0[3]	13.7	6.6[3]	5.9	1.6	1.6	20.2	21.3	41.5	47.6	46.1
Portugal[2]	8.7	13.3	3.6	4.8	0.5[5]	0.9	12.9	19.0	40.2	44.5	44.7
Spain	8.8	10.3	6.3	6.0	0.7	0.9	15.8	17.1	37.7	42.5	38.6
Sweden	..	..	..	..	1.7	1.7	..	..	60.3	62.4	55.9
Switzerland	19.7	..	11.4		..	..	..	..	..	..	..
United Kingdom	10.2	12.1	3.2	3.6	2.0	1.5	15.5	17.2	43.0[7]	44.4	39.9
Unites States	..	..	..	..	4.1	2.8	..	..	33.8	32.9	30.1

1. 1993 instead of 1995.
2. 1992.
3. 1988.
4. 1994.
5. 1984.
6. 1986.
7. 1987.
The concept of "productive" government spending is based on a taxonomy used by Barro (1991).
Source: OECD.

government spending. The potential role of the structure of financing and expenditure is considered by looking separately at direct and indirect taxes and different components of government expenditure. In this context, the human capital variable discussed above may be taken to represent past and present governments' efforts in financing education.[4] Likewise, public spending on research and development are clearly identified in the extended models that include R&D (see below). Finally, public investment has been included as distinct from consumption to test if that distinction is pertinent.

Financial development and growth

Financial systems also contribute to economic growth by providing funding for capital accumulation and by helping the diffusion of new technologies. A well-developed financial system is likely to mobilise savings by channelling small savings of individuals into profitable large-scale investments, while offering savers a high degree of liquidity. It also provides insurance to individual savers against idiosyncratic risk through diversification, and it reduces the costs of acquiring and evaluating information on prospective projects, for example through specialised financial advisory services. All these services are likely to contribute to economic growth, but there could, in theory, also be opposite effects. For example, lower risk and higher returns resulting from diversification may prompt households to save less, if income effects dominate substitution effects. Furthermore, to some extent growth may prompt the development of financial systems, thus there may be an element of reverse causality.

Ideally, we would like to use qualitative indicators of the possibilities offered to firms to access external funds and the ease with which investors can get adequate returns. However, available information is only limited to quantity indicators (Leahy *et al.*, 2001). In particular, we consider the total claims of deposit money banks on the private sector, which measures the degree of financial intermediation via the banking system. Moreover, we look at stock market capitalisation (the value of listed shares), which is an imperfect indicator of the ease with which funds can be raised in the equity market.

International trade and growth

Aside from the benefits of exploiting comparative advantages, theories have suggested additional gains from trade arising through economies of scale, exposure to competition and the diffusion of knowledge. These could result both in higher overall efficiency and possibly a higher level of investment (*e.g.* if the adoption of foreign technologies requires investment in new types of capital). The progress OECD countries have made in reducing tariff barriers and dismantling non-tariff barriers would therefore suggest positive gains from trade.[5] However,

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trade may also be endogenous to the process of growth. The relatively open stance towards trade in OECD countries would suggest that the amount of trade conducted reflects patterns of growth (and to some extent geography, size and transport costs) as much as it reflects constraints in the form of tariff and non-tariff barriers.[6]

The possible reverse causality problem in the relationship between trade and economic growth suggests some caution in interpreting empirical results. In particular, we treat the intensity of trade in the growth equation as an indicator of trade exposure – capturing features such as competitive pressures – rather than one with direct policy implications. Apart from bearing this caveat in mind, the empirical analysis also has to take into account that small countries are naturally more exposed to foreign trade, regardless of their trade policy or competitiveness, while competitive pressure in large countries to a large extent stems from domestic competitors. To better reflect overall competitive pressures, the indicator of trade exposure was adjusted for country size by regressing the crude trade exposure variable on population size and taking the estimated residuals from this exercise as the (adjusted) trade variable in the analysis.

SPECIFICATION OF THE GROWTH EQUATION AND ESTIMATION TECHNIQUE

The estimated growth equations

Formally, the policy-augmented growth equation can be derived from a growth model built around a constant-returns-to-scale technology (see Appendix I for the derivation of the model). Output is a function of capital, employment, the efficiency with which they act together, and the level of technology. Given straightforward assumptions on how the factors of production evolve over time, the steady-state level of output per capita can be expressed as a function of the propensity to accumulate physical capital, the population growth rate, the level and growth rates of technological and economic efficiency, and the rate of depreciation of capital. Moreover, if the concept of capital is widened to include human capital, then the propensity to accumulate the latter is also a factor shaping the steady-state path of output per capita.

If countries were at their steady state – or if deviations from the steady state were random – growth equations could be simply based on the relationship linking steady-state output to its determinants. However, actual data may well include out-of-steady-state dynamics due, among other things, to a slow convergence to the steady state (see, amongst others, Mankiw *et al.*, 1992, for a discussion). Hence, the observed growth in output in any given period, abstracting from cyclical fluctuations, can be seen as the combination of three different forces: *i*) underlying tech-

nological progress – which is assumed to be exogenous; *ii*) a convergence process towards the country-specific steady-state path of output per capita; and *iii*) shifts in the steady state (growth or level of GDP per capita, see below) that can arise from changes in policy and institutions as well as investment rates and changes in population growth rates.

The empirical approach adopted in this paper starts with a parsimonious specification of the growth equation and then analyses extended models. The initial specification is consistent with the standard neo-classical growth model and includes only a convergence factor and the basic determinants of the steady state, namely the accumulation of physical capital and population growth. The first extension involves the introduction of human capital while further extensions consider R&D and a set of policy and institutional factors potentially affecting economic efficiency.

The OECD sample permits the use of annual data instead of averages over time, as often done in the cross-country empirical literature.[7] However, year-to-year variations in output include cyclical components. These have been controlled for by including first differences of the steady-state determinants as short-run regressors in the estimated equations. Considering pooled cross-country time series (*i* denotes countries, *t* time) the growth equation, in its more general form, can be written as follows:

$$
\Delta \ln y_{i,t} = a_{0,i} - \phi_i \ln y_{i,t-1} + a_{1,i} \ln sk_{i,t} + a_{2,i} \ln h_{i,t} - a_{3,i} n_{i,t} + \sum_{j=4}^{m} a_{j,i} \ln V_{i,t}^{j} + a_{m+1,i} t
$$

$$
+ b_{1,i} \Delta \ln sk_{i,t} + b_{2,i} \Delta \ln h_{i,t} + b_{3,i} \Delta n_{i,t} + \sum_{j=4}^{m} b_{j,i} \Delta \ln V_{i,t}^{j} + \varepsilon_{i,t} \tag{1}
$$

where *y* is GDP per capita, *sk* is the propensity to accumulate physical capital; *h* is human capital; *n* is population growth; the V^j is a vector of variables affecting economic efficiency; *t* is a time trend; the *b*-regressors capture short-term dynamics and ε is the usual error term.

It should be stressed that equation [1] is a fairly general specification, and different growth models are nested in it. This is important for the interpretation of the policy variables which could be taken to represent either growth effects or level effects (see above). The estimated parameters of equation [1] allow to distinguish amongst some of these models. In particular, a significant coefficient on the lagged level of GDP per capita, *i.e.* the existence of convergence towards a country-specific steady state, would exclude one class of endogenous growth models (*i.e.* those *à la* Romer, 1986).[8] However, this would not be sufficient evidence to rule out other endogenous models (*e.g. à la* Lucas, 1988).[9] Indeed, even in the presence of convergence, a number of empirical papers have interpreted the estimated policy coefficients as persistent *growth* effects.[10]

The distinction between temporary or permanent growth effect may seem somewhat semantic if the speed of convergence to the steady state is very slow, as it is the case in most empirical studies focussing on a large set of countries.[11] However, consistent with some recent studies focussing on panel data, we find a relatively rapid speed of convergence for the OECD countries and thus, the choice between the two alternative interpretations of the results does matter in drawing policy conclusions. We take a prudent view and interpret the estimated coefficients as indication of temporary effects on growth due to the shift effect on the steady-state path of output per capita.

The econometric technique

The main advantage of pooled cross-country time-series data for the analysis of growth equations is that the country-specific effects can be controlled for, *e.g.* by using a dynamic fixed-effect estimator (DFE). However, this estimator generally imposes homogeneity of all slope coefficients, allowing only the intercepts to vary across countries. The validity of this approach depends critically on the assumption of a common growth rate of technology and a common convergence parameter (see Lee *et al.*, 1997). The first assumption is difficult to reconcile with evidence on multifactor productivity patterns across countries (see *e.g.* Scarpetta *et al.*, 2000). The second assumption is not consistent with the underlying growth model, where the speed of convergence depends, amongst other factors, upon the rate of population growth (see Appendix 1).[12] An alternative approach is to use the mean-group approach (MG) that consists of estimating separate regressions for each country and calculating averages of the country-specific coefficients (*e.g.* Evans, 1997; Lee *et al.*, 1997). While consistent, this estimator is likely to be inefficient in small country samples, where any country outlier could severely influence the averages of the country coefficients (see below).

