What determined the uneven growth of Europe´s Southern regions? An empirical study with panel data*

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Abstract
Since 1975, the extent of catching-up has been very different across Southern regions. Starting from the common arguments of growth theory, the paper wishes to show whether differences in regional income and growth can be attributed to different endowment in human capital, differences in private or public investment level, to structural imbalances, and labour force participation. The investigated panel consists of regional time series for the period 1975 to 1994 and includes NUTS II level regions of Greece, Spain, and the Italian South. Estimation of the impact of the variables on regional income is effected in a dynamic panel data model applying a GMM estimation procedure. The results indicate that the income level of Southern EU regions is largely determined by employment/educational levels and past public investment, while the impact of private investment is not significant. One may follow that EU regional policies should predominately focus on the human factor. Assistance to member countries to upgrade public infrastructures may be continued, but private investment incentives should be curbed.

JEL: O40, O15, O16, O52, C5.
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1. Introduction

The regions of the EU cohesion countries and the Mezzogiorno, whenever considered in general altogether as the EU´s less developed objective 1 areas, show marked disparities in regional income and registered quite a different growth performance over the past 20 years. Some realized rapid catching-up, while others stagnated in income level.

In this paper we wish to show, which factors are responsible for this mixed growth performance, and what have been the strongest determinants of regional growth and income development in the cohesion countries and the Mezzogiorno in the past decades. Specifically, we analyse the impact of private investment, government investment, education, and employment structures in the regional growth process.

The evidence from cross-country growth analysis suggests that growth requires abundant private investment (Barro and Sala-i-Martin 1991), public investment would promote growth through a reduction of producer costs (Aschauer 1989), and the accumulation of human capital as well is considered as an essential factor for income growth (Romer 1986, Lucas 1988). Further, sector employment shares should be relevant. However, it is exactly a lack of private capital formation which burdens poorer regions and consequently prevents the creation of business activities in order to initiate growth. With the objective to raise investment levels, government policies have provided investment incentives since many years. Similarly, public infrastructures are a shortage in the peripheral regions and investment is usually too small to overcome public infrastructure deficits. Many of the poorer regions have therefore received substantial national or EU financial transfers to raise public investment. In addition, compared to the developed European core, human capital is short in the periphery. Policies were started to raise education levels. Given all these policy efforts, we would like to know which factors in reality did have the strongest impact on growth. On which areas should future policies consequently concentrate?

So far, the determinants of regional income and growth in the EU have been poorly investigated on the cross-country level. For the objective 1 areas in the periphery in particular, as to our knowledge, there exist no empirical studies. A number of works, however, have investigated regional growth factors within single countries (e.g. Paci/Pigliaru 1995, de la Fuente 1996, Mas et al. 1996). This paper wishes to fill this gap in empirical growth research.

Our empirical analysis covers 38 NUTS II level regions from Spain, Greece, the Mezzogiorno, and, in addition, Ireland and Portugal at the country level. In a first analysis, the major trends in regional income, private and public investment rates, and enrolment in education are analyzed, and possible causal relationships are explored, including cointegration tests of variables for each region. The actual estimation of the contribution of the various growth factors in the whole set of regions is effected in a dynamic panel data model, applying a GMM estimation procedure on several model specifications and the Anderson-Hsiao estimator. These econometric techniques provide appropriate methods to account for the problems of error correlation and endogeneity of variables, which exist in the typical dynamic panel data growth model specification, and deliver unbiased and efficient estimates. In addition, the particular method of the GMM procedure to form instruments assures that the long-term level and trend of explanatory variables enters into the growth model. Thus our estimation results show the long-term effect of private investment levels, governments investment spending and education.

The existing empirical growth literature, in contrast, is largely restricted to OLS estimation, or at best uses a static panel data model with fixed effects.

The paper is organized as follows: Section 2 provides an overview of empirical research on growth factors. Section 3 describes the data set. Section 4 sketches the theoretical relationships with income and growth, describes the main trends in the variables and shows their country characteristics. In addition, it contains a first analysis on possible relations between variables, including cointegration tests. Section 5 describes the econometric model for the panel data estimation and the GMM estimator. Section 6 presents the results of the estimation and section 7 concludes.

2. The determination of income and growth in the empirical literature

Following the seminal paper of Barro (1991a), empirical growth studies investigated a huge number of economic and socio-political variables. The arguments for the essential role of investment and human capital are particularly interesting in the design of development policies for Europe´s peripheral regions. Barro (1991a) and Levine and Renelt (1992) concluded that the level of total investment rates had a positive impact on growth. In addition, much attention was given to the possible impact of government investment, and in particular infrastructure investment, since the works of Aschauer (1989) and Munnell (1990), who found that the stock of public capital significantly enhances growth. Mankiw, Romer and Weil (1992) provided strong arguments for an essential role of human capital in the growth process. Fortunately, these factors are commonly accessible for a quantification on the regional scale. For many other interesting variables no regional statistics are available.

In the neo-classical Solow growth model, the level of per capita income is determined by the amount of physical capital per person, which in turn is a consequence of the level of saving, equivalent to investment. A higher level of physical capital per worker corresponds to a higher steady state income (see e.g. Barro and Sala-i-Martin 1995: 19). However, due to the decreasing marginal product of capital, the rate of investment must decline towards the steady state income in the neo-classical growth model. In the stead state, the stock of capital per person is constant. The investment rate is equal to effective capital depreciation. Therefore, one may expect that data series on investment rates and per capita income exhibit two phenomenon: (a) A higher investment rate over a long time period would indicate a higher steady state income. (b) A higher investment rate is a transitional phenomenon.

In contrast, in endogenous growth theory - at least in its pure form - there are no transitional dynamics of capital accumulation. There is a clear relation between the level of investment rates and the level of per capita income. In addition, Romer (1986) suggests that there is a steady linear relation between the investment rate and the growth rate, drawing on the arguments of learning by doing and knowledge spillovers, which prevent decreasing marginal returns to capital on the global level of the economy.

