How productive are capital investments in Europe?

When the only tool you own is a hammer,
every problem begins to resemble a nail.
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1. Introduction

Economists agree at least on this: it is difficult to find evidence for, or merely to imagine any growth mechanism that does not work through the increase of a stock of capital in one way or another. From a more policy point of view - in particular in terms of the debate of economic development and convergence in standards of living - an important question then is when spending on investment is best done by the government itself, and when public funds should be used to support investment by the private sector.

A key concept in this issue is the degree of external benefits, or spillovers, of investment. These notions refer to the fact that sometimes a certain action by an economic agent results indirectly in productivity gains for others that cannot be completely captured by the principal investor in his price setting behaviour.

Under the standard textbook assumptions, property rights are complete and possible externalities are supposed not to be important enough to offset the decreasing marginal productivity of capital and labour. The market outcome will then be such that production factors are optimally allocated - the role for active policy intervention is in that case henceforth rather limited. However, if some investments yield external benefits, their full rate of return for society will exceed that of comparable yet perfectly excludable and rival assets. There may consequently be scope for public intervention from an efficiency (as opposed to redistributive) point of view (see the contributions of Martin and Thisse, this volume). An important policy instrument here is public investment.

Substantial positive external benefits associated with physical capital provide indeed a basic rationale for public investment. The intuition behind this is as follows. Private agents will be hesitant to invest in those goods for which they cannot completely exclude others from benefiting from them - by doing so the investor would give a free input to competitors. The inability to charge a market price for this indirect service implies that the agent will not be able to reap the full profit of his investment. Thus, the larger the external benefits, the less likely private agents are to invest in the considered goods. Public finance theory stresses therefore that the government should supply such capital.

Public investment is not only motivated because of possible external effects. One can also make a plausible theoretical case in favour of public investment along the lines of market failures. For instance, long-term unemployed that want to invest in education may find it difficult to borrow against their future productivity to finance the investment. Reasons for this are uncertainty and asymmetric information, so that providing public schools solve, at least in part, some of these market failures.

Yet, even though publicly provided goods may be characterised by positive externalities, they have to be financed with tax money. Levying taxes presumably reduces the private savings and investment behaviour, so that public investment may crowd out private investment. However, some public goods may at the same time make private investments more attractive and productive. From

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a theoretical point of view, the net effect is not evident and empirical investigations will have to provide an answer.

This leads to a number of questions. Is there any evidence of external benefits? Do public and private capital investments equally contribute to increases in the standard of living? Are there differences between productiveness at the national and regional level? Although considerable effort has been undertaken to investigate these questions for the United States and different specifications have been applied to a cross-section of both developed and less developed countries, they have not extensively been studied for economies within the European Union. The current paper tries to bridge that gap.

We have organised the remainder of the paper as follows. In the next section we will review some methodological issues and different approaches that have been suggested in the economic literature to investigate the issue. Section 3 thereafter reports the empirical regularities for Europe, both on the national and the regional level. Section 4 summarises and concludes.

2. Methodological issues and approaches

2.1 Comparing measures of standard of living

When talking about benefits for society, it is good to clarify what one means by that. A natural interpretation would be to argue that economic growth translates into an increase in the quantity and quality of available goods through an improvement of efficiency by which the production factors are employed. In that way people can buy more and improved goods in the next period with the income they earn from participating in the production process. Macroeconomists therefore take the per capita income as a fairly suitable proxy for the standard of living (1).

Comparing levels of standards of living among countries or regions by using these indicators can nonetheless be difficult a task, and one has to be rather careful in doing so. The obvious method would be to value each country's production of final goods and services at domestic prices, to apply the GDP deflator in order to express these numbers in real terms, and thereafter to convert these figures into a common monetary currency using the relevant exchange rates.

In theory, exchange rates should adjust through the action of the market so that the local currency prices of a group of identical goods and services indeed represent equivalent value in every nation. In practice such adjustments can, however, lag far behind rapidly changing economic circumstances. There are consequently often large and systematic departures of exchange rates from the "purchasing power parities" (PPP) - a given amount of euro will buy different bundles of goods in different countries. International comparisons based on market exchange rates can hence greatly over- or understate the purchasing power value of a nation's real economic activity.

An alternative approach is therefore based on estimates of the purchasing power of different currencies, rather than their market exchange rates. The construction of national accounts in purchasing power parities that are comparable across space and time is not easy though. It relies on obtaining price data for a wide range of goods, and building suitable aggregation procedures

1) While income per employed person is used as a measure for average labour productivity. However, since age-structures may differ substantially between economies, a more appropriate indicator for cross-economy comparisons is the income per person of working age, where the working age is defined as 15 up to 64.

to obtain a regional or national PPP adjusted GDP. A blend of extrapolated and regression-based numbers for this concept is available from different sources such as Eurostat, the OECD, the World Bank and the so-called Penn World Tables. However, these data are primarily designed to compare countries within the same year, and should strictly spoken not be used in time-series comparisons (2). Doing so might very well result in an intuitively attractive rank ordering of countries, it yields, however, implausible results for annual average growth rates. This is often overlooked when analysing determinants of economic growth in empirical exercises (3).

The current paper focuses on the productivity of public and private investment in European countries and regions.

Thus, we must return to the first option to employ GDPs expressed in prices and exchange rates of a particular year. Although in this approach the growth rates reflect more consistently the changes in the volume of real output, one has to keep in mind that real exchange rate appreciations over time are not captured here. As an illustration Table 1 compares the OECD PPP data with this major alternative. The table suggests that the major drawback of the methodology we propose is that it significantly overvalues the standard of living in Sweden and Finland, and ranks Belgium and the Netherlands too low.

Table 1. Comparison of real and PPP GDP per person of working age. EU-15 countries, 1990-97.

Countries are ranked according to their situation in 1997							
	Exchange Rates and Prices of 1990, USD				PPPs USD		
	Income per worker in		Average Annual Growth		Income per worker in		Average Annual Growth
Country	1990	1997	1990-97	Country	1990	1997	1990-97
Luxembourg	39.145	51.015	3.86%	Luxembourg	32.917	49.558	6.02%
Denmark	38.510	45.112	2.29%	Denmark	25.383	37.844	5.87%
Sweden	41.653	42.946	0.44%	Belgium	24.888	35.313	5.13%
Finland	40.168	42.089	0.67%	Austria	24.818	34.127	4.66%
France	31.980	34.104	0.92%	France	26.329	32.551	3.08%
Austria	30.638	33.573	1.32%	Netherlands	23.154	32.481	4.95%
Germany[a]	30.660	32.692	1.08%	Germany[a]	24.786	32.271	4.50%
Belgium	29.388	32.575	1.48%	Sweden	26.414	32.034	2.79%
Netherlands	27.528	31.622	2.00%	Ireland	18.550	31.814	8.01%
Ireland	21.165	30.969	5.59%	UK	24.256	31.512	3.81%
Italy	28.135	30.042	0.94%	Italy	23.720	31.089	3.94%
UK	25.942	28.691	1.45%	Finland	24.046	30.780	3.59%
Spain	19.031	20.772	1.26%	Spain	17.714	23.426	4.07%
Greece	12.264	13.060	0.90%	Portugal	14.537	21.398	5.68%
Portugal	10.579	11.923	1.72%	Greece	13.800	20.451	5.78%

Source: GDP: OECD National Accounts. Number of people of working age: AMECO.
[a]: 1991-97

2) To quote the World Bank's World Resources (1996, p. 171): "Although considerable effort has been made to standardize economic data according to the UN system of National Accounts, care should be taken in interpreting them. Intercountry and intertemporal comparisons using economic data involve complicated technical problems that are not easily resolved; therefore, readers are urged to read these data as characterizing major differences between economies rather than as precise, quantitative measurements".