An intermediate choice between imposing homogeneity on all slope coefficients (DFE) and imposing no restrictions (MG) is the pooled mean group estimator (PMG) that allows intercepts, the convergence parameter (ϕ),[13] short-run coefficients (b_s) and error variances to differ freely across countries, but imposes homogeneity on long-run coefficients. There are good reasons to believe in common long-run coefficients for the OECD countries, given that they have access to common technologies, and have intensive intra-trade and foreign direct investment, all factors contributing to similar long-run production function parameters. Under the assumption of long-run slope homogeneity, the PMG estimator increases the efficiency of the estimates with respect to mean group estimators (Pesaran *et al.*, 1999). Formally, conditional on the existence of convergence to a steady state path, the long-run homogeneity hypothesis permits

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the direct identification of the parameters that affect the steady state path of output per capita ($a_{s,i}/\phi_i = \theta_s$, see below). In other words, with the PMG procedure, the following restricted version of equation [1] is estimated on pooled cross-country time-series data:

$$\Delta \ln y_{i,t} = - \phi_i \left(\ln y_{i,t-1} - \theta_1 \ln sk_{i,t} - \theta_2 \ln h_{i,t} + \theta_3 n_{i,t} - \sum_{j=4}^{m} \theta_i \ln V_{i,t}^j - a_{m+1} t_i - \theta_{0,i} \right)$$

$$+ b_{1,i} \Delta \ln sk_{i,t} + b_{2,i} \Delta \ln h_{i,t} + b_{3,i} \Delta n_{i,t} + \sum_{j=4}^{m} b_{j,i} \Delta \ln V_{i,t}^j + \varepsilon_{i,t} \qquad (2)$$

Similarly, the investment equation has the general form:

$$\Delta \ln sk_{i,t} = - \rho_i \left(\ln sk_{i,t-1} - \gamma_1 \ln y_{i,t} - \gamma_2 \ln h_{i,t} - \sum_{j=3}^{m} \gamma_j \ln V_{i,t}^j - \gamma_{0,i} \right)$$

$$+ c_{1,i} \Delta \ln y_{i,t} + c_{2,i} \Delta \ln h_{i,t} + \sum_{j=3}^{m} c_{j,i} \Delta \ln V_{i,t}^j + \varsigma_{i,t} \qquad (3)$$

i.e. the share of business sector investment in GDP is assumed to depend on the level of GDP per capita, human capital and a set of policy and institutional factors.

In both equations, the hypothesis of homogeneity of the long-run policy parameters cannot be assumed *a priori* and is tested empirically in all specifications.[14] Moreover, given the limited degrees of freedom in the country-specific policy-augmented growth regressions, the time trend was not included. Indeed, a sensitivity analysis suggested that a time trend was only statistically significant when human capital is omitted.[15] In addition, a sensitivity analysis suggests the presence in our database of a handful of observations that significantly increase the standard error of the regression and/or affect the estimated coefficients. Thus, these observations have been removed from the sample.[16]

REGRESSION RESULTS AND INTERPRETATION

The growth equations were estimated for 21 OECD countries over the period 1971-1998.[17] The countries were chosen because they have continuous annual series for most of the variables used in the growth equations over the bulk of the 1971-98 period. Details on the variables used in the regression are in Box 1. This section presents the core results of the econometric analysis, while a detailed sensitivity analysis is presented in an extended version of this paper (Bassanini *et al.*, 2001).

Box 1. **Description of the variables used in the empirical analysis**

The baseline equation includes the following explanatory variables (see Appendix 2 for more details):

- D*ependent variable* (ΔlnY). Growth in real GDP per head of population aged 15-64 years expressed in (1993) Purchasing Power Parities (PPP).
- C*onvergence variable* (lnY_{-1}). Lagged real GDP per head of population aged 15-64 years, in PPP.
- P*hysical capital accumulation* (lnSk). The propensity to accumulate physical capital is proxied by the ratio of real private non-residential fixed capital formation to real private GDP.
- S*tock of human capital* (lnH) is proxied by the average number of years of schooling of the population from 25 to 64 years of age.
- P*opulation growth* (ΔlnP). Growth in population aged 15-64 years.

The auxiliary policy-related variables included in the augmented growth regressions were as follows:

- M*easures of inflation*: *i*) the rate of growth of the private final consumption deflator (I*nfl*); and *ii*) the standard deviation of the rate of growth in private final consumption deflator (SDI*nfl*) – estimated as a centred three-year moving-average.
- I*ndicators of government size and financing*: *i*) the share of general government current nominal tax and non-tax receipts in nominal GDP (*ln*Tax); *ii*) the ratio of direct to indirect tax receipts (*ln*(T*ax distr*); *iii*) the ratio of government nominal final consumption expenditure to nominal GDP (*ln*(G*ov cons*)); and *iv*) the ratio of government real fixed capital formation to real GDP (lnSk^{gov}).
- M*easures of R&D intensity*: *i*) gross domestic expenditure on R&D as a percentage of GDP (lnR&D^{tot}); *ii*) business sector expenditure on R&D as a percentage of GDP (*ln*BERD); and *iii*) the difference between gross domestic expenditure on R&D and business sector expenditure on R&D as a percentage of GDP (lnR&D^{pub}).
- I*ndicators measuring financial development*: *i*) private credit of deposit money banks provided to the private sector as a percentage of GDP (*ln*(P*riv Credit*)); and *ii*) stock market capitalisation as a percentage of GDP (*ln*(S*tock Cap*)).
- I*ndicators of the exposure of countries to foreign trade*: a weighted average of export intensity and import penetration. It is calculated as follows: T*rade* E*xp* = X*i* + (1 − X*i*)*M*p*, where X*i* is the ratio of exports to GDP and M*p* is the ratio of imports to apparent consumption (domestic production minus exports plus imports). In the empirical analysis this measure was adjusted for country size as described above (ln(Trade exp)^{adj}).

All the auxiliary policy-related variables, with the exception of those related to R&D, have been introduced with a lag to better identify their impact on output.

The role of convergence and capital accumulation in the growth process

Table 2 reports the estimated coefficients and implied parameters for physical and human capital and convergence from different specifications of the growth equation. In all specifications the convergence parameter is significant, suggesting a (conditional) process of convergence and supporting the specification adopted in equation [2]. In the human capital augmented equations, the speed with which countries converge to their specific steady state path of output per capita is, however, higher than what is generally found in growth regressions focussing on larger sets of countries. Estimates reported in Table 2 suggest that, following a change in a steady-state variable, it takes about 4-5 years to go half way to the new steady state output per capita. With rapid convergence, a policy change will have only a temporary impact on growth, but its potential effect on living standards will be quickly felt. Hence, observed changes in factor inputs as well as in policies over past decades are likely to have significantly affected growth patterns and are of importance in the assessment of cross-country differences.

In all specifications where they are included, the coefficients on both physical and human capital appear with the expected sign and are highly significant. There is, however, some variability in the estimated coefficients that implicitly underlines the importance of model specification. The three right-hand-side specifications in Table 2 indicate an implied value for the capital share of about 20 per cent, which is broadly consistent with National Accounts data. The estimated share of human capital is, however, quite large (60 per cent in the preferred specifications).[18] This implies that one extra year of average education (corresponding to a rise in human capital by about 10 per cent) would lead to an average increase in steady-state output per capita by about 4-7 per cent.[19] These values contrast with (many) growth studies that have found no or very limited effects of human capital on growth (see, for example, Benhabib and Spiegel, 1994; Barro and Sala-i-Martin, 1995), although the lowest of the present estimates are broadly consistent with estimated returns to schooling in the microeconomic literature (see Psacharopoulos, 1994).[20]

Taken at face value, the results on human capital might imply significant positive spillovers and a gap between private and social returns to education, or that the human capital indicator is acting as a proxy for other variables (over and above those included as framework conditions), an issue also raised in some microeconomic studies. The first interpretation of the results potentially has important policy implications. Insofar as policy affects the accumulation of human capital (most prominently through education policy), and the spill-over effects are sufficiently large to imply overall non-declining returns over some range, its effect on growth may not be limited to a shift in the steady-state output level but possibly lead to more persistent (although not necessarily irreversible) effects.

Table 2. **The role of convergence and capital accumulation for growth:
summary of regression results**
(Pooled Mean Group Estimates)

Estimated coefficients	Standard equation[1]	Human-capital augmented	Trade-and-policy-augmented equations		
			A[2]	B[3]	C[4]
LnSk	0.39 ***	0.18***	0.25***	0.23***	0.24***
	(0.11)	(0.04)	(0.04)	(0.04)	(0.04)
LnH	…	1.00***	0.41***	0.70***	0.71***
		(0.10)	(0.13)	(0.16)	(0.13)
LnY$_{-1}$	−0.05***	−0.12***	−0.17***	−0.15***	−0.15***
	(0.01)	(0.02)	(0.02)	(0.03)	(0.03)
Partial output elasticities:[5]					
Physical capital	0.28	0.15	0.20	0.19	0.20
Human capital	…	0.85	0.33	0.57	0.57
Half way to convergence[6]	13.9 years	5.3 years	3.9 years	4.3 years	4.3 years

All equations include a constant country-specific term and control for outliers. The variables are defined in Box 1.
Standard errors are in brackets.
* : significant at 10 % level; ** at 5% level; *** at 1 % level.
1. The standard equation includes investment share in physical capital, population growth and lagged output per capita.
2. The equation also includes trade exposure, inflation and standard deviation of inflation.
3. The equation also includes trade exposure, standard deviation of inflation and tax and non-tax receipts.
4. The equation also includes trade exposure, standard deviation of inflation and government consumption.
5. Implied parameters of the production function .
6. Time to cover half way to convergence as implied by the estimated average coefficient of lnY$_{-1}$.