The results of empirical studies on the growth impact of the investment rate vary considerably. Levine and Renelt (1992), who carried out a sensitivity analysis of growth factors with a dataset for 119 countries (essentially the Summers and Heston data), found that the investment rate was one of the few variables for which a robust and positive relationship with growth can be established. Easterly (1997: 20), in contrast, estimated the growth impact of different investment rates with the updated Summers and Heston data (146 countries) and found a positive and significant relationship only for a small fraction of countries. For a considerable number of countries the relationship was even negative. Bacchetta (1994) estimated the growth impact of investment for 30 European regions (among them Spanish regions) for the period 1977-87 and could not find a significant relationship.

With respect to the impact of public capital, growth theory suggests that it is a complementary to private capital and permits a higher rate of return if included in the production function. Thus, the addition of public capital in the growth process would enable endogenous growth (see Barro 1990, Aschauer 1997, Glomm/Ravikumar 1997). According to the pioneering studies of Aschauer (1989) and Munnell (1990), who estimated the impact of public capital on productivity growth in 48 states of the US, public capital plays an important role in the growth process. A number of consequent studies, however, obtained very different estimates on the role of public capital. Holtz-Eakin (1992) e.g., showed that the results can differ according to the econometric technique employed. Controlling for state-specific effects, he found practically no contribution of public capital to growth in the US states. Aschauer (1997) dissociates from his earlier findings and confirms the insignificance of public capital in an econometric model with fixed effects, as found by Holtz-Eakin. In contrast, Cazzavillan (1993) found an output elasticity of 0.25 of public capital for European countries. A particular type of public capital, namely public infrastructure, seems to be essential for the positive growth impact: Easterly and Rebelo (1993) found a positive correlation between public infrastructure investment and growth, but not of aggregate public investment.

There are a few empirical studies, which have also investigated the issue of the role of public capital for the cohesion countries of the EU. De la Fuente (1996a) attributes an important role to public capital when analyzing the growth process of Spanish regions between 1981 and 1990. During that period, the concern for public infrastructures in poorer provinces, which originally showed a large deficit in 1981, had contributed to their growth. In contrast, Garcia-Mila and McGuire (1996) argue that a rise of public investment rates had failed to trigger growth of poorer Spanish regions, since additional public investment did not enhance private investment, as commonly argued in the causal relationship with growth. However, they consider that the change in public investment levels in poorer provinces is too recent to permit an assessment of its impact.

The importance of knowledge and human capital for growth is the cornerstone of endogenous growth theory. The influential contribution to theory of Romer (1986) and Lucas (1988) demonstrate how human capital leads to endogenous growth. In empirical growth studies, human capital received much attention since the study of Mankiw, D. Romer and Weil (1992). Originally intending to show how different growth rates of saving and labour force growth rates can explain different per capita income growth rates, they found an unusually high elasticity of output with respect to capital and followed that capital needed to be understood in a broad sense, namely including human capital. Explicitly including human capital in the production function improved the plausibility of their estimates. Mankiw, Romer and Weil measured human capital by the fraction of working population with secondary education. Barro and Sala-i-Martin (1995) chose the average number of years spent in secondary school as indicator for human capital. Both studies found a strong and significant impact of human capital on growth.

Of course, there are other prominent growth factors. Certainly, how much an economy is engaged in foreign trade activities, is an important factor for growth, mainly because trade encourages technology diffusion and raises the propensity of innovation, as suggested by Grossman and Helpman (1991) and shown empirically by Levine/Renelt (1992), Baldwin/Seghezza (1996), Breuss (1998), and others. Further, it would be interesting to study the role of a variety of socio-economic, institutional and cultural factors in the development process of regions highly lagging behind. Barro (1991b), consequently Sala-i-Martin (1997) and Sachs and Warner (1997) investigated such factors for developing countries and showed that indeed institutional and political factors can explain development weaknesses.

Unfortunately, an empirical growth study for regions has to arrange with much more data constraints than one on the country level, for which large datasets for a considerable number of variables are readily available (e.g. the Penn World tables). For example, in this study we had to renounce our original intention to include variables on export activity, due to a lack of data availability. Similarly, the regional endowment with transport infrastructure cannot be quantified for all regions, as the degree of detail of public investment sub-categories differs a lot. Finally, some countries, as Ireland and largely Portugal, do not elaborate regional economic statistics at all.

However, we considered two other factors well covered by regional statistics, namely the participation rate and the agricultural employment share. Evidently sector imbalances, in particular the dominance of agriculture, were responsible for development problems in Northern European peripheral regions. It may be a cause for lagging regional development in the EU periphery as well. Therefore we have included this factor in our analysis. It seems also plausible that a low participation rate in the work process, caused by high unemployment or due to demographic structures, has a negative impact on per capita income, as produced output needs to be shared between those in the production process and those outside.

3. The data set

The data covers 38 NUTS II level regions from Spain, the Mezzogiorno, and Greece, and in addition, country level data of Ireland and Portugal. As these countries´ development performance is interesting in the context of the EU periphery´s development problems, Ireland and Portugal are included in the analysis, although we do not possess regional data. However, both are small countries, which are similar in size of surface and population to some other NUTS II level regions, e.g. Andalucia. The time series of the variables generally cover the period 1975 to 1994. For some variables data reaches back to 1970.

The set of variables includes (a) regional gross value-added per capita as an indicator for regional per capita income, (b) private investment as a share of regional gross value-added, (c) public investment as a share of regional gross value-added, both as proxies for private respectively public capital, (d) the rate of enrolment in upper secondary education in the age group 15-19 years, (e) the share of agricultural employment in total employment, and (f) the participation rate, i.e. the number of employees in total population.

Regional gross value-added per capita (GVA p.c.) is at market prices, given in 1985 prices in ECU. It deviates from the commonly used income indicator GDP p.c. in so far as it does not include value-added taxes. The data comes from Cambridge Econometrics which compiled the time series of regional GVA on the basis of the Eurostat Regio database and national statistics. The author is grateful for kind permission to work with the database. Data for the participation rate and agricultural employment is taken from the same database.