3) e.g. Quah 1993, 1996, 1997a,b. The regional PPP data by Eurostat (Nuts 2 and 3 level) show for instance typical average annual growth rates of per capita GDP of 8 percent and much more. Some researchers do not seem to take this problem into account, nor that the definition of the PPS has changed with every enlargement of the EU.

2.2 Assessing the impact of input factors on the standard of living: What does economic theory suggest?

To produce their output, economies have access to similar types of inputs: a certain amount of the population - the active labour force which represents a mixture of skills or human capital - and the stock of physical capital. All of them are combined with a particular efficiency. Economic growth consequently results from continuous increases in these variables.

A natural question henceforth is whether it is efficient to reduce private saving through taxation and to inject those means as public investment to improve regional development. Although many policy maker in the 1950s believed so, the enthusiasm for active interventions among economists waned, as the neo-classical paradigm became more prevalent during the sixties and beyond. It has somewhat revived however, with the recent arrival of theories on endogenous growth and "new" economic geography.

How can one think about the issue of making backward economies catch-up? Growth theories provide useful frameworks here. A key concept and starting point in these theories is always the production function. In its most simple form, it is assumed that there exists a link between the total amount of goods and services that an economy can produce per unit of time (Y), the available input factors such as domestic physical capital (K) and labour (L), and their total factor productivity or efficiency (A).

$$(1) \quad Y_t = f(L_t, K_t, A_t)$$

Economic growth results from continuous increases in the stocks of capital and efficiency with which these stocks are used.

In this respect, a frequently used specific form for this function is the Cobb-Douglas type:

$$(2) \quad Y_t = A_t \cdot K_t^{\alpha_1} \cdot L_t^{\alpha_2}$$

which in terms of per capita income reads:

$$(3) \quad y_t \equiv \frac{Y_t}{L_t} = A_t \cdot \left[\frac{K_t}{L_t}\right]^{\alpha_1} \cdot L_t^{\alpha_1+\alpha_2-1} = A_t \cdot k_t^{\alpha_1} \cdot L_t^{\alpha_1+\alpha_2-1}$$

Of particular interest here are the coefficients α_1 and α_2, which, in fact, indicate how responsive the standard of living is to changes in the input factors. When they sum up to one, production takes place under constant returns to scale. That is, doubling every factor of production will result in twice the amount of total output, and income per worker remains unchanged. If they are also each strictly positive and smaller than one, capital and labour are characterised by diminishing marginal productivity. Investing a constant fraction of output every period will then consequently result in decreasing additions to output over time. In that way, a boost in the investment share causes a jump in income, but the growth effect will fade out. These are the well-known standard neo-classical predictions. Moreover, when markets are competitive so that each factor is valued according to its productivity, α_1 and α_2 represent the shares of GDP which are made as a payment to the capital and wage bill, respectively. According to the national accounts, the total wage bill in economies is typically about two-thirds of GDP while approximately one-third of it goes to the remuneration for capital. Thus, $\alpha_1 \approx 0.3$ and $\alpha_2 \approx 0.7$.

Substantial positive external benefits associated with physical capital would provide a basic rationale for government intervention.

Now let us turn back to the issue of external benefits. If externalities exist for physical capital, investment by one agent will benefit productivity and output for other agents as well. Thus, if one were able to double both capital and labour, total output would in that case more than double. The sum of α_1 and α_2 will then exceed one. Increasing returns to scale provide a growth bonus for the economy and are a necessary condition for sustained growth in the absence of (exogenous) efficiency increases (see the contribution of de la Fuente, this volume).

It is the merit of "new" growth and geography theory of providing economic underpinned rationale for possible external benefits. Learning-by-doing is one example (see Arrow, 1962; Romer, 1986). Overcoming problems and improving equipment accordingly results in technological change, new investment, and productivity gains. These investments will in turn lead to new experiences and new solutions, and will end up in the realisation of further increases in efficiency. If the breakthroughs are important, other firms will follow soon so that the initial investment benefits the whole sector. It is clear that the learning-effect will be more substantial if the human capital carried by each worker is higher.

Thus, external benefits do not solely appear as a side effect from accumulating *physical* capital. *Human* capital accumulation is another factor which has been put forward to explain sustained growth (Uzawa, 1964; Lucas, 1988; Stokey, 1988) (4). On the one hand, human capital must have some effect that is internalised otherwise no one would spend valuable resources on schooling, training, business seminars, etc. On the other, people learn from one another so that the total gains of investments in human capital cannot be completely captured by the agent investing in it.

2.3 Quantifying the contribution of input factors to the standard of living: Empirical evidence

Research on economic growth and convergence has proceeded through several stages, each of them characterised by a specific empirical methodology. A very basic one is the *accounting approach* to economic growth (5), which simply checks whether changes in total output are identical to the sum of the changes in the stocks of capital and labour weighted with their factor shares as reported in the national accounts. The major contribution from these kind of exercises is that a substantial part (often over 50%) of economic growth remains unexplained. This residual is referred to as the Solow residual, total factor productivity (TFP) growth, or technological change. Growth accountants have, however, made little progress in answering what economic variables correlate with total factor productivity. As such they have not brought us particularly further in understanding why TFP growth rates may differ across time and space (6).

Also, by imposing the elasticities of output to inputs, rather than estimating them, one typically presumes that there are no external benefits, that production takes place under constant returns to scale and that there is perfect competition. In fact, from a theoretical point of view it is very difficult to motivate the use of this technique to assess the importance of public capital: as there is no (market driven) remuneration for this sort of capital, its factor share - the crucial weighting factor for public

4) Externalities may also arise from an activity such as research and development (R&D). See Romer, 1990.

5) See Solow, 1957; Denisson, 1967; Maddison, 1982, 1989, 1991.

6) An interesting application, however, is a contribution by Coe and Helpman, 1995. They compute TFP in the traditional way, and then regress it on measures for domestic and international R&D stocks as suggested by new growth theory. The authors find that variation in total factor productivity growth in OECD countries can be attributed to variations in these stocks, and they find strong evidence of international knowledge spillovers.

capital in the accounting exercise - would be zero. Consequently, it cannot make a contribution to growth of the standard of living, by definition. In general it is therefore difficult to extract any policy recommendations from growth accounting results.

Aschauer introduced in 1989 the obvious, but until then neglected, notion that the stocks of public infrastructures and private capital may be a key to explaining the level of national output in the private sector. We can illustrate his methodology by distinguishing between public (K_g) and private (K_p) infrastructure in the earlier shown type of production function:

$$(4) \quad Y_{P_t} = A_{P_t} \cdot K_{P_t}^{\alpha_1} \cdot L_{P_t}^{1-\alpha_1} \cdot K_{g_t}^{\alpha_3}$$

where Y now refers to a measure of real output in the private sector, rather than in the whole economy, and we impose that all markets in the private sector are perfectly competitive and free of external benefits ($\alpha_2=1-\alpha_1$). Dividing both sides by the total stock of private capital yields an expression for the amount of output produced by each unit of private capital - the private capital productivity. After taking logarithms one obtains:

$$(5) \quad \ln\left[\frac{Y_{P_t}}{K_{P_t}}\right] = \ln\left[A_{P_t}\right] + (1-\alpha_1) \ln\left[\frac{L_{P_t}}{K_{P_t}}\right] + \alpha_3 \ln\left[K_{g_t}\right].$$

Thus, output per unit of capital relates positive to the labour-to-capital ratio. At the same time and other things being equal will economies with an extensive stock of public infrastructure experience a high capital productivity in the private sector, at least in theory. If the coefficient α_3 is strictly positive, one can conclude that public infrastructure result in external benefits (7).

Variations to this basic equation have subsequently been taken to the data in a number of studies, mainly focusing on the US. Interestingly, in virtually all cases the level of public capital is found to be significantly productive. Results from *Aschauer type of regressions* have, however, been widely criticised as being implausible because of their sheer magnitude: the reported production elasticities imply a stratospheric marginal product of government capital of over 100% per annum or more.