The estimated coefficients on broad capital (physical and human) and the speed of convergence, taken together, are not consistent with the standard neo-classical growth model. In particular, a high output elasticity to broad capital should be associated with a very low speed of convergence to the steady state or *vice versa*.[21] The fact that the output elasticity to broad capital is close to unity suggests that the OECD data are more consistent with an endogenous growth model that allows for conditional convergence. In particular, as discussed in Bassanini and Scarpetta (2002), an endogenous growth model *à la* Uzawa-Lucas with constant returns to scale to "broad" (human and physical) capital can be observationally equivalent to a more standard neo-classical model with diminishing returns to broad capital.

The role of macroeconomic policy and institutions on growth

Tables 3 and 4 report the estimation results relating to the role of variables reflecting macro policy, trade exposure and financial development. Where appropriate, a version of the regression allowing the long-run coefficient of the addi-

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Table 3. **Macro policy influences on growth**[1]
(Pooled Mean Group Estimators)

Dependent variable: ΔlnY	With control for inflation variables	With control for taxes and government expenditures		With control for both inflation and fiscal policy		
Long-Run Coefficients						
LnSk	0.25***	0.36***	0.14***	0.29***	0.23***	0.24***
	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)
LnH	0.41***	1.26***	0.92***	0.88***	0.70***	0.71***
	(0.13)	(0.22)	(0.13)	(0.19)	(0.16)	(0.13)
ΔlnP	−5.69***	−3.86[2]	−15.70***	−11.01***	−9.76***	−7.87***
	(1.02)	(3.82)	(3.96)	(1.57)	(1.31)	(1.21)
$SDinfl_{-1}$	−0.02***			−0.02***	−0.03***	−0.03***
	(0.00)			(0.01)	(0.00)	(0.00)
$Infl_{-1}$	−0.01***					
	(0.00)					
$LnSk^{gov}_{-1}$		0.07***	0.09***	−0.02		
		(0.03)	(0.02)	(0.02)		
$Ln(Gov\ cons)_{-1}$		0.19***	−0.15**	0.04		−0.10**
		(0.04)	(0.06)	(0.07)		(0.05)
$LnTax_{-1}$		−0.44***		−0.18**	−0.12**	
		(0.10)		(0.07)	(0.05)	
LnTaxDistr		−0.08**				
		(0.04)				
$Ln(Trade\ exp^{adj})_{-1}$	0.20***	0.20***	0.10*	0.14**	0.20***	0.22***
	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)	(0.06)
Convergence coefficient						
LnY_{-1}	−0.17***	−0.17***	−0.21***	−0.13***	−0.15***	−0.15***
	(0.02)	(0.04)	(0.05)	(0.03)	(0.03)	(0.03)
No. of countries	21	17	21	17	18	21
No. of observations	523	427	522	427	444	523
Log likelihood	1 553	1 362	1 541	1 595	1 349	1 556

1. All equations include short-run dynamics and country-specific terms. Moreover, they control for outliers. The variables are defined in Box 1.
   Standard errors are in brackets.
   *: significant at 10 % level; ** at 5% level; *** at 1 % level.
2. The Hausman test rejected the hypothesis of common long-run coefficient and thus the coefficient was estimated without cross-country restrictions.

tional variable of interest to vary across countries is reported alongside results where the homogeneity of long-run coefficients is imposed. It should be recalled that all the augmented regressions include investment (in physical capital) as an explanatory variable. Hence, the results can be interpreted as showing the effect on output over and above that which may be operating indirectly via investment. Since our results suggest a significant (positive) impact of trade exposure on GDP per capita, whenever possible the equations include this variable in the specification of the growth equation.

Table 4. **Regressions including indicators of financial development**[1]
(Pooled Mean Group Estimators)

Dependent variable: ΔlnY	with private credit	... and control for inflation	with stock market capitalisation
Long-Run Coefficients			
LnSk	0.07	0.30***	0.14***
	(0.06)	(0.06)	(0.02)
LnH	1.04***	0.99***	0.93***
	(0.12)	(0.14)	(0.15)
ΔlnP	−14.48***	−11.54***	−4.80***
	(2.34)	(1.77)	(0.89)
Ln(Priv credit)$_{-1}$	−0.14***	0.04**	
	(0.04)	(0.02)	
Ln(Stock cap)$_{-1}$			0.09***
			(0.01)
SDinfl$_{-1}$		−0.02***	
		(0.00)	
Convergence coefficient			
LnY$_{-1}$	−0.10***	−0.13***	−0.22***
	(0.02)	(0.02)	(0.05)
No. of countries	21	21	18
No. of observations	523	523	338
Log likelihood	1449	1498	1058

1. All equations include short-run dynamics and country-specific terms, and control for outliers. Variables are defined in Box 1.
   Standard errors are in brackets.
   *: significant at 10 % level; ** at 5% level; *** at 1 % level.

Overall, the results suggest a significant impact of macro policy settings on output per capita across countries and over time. The regression results suggest that the variability of inflation has an important influence on output per capita: its estimated coefficient is always negative and more than two standard errors from zero (Table 3). This result supports the hypothesis that high variability of inflation adds noise to capital and other markets, with the repercussion likely including an inefficient choice of potential investment projects, with lower average returns of the set of projects actually undertaken. The effect of the level of inflation is less clear-cut:[22] in the trade-augmented specifications presented in Table 3, the level of inflation seems to have a negative and significant impact on the steady state level of GDP per capita, but this is not always so when the trade variable is excluded.[23]

The hypothesis that the size of government has an impact on growth receives some qualified support (Table 3). The overall measure of tax and non-tax revenue can be used only for a sub-sample of 18 OECD countries, due to data availability.

The sample is further reduced to 17 countries when a distinction between direct and indirect taxes is introduced. The overall tax burden is found to have a negative impact on output per capita.[24] Furthermore, controlling for the overall tax burden, there is an additional negative effect coming from an extensive reliance of direct taxes. With control for the overall size and distribution of the tax burden, both government consumption and investment seem to have a positive impact on output per capita. The second specification on fiscal policy considers only the expenditure side of the government budget, and allows extending the sample to 21 countries. In this case, the coefficient on government consumption becomes negative (and statistically significant). This suggests that focusing on one side of the budget and ignoring the other leads to systematic biases associated with the "implicit financing" assumption.[25] In particular, given the high within-country correlation between the tax variable and government consumption,[26] the coefficient on consumption when the tax variable is not included should be taken to indicate the effect on growth of the "size" of government, rather than the true effect on growth of one specific element of total expenditure.

The equations in the last three columns of Table 3 include both the variability of inflation and the different fiscal policy variables. The key result is the stability of the coefficient for the variability of inflation across all specifications and the continued negative, if somewhat uneven, impact of government size, whether proxied by total tax burden or by government consumption in the last column of the table. By contrast, government investment becomes insignificant as soon as the model is extended and is dropped in the final specifications on the right-hand side of the table.

Some indication of the link between financial development and growth is presented in regressions including indicators of private credit from the banking sector and stock market capitalisation (see also Leahy *et al.*, 2001). Table 4 gives general support to the notion that the level of financial development influences growth, even after controlling for the propensity to invest. This perhaps points to a greater capacity of more developed financial systems to channel resources towards projects with higher returns. The results point to a robust link between stock market capitalisation and growth, while that between private credit provided to the private sector and growth has the wrong sign, when there is no control for inflation variability. This may reflect the fact that the banking credit indicator is related to other monetary variables, including money supply and demand conditions. Indeed, an extended model that also includes inflation variability points to a positive relationship between private credit and growth.

Research and development

The analysis of the determinants of growth can be further extended to include R&D activities, even though the sample is smaller and inference therefore more

tentative. In particular the analysis is restricted to 14-17 countries depending on the specification, and to the period 1981-98 (and for some countries the period is shorter). The shorter time-series significantly restrict the number of variables that could be considered in the regressions. These include, in addition to the R&D variables, the basic controls and trade exposure, whenever possible.[27] The indicators of R&D activity used here are expenditures on R&D as collected in national accounts expressed as a percentage of GDP and are thus indicators of the "intensity" of R&D within each country. The results (Table 5) support previous evidence suggesting a significant effect of R&D activity on the growth process.[28] Furthermore, regressions including separate variables for business-performed R&D and the R&D performed by other institutions (mainly public research institutes) suggest that it is the former that drives the positive association between total R&D

Table 5. **Regressions including R&D intensity**[1]
(Pooled Mean Group Estimators)

Dependent variable: $\Delta \ln Y$	With total R&D	With distinction between business and non-business R&D	With business R&D only
Long-Run Coefficients			
LnSk	0.31***	0.28***	0.34***
	(0.03)	(0.02)	(0.02)
LnH	1.13***	1.76***	0.82***
	(0.16)	(0.05)	(0.18)
$\Delta \ln P$	−12.15***	−33.19**[2]	−16.43***
	(1.64)	(13.94)	(2.02)
LnR&D^{tot}	0.14***		
	(0.03)		
LnBERD		0.26***	0.13***
		(0.01)	(0.02)
LnR&D^{pub}		−0.37***	
		(0.04)	
Ln(Trade exp^{adj})$_{-1}$	0.33***		0.32***
	(0.05)		(0.05)
Convergence coefficient			
LnY$_{-1}$	−0.22***	−0.23**	−0.18***
	(0.05)	(0.11)	(0.04)
No. of countries	16	15	16
No. of observations	252	236	251
Log likelihood	860	831	849

1. All equations include short-run dynamics and country-specific terms. Variables are defined in Box 1. Moreover, they control for outliers.
   Standard errors are in brackets.
   *: significant at 10 % level; ** at 5% level; *** at 1 % level.
2. The Hausman test rejected the hypothesis of common long-run coefficient and thus the coefficient was estimated without cross-country restrictions.