We decided to use data from Cambridge Econometrics in preference to the regional data collection of Eurostat, since the first provides longer and more complete time series. Especially for the cohesion countries, Eurostat data is highly incomplete. Cambridge Econometrics pays also more attention to harmonized data definition. Checking series of both data sources showed that Cambridge Econometrics data series are more accurate.

We can not use an indicator for the stock of public capital, since there are no regional public capital figures available for all our countries of interest. To capture the effect of public capital, the public investment rate is used as a proxy. In theory, it would be possible to construct the stock of public capital with the perpetual inventory method from the investment data series. However, our time series do not reach back long enough and there is no information on regional public investment depreciation rates. Nevertheless, as construction of the instrument matrix in our GMM estimation procedure considers the sum of all past periods investment rates, an accumulated investment rate, which is a certain measure for the region´s level of public capital, enters into the estimation. Unfortunately, it is not possible to consider different categories of public investment, as e.g. transport infrastructure, or telecommunication, as those are not available for all countries. The data for Spanish regional public investment stems from Fundacion Banco Bilbao Viscaya (1996). Data on Greek regional public investment is from the Greek national accounts and Psicharis (1997). Public investment of the Mezzogiorno regions comes from the Crenos databank (1995) and Istat. Public investment data for Ireland and Portugal are from OECD Economic Studies. Data series cover the period back to 1970, with the exception of Greek data.

As with public capital, there is no statistical data for the private capital stock. Hence, we need to use the private investment rate. The same arguments as with the public investment rate apply. Referring to data on regional private investment, the figures for Spain come from Fundacion Banco Bilbao Viscaya (1996), those for the Mezzogiorno from Crenos (1995) and Istat, those for Greece from the Greek National Accounts, and those for Ireland and Portugal from OECD Economic Studies and OECD National Accounts. Time series go back to 1970, except for Greece.

To capture the quality of regional human capital, the degree of participation in upper secondary education is a meaningful measure. Upper secondary schooling is commonly rather limited in the Southern EU countries, in relation to richer EU members. Ideally, the percentage of the workforce, which has finished upper secondary education, should be used as an indicator for human capital. Unfortunately, such statistics are only available for the national census years. In order to make an assessment of enforced schooling policies, which were started in many regions, the school enrolment rate was selected as indicator for human capital. Enrolment rates are considered to become effective for labour force quality with a lag of some years.

School enrolment was calculated from figures on the number of pupils in secondary upper education and the number of persons in the age group 15-19 years, which is the age when upper secondary education takes place. Schooling comprises general education and professional education. Over time, in practically every country, several reforms of the school system took place. Explanations for the national school systems, given in OECD series "Education at a glance", were used in order to select the correct school types, which account for upper secondary education. Data on upper secondary education enrolment is compiled from Cabrera (1996), Istat, the National Statistical Yearbook of Greece, and the statistical yearbooks of Ireland and Portugal. Data on the population in age group 15-19 is from national statistical sources. Fortunately, time series reach back to 1971 for all regions.

4. Empirical developments

4.1. Income disparities and growth performance of Southern regions

If we look at the regional landscape in 1994, Europe´s Southern regions divide into a group of relatively richer regions, including the North Eastern part of Spain and the Mezzogiorno, and a group of much poorer regions, consisting of the rest of Spain, the Greek and Portuguese regions. Compared with 1975, the income ranking order of regions has much changed. In 1975, the Mezzogiorno was clearly leading. Spanish regions followed only with a considerable gap. Greek regions then showed a higher income level than Portuguese, opposite to the situation in 1994.

Evidently, growth dynamics are different across Southern regions (see Figures 1 and 2, and Tondl 1998). On the one hand, Spain´s North-Eastern regions settled on a superior growth path since the early 80s, joined by Portuguese regions by the mid-80s. On the other hand, growth was lower in many Greek regions, in the South and Centre of Spain and the Mezzogiorno, and particularly weak in Western and Central Greece, Calabria and Sicily.

Figure 1: Per capita gross value-added in 1975
and real cumulative growth 1975-94.