Table 2. Some results from Aschauer type of regressions

Authors	Output Elasticity of *Private* Capital	Output Elasticity of *Public* Capital	Level of aggregation
Aschauer, 1989	0.56	0.38	US, national level, time series
Munnell, 1990a	0.62 - 0.64	0.31 - 0.37	US, national level, time series
Munnell, 1990b	0.31	0.15	US, regions (States), panel data
Berndt and Hansson, 1991	0.37 - 0.66	0.68 - 1.60	Sweden, time series
Garcia-Mila and McGuire, 1992	0.37 - 0.45	0.10 - 0.03	US, regions (States), panel data
Holtz-Eakin, 1994	0.11 - 0.50	-0.12 - 0.20	US, regions (States), panel data
Karras, 1997	0.12 - 0.23	0.15 - 0.18	20 OECD countries, national level, panel data

7) Aschauer also provides a specification in which he controls for congestion effects, and an equation in which total factor productivity is related to the stock of public infrastructure.

As a result controversy arose about the method of estimation and about the interpretation of the elasticities. Three major critiques have appeared in the literature. First, the time series estimates that show a positive and significant effect of the public capital stock on private sector productivity do so because of a statistical fallacy: they result from a "spurious regression". Trends in time series - in this case output and the stock of public infrastructure - may exhibit an apparent statistical relationship, even though no economic relationship between them exists. A solution to this problem - namely removing the trends by taking first differences - mostly yield results showing that public capital's effect is rather small and in general not statistically significant. Second, it is argued that the wide range of estimates reported in various studies renders the coefficients suspect. Finally, the direction of causality is doubtful: causation may not run from the stock of public capital to output, but rather in the opposite way. The empirical linkage between output and public capital based on this approach has therefore been discredited and said to be fragile at best.

Other than that, it is hard to employ the Aschauer approach if the focus is to assess the speed of convergence to the long-run equilibrium. Neo-classical growth models offer more appropriate testable equations in this respect. In fact, they take the production function technique one step further in the sense that the stock of capital is determined endogenously. In its simplest form, it is assumed that in every period of time, a fraction s_k of total output is forgone, and re-injected in the economy as physical capital. Production factors are, however, characterised by diminishing marginal productivity. Investing a constant fraction of output over time henceforth leads to smaller additions as time evolves. Moreover, production is assumed to take place under constant returns to scale ($\alpha_1+\alpha_2=1$). In other words, the (testable) hypothesis is that possible externalities are not sufficiently large to offset the decreasing marginal products. Economies will therefore converge towards a per capita income that grows solely because of (exogenous) factors that influence the productivity of the inputs, such as technological change or improvements in the management system, etc.

The neo-classical convergence property has been the subject of many debates. In the late 1980s it was studied under the implicit assumption that all countries would converge towards the same long-run *levels* of per capita income (Baumol, 1986, is a good example). This became later known as *absolute* convergence. Barro and Sala-i-Martin, 1992, and Mankiw, Romer and Weil, 1992, introduced, and rigorously defined the concept of *conditional* convergence. It was emphasised that growth theory did not imply *identical* long-run per capita incomes for all countries, and that one has to control for factors that influence this long-run level of income other than the initial condition, such as the investment share and population growth. Yet, when empirically tested, the basic model that only included physical capital did not yield theory-consistent results for the output elasticities, α_1 and α_2. It was the merit of Mankiw, Romer and Weil, 1992, to point out that the data behave consistent in a neo-classical manner only if one includes human capital in the production function. In that case, α_1 is indeed estimated to be about one-third in a comprehensive sample of developed and less developed countries - an appealing value for it is comparable to capital's share in GDP (8).

8) The model nonetheless still performs rather poor in explaining variations in standards of living in OECD countries. Nonneman and Vanhoudt, 1996, argue that this might be due to the fact that technological knowledge capital is important in such highly developed countries, yet it is not included as a factor of production in the Mankiw et al., *paper. The authors consequently augment the model with investment in research and development and show that this considerably improves the explanatory power of the regressions (measured by the adjusted* R^2*).*

Box 1. Research on EU convergence and the productivity of capital

In its "Periodic Reports" the Commission provides an indepth description of the economic performance in the EU regions, as well as of the role of the EU structural actions in assisted areas. In addition, the "Single Market Review - Regional Growth and Convergence: Aggregate and Regional Impact" attempted to analyse the sources of differences in standard of living within European countries. The latter research has assessed the impact of total investment in physical and human capital at the national level by means of traditional cross-section growth regressions. A major problem in doing cross-country growth regressions for the EU is, unfortunately, the low number of observations.

However, no serious attempt so far has been made to address the productivity of different types of physical capital for European economies. Following Neven and Gouyette, 1995, and Sala-i-Martin, 1996, research at the European regional level has remained rather limited to testing for conditional convergence based on panel data regressions that control for differences in countries' economic situation by including dummy variables. When it comes to public infrastructure, sometimes an ad hoc and debated index (e.g. the Biehl index) for public infrastructure (see for instance Capron, 1997), or physical indicators for infrastructure - such as motorways per capita, air freight per capita, or air passengers per capita - are included. A recent unpublished study for the Commission indicates, however, that infrastructure indicators explain only a very small part (about 8%) of the variation in standards of living (Pinelli, 1998). Based on the latter study the 6th Periodic Report mentions that four other factors are possibly linked with regional differences in GDP measures: 1) the structure of the economic activity, 2) the extent of innovative activity, 3) regional accessibility and 4) the skills of the work force.

The main advantage of employing specifications from a model is that such implicit hypotheses can be tested. However, researchers have also tried to explain growth performances in often highly *ad hoc* ways. In these *Barro-type* of regressions - named after the methodology proposed by Barro, 1991 - growth rates are regressed on whatever data or indicators are available (9). Although not rigorous from a theoretical point of view, these kind of exercises can be useful in discovering robust correlations and stylised facts when combined with a sensitivity analysis.

The latter approach has been employed to investigate issues such as the social rate of returns to various types of investment (equipment, infrastructure, etc.) (10). It has also been used to examine the productivity of public capital in various samples of countries (11). In these studies the main consensus so far seems to be that the effect of private investment on nation-wide growth is robustly positive while the one for public investment highly depends on the sample used. For instance, Barro, 1991, finds in a cross-section of 76 countries that public and private investment have similar effects on growth. Easterly and Rebelo, 1993, report that there is an important role for infrastructure capital, especially transportation and communication, in a broader sample of one hundred countries. Based on the US experience, Holtz-Eakin, 1994, argues however, that such a finding

9) "I just ran two million regressions" by Sala-i-Martin, 1997, illustrates this pure empiricism very well.
10) See e.g. De Long and Summers, 1991, 1992, and Auerbach, Hassett and Oliner, 1994.
11) See for instance Easterly and Rebelo, 1993, Crihfield and Panggabean, 1995. Aschauer, 1998, and Vanhoudt, 1999, derive their specifications from the neo-classical theory. A good review of growth evidence can be found in Temple, 1999. Gramlich, 1994, provides a review of the literature on infrastructure investment.

crucially depends on the estimation technique used and that the positive effect from public capital largely disappears when one allows for unobserved, state specific characteristics. In addition, Hulten, 1996, finds little or no support in the US data for an important effect of public capital on productivity after controlling for the efficiency use of public capital.

EU related research so far has failed to take into account the effect of different forms of capital on real convergence.

The cross-section methodology on which these analyses are based can clearly not be subject to the critique of spurious regression results due to non-stationary variables. However, there are other caveats. Although simultaneity issues also plagued the time-series literature, an additional important shortcoming in the cross-section literature is the assumption of strict homogeneity of the technology shift parameter in economies' production functions (i.e. the parameter A in equation (3)). Panel data techniques that control for fixed or random effects provide a useful tool and solution in this respect (12).