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intensity and output growth.[29] The results also indicate that the coefficient on business-sector R&D is somewhat lower in the regression with the indicator of trade exposure. This suggests possible interactions between R&D and international trade: the estimated impact of R&D on growth may be overestimated if no proper account is taken of the degree of market openness of a country. Nevertheless, the R&D coefficients remain largely significant in this augmented regression.

The negative results for public R&D needs some qualification. Taken at face value they suggest publicly performed R&D crowds out resources that could be alternatively used by the private sector, including private R&D. There is some evidence of this effect in studies that have looked in details at the role of different forms of R&D and the interaction between them.[30] In particular, it is found that defence research performed by the public sector does indeed crowd out private R&D, partly by raising the cost of research. However, there are avenues for more complex effects that regression analysis cannot identify. For example, while business-performed R&D is likely to be more directly targeted towards innovation and implementation of new innovative processes in production (leading to improvement in productivity), other forms of R&D (*e.g.* energy, health and university research) may not raise technology levels significantly in the short run, but they may generate basic knowledge with possible "technology spillovers". The latter are difficult to identify, not least because of the long lags involved and the possible interactions with human capital and associated institutions.[31]

Bearing these caveats in mind, the coefficient on business-performed R&D intensity, if interpreted structurally, suggests that a persistent 0.1 percentage point increase in R&D intensity (about 10 per cent increase with respect to average R&D intensity) would have a long-run effect of about 1.2 per cent higher output per capita under the "conservative" view that changes in R&D do not permanently affect output growth. However, in the case of R&D it is perhaps more appropriate to consider a permanent effect on GDP per capita growth (*i.e.* a fall in R&D intensity is not likely to reduce the steady-state level of GDP per capita but rather reduce technical progress). If the R&D coefficient is taken to represent growth effects, a 0.1 percentage point increase in R&D could boost output per capita growth by some 0.3-0.4 per cent. These estimated effects are large, perhaps unreasonably so, but nevertheless point to significant externalities in R&D activities.

Policy and institutional influences on capital accumulation

To explore whether a given policy influences growth (or, in our interpretation, the steady-state level of output) indirectly *via* its impact on the accumulation of physical capital, investment-share regressions are shown in Table 6. The estimation approach is similar to that of the growth regressions. Following experimentation

Table 6. **Investment regressions**[1]
(Pooled Mean Group Estimators)

Dependent variable: ΔLnSk

Long-Run Coefficients				
$Sdinfl_{-1}$	−0.02*	−0.01*		
	(0.01)	(0.01)		
$Infl_{-1}$	−0.02***	−0.03***	−0.02***	−0.03***
	(0.01)	(0.00)	(0.00)	(0.01)
$LnSk^{gov}_{-1}$	−0.21***	−0.11**	0.02	−0.05
	(0.06)	(0.04)	(0.03)	(0.03)
Ln(Gov cons)$_{-1}$	−0.26*		−0.71***	
	(0.15)		(0.14)	
$LnTax_{-1}$		−0.77***		−0.36**
		(0.12)		(0.14)
Ln(Stock cap)$_{-1}$			0.14***	0.17***
			(0.01)	(0.02)
Ln(Priv credit)$_{-1}$	0.09**	0.06		
	(0.03)	(0.04)		
Ln(Trade exp^{adj})$_{-1}$	−0.32***	−0.05	0.05	−0.31***
	(0.12)	(0.08)	(0.10)	(0.09)
Convergence coefficient				
$LnSk_{-1}$	−0.15***	−0.22***	−0.27***	−0.26***
	(0.03)	(0.05)	(0.07)	(0.05)
No. of countries	21	18	18	16
No. of observations	531	443	338	301
Log likelihood	936	776	693	601

1. All equations include short-run dynamics and country-specific terms, and control for outliers. Variables are defined in Box 1.
   Standard errors are in brackets.
   *: significant at 10 % level; ** at 5% level; *** at 1 % level.

with three control variables – lagged output per capita, human capital and lagged trade exposure – the preferred specification includes only a control for trade exposure.

The variability of inflation has a negative coefficient but it is not significant at the standard levels. Interestingly, the coefficient of the level of inflation is strongly significant and negative in the investment equation, in contrast with the weaker result in the growth regressions. These results are consistent with the view that uncertainty about price developments mainly influences growth via distortions in the allocation of resources (as discussed in the context of the growth equation), rather than via discouraging the overall accumulation of physical capital, while high levels of inflation indeed discourage saving and investment. There is also evidence that the "size" of government may be negatively associated with the rate of accumulation of private capital. This can be seen by looking at the coefficients

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on either taxes or government consumption (estimation with the latter allows the use of a larger sample). Possible interactions between private and government investment were also tested, but the results do not yield robust results of either a negative or positive link.

The coefficients on financial variables in the investment regressions in Table 6 have the expected signs and are (mostly) significant. As in the growth regressions, the indicator of credit provided by the banking sector appears to be only weakly associated with investment, while the stock market capitalisation has a stronger bearing on investment.

SOME QUANTITATIVE IMPLICATIONS OF THE REGRESSION RESULTS

The estimated coefficients of the different growth regressions can be used to shed light on the role of policy and institutional settings for the growth experience of different countries over the past two decades. Two important caveats need to be borne in mind in this exercise. As discussed above, it is assumed that the policy and institutional variables affect only the *level* of economic efficiency and not the steady-state growth rate. Moreover, the calculations should only be taken as broad indications, given the variability of coefficients across the specifications, and interaction effects that may be important but cannot be taken into account. The estimated coefficients are used to perform three calculations: *i*) the effect of a given change in a policy or institutional variable on steady-state output per capita; *ii*) the decomposition of observed differences in average growth rate across countries over a 20-year period; and *iii*) the decomposition of observed changes in growth rate within each country into its determinants. In the first calculation, the direct effect of a policy change and the indirect effect (via investment) are considered, while in the other two calculations only the direct effect is estimated and investment in physical capital is considered as one of the exogenous components of the decomposition. Hence, in the last two calculations the overall contribution of different policy levers to differences and changes in growth rates may well be different if one takes into account their impact via the investment channel.

The long-run effect of policy and institutional changes

Bearing the above-mentioned caveats in mind, the total effects of policy and institutional changes on GDP per capita can be summarised as follows (see Table 7):

- The point estimate for the variability of inflation suggests that a reduction by 1 percentage point in the standard deviation in inflation – *e.g.* about one and a half times the reduction recorded on average in the OECD countries

Table 7. **Estimated impact of changes in institutional or policy factors on GDP per capita**[1]

Variable	Impact on output per working age person (per cent)[2]			Order of magnitude with respect to OECD experience (1980s-90s)[3]
	Effect via economic efficiency	Effect via Investment	Overall effect	
Inflation rate (fall of 1% point)		0.4 to 0.5	0.4 to 0.5	about 1/4 the observed fall
Variability of inflation (1% point fall in SD of inflation)	2.0		2.0	about 1.5 times the observed fall
Tax burden[4] (increase of 1% point)	−0.3	−0.3 to −0.4	−0.6 to −0.7	about ⅔ of the observed increase
Business R&D intensity[4] (increase of 0.1% points)	1.2		1.2	about the increase observed
Trade exposure[4] (increase of 10% points)	4.0		4.0	about the increase observed

1. The values reported in this table are the estimated long-run effects on output per working-age person of a given policy change. The range reported reflects the values obtained in different specifications of the growth equation.
2. The direct effect refers to the impact on output per capita over and above any potential influence on the accumulation of physical capital. The indirect effect refers to the combined impact of the variable on the investment rate and by that channel, on output per capita.
3. Average change from the 1980 average to the 1990 average in the sample of 21 OECD countries, excluding new Members as well as Iceland, Luxembourg and Turkey.
4. In percentage of GDP.

from the 1980s to the 1990s – could lead to an increase in long-run output per capita by 2 per cent, *ceteris paribus*.

- The effect of the level of inflation mainly works through investment: a reduction of one percentage point – *e.g.* one-fourth of what was recorded in the OECD between 1980s and 1990s – could lead to an increase in output per capita of about 0.4-0.5 per cent, over and above what could also emerge from any accompanying reduction in the variability of inflation.

- Taxes and government expenditures affect growth both directly and indirectly through investment. An increase of about one percentage point in the tax pressure – *e.g.* two-thirds of what was observed over the past decade in the OECD sample – could be associated with a direct reduction of about 0.3 per cent in output per capita. If the investment effect is taken into account, the overall reduction would be about 0.6-0.7 per cent.