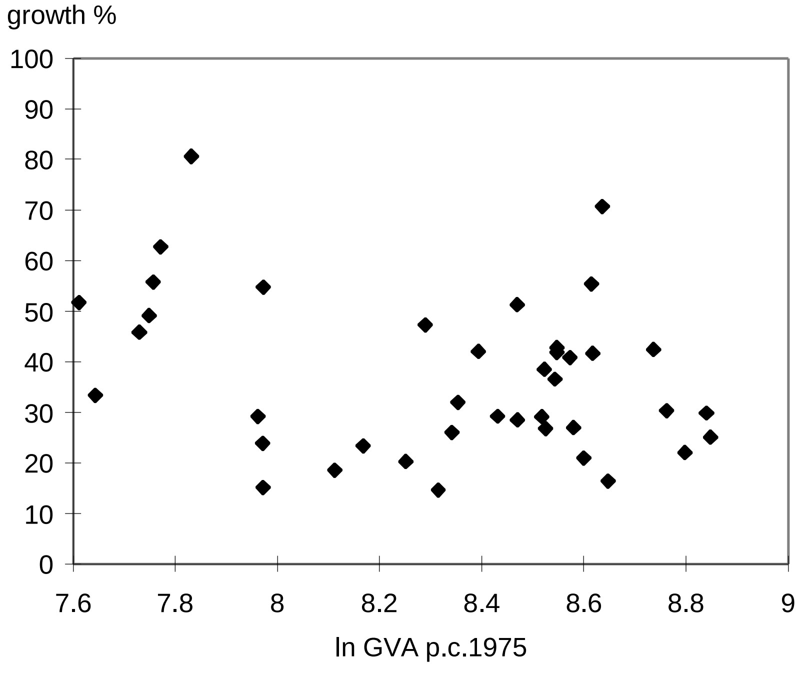
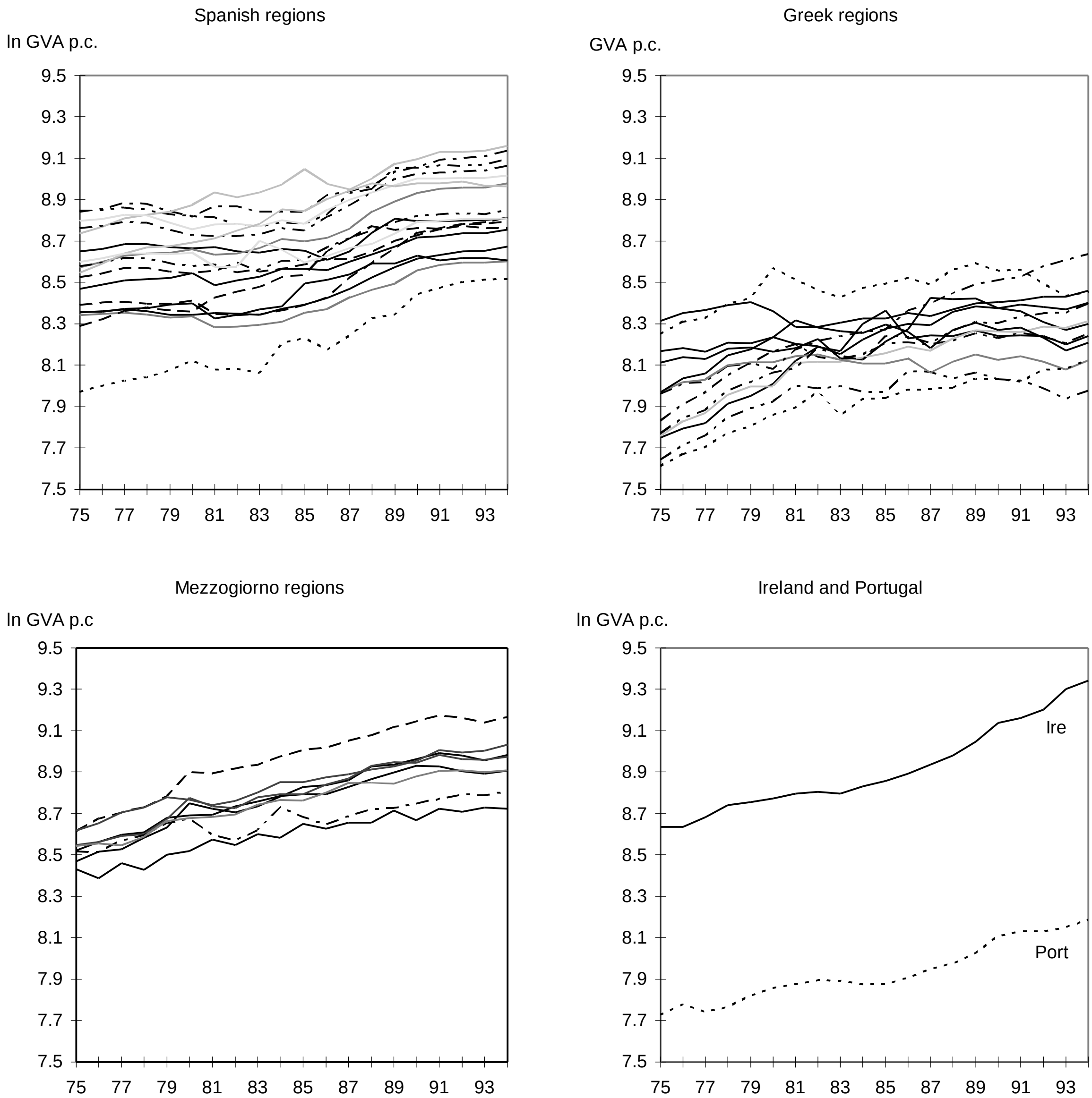


Figure 2: Development of real gross value-added per capita (1985 prices)



4.2. Developments in income and growth determining factors

In the following we will discuss the major trends observable in the time series of growth determining variables, the private investment rate, the public investment rate, and the school enrolment rate.