In the empirical part of this study we will continue to take the neo-classical paradigm as the reference, and derive empirically testable equations from an extended Solow model (see Box 1). Our research will be focused on the EU-15 countries and regions. Although the European Commission has put considerable effort in investigating the issue of convergence in Europe (see Box 2), EU related research so far has failed to take into account the effect of different forms of capital on real convergence at the *national* level, nor has an analysis of the impact of investment at the *regional* level been presented. With the current paper we would like to pick up these issues and contribute to the debate on this subject.

12) See Islam, 1995. The coefficient for human capital in this study is however estimated with a rather implausible yet statistically not significant negative sign for all the samples (98 non-oil countries, 75 countries with "high quality data", and 22 OECD countries). See Lee et al., *1998, for a comment and Islam, 1998, for a reply.*

Box 2. Deriving the extended neo-classical model

For simplicity we assume that countries are specialised in producing a domestically manufactured good (or composite of goods), symbolised by Y. We presume that output of this product (or composite of products) at time t is generated according to the following Cobb-Douglas production function:

$$(6)\quad Y_t = \left[A_t \cdot L_t\right]^{\left(1-\sum_i \alpha_i\right)} \cdot \prod_i K_{i_t}^{\alpha_i} \qquad \sum \alpha_i < 1$$

with L being employment and K_i capital of type i. In the absence of market imperfections, the α_i's reflect the respective shares of the production factor in total output (Euler's theorem). Finally, A is a shift variable representing other, currently unspecified, economic 'environment' conditions that may be important to the production process. Traditionally this variable has been interpreted as an indicator of the state of the art of the technology, management or government efficiency etc.

Equation (6) implies that income per (effective) worker reads:

$$(7)\quad y_t = \prod_i K_{i_t}^{\alpha_i} .$$

Lower case letters in expressions throughout the paper denote variables per unit of effective worker: $y = Y/\left[AL\right]$ and $k_i = K_i/\left[AL\right]$. Further, the rates of growth of labour and technology are assumed to be out of the direct influence of the policy maker - they evolve at an exogenous rate of n and x respectively.

Every period in time society forgoes an amount of consumption and chooses to re-inject it in the economy as capital formation. Let us denote the fraction of output that is invested in capital component i by s_i. By definition, the difference (per unit of time) of the stock of capital of type i equals new investment minus total deprecation: $dK_i/dt = s_i.Y - \delta_i.K_i$ with δ_i being the capital specific rate of depreciation. The laws of motion that govern the evolutions of the different stocks of capital per effective worker accordingly are:

$$(8)\quad \frac{dk_i}{dt} = s_i \cdot y - (n+x+\delta_i) \qquad \forall i = 1 \ldots m$$

which yields a system of m differential equations. Long-run equilibria or "steady state values" for the relative capital stocks can be found by substituting the production function (7) into the set of differential equations. After taking logs, the resulting log-linear system can be easily solved. To be more precise (see e.g. Vanhoudt, 1999, for formal proof), the closed form solution for these steady state values are:

$$(9)\quad k_{i*} = \left[\left(\frac{s_i}{n+x+\delta_i} \right)^{1-\sum_{\substack{j=1 \\ j \neq i}}^{m} \alpha_j} \cdot \prod_{\substack{r=1 \\ r \neq i}}^{m} \left(\frac{s_r}{n+x+\delta_r} \right)^{\alpha_r} \right]^{\frac{1}{1-\sum_{j=1}^{m} \alpha_j}}$$

It is noteworthy that the equilibrium value for capital component i is in this framework not only determined by its own investment share, but also by the shares invested in all the other components. Injecting capital in one particular sector of the economy may henceforth lead to capital formation by agents in others sectors as a side effect. Equation (8) shows why: an increase in a particular capital component will boost income per worker (y), so that all other steady state capital-to-worker ratios will

start to change as well. This dynamic process will continue until the economy has reached its new equilibrium values.

Replacing the k_is in equation (7) by their long-run values reported in (9), results in an expression for the long run output per worker. After taking logs, this expression reads:

$$(10)\quad \ln\left[\frac{Y}{L}\right]_* = \ln\left[A_0\right] + x\cdot t + \sum_{i=1}^{m} \frac{\alpha_i}{1-\sum_{j=1}^{m}\alpha_j}\cdot\left(\ln\left[s_i\right] - \ln\left[n+x+\delta_i\right]\right).$$

This equation says that the long-term standard of living in a particular economy will be higher, the higher the investment shares in the different types of capital, other things being equal.

The estimated values for the α_is can thereafter be applied to compute steady-state marginal products for each capital component, which are indicators for the social rates of return. In this kind of model the latter are equal to:

$$(11)\quad MP_i = \alpha_i \cdot \frac{n+x+\delta_i}{s_i}.$$

The assumption that countries are in their steady state may be too stringent and not appropriate for some countries. However, it is possible to derive a "dynamic" specification that holds regardless of the deviation from the long-run equilibrium and is henceforth applicable to all economies. By using a log-linearization of the growth rate, evaluated at the steady state, it is possible to derive a growth equation (see Barro and Sala-i-Martin, 1992, 1995, or Mankiw, Romer and Weil, 1992):

The growth equation

$$(12)\quad \ln\frac{(Y/L)_t}{(Y/L)_0} = (1-e^{-\lambda t})\left(\ln\left[\frac{Y}{L}\right]_* - \ln\left[\frac{Y}{L}\right]_0\right)$$

in which $\ln\left[Y/L\right]_*$ can be replaced by equation (10). In this equation, the left-hand side variable is the cumulative growth rate over a period of t years, and the parameter λ indicates the speed at which economies converge (conditionally) towards *their* individual long-run equilibrium.

Note that for one particular production factor - human capital - investment shares over a long period of time are not readily available. We can overcome this lack of data by including the accumulated end of period stock of human capital per worker in the analysis (see also Islam, 1995) and presume that this stock is the equilibrium one, or that deviations from the equilibrium value are at least random. Equation (10) will in that case read:

The level equation

$$(13)\quad \ln\left[\frac{Y}{L}\right]_* = \ln\left[A_0\right] + x\cdot t + \sum_{\substack{i=1\\ i\neq n}}^{m} \frac{\alpha_i}{1-\sum_{\substack{j=1\\ j\neq n}}\alpha_j}\cdot\left(\ln\left[s_i\right] - \ln\left[n+x+\delta_i\right]\right) + \frac{\alpha_n}{1-\sum_{\substack{j=1\\ j\neq n}}\alpha_j}\cdot \ln\left[h_*\right]$$

This approach differs in three ways from Aschauer's. Firstly, variation in economic performances are here no longer explained in terms of differences in capital stocks, but rather in terms of differences in

fundamentals that drive the evolution of the stocks. These fundamentals are of direct relevance for policy. Secondly, the methodology allows us to distillate a speed of convergence (λ). Knowledge on the magnitude of this speed is quite important since the scope for policy may be more substantial if convergence is a slow process. Thirdly, growth rates and investment shares are usually integrated of order zero, so that it is unlikely that the obtained estimations are subject to the spurious regression critique in a time series or panel data set-up.

Nonetheless some caveats remain. For instance, the neo-classical and Aschauer models typically depart from a closed economy - it is implicitly assumed that there are no systematic current account surpluses or deficits. This may not be a very appropriate theoretical simplification, especially when considering regions as the unit of analysis. Secondly, the underlying production function presumes that public and private capital are close substitutes. Although economic theory provides no guidelines on this issue, one can equally well argue that publicly provided goods are part of the 'environmental' variable (A). Finally, in the neo-classical models there is no room for unemployment.