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- Finally, an increase in trade exposure of 10 percentage points – about the change observed over the past decade in the OECD sample – could lead to an increase in steady-state output per capita of 4 per cent.

Explaining cross-country differences in average growth rates

Differences in growth rates across countries depends on two factors: *i*) differences in the long-run equilibrium level of GDP per capita; and *ii*) differences in the initial conditions (the actual level of GDP per capita at the beginning of period considered). A country with the same initial level of GDP per capita but better framework conditions – and thus a higher steady state level of GDP – than another country will grow faster. This is due to the greater distance from its own steady state. Similarly, a country with a lower initial level of GDP than another country but the same steady state level will grow faster, again, because of the wider gap to be closed. Moreover, within any period of time, the steady-state level of GDP per capita could change because of changes in framework conditions, and this third factor has also to be taken into account. Formally, for each country, the decomposition of observed increases in GDP per capita over a time-period of length *t* into a set of explanatory variables over the same period can be expressed as follows:

$$(\ln y - \ln y_{-t}) = \left[(1-\phi)^t - 1\right]\ln y_{-t} + \sum_j \sum_{m=1}^{t} (1-\phi)^{m-1}\phi \cdot \theta_j X_{j,-(m-1)} \qquad (4)$$

where $\mathbf{X} = \{\ln k, \ln h, n, \mathbf{V}\}$ is the vector of independent variables (determinants of the steady state), θ is the vector of their long-run coefficients, ϕ is the convergence coefficient; $-t$ indicates initial conditions and $-m$ indicates that the variable is lagged m periods.[32] The first term on the right-hand side identifies the effect of initial conditions on changes in GDP per capita, while the second accounts for the determinants of the steady state. This decomposition can be used for two purposes: *i*) to compare average growth rates across countries and assess the role of initial conditions and differences in *levels* of determinants of the steady-state; and *ii*) to track changes in GDP per capita growth rates within each country over sub-periods and identify the impact of *changes* in the determinants of the steady state. For example, the average level of human capital in Spain was below the OECD average over the period 1970-98 and, thus, this contributed to a lower than average growth in GDP per capita (*ceteris paribus*). At the same time, however, human capital has grown rapidly in Spain from the 1970s to the 1980s and 1990s, pushing forward Spain's steady state GDP per capita more than in most of the other countries: this has resulted in an acceleration in GDP per capita growth, again *ceteris paribus*.

The formula is derived from equation [2] above (omitting short-run dynamics for the independent variables), that is:

$$\ln y = (1-\phi)\ln y_{-1} + \phi \sum_j \theta_j X_{j,0} \tag{5}$$

Iterating equation (5) t-1 times yields:

$$\ln y = (1-\phi)^t \ln y_{-t} + \phi \sum_{m=1}^{t} \sum_j (1-\phi)^{m-1} \theta_j X_{j,-(m-1)} \tag{6}$$

Then, equation (4) can be derived by rearranging equation (6).

Table 8 shows the decomposition in relative terms (to the OECD simple average). To maximise the country coverage, we use the growth regression on the right-hand-side of Table 3. This is run on 21 countries and uses government consumption as a proxy for the effect of government "size" on growth. The results suggest that the model fits the data rather well: there are only three countries where the unexplained growth rate differential is large in absolute terms (last column of Table 8).[33] In two of these three countries (Greece and Portugal) the model would have predicted a higher growth rate than that actually recorded. By contrast, the model under-predicts the average growth rate in the United States. In these three countries, additional factors not accounted for in the present analysis therefore played a significant role in shaping the growth process. The results in Table 8 confirm some priors about the driving forces of output growth in the OECD countries. In the English-speaking countries, a relatively low saving/ investment rate had a negative impact on growth, *ceteris paribus*. A relatively low level of human capital compared with the OECD average over the period negatively influenced growth in a number of European countries, but especially in Portugal and Spain. In addition, some countries, including Australia, Canada, Ireland and New Zealand, had a somewhat lower per capita growth as a result of a rapidly growing population. Average macro policy conditions also had a bearing in shaping cross-country differences in growth. Thus, the higher than average variability of inflation had a negative impact in Greece and, to some extent in Portugal, while the large "size" of government seems to have negatively influenced growth in Denmark and Sweden. Finally, the relatively low exposure to foreign trade (after controlling for the size of each country) seems to have had a negative impact on growth in Australia and New Zealand, possibly reflecting geographical location, while the reverse occurred in Belgium and Netherlands – though the trade exposure for these two countries reflects, to some extent, the large cross-border transactions amongst themselves – as well as in the United Kingdom.

Table 8. **Decomposition of country deviations from OECD average output per capita growth rates, 1970s-1990s[1]**
(annual percentage point growth rates)

	Annual average growth rate	Growth differential	Initial conditions (real GDP/pop)	Investment share (Sk)	Human capital (H)	Population growth (ΔLnp)	Variability of inflation (SDinfl)	Government consumption (Gov cons)	Trade exposure (Trade exp^{adj})	Residual country specific effect
Australia	1.68	**0.13**	-0.37	0.20	0.52	-0.25	0.03	0.01	-0.41	0.40
Austria	1.57	**0.02**	-0.41	0.07	0.26	0.01	0.05	0.00	0.03	0.01
Belgium	1.66	**0.11**	-0.53	0.02	-0.15	0.20	0.03	-0.05	0.53	0.06
Canada	1.32	**-0.23**	-0.90	-0.21	0.62	-0.18	0.04	-0.07	0.14	0.32
Denmark	1.69	**0.14**	-0.57	0.28	0.21	0.12	0.02	-0.14	-0.05	0.27
Finland	1.82	**0.27**	0.51	0.05	0.02	0.15	0.00	-0.06	-0.26	-0.14
France	1.35	**-0.20**	-0.59	-0.09	-0.10	0.07	0.07	-0.08	0.05	0.48
Greece	1.15	**-0.40**	2.00	0.19	-0.56	-0.07	-0.16	0.17	-0.51	-1.48
Ireland	3.02	**1.47**	1.54	-0.18	-0.32	-0.18	0.01	0.09	0.17	0.34
Italy	1.73	**0.18**	0.22	-0.13	-0.69	0.13	0.02	0.01	0.14	0.48
Netherlands	1.26	**-0.29**	-0.47	-0.03	0.25	0.01	0.06	-0.13	0.52	-0.50
New Zealand	0.53	**-1.02**	0.34	-0.17	0.31	-0.29	-0.07	0.10	-0.36	-0.87
Norway	1.72	**0.17**	-0.12	-0.05	0.35	0.07	0.03	-0.06	-0.04	-0.01
Portugal	2.15	**0.60**	2.56	0.58	-1.20	0.07	-0.10	0.10	0.11	-1.52
Spain	1.28	**-0.27**	0.73	0.04	-1.12	0.00	0.03	0.07	-0.14	0.11
Sweden	1.20	**-0.35**	-0.60	-0.10	0.21	0.11	-0.10	-0.17	0.01	0.30
Switzerland	0.81	**-0.74**	-1.75	0.08	0.59	-0.04	0.00	0.15	0.02	0.21
United Kingdom	1.63	**0.08**	0.05	-0.21	0.17	0.15	-0.03	-0.02	0.31	-0.34
United States	1.93	**0.38**	-1.62	-0.34	0.63	-0.09	0.07	0.09	-0.25	1.89

1. Decomposition of cross-country differences in annualised growth rate (in %) from the average output per capita of 1974-77 to the average output per capita of 1994-97. See main text for details on the decomposition.

The role of policy and institutions in shaping the growth process over the past two decades

Policy and institutional settings have changed significantly over the past decades and it is also important to examine the possible impact of these changes on the growth path of each country (Figure 4). The improvement in human capital has been one of the key factors behind the growth process of the past decades in all OECD countries, but especially so in Germany, Italy, Greece, Netherlands (mainly in the 1980s) and Spain, where the increase in human capital accounted for more than half a percentage point acceleration in growth (in both the 1980s and 1990s) with respect to the previous decade (even though the level of human capital remained low compared to other countries). The contribution stemming from changes in the investment rate is more mixed. Some countries are estimated to have benefited from an increase in the investment rate in the past two decades with respect to the 1970s (*e.g.* Japan, Canada, Austria, Belgium, New Zealand), while others could have had a negative impact from lower investment rates (*e.g.* Italy and Ireland in the 1980s, Finland in the 1990s).

There have also been important changes in policy and institutional settings in each country that have contributed to growth, over and above the changes in factor inputs. Most countries have benefited, especially in the 1990s, from reduced uncertainty due to a lower variability of inflation. The most noticeable examples include the United Kingdom and Japan (in the 1980s) and Portugal and New Zealand (in the 1990s) where about half a percentage point higher annual output per capita growth rate is estimated to be due to the lower variability of inflation, *ceteris paribus*. By contrast, in spite of public spending restraint, especially in the last decade, the rise in the size of government contributed to slow down growth in most countries. Notable exceptions include the United States, Ireland and the Netherlands where a reduction in taxes and expenditures as a share of GDP somewhat boosted output per capita growth in the 1990s. Finally, but not least, the generalised process of trade liberalisation in which all OECD countries have been involved is estimated to have increased growth by up to two-thirds of a percentage point annually over the past decade.