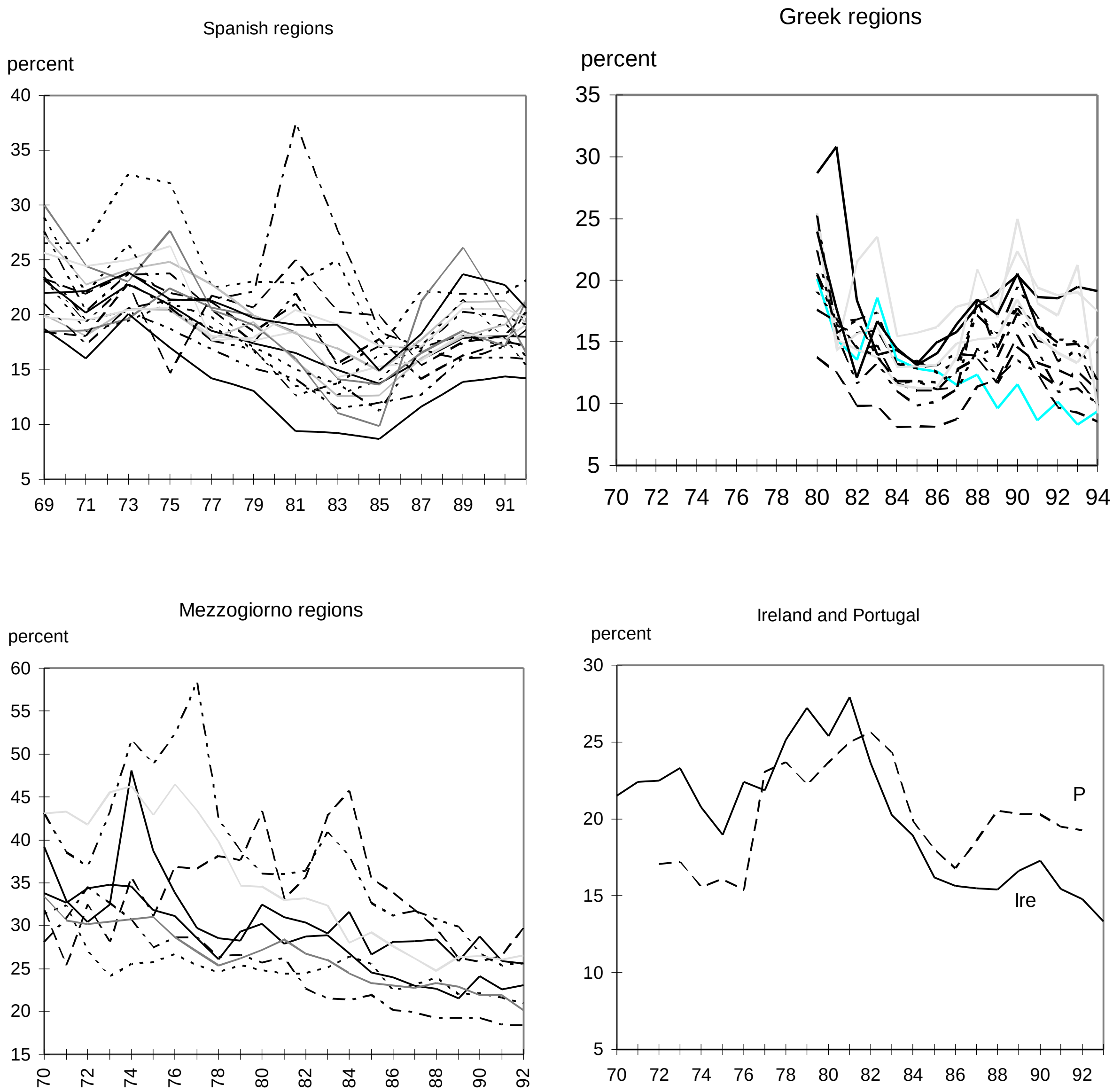
With respect to *private investment* (see Figure 3), one can note that the Mezzogiorno regions show the highest investment rate of all regions concerned. In 1974/75 the rate ranged between 30 to over 40 percent, while it reached 22 percent in Ireland, 17-20 percent in Spain, and 17 percent in Portugal. Greek regions, for which we have no data for that year, should also have had a rather high investment share of almost 30 percent if one looks at national data. In 1992, with 20-30 percent, the rate of private investment is still highest in the Mezzogiorno´s regions, whenever private investment had steadily declined over the past two decades. Second to the Mezzogiorno, Spanish regions show an investment rate of 15-25 percent, and Portugal a rate of 20 percent. Surprisingly, Irish investment had fallen to 15 percent over the 80s. Investment of Greek regions had become the lowest of all, with 10-20 percent.

The private investment rates show a kind of cyclical pattern. In Spain, Greece, Portugal and Ireland investment shows a trough in 1985/86, but not so in the Mezzogiorno. Similarly, the peak in investment in Ireland and Portugal in 1982 is a cyclical phenomenon. In the Mezzogiorno regions no such cyclical trends appear.

Regional investment rates have become more similar in their level within Spain as well as within the Mezzogiorno, while regional differences have become larger in Greece.

Some regional developments of investment should be mentioned separately. In Spain, the investment rate was surprisingly high over past periods in the less developed Centre (Castilles, Extremadura), with about 22 percent. The highest investment rate of 25 percent on average was registered in the tourism-oriented islands Baleares and Canaries. In contrast, the relatively rich regions Pais-Vasco, Cataluna and Comunidad Valencia showed an investment rate of only 16 percent on average. Similarly, as pointed out above, Ireland´s investment had distinctly dropped and settled at a lower level, while the country experienced high growth (see also Fuente/Vives 1997, Bradley et al. 1995: 30, Artis/Neaver 1994: 43). In the Mezzogiorno, the high investment rates of the Basilicata, Molise and Sardegna are noteworthy, particularly until the mid-80s. On the opposite, investment in the equally developed, but economically stagnating Sicily had remained the lowest in the Italian South throughout the period. In general, investment of the Mezzogiorno regions had always been above investment in North Italian regions by about 5 percentage points. As emphasized in Paci and Pigliaru (1995: 13), Southern Italian regional investment was effected to a large extent as a response to generous investment incentives. These examples suggest that there may not be a unique relationship between the level of investment and a region´s income level and growth.

Figure 3: Private investment in percent of gross value-added



The rate of *public investment* not only differs considerably across the regions of the cohesion countries and the Mezzogiorno, but follows also opposite development trends. Looking at Figure 4, one can see that the public investment rate of Greek regions has been substantially higher than those of other countries´ regions, reaching 4 to over 10 percent in the early 90s. (The Figure does not show the series for Western Macedonia´s public investment, which is almost 35 percent due to a considerable amount of public investments in national defence.) In addition, it is noteworthy that public investment continuously expanded in Greek regions, if one disregards short drops in 1980 and 1987. Southern Italian regions which exhibited an equally high rate of public investment as the Greek in the early and mid-70s of 2-8 percent, registered a constant decline of public investment. Remarkably, the largest beneficiaries of public investment in the Italian South, which were Basilicata, Calabria and Molise, showed one of the weakest growth performance.

Public investment of the Spanish provinces clearly lies in a lower range. (The peak of investment which can be noted with some provinces in the late 70s in Figure 4 are caused by large public works in the Pyrennees.) Throughout the 70s, public investment rates were rather stable in the Spanish provinces. Since the beginning of the 80s, public investment increased at a constant, but much more modest rate than in Greek regions, to reach 2-6 percent in the early 90s. For the Spanish regions as well, one can note that public investment has been particularly high in the poorer regions, e.g. the Castilles and Extremadura in the Centre, Andalucia in the South, while, during the 80s, it became the lowest in Cataluna, Comunidad Valencia and the Baleares. Ireland´s public investment rate was similar to the Spanish rate in the 70s, but dropped to half of its previous level in the 80s, to stand now at 2 percent, the lower boundary of all regarded areas. Portugal´s public investment rate has traditionally been among the lowest, but moved gradually from 2 percent in the early 70s to 4 percent in the early 90s.