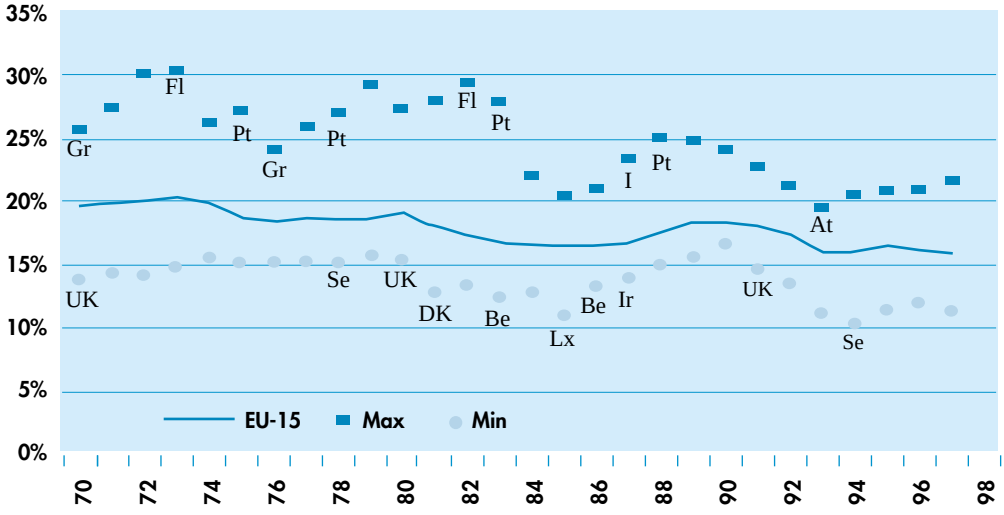
3. Empirical implementation

3.1 A closer look at the European data

Before we assess the impact of the different fundamentals on economic performance, it is useful to define the key data precisely, and to provide some descriptive statistics on them.

Figure 1 presents the private investment share, i.e. gross fixed capital formation done by households and the business sector relative to GDP. This variable refers to investments in market sector activities, and captures as such also capital outlays by quasi-corporate enterprises. On average there has been a slight decline in the private investment share. While the EU-15 average mounted to 20% of EU-15 GDP in 1970 it has reduced to about 16% of EU-15 GDP today. The variation around the average is however, substantial. Currently, the business sector with the highest investment relative to its country's GDP is located in Austria while the country with the lowest private investment share is Sweden. The difference is roughly two to one.

Figure 1. Private investment relative to GDP



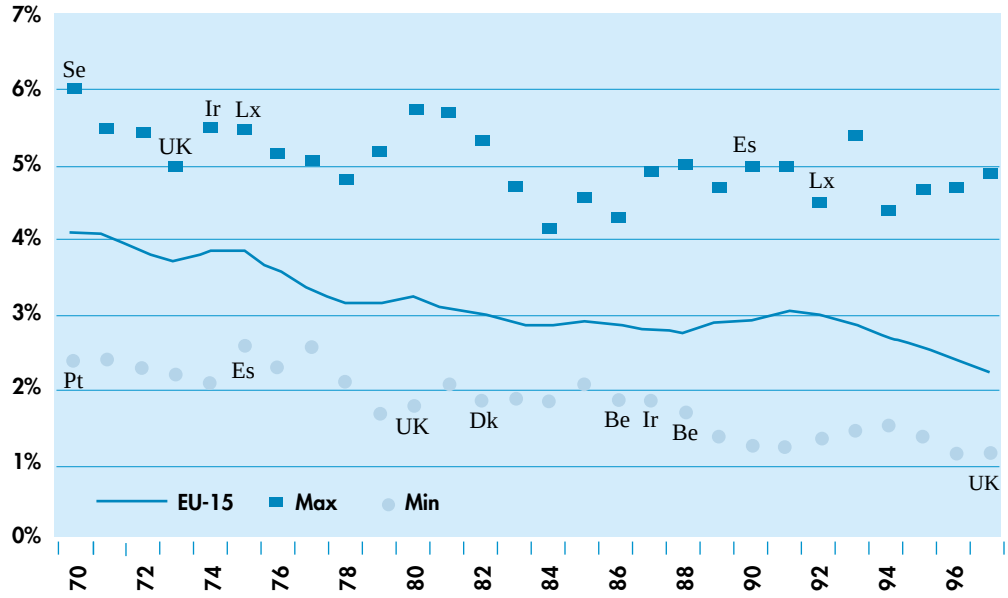
Note: the country labels as maximum or minimum remain valid over time until another country takes over.

By public investment, on the other hand, we mean capital formation by the general government. The majority of these outlays go mainly to four categories: the most important one is the provision and maintenance of transport infrastructure (in particular roads and bridges) which accounts for roughly a third, about 10 to 15% goes to education and health (school buildings, hospitals, etc.), approximately 10% is devoted to the provision of housing and community amenities, and another 10% is taken up by general public services. The remaining part is split amongst defence, public order and safety, recreational, cultural and religious affairs, etc.

Public investment is typically much lower than capital formation by the business sector. Figure 2 shows that the Union's average at the moment is approximately 2% of the EU-15 GDP, and has shown a continuous downward trend over the last decades. This negative trend has accelerated since the early 1990s due to the fiscal constraints of the Maastricht criteria.

The spread around this average is, again, substantial. While the UK's public investment share these days is only half the EU average, the Luxembourgish one is about two and a half times as high.

Figure 2. Public investment relative to GDP



Note: the country labels as maximum or minimum remain valid over time until another country takes over

13) These administratively defined regions vary substantially in size. In terms of surface, the largest region in our sample is Castilla y León (Es) with 94 010 km², the smallest one is Bremen (De) with only 404 km². The average region accounts for 21 930 km². In terms of population, the largest region is Nordrhein-Westfalen (De) with roughly 17.8 m inhabitants while Valle d'Aosta (It) has a population of only slightly over 0.1 m. The average region in the sample has approximately 2.9 m people. As for population density, Castilla-la Mancha (Es) has about 25 people per km² and is as such the least densely populated region in the sample. Hamburg (De), on the other hand, has some 2200 people living on one squared kilometre. The average population density is roughly 250 persons per km².

At the regional level data are not so readily available.

At the regional level data are not so readily available and comparable. After carefully examining and selecting the figures we were able to compose a sample of 78 administrative regions among eight countries: Denmark (Nuts 1), Luxembourg (Nuts 1), France (Nuts 2), Germany (Nuts 1), Ireland (Nuts 1), Italy (Nuts 2), The Netherlands (Nuts 2) and Spain (Nuts 2)(13). Public investment at the regional level refers to gross fixed capital formation in the non-market sector as reported by Eurostat. As becomes clear from Figure 3, poorer regions have shown a tendency to receive more public investment than richer ones. The two outliers are Valle d'Aosta, the smallest and less dense populated area situated in the north-west of Italy, and Zeeland, a south-western region in The Netherlands. Geographical obstacles characterise both. While Valle d'Aosta is a mountainous area, Zeeland was exposed to the threat of flooding from the North Sea. The governments have consequently carried out and maintained major infrastructure works to overcome these inconveniences. Over the considered time span, a stretch of about 50 kilometres of highway towards the Mont Blanc passage was built in Valle d'Aosta, consisting purely of bridges and tunnels. Zeeland hosts what has been the most expensive environmental investment in the world: an ingenious system to prevent the region from flooding, known as the Delta-water works.

At the same time, there is a clear positive correlation between the regional standard of living and the level of human capital per worker - see Figure 4.