CONCLUDING REMARKS

In broad terms, the estimated growth regressions explain much of the observed growth paths across countries and over time. One striking result of our study is the high speed with which countries seem to converge to their steady-state growth path compared with previous estimates based on a larger set of countries and cross-section data. This implies that observed cross-country

Figure 4. **The estimated effect of changes in explanatory variables to changes in output per capita growth rates**[1]
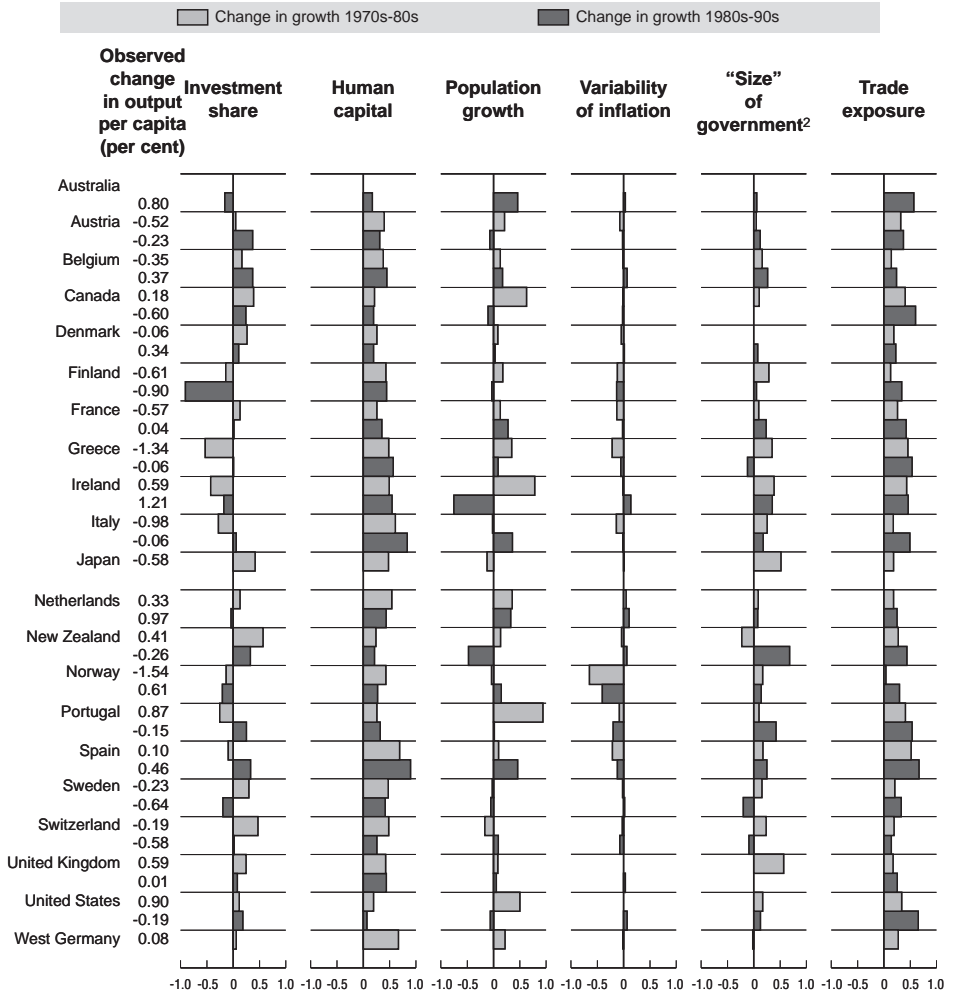
Notes: The calculations are from decompositions of differences in growth rates based on the results of multivariate regressions. The estimated impact of initial levels of GDP per capita and the component unexplained by the regressions are not shown.

1. The changes in growth are based on differences in average growth in GDP per person of working age over each decade.

2. Government consumption as a percentage of GDP is used as a proxy for the size of government due to data availability. This variable is highly correlated in most countries with the tax and non-tax receipts (as a share of GDP) for which, however country coverage is more limited.

differences in GDP per capita levels may be largely the result of differences in steady-state levels rather than different positions of countries along similar transitional paths. In consequence, differences in investment rates and human capital as well as in R&D, trade exposure, financial structures and macroeconomic conditions and policy settings seem to play an important role for observed GDP per capita patterns across countries. Changes in these factors can be rapidly translated into changes of living standards. The other main results of our study are as follows:

- The estimated partial elasticity of output to physical capital is consistent with the values implied in National Accounts data, even though it is on the low side of the range. By contrast, and if taken at face value, the estimated elasticity of output to human capital points to potential externalities in investment in education, *i.e.* social returns seem higher than private returns at least over the past decades, when education levels were relatively low.

- The evidence suggests that high inflation is negatively associated with the accumulation of physical capital in the private sector and, through this channel, has a negative bearing on output. Moreover, a high variability of inflation affects GDP per capita, possibly because it leads to a shift in the composition of investment towards less risky but also lower return projects.

- In addition, the empirical evidence lends some support to the notion that the overall size of government in the economy may reach levels that hinder growth. Although expenditure on health, education and research clearly sustains living standards in the long term, and social transfers help to meet social goals, all have to be financed. The results suggest that for a given level of taxation, higher direct taxes lead to lower output per capita, while, on the expenditure side, government consumption and government investment tend to have non negative effects on output per capita. Government investment may also influence growth by improving the framework conditions (*e.g.* better infrastructure) in which private agents operate.

- Research and development (R&D) activities undertaken by the business sector seem to have high social returns, while no clear-cut relationship could be established between non-business-oriented R&D activities and growth. There are, however, possible interactions and international spillovers that the regression analysis cannot identify. Moreover, non-business oriented R&D (*e.g.* energy, health and university research) may generate basic knowledge with possible "technology spillovers" in the long run.

- The empirical evidence also confirms the importance of financial markets for growth, both by helping to channel resources towards the most rewarding activities and in encouraging investment. In particular, the degree of

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stock market capitalisation is found to be strongly related with both output per capita (while controlling for investment) and with the investment rate.

All in all, the results suggest that differences in GDP per capita across the OECD countries can be largely explained by different policy and institutional settings and that countries can learn from each other on the optimal growth strategy. Notwithstanding persistent differences in living standards, recent policy changes seem to go in the right direction to enhance growth. Most countries have made significant progress towards price stability and avoiding excessive macroeconomic fluctuations. However, while there have been successful efforts to reduce public-sector deficits, the overall tax pressure is still high in a number of them and has risen in the past decade. On the structural side, most OECD countries have recorded significant increases in their human capital, not least because of government interventions. Even if it is possible that there are diminishing social returns to any given increase in education levels, these developments have had (and will have in the future) a positive impact on observed growth patterns. Furthermore, the amount of resources devoted to R&D has generally increased from the 1980s to the 1990s – though there has been some reduction in recent years largely due to falls in defence-related government outlays. Moreover, more resources seem to be channelled directly to the business sector with a greater role played by industries themselves. Beyond these considerations, there remain significant differences in growth rates across countries, possibly due to differences in other framework conditions (*e.g.* regulation in the product and labour markets) which have not be taken into account in this paper.

NOTES

1. It should also be stressed that evidence of convergence in GDP per capita amongst OECD countries is largely concentrated in the post-war period: during most of the 19th century, most OECD countries were falling behind the United Kingdom and during the first half of the 20th century most of them were falling behind the United States. See Maddison (2001).

2. Indeed, new-growth models that incorporate a knowledge-producing sector can be interpreted as incorporating the role that, for example, research universities may play in the growth process. An early example of this type of model is in Uzawa (1965), later examples include Lucas (1988), Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1998).

3. Amongst the several studies that suggest a negative association between uncertainty on the one hand, and investment and growth, on the other, see Dixit and Pindyck, 1994 and Bertola and Caballero, 1994. Amongst the studies that have put into question the negative association between uncertainty and investment are Abel (1983) and Hartman (1972). They suggest that in an economy with no frictions, an increase in uncertainty could even lead to higher investment rates.

4. In most OECD countries, government finances the bulk of expenditure on educational institutions. See OECD (2001) for more details.

5. For example, Coe and Helpman (1995) find significant interaction between import propensities and the ability to benefit from foreign R&D: *i.e.* for a given level of R&D performed abroad, countries with higher import propensity have higher productivity growth. Moreover, small countries benefit more from R&D performed abroad than from domestic R&D. Sachs and Warner (1995) claim trade openness as being an important constraint to convergence for many of the world's economies. Using aggregate data on trade between (mainly) OECD countries, Ben-David and Kimhi (2000) find evidence to support the idea that increasing trade between pairs of countries is associated with an increased rate of convergence.

6. See *e.g.* Frankel and Romer (1999) and Baldwin (2000).

7. Where data for a large number of countries was available, growth regressions have typically taken averages over long time periods (*e.g.* 20 years). Other studies have taken averages over five-year periods (see *e.g.* Islam, 1995; Caselli *et al.*, 1996). This choice, however, implies a potential loss of information. Moreover, the lack of synchronisation in country business cycles does not purge five-year averages from cyclical influences.

8. This is, for example, the case in one-sector models of endogenous growth in which capital is not characterised by diminishing returns (see *e.g.* Romer, 1986; Rebelo, 1991).