It is also worth to regard the relation between public and private investment: One can note, that the expansion of public investment in Greek regions coincides with a decline in private investment. In Spain, both rates move in the same direction, and, in particular, Spanish regions watched rising investment rates of both private and public investment during the 80s. In contrast, the Mezzogiorno regions had to register a decline in both private and public investment. Similarly, the drop of investment in Ireland during the 80s refers to both rates. Portugal as well had synchronized investment cycles, which showed an increase until 1982, a declining phase until 1986 and a new rise thereafter.

Figure 4: Public investment in percent of gross value-added

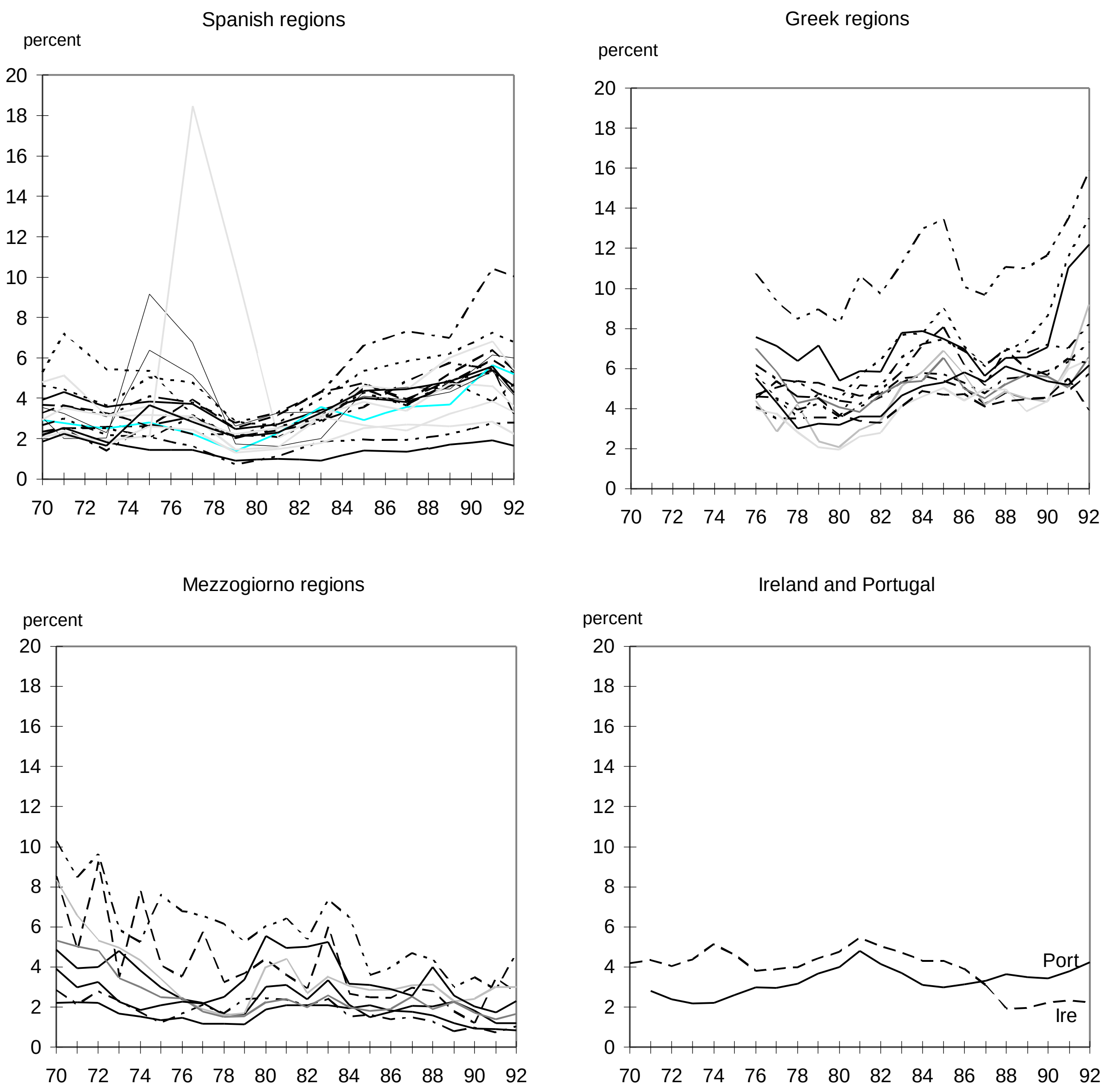
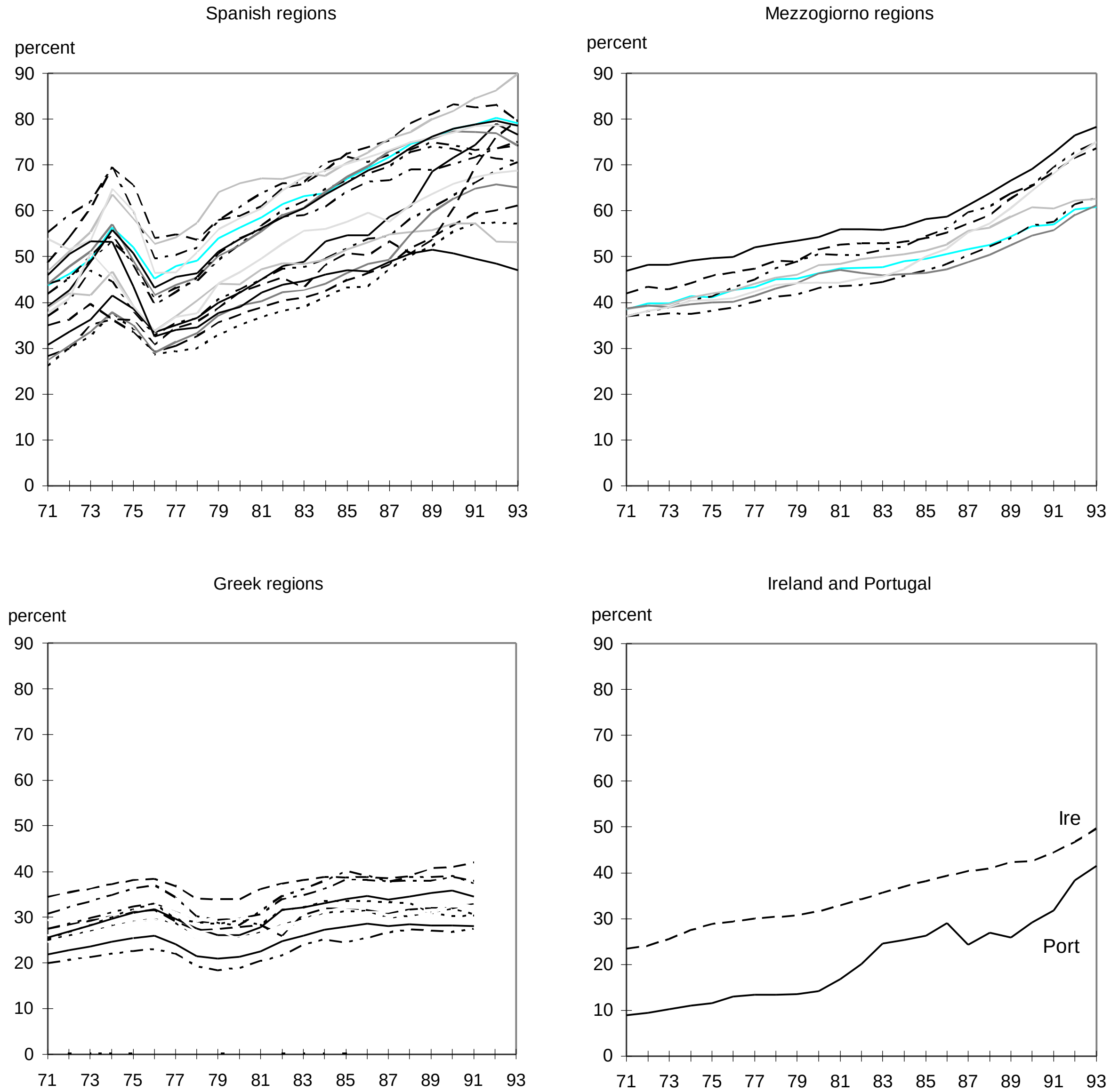