Figure 3. Regional public investment vs. initial GDP per worker

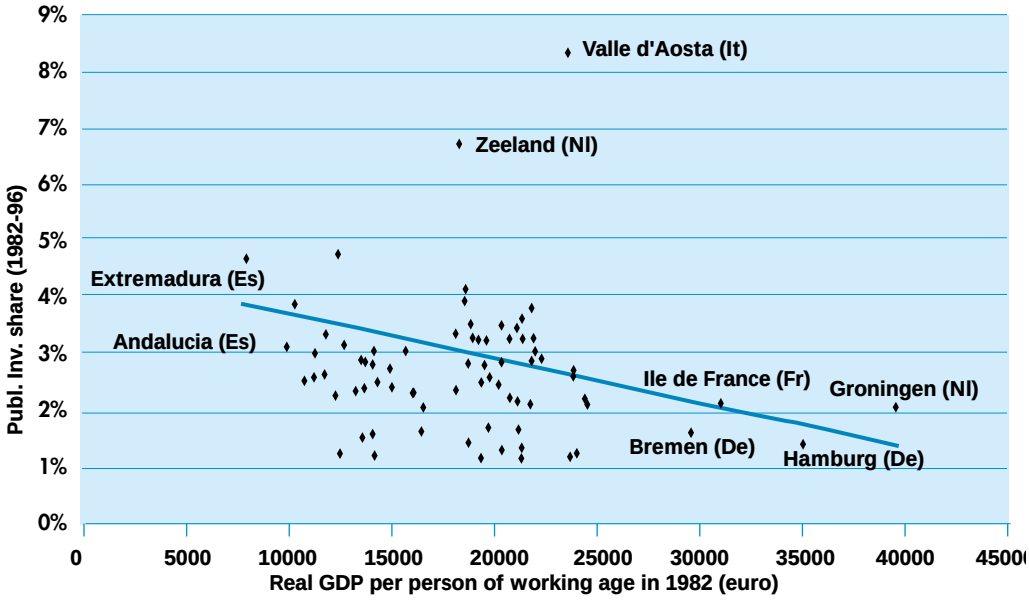
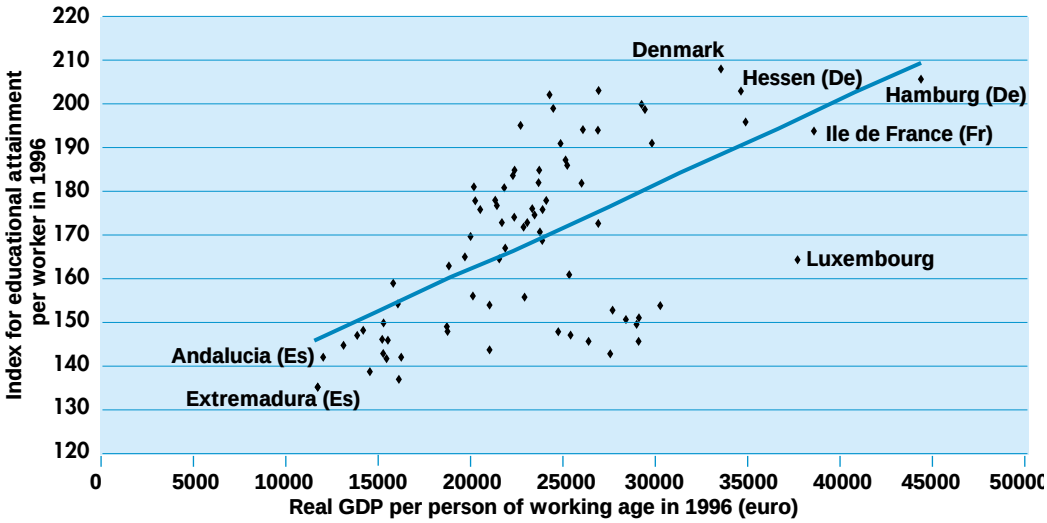


Figure 4. Human capital per worker vs. regional GDP per worker

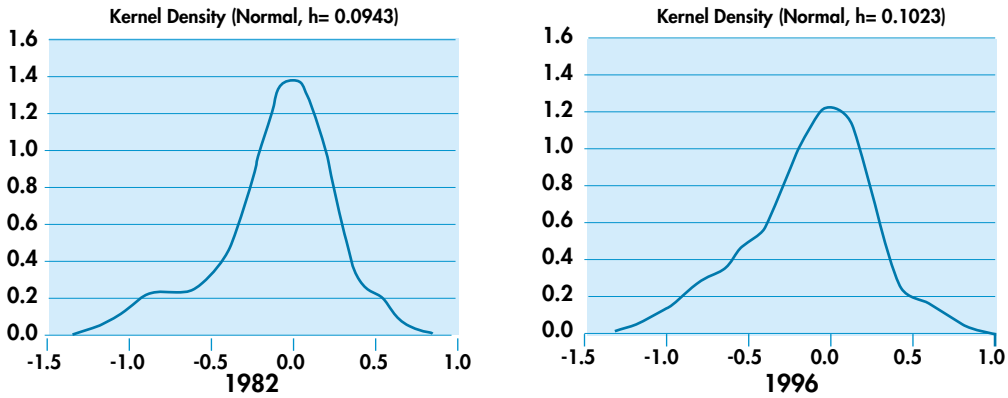


Note: the human capital indicator is a weighted index based on Eurostat data for 1996, computed as: 1x the fraction of the work force with basic education + 2x the fraction with secondary education + 3x the fraction with higher education.

While the standard deviation has remained virtually constant, there have been important changes within the distribution.

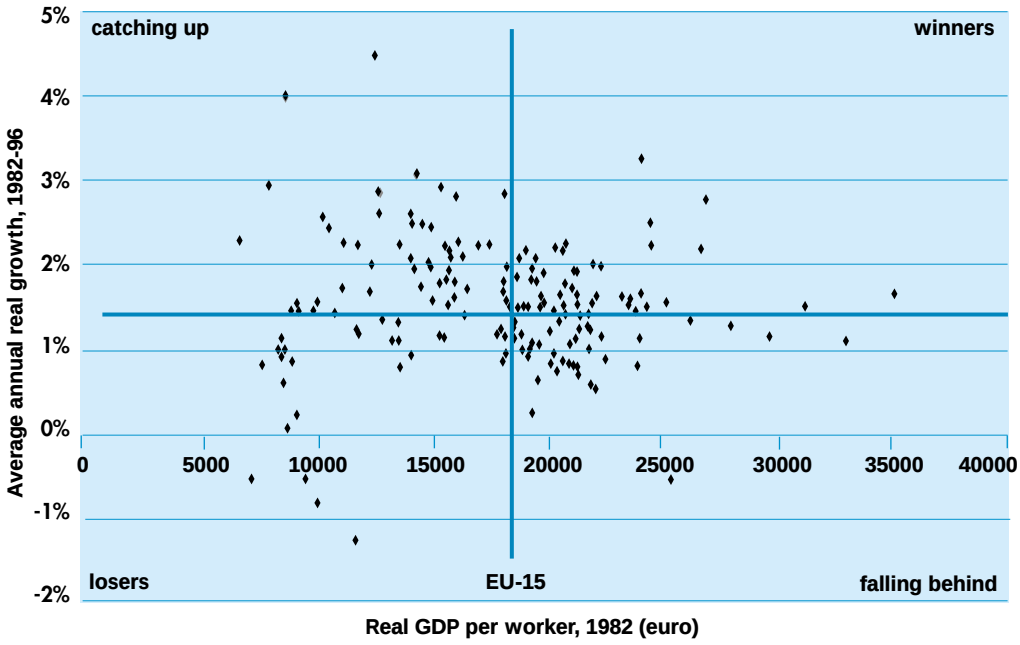
Finally, Figures 5 and 6 give an impression about the economic dynamics that have been at play in NUTS 2 regions. From the snapshots in Figure 5 one would be inclined to conclude that not much convergence has actually taken place. Indeed, the standard deviation of those distributions - which is taken as a measure of dispersion - has remained virtually constant over time. The small increase is attributable to the entry of the New German Länder in the Union. However, plotting the average annual growth performance of regions against their starting position nonetheless indicates that there have been important changes *within* the distribution. To be more precise, one can observe "*winners*" (i.e. regions that had an initial per capita income higher than the EU average and have grown faster than the average), "*losers*" (with an initial standard of living below the EU average and growing at a slower pace than the average), "*catch-ups*" (also regions with an initial below average income per head, yet growing faster than the average), and "*fall-behinds*" (initially situated above the average, but growing towards a per capita income below average).

Figure 5. Distributions compared



Note: The charts plot the standardised distribution of the deviation from the European average income per person of working age.