9. This is the case in models of endogenous growth, which explicitly consider different types of capital goods (*e.g.* physical and human), each characterised by its own accu-

mulation process (*e.g.* investment and education). See Uzawa (1965); Lucas (1988); Barro and Sala-i-Martin (1995).

10. As discussed in detail by Klenow and Rodríguez-Clare (1997), most cross-section studies of growth (*e.g.* Barro and Sala i Martin, 1995) estimate a regression of the general form:

$$\Delta \ln y_{i,T} = -b \cdot \ln y_{i,0} + \text{policy and institutional variables} + u_{i,T}$$

where $\Delta \ln y$ is the growth rate of GDP per capita over a period of time (0 to T); $\ln y_0$ is the log of GDP per capita at time 0; and *i* identifies each country. They derive this equation from a simple neo-classical growth model:

$$\Delta \ln y_{i,T} = g_i + \beta \cdot \left(\ln y_{i,0}^* - \ln y_{i,0} \right) + \varepsilon_{i,T}$$

where $\ln y_{i,0}^*$ is the log level of GDP per capita on the country's steady-state path. However, it is not clear whether the policy and institutional variables in the first equation are proxying for differences in country steady-state GDP per capita levels ($\ln y_{i,0}^*$) (consistent with conditional convergence) or for cross-country differences in the long-run growth rates g_i.

11. Estimates of the speed of convergence to steady-state output vary in the literature: while most studies estimated values around 2-3 per cent per year (Mankiw, *et al.*, 1992; Barro and Sala-i-Martin, 1995) – which implies that an economy spends about 20-30 years to cover half of the distance between its initial conditions and its steady state – a few have found values of 10 per cent or more for the OECD countries (*e.g.* Caselli *et al.*, 1996), which imply less than nine years to cover half of the distance.

12. Under slope heterogeneity, estimates of a uniform convergence parameter are affected by a downward heterogeneity bias (Pesaran and Smith, 1995).

13. In a theoretical growth model, ϕ is a function of population growth ($n_{1,t}$) and technological progress ($g_{i,t}$) and thus could vary across countries and over time. For the purpose of the econometric analysis, time homogeneity had to be imposed, but the parameters are allowed to vary across countries.

14. If the homogeneity assumption was not retained, the reported coefficient in the tables is the simple average of country-specific coefficients.

15. This result may arise because for a number of OECD countries the average number of years of schooling has increased steadily over the sample period. Our sensitivity analysis (Bassanini and Scarpetta, 2001) suggests that a time trend is only statistically significant when human capital is omitted and is not statistically significant at standard confidence levels when human capital is included. Consequently, in the retained specification, human capital was included while the time trend was dropped.

16. The identification of outliers is based on the analysis of *studentised residuals* and *leverage values* (see Belsley *et al.*, 1980). The *studentised residuals* are obtained by considering a mean-shift outlier model in which the basic equation is augmented by a dummy variable that has the *ith* element equal to one and all other elements zero. The studentised residual is the t-statistics of the dummy variable. The *leverage point* is identified by the diagonal elements of the least-squared projection matrix, also called the *hat* matrix. It proxies the distance between the *ith* observation and the centre of the data. The outliers that have been removed from the sample are those with a studentised residual greater than 2.5 and a leverage point above the cut-off value suggested by Belsley *et al.* (1980). Eight outliers have been identified using dynamic fixed effect

estimators: the 1972-73 observations for New Zealand; 1995-97 for Ireland; 1972 for Finland and 1972-73 for Portugal.

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

18. However, it should also be stressed that the evidence on the returns to education reflects average rates of return based on historical data, whereas future marginal returns may not be as high.

19. It should be stressed that these conclusions do not depend on a particular specification of the growth equation: inclusion of a linear time trend, introduction of country-specific time dummies, sample variations across countries and over time, all lead to similar results (Bassanini and Scarpetta, 2001).

20. One of the reasons behind the difference in the present results on human capital has to do with the quality of the data used in this paper compared with previous attempts. We used a revised version of the Barro and Lee (1996) database as assembled by de la Fuente and Doménech (2000) in combination with more recent OECD data (see Appendix 2). Revisions were largely aimed at removing time and cross-country inconsistencies in the original database. Using a similar proxy, de la Fuente and Doménech (2000) also found a strongly significant coefficient for human capital in level and growth equations.

21. The neo-classical model makes precise predictions on the value of the estimated long-run parameters of the human and physical capital, as well as on population growth. Furthermore, the speed of convergence $[-\log(1-\hat{\phi})]$ can be expressed formally as a function of the rate of technological progress, the rate of growth of the population, the depreciation rate of physical and human capital as well as output elasticities to human and physical capital, the latter being derived from the coefficients on sk and h in equation [2] above. The estimated speed of convergence to the steady state path of output per capita in our equations is too high with respect to what would be implied by the estimated value of the elasticity of output with respect to "broad" (physical and human) capital, which would imply very slow convergence (see Bassanini and Scarpetta, 2001).

22. The uncertain result for the level of inflation is in line with Alexander (1997) who also used an OECD sample. However, other papers that did not include the variability of inflation in the growth equation found more solid links between the level of inflation and growth, even in the OECD samples. See, for example, Andres and Hernando (1997) and Englander and Gurney (1994).

23. The cross-country homogeneity restriction on the coefficient of the level of inflation is rejected at the 5 per cent level in the model that does not include the trade exposure variable and, once allowed to vary across countries, this coefficient becomes statistically insignificant.

24. The latter result is consistent with that of Folster and Henrekson (1998, 2000) who focus on the link between the "size" of government and growth in OECD countries. However the conclusions reached by Folster and Henrekson have been questioned by some researchers, notably Agell *et al.* (1997).

25. See Helms (1985); Mofidi and Stone (1989); Kneller *et al.* (1998).

26. The cross-country correlation between the government consumption variable and the tax and non-tax receipts variable is greater than 0.5 in each year of the sample and

always greater than 0.6 after 1976. In time-series the correlation is greater than 0.9 in 9 out of 18 countries and greater than 0.7 in all but three countries (Belgium, the Netherlands, and the United States).

27. The growth regression maintains its basic properties when estimated over the smaller sample used in the R&D regressions. The coefficients on both physical and human capital maintain their sign and statistical significance, although the convergence is higher than in the regression estimated over the larger sample. This latter result is not driven by the small country sample but rather by the shorter time period over which the model is estimated.

28. In terms of previous evidence, Fagerberg (1994), for example, found a patent-based index significant in growth regressions; and Englander and Gurney highlighted R&D expenditure as a robust variable in their growth regressions.

29. Park (1995) also found private-sector R&D more important than public R&D in OECD-based growth regressions.

30. Lichtenberg (1988) finds that non-competitive R&D procurement tends to crowd out private R&D investment, while competitive procurement stimulates private R&D investment. See David *et al*. (1999) for a survey. By contrast, Guellec and Van Pottelsberghe (1997, 2001) support the complementarity hypothesis.

31. Given the short time period that can be used in this sample, lagging the R&D variable would have induced an excessive loss of degrees of freedom.

32. Taking for simplicity the case of a hypothetical independent variable X that is constant over time, equation [4] suggests that the weight of this variable is greater (in absolute terms) the longer the time span over which the decomposition is performed. This property generalises to time-varying independent variables. Hence, to be comparable across countries and/or over time, growth decompositions undertaken according to equation [4] have to refer to the same time span t.

33. A positive country-specific effect implies that actual growth was higher than predicted by the model, and *vice versa*.

Appendix 1

THE POLICY-AND-INSTITUTIONS AUGMENTED GROWTH MODEL

T*he growth equation*

Following a standard approach (see *e.g.* Mankiw *et al.*, 1992; and Barro and Sala-i-Martin, 1995), the standard neo-classical growth model is derived from a constant returns to scale production function with two inputs (capital and labour) that are paid their marginal products. Production at time *t* is given by:

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} \big(A(t)L(t)\big)^{1-\alpha-\beta} \tag{A1}$$

where *Y*, *K*, *H* and *L* are respectively output, physical capital, human capital and labour, α is the partial elasticity of output with respect to physical capital, β is the partial elasticity of output with respect to human capital and $A(t)$ is the level of technological and economic efficiency. It can be assumed that the level of economic and technological efficiency *At*) has two components: economic efficiency $I(t)$ dependent on institutions and economic policy, and the level of technological progress $\Omega(t)$ (see amongst others, Cellini *et al.*, 1999 for a similar formulation). In turn, $I(t)$ can be written as, *e.g.* a log-linear function of institutional and policy variables, while $\Omega(t)$ is assumed to grow at the rate $g(t)$.