Figure 5: Enrolment in upper secondary education in percent of age group 15-19.



With respect to *enrolment in upper secondary education*, Figure 5 shows that Spanish regions and the Mezzogiorno have been ahead of the other throughout the past two decades. However, disparities of enrolment are quite large between Spanish regions. In Spain, in the early 70s, the share of 15-19 years old in upper secondary education ranged between 30-60 percent, whereas in 1993 it was 40-80 percent. In the Mezzogiorno that share moved from 40-50 percent in 1972 to 60-70 percent in 1993. In the Greek regions, enrolment in upper secondary education increased only moderately over the past 20 years, the drop for several years after 1976 was a serious break in the advance of educational levels in Greek regions. One notes that the drop in educational enrolment in Spain, obviously linked to similar political circumstances, was only a short episode in a rapid rise of educational standards. In contrast, Greek upper secondary education enrolment today is the lowest among all regions regarded and lies at 2.5 - 4 percent. Both Ireland and Portugal, which started with the lowest record of education in 1971: Ireland 20 percent and Portugal only 10 percent enrolment in upper secondary, climbed to 50 percent and 40 percent respectively.

In addition to investment and education, we consider agricultural employment and the participation rate as factors determining regional growth.

With respect to employment in agriculture, without discussing in this place the detailed developments, one can note a large drop of the agricultural employment share in Spain and Portugal since the 70s. In Spain, agricultural employment dropped to 20 percent in 1993 compared to over 30 percent in 1980. In the Mezzogiorno, agricultural decline was more pronounced in the 70s, however, also apparent in the 80s. Agricultural employment still amounts to 25 percent today. In contrast, employment structures have only modestly changed in Greek regions. Agricultural employment today still ranges between 25-50 percent.

4.3. The impact of investment and education on income and growth: Some stylized facts

4.3.1 Theoretical effects

Let us assume the following production function:

$$Y = K^a H^b G^y (AL)^q \qquad \text{with } 0 < \alpha, 0 < \beta, 0 < \psi, 0 < \theta,$$

$$\alpha + \beta + \psi + \theta \geq 1 \qquad (1)$$

Output Y is given by physical capital K, human capital H, and public capital G, AL is effective labour. This growth model can be either a Solow type model with constant returns to all production factors ($\alpha + \beta + \psi + \theta = 1$), or an endogenous growth model with increasing returns ($\alpha + \beta + \psi + \theta > 1$). Note that we would also find an endogenous growth model if part of production factors shows together constant returns, e.g. K and H so that $\alpha + \beta = 1$, or K and G so that $\alpha + \psi = 1$.

Defining $k = K / AL$, $h = H / AL$, and $g = G/ AL$, output can be written in per capita terms:

$$y = k^a hc^b g^y \qquad (2)$$

Capital stocks are accumulated as:

$$k = \sum_{t=-\infty}^{p} i_{k,t} \cdot y_t \tag{3}$$

$$g = \sum_{t=-\infty}^{p} i_{g,t} \cdot y_t \tag{4}$$

$$hc = \left(\sum_{t=-\infty}^{p} e_t \cdot POP_t \right) / AL \tag{5}$$

where $i_{k,t}$ is the private investment rate, $i_{g,t}$ is public investment rate, e_t is school enrolment rate, and POP_t is population in the age group 15-19 years. For simplicity, capital depreciation is neglected. Thus the stock of capital which enters into the production function is a consequence of investment from $t = -\infty$ to the present time *p*.