Figure 6. Within-distribution changes



3.2 Econometric evidence on the role of public and private investment

How are those economic dynamics related to the discussed fundamentals? To investigate this, we will test the level and growth equations as derived in Box 2. The data allowed us to carry out these exercises both at 14 national levels (that is, the EU-15 minus Luxembourg, which lacks a reliable time series on human capital), and for the above-mentioned 78 administrative regions. While we will employ a panel data set-up at the national level, the data availability forced us to apply a more traditional cross-section investigation at the regional level.

Following conventional practice in the panel data growth empirics, every observation for the explanatory variables in our national database represents a five-year average (14) while for the subset of regions the independent variables are averages over the considered time span. Table 3 presents the source and definition of the variables in more detail.

A few remarks are in place before we present the results. A first one concerns the level regressions. When we ran the steady-state regression for the whole EU sample, the results were neither satisfactory nor plausible. Leaving out the Cohesion countries improved the performance of the model drastically, indicating that the assumption of equilibrium is less suitable for these countries than for the more advanced ones. As for the regional sample, we left out the Dutch province of Groningen since variation in income in that region is purely related to the gas production.

In addition, we experimented with different rates of depreciation for the capital components (taken from Beutel, 1996, and Verughese *et al.*, 1997). The results, were, however, not sensitive to reasonable changes in these parameters. For comparisons with earlier studies, we followed the

14) Except for the three years from 1995 to 97, which is added in the level regressions as a separate observation for each country.

standard setting in these kinds of regressions and assumed that the rate of improvements in technological efficiency (x) plus depreciation (δ) equals five percent for every capital component. Concerning fixed effects in the panel data regressions we did not find evidence that country specific effects differed significantly between EU countries during the econometric procedures. The reported panel data results consequently refer to estimations with only time specific fixed effects. Finally, the index for the stock of human capital per worker did not, unfortunately, allow us to compute a plausible rate of return to human capital.

Table 3. Description and source of the data

Variable	Description	Source
human	Stock of human capital per worker	National: Average schooling years in total population over age 25, taken from Barro and Lee, 1992. Figures for 1990, 1995: staff estimates. 5 year intervals.
		Regional: Weighted index based on Eurostat data for 1996: 1x fraction of work force with basic education + 2x fraction of work force with secondary education + 3x fraction of work force with higher education.
n	Growth rate of the work force (people of working age)	National: AMECO, Commission. 5 year averages 1960-94, three year average 1995-97.
		Regional: Regio, Eurostat. Average 1982-96, where available.
s	Total investment share	National: National Accounts, Eurostat, gross fixed capital formation divided by GDP, except for Luxembourg: OECD (in current prices and national currencies). 5 year averages 1960-94, three year average 1995-97.
		Regional: Regio, Eurostat. Average 1982-96, where available.
s_{pub}	Public investment share	National: Figures from the Commission's DG Ecfin, updated with Eurostat values. 5 year averages 1960-94, three year average 1995-97.
		Regional: Gross fixed capital formation in the non-market sector as a percentage of GDP, Regio, Eurostat. Average 1982-96, where available.
y	Income per person of working age	National: National Accounts, OECD, Table 1 (Main Aggregates), USD in prices and exchange rates of 1990. 5 year intervals.
		Regional: Regio, Eurostat. Euro in prices and exchange rates of 1990.
y_{EU}	EU average income per person of working age	

Notes: The private investment share (s_{priv}) is computed as the difference between the total and the public one. East and West Germany are treated as two separate entries in the panel of data. The interested reader can find a detailed description of the regional data used here in a technical EIB working paper (Mathä and Smid, 2000)

Public investment may result in short-term Keynesian effects but the more structural and long-term supply-side impact is debatable.

Tables 4 and 5 present the results of our estimations, which in general provide the same broad messages. Let us first consider the level regression at the national level. From the last lines in the second column of Table 4 we observe that the output elasticity for capital formation by the private sector (α_{priv}) has been larger than the one for capital formation by the government (α_{pub}). The total capital elasticity

($\alpha_{priv}+\alpha_{pub}$) - which we expected to be roughly one third based on the theory and the evidence reported in the national accounts - amounts to an acceptable 31%. We cannot, moreover, reject the hypothesis of a share of human capital of about one-third at the national level (15).

According to the formulas obtained in Box 2, the estimated coefficients imply a social rate of return to private capital of about three percent, which is about the average real interest rate observed over the considered time span. This is consistent with the neo-classical assumption that this sort of capital receives its marginal product, and indicates that there is little evidence to presume large externalities at the aggregate level for private capital. The obtained elasticity for public capital is somewhat lower than values put forward in studies for other samples of countries, implying a rate of return for public capital of approximately ten percent - more than three times the value obtained for private investment. Consequently, this would be a strong indication that public investment takes place in capital goods that induce large externalities.

However, one has to be careful in drawing conclusions solely based on the level regression. When we turn to the growth regression (last column of Table 4), it becomes clear that public investment is negatively related to growth performances. In other words: countries that had high public investment shares have in general experienced low growth, other things being equal. The combined regressions teach us that an important issue of reverse causality is likely to be at play here: richer countries have been able to provide more public capital, but it came at an opportunity cost of lower growth. In that respect, public investment is simply a form of demand-driven consumption: at high levels of income, one is prepared to pay for having utility from better infrastructure. As such, public investment may result in short-term Keynesian effects, the long-term supply-side impact is, however, debatable (see also Martin's contribution, this volume). Capital formation by the government does presumably not directly contribute to productivity growth, but it lowers private saving and growth through the distorting effects from taxation with which those investments are financed.

Causality does not run from public investment to growth, but rather the opposite.

Reverse causality leaves the rate of return to public capital, as obtained from the level regression, meaningless. It is a mistake to argue the existence of large externalities based on the estimate for public investment by looking only at a level regression. Unfortunately this is the case in most of the production function based literature.

In addition, the growth regression implies a speed of convergence of only about one percent. This is half the value reported for the United States, and indicates that factor mobility in Europe has been extremely low. In fact, earlier studies have indeed reported that labour mobility in the US is currently about twice as high as in Europe, which would explain the difference in the estimated speed of convergence rather well (16).

15) Gauging a reasonable value for the share of human capital in GDP is difficult, however. Mankiw, Romer and Weil, 1992, report that the minimum wage - roughly the return to labour without human *capital - has averaged about 30 to 50% of the average wage in manufacturing. This suggests that 50 to 70% of total labour income represents the return to human capital, implying that α_{human} should be estimated in the interval one-third to one-half. Since the minimum wage in Europe is higher than the one in the US, α_{human} should presumably be estimated closer to one-third than to one-half based on European data.*

16) These results are reinforced when an efficient (i.e. GMM) estimation technique is used. The Gauss procedure to apply this method on a panel of data was provided by the courtesy of Rien Wagenvoort, EIB.

Table 4. Regressions for the EU countries (panel data, 1960-97, GLS)

Variable	Dependent variable: $\ln[y]_t$ Level regression	Growth regression
Constant	+9.121 (0.112)**	+0.374 (0.124)**
$\ln[s_{priv}]-\ln[n+x+\delta]$	+0.327 (0.065)**	+0.088 (0.026)**
$\ln[s_{pub}]-\ln[n+x+\delta]$	+0.128 (0.039)**	-0.028 (0.013)**
$\ln[human]$	+0.487 (0.023)**	-0.004 (0.011)
$\ln(y_{t-5})$	-	+0.965 (0.014)**
Time Effects:		
60-64	-0.669 (0.029)**	-
65-69	-0.517 (0.034)**	+0.007 (0.009)
70-74	-0.365 (0.028)**	-0.007 (0.010)
75-79	-0.220 (0.026)**	-0.032 (0.012)**
80-84	-0.165 (0.024)**	-0.119 (0.019)**
85-89	-0.084 (0.023)**	-0.021 (0.016)
90-94	-0.056 (0.025)**	-0.099 (0.017)**
95-97	-	-
R^2	76.95%	99.41%
s.e.r.	0.131	0.042
# obs	66 (non-Cohesion)	81 (EU-14)

Note: White heteroskedasticity-consistent standard errors in parentheses.
* denotes significance at the 10% level;
** denotes significance at the 5% level or better.