The time paths of the right-hand side variables are described by the following equations (hereafter dotted variables represent derivatives with respect to time):

$$\dot{k}(t) = s_k(t)A(t)^{1-\alpha-\beta} k(t)^{\alpha} h(t)^{\beta} - (n(t)+d)k(t)$$
$$\dot{h}(t) = s_h(t)A(t)^{1-\alpha-\beta} k(t)^{\alpha} h(t)^{\beta} - (n(t)+d)h(t)$$
$$A(t) = I(t)\Omega(t)$$
$$\ln I(t) = p_0 + \sum_j p_j \ln V_j(t) \tag{A2}$$
$$\dot{\Omega}(t) = g(t)\Omega(t)$$
$$\dot{L}(t) = n(t)L(t)$$

where *k = K/L*, *h = H/L*, *y = Y/L*, stand for the capital labour ratio, average human capital and output per worker respectively; s_k and s_h stand for the investment rate in physical and human capital respectively; and *d* stands for the (constant) depreciation rate. Under the assumption

that $\alpha + \beta < 1$ (*i.e.* decreasing returns to reproducible factors), this system of equations can be solved to obtain steady-state values of k^* and h^* defined by:

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

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

(A3)

Substituting these two equations into the production function and taking logs yields the expression for the steady-state output in intensive form. The latter can be expressed either as a function of s_h (investment in human capital) and the other variables or as a function of h^* (the steady-state stock of human capital) and the other variables. Since in this paper human capital is proxied by the average years of education of the working age population, a formulation in terms of the stock of human capital was retained. The steady-state path of output in intensive form can be written as:*

$$\ln y^*(t) = \ln \Omega(t) + p_0 + \sum_j p_j \ln V_j(t)$$

$$+ \frac{\alpha}{1-\alpha} \ln s_k(t) + \frac{\beta}{1-\alpha} \ln h^*(t) - \frac{\alpha}{1-\alpha} \ln(g(t)+n(t)+d)$$

(A4)

However, the steady-state stock of human capital is not observed. It can be shown that an expression for h^* as a function of actual human capital is:

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

(A5)

where ψ is a function of (α, β) and $n + g + d$.

Equation [A4] would be a valid specification in the empirical cross-country analysis only if countries are in their steady states or if deviations from the steady state are independent and identically distributed. If observed growth rates include out-of-steady-state dynamics, then the transitional dynamics have to be modelled explicitly. A linear approximation of the transitional dynamics can be expressed as follows (Mankiw *et al.*, 1992):

$$\Delta \ln y(t) = -\phi(\lambda)\ln(y(t-1)) + \phi(\lambda)\frac{\alpha}{1-\alpha}\ln s_k(t) + \phi(\lambda)\frac{\beta}{1-\alpha}\ln h(t) + \sum_j p_j\phi(\lambda)\ln V_j(t)$$

$$+ \frac{1-\psi}{\psi}\frac{\beta}{1-\alpha}\Delta \ln h(t) - \phi(\lambda)\frac{\alpha}{1-\alpha}\ln(g(t)+n(t)+d)$$

$$+ \left(1 - \frac{\phi(\lambda)}{\psi}\right)g(t) + \phi(\lambda)(p_0 + \ln \Omega(0)) + \phi(\lambda)g(t)t$$

(A6)

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* Strictly speaking, equation (A4) is written under the simplifying assumption that policy and institutional variables do not change persistently in the long-run. If this is not the case, $\ln (g + n + d)$ must be augmented by a term reflecting the rate of change of policy and institutional variables. As the estimable equation is linearised and contains short-run dynamics anyway, this term will be omitted hereafter for simplicity.

where $\lambda = (1 - \alpha - \beta)(g(t) + n(t) + d)$. Adding short-term dynamics to equation (A6) yields:

$$\Delta \ln y(t) = a_0 - \phi \ln y(t-1) + a_1 \ln s_k(t) + a_2 \ln h(t) - a_3 n(t) + a_4 t + \sum_j a_{j+4} \ln V_j$$
$$+ b_1 \Delta \ln s_k(t) + b_2 \Delta \ln h(t) + b_3 \Delta \ln n(t) + \sum_j b_{j+4} \Delta \ln V_j + \varepsilon(t) \tag{A7}$$

Equation (A7) represents the generic functional form that has been empirically estimated in this paper. Estimates of steady state coefficients as well as of the parameters of the production function can be retrieved on the basis of the estimated coefficients of this equation by comparing it with equation (A6). For instance, an estimate of the elasticity of steady state output to the investment rate (that is the long-run effect of the investment rate on output) is given by $\hat{a}_1 / \hat{\phi}$, where ^ identifies estimated coefficients. Conversely, an estimate of the share of physical capital in output (the parameter α of the production function) can be obtained as $\hat{a}_1 / (\hat{\phi} + \hat{a}_1)$.

Appendix 2

THE DATA

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

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

- Data on Research and Development (R&D) are from the OECD *Main Science and Technology Indicators* (MSTI) database. A few missing observations were obtained by interpolation.

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

- The indicators measuring financial market developments are from the World Bank's financial development database (see Beck *et al.*, 1999). For more details on the pros and cons of these two indicators and for the motivation of their inclusion, see Leahy *et al.* (2001).

The definition of each variable is provided in Box 1 of the main text. The exact country coverage of the variables is presented in Table A2.1, while the basic statistics are in Table A2.2.

Table A2.1. **Details on data availability**

Variable	Start date	End date	Exceptions
Real GDP per person of working age (**Y**)	1971	1998	1971-1997 for Portugal and Spain; 1971-1996 for Greece; 1971-1994 for Western Germany.
Accumulation of physical capital (**Sk**)	1971	1998	1971-1997 for Austria, Belgium, Ireland, Italy, New Zealand, Portugal, Spain and Sweden; 1971-1996 for the United Kingdom; 1971-1995 for Switzerland; 1971-1990 for Western Germany; 1975-1998 for Australia.
Human capital (**H**)	1971	1998	1971-1990 for Western Germany and Japan
Growth of working age population (Δ**LnP**)	1971	1998	1971-1997 for Spain; 1971-1996 for Greece; 1971-1994 for Western Germany.
Standard deviation of inflation (**S$dinfl_{-1}$**)	1971	1998	
Inflation (**Infl_{-1}**)	1971	1998	
Government consumption (**Gov$^{cons}_{-1}$**)	1971	1998	
Accumulation of physical capital by government (Sk$^{gov}_{-1}$)	1971	1998	1971-1997 for Switzerland; 1971-1996 for Portugal; 1971-1995 for Western Germany.
Tax and non-tax receipts as a share of GDP (**Tax$_{-1}$**)	1971	1998	1971-1997 for Portugal; 1971-1995 for Western Germany; 1978-1998 for Ireland; 1987-1998 for New Zealand; 1988-1998 for the United Kingdom; no data for Switzerland.
Ratio of direct/indirect taxes (**Tax distr$_{-1}$**)	1971	1998	1971-1998 for Switzerland; 1971-1996 for Portugal; 1971-1995 for Western Germany; 1978-1998 for Ireland; 1987-1998 for New Zealand; 1988-1998 for the United Kingdom.
Total R&D expenditure as a share of GDP (**R&D^{tot}**)	1981	1998	1981-1997 for Greece, Ireland, the Netherlands, Sweden and the United Kingdom; 1981-1996 for Australia and Switzerland; 1982-1997 for Portugal; 1983-1995 for Belgium; 1989-1997 for New Zealand; no data for mainland Norway.
Business-performed R&D expenditure as a share of GDP (**BERD**)	1981	1998	1981-1997 for Australia, Greece, Ireland, the Netherlands, Sweden and the United Kingdom; 1981-1996 for Switzerland; 1981-1995 for Belgium; 1981-1993 for Austria; 1982-1997 for Portugal; 1989-1997 for New Zealand; no data for mainland Norway.
Non-business performed R&D expenditure as a share of GDP (**R&D^{pub}**)	1981	1998	1981-1997 for Greece, Ireland, the Netherlands, Sweden and the United Kingdom; 1981-1996 for Australia and Switzerland; 1981-1993 for Austria; 1982-1997 for Portugal; 1983-1995 for Belgium; 1989-1997 for New Zealand; no data for mainland Norway.

Table A2.1. **Details on data availability** (*cont.*)

Variable	Start date	End date	Exceptions
Private credit as a share of GDP (**Priv credit**$_{-1}$)	1971	1998	1971-1997 for Ireland and Portugal; 1971-1992 for Western Germany.
Stock market capitalisation as a share of GDP (**Stock cap**$_{-1}$)	1977	1998	1977-1997 for Belgium and Switzerland; 1977-1991 for Western Germany; 1979-1995 for Portugal; 1982-1998 for Norway; 1984-1998 for Finland; 1986-1998 for New Zealand; 1996-1998 for Ireland.
Trade exposure (**Trade exp**$_{-1}$)	1971	1998	

Table A2.2. **Basic Statistics**

Variables (in per cent)	Sample mean (absolute values or per cent)	Standard deviation
Y (1993 PPP \$)[1]	23 951.0	5 783.0
Sk (%)	17.11	4.46
H (years)[2]	10.15	1.69
ΔLnP (%)	0.79	0.62
Sdinfl$_{-1}$	1.51	1.27
Infl$_{-1}$ (%)	6.87	4.89
Gov cons$_{-1}$ (%)	18.46	5.11
Sk$^{gov}_{-1}$ (%)	3.70	2.06
Tax$_{-1}$ (%)	39.62	9.19
Tax distr$_{-1}$ (%)	11 2.44	43.44
R&D^{tot} (%)	1.72	0.80
BERD (%)	1.05	0.64
R&D^{pub} (%)	0.66	0.21
Priv credit$_{-1}$ (%)	56.98	29.50
Stock cap$_{-1}$ (%)	33.79	28.86
Trade exp$_{-1}$ (%)	43.25	18.18

1. In 1995 US\$ (Expressed in 1993 EKS PPPS).
2. Average years of education.

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