	Implied speed of convergence	
Implied λ	-	0.9 %

	Implied output elasticities	
Implied α_{priv}	0.225	-
Implied α_{pub}	0.088	-
Implied α_{human}	0.335	-

Note: The fixed time effects should be interpreted relative to the constant term. In the level regression they indicate as such that per capita income has continuously increased over time. In the growth regression the time effects suggest that increases in the standard of living were significantly lower after 1975 (with the exception of 1985-89) than before. This observation is often referred to as the productivity slow down.

Similar messages can be concluded from the regional regressions, although one has to keep in mind that a major number of regions in the sample belong to just three countries (France, Italy and Spain) (17). Nonetheless, in this case the estimated coefficients in the level regression (second column in Table 5) imply a total capital share that is implausibly low, mainly because of a negative public capital elasticity. Proponents of increased spending argue that this finding may be due to the fact that disaggregating the data reduces the potential to capture geographical spillovers very precisely (18). A negative capital elasticity is, however, only conceivable if the social rate to return is negative. This could for instance be the case if resources are withdrawn from high productivity regions and injected in low productivity ones, without affecting productivity in the latter. Recall from Figure 3 that public investment has indeed been higher in poorer regions. Another explanation may very well be mis-judgement of policy makers in the sense that they did not optimise an economic objective function: independent of the question whether or not public capital formation contributes to productivity, new infrastructures are likely to attract votes, especially when local agents are involved in the construction process.

From the regional growth regression (last column in Table 5) we learn moreover that public investment has not been a source of economic growth, on the contrary. Again, regions that have had a high investment share have known low growth, other things being equal. In addition, this regression reveals a speed of convergence that is exactly the same as the one found at the national level: one percent. Regional policy may consequently have the capacity to be more effective in Europe than suggested in the literature (e.g. by Sala-i-Martin, 1996).

In other words, our results indicate that public capital investments have mainly been used as an instrument for redistribution in Europe; they have not, however, been an engine of regional growth and convergence.

What can we conclude on human capital? The tables point out that the level of human capital is an important factor in explaining the variation in the *levels* of standards of living between regions and countries. In fact, its elasticity is at least as important as the one for private physical capital. However, the stock of human capital has only had a significant impact on *regional growth rates*, not on *nation-wide* economic growth in the EU. This finding has been reported in greater detail in previous growth studies for a sample of highly developed countries such as the OECD (19), and can easily be understood. The average level of human capital has increased substantially for all countries, yet in spite of this there has been a nation-wide productivity slowdown since the early 1970s - a trend that does not unequivocally hold at the regional level. It should therefore not surprise us that the stock variable we employed has had no significant explanatory power in the national growth regression. From a policy point of view our results suggest a regional approach: focussing on improving the human capital of people living in backward regions by providing the appropriate incentives may be an effective tool to promote regional convergence.

Capital formation by the business sector has been effective in stimulating growth. Targeting education in lagging regions seems to be another key towards convergence.

17) We did not find evidence of strong differences in country specific intercepts in the regional regressions.

18) See e.g. Munnell, 1992: "As the geographic focus narrows, the estimated impact of public capital becomes smaller. The most obvious explanation is that, because of leakages, one cannot capture all of the payoff to an infrastructure investment by looking at a small geographic area".

Table 5. Regressions for the EU regions (cross-section, 1982-96, OLS)

Variable	Dependent variable: $\ln[y]_{1996}$ Level regression	Growth regression
Constant	+9.178 (0.477)**	+0.761 (0.362)**
$\ln[s_{priv}]-\ln[n+x+\delta]$	+0.187 (0.239)**	+0.216 (0.070)**
$\ln[s_{pub}]-\ln[n+x+\delta]$	+0.161 (0.079)**	-0.093 (0.033)**
$\ln[human]$	+0.182 (0.090)**	-0.118 (0.033)**
$\ln(y_{1982})$	-	+0.880 (0.040)**
R^2	23.35%	90.36%
s.e.r.	0.244	0.086
# obs	78	78

Note: White heteroskedasticity-consistent standard errors in parentheses.

* denotes significance at the 10% level;

** denotes significance at the 5% level or better.

Implied speed of convergence		
Implied λ	-	0.9 %
Implied output elasticities		
Implied α_{priv}	0.183	-
Implied α_{pub}	-0.156	-
Implied α_{human}	-0.178	-

4. Summary and conclusion

Are public and private capital investments equally productive, and - if so - is there a difference between productivity at the national and regional level? These were the main motivational questions behind our investigations.

At the regional level, public capital investments have mainly been used as an instrument for redistribution in Europe. They have failed to close the productivity gap.

Our research contributes in two ways to the existing literature. First, we explicitly focused on the European countries and regions, rather than at a mixture of developed and less developed nations. Second, we carried out regressions that are consistent with the theory: we have properly controlled for different investment shares while we have also allowed human capital to be a factor of production.

19) E.g. Levine and Renelt, 1992, Mankiw, Romer and Weil, 1992; Islam, 1995; Nonneman and Vanhoudt, 1996; Vanhoudt, 1999. The empirical evidence from cross-country growth regressions on the effect of human capital is indeed ambiguous, see Pritchett, 1997, for a survey.

The qualitative results from our exercises are clear and consistent. Three main findings are noteworthy.

- The first one is a message of reverse causality. Our results indicate that causality does not run from public investment to growth, but rather in the opposite way. What seems to be the case is that richer countries have been able to invest more in public capital, thereby willing to accept a lower pace of growth. Put bluntly, public investment strongly resembles demand driven consumption. As such it undoubtedly has had short-run Keneysian effects, but it can hardly be considered as an engine for long-run - structural - growth. At the regional level, public capital investments have mainly been used as an instrument for redistribution in Europe; they have not, however, closed the productivity gaps. We are able to conclude that private capital, on the other hand, has been effective in stimulating growth and reducing disparities.
- A second one reinforces human capital theory: the formation and quality of human capital is an important economic factor to make regions catch up. Targeting the level of schooling in lagging regions seems to be a key towards convergence.
- Thirdly, the speed of (conditional) convergence in Europe is only half the size of the one reported for the US. This may reflect a low degree of factor mobility - especially labour mobility in Europe.

Our conclusions should nonetheless be somewhat put into perspective. It would be wrong and a departure from common sense to deduce from the analyses that the large stock of public capital and infrastructures provides no benefits (broadly defined) or utility to society. The main message from the regressions in this essay rather is that the use of aggregated national and regional data does not reveal sufficiently large linkages between public sector investment and positive developments in average income per person of working age. Put differently: even though public capital may yield benefits to citizens, it has not been a significant driving force behind regional development and convergence from an aggregate point of view.

However, there is presumably a wide array of public capital investments that would survive a rigorous economic cost-benefit analysis, even ex-post, and that would contribute to local growth. Project selection and performance need to be studied in more detail. This clearly calls for a complementary bottom-up approach that links actual realised economic rates of return at the micro-level to project selection criteria, while one controls at the same time for the quality of economic policies in the receiving region (see Rossert's contribution in the previous volume).

Though public capital has not been a significant force behind convergence from an aggregate view, a wide range of investments are likely to achieve this at the local level.

Finally, our regional database covered a time period of only fourteen years, which may be too short for the purpose we had in mind. Indeed, time horizons for public projects are typically much longer than those of private capital investments, which respond faster to market signals and needs. We were moreover unable to include all European administrative regions because of either lack of (investment) data or data inconsistencies.

Therefore, even though the conclusions we obtained for this sample point in the same direction as those reached from national sources, we are aware that our regional results are indicative at best. The exercise should consequently be carried out again when the regional accounts for all member countries will have been standardised and made available by Eurostat.

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