In the context of the neoclassical growth model, where each type of capital has decreasing marginal returns, and no combination of capital inputs has constant returns, a permanent rise in the investment rate of one capital factor, say physical capital, temporarily raises growth. The regional economy would move to a higher balanced growth path, with a higher steady state income where the steady state physical capital stock per person is higher. Note that the rise in physical capital will be accompanied by a rise in *hc* and *g* (alternatively for accumulation of human capital in equation (5) one may also write : $h\dot{c} = i_{hc} \cdot y = i_{hc} \cdot (k^a hc^b g^y)$ and public capital accumulation is $\dot{g} = i_g \cdot y = i_g \cdot (k^a hc^b g^y)$. Hence, the rise in *k* will lead to an increase in *hc* and *g*. Once the region has reached its new steady state, per capita capital stocks remain constant, $\dot{k} = 0, h\dot{c} = 0, \dot{g} = 0$, and per capita income only grows at the rate of technological progress. (see D. Romer 1996: 129-132))

On the other hand, if an endogenous growth model would apply, i.e. if one capital factor (e.g. human capital), or a combination of two factors, has constant returns, and therefore the production function of the economy as a whole increasing returns, a permanent rise in the investment rate of one capital factor would lead to sustained income growth. The rise in one capital factor induces an increase in the other capital factors, until an equilibrium ratio is obtained, where marginal products are equal. Thereafter, per capita capital stocks continue to grow at constant rates and so does per capita income. (see Barro 1995: 176)

Consequently, under a growth theory perspective, one would expect to find the following relationships in our data:

(a1) Present per capita income y_t should be positively related to the level of past private investment rates $i_{k,t}$, for time $t = -\infty, \ldots, p$. Regions with a higher private investment rate in the past should show higher present per capita incomes. This relation should be found irrespective of the type of growth model which applies.

(a2) A permanent rise in the investment rate $(i_{k,t} - i_{k,t-1}) > 0$ should result into higher GDP p.c. growth $(g_t - g_{t-1}) > 0$, with g_t indicating per capita income growth .

However, as discussed above, the duration of this effect depends crucially on the behaviour of capital´s marginal product. If capital has the property of decreasing marginal products as in the neoclassical model, the rise in growth rates is only temporarily. Growth rates may grow for a while when capital still has an increasing marginal product, but will finally drop. In addition, with a repeated upward movement of the investment rate the point where growth rates decline again could be shifted into the future. In summary, if physical capital has the property of diminishing marginal returns, one will not observe a significant relation between investment rates and growth.

Alternatively, if physical capital has the property of constant marginal products, alone or with another input factor, as in the case of the endogenous growth model, a permanent increase in investment would lead to persistent higher income growth and we should find a significant relationship in our data.

The hypotheses for empirical relationships with respect to public investment, respectively schooling and income/growth are very similar:

(b1) The level of per capita income y_t should be positively linked to the level of past public investment rates $i_{g,t}$, for time $t = -\infty, \dots, p$. Regions with a higher public investment in the past should show higher present incomes since the level of the stock of public capital which enters into the production function depends on past investment rates.

(b2) A rise in a region´s public investment rate $(i_{g,t} - i_{g,t-1}) > 0$ should lead to higher per capita income growth $(g_t - g_{t-1}) > 0$. As with private investment, we may find a permanent growth effect or a temporary, depending on whether public capital, alone or with another input, has the property of constant returns or not (endogenous or neoclassical growth model). Eventually, we may also observe a negative growth effect due to a negative tax effect linked to high public investment rates (Barro 1995: 154-55).

(c1) The level of GDP p.c., y_t, should be positively linked to the level of the school enrolment rate e_t, for time $t = -\infty, \dots, p$ (assumption of indefinitely long living households). Strong accumulation of human capital in the past would have resulted into a higher stock of human capital and hence a higher per capita income should be observed.

(c2) A rise in a region´s schooling participation rate $(e_t - e_{t-1}) > 0$ should lead to a rise in GDP p.c. growth $(g_t - g_{t-1}) > 0$. With an increase of schooling one should observe higher growth rates. Again, the duration of the growth stimulus depends on the marginal product property of human capital. If in our set of regions human capital, alone or together with other inputs, has constant returns so that endogenous growth is possible we should be able to observe a permanent increase of growth rates linked with higher schooling.

From a first view on the data series, it is rather unclear at which extent the expected relationships will be verified. There are several puzzles:

Are high private investment rates the key to high per capita income (hypothesis a1)? From the data, one can observe fairly high investment rates in the comparatively wealthy Southern Italian regions, but also in the less rich areas of Central Spain. Does a decrease of the investment rate result in a decline of GDP p.c. growth (hypothesis a2)? The evidence from

Southern Italy suggests yes, that from Ireland the opposite. In contrast, we watch a rise of private investment rates together with rising GDP growth in Spain, as one would expect from theory.

As to the possible impact of the level of public investment rates, there is as well ambiguous evidence at first view. With respect to hypothesis (b1), one observes that the public investment share was rather high, both in Greek regions and in Southern Italy. While the first regions rank among the poorest areas of the periphery, the second are relatively rich. As to hypothesis (b2), public investment rates declined in Southern Italy together with stagnating per capita income growth, and rose with strengthening growth in Spanish regions. Paradoxically, however, public investment rates rose with fading growth in Greek regions and declined with mounting growth in Ireland.

Only with respect to the impact of school enrolment, first view evidence from the data shows a clear relationship. The relatively rich regions of Spain and Southern Italy had a high enrolment in upper secondary schooling ever since 1970, while participation was lowest in the relatively poor Greek regions (hypothesis (c1)). A steady rise of schooling accompanied the rise of GDP growth in Spanish regions, Ireland, and Portugal (hypothesis (c2)).

4.3.2. Cross-section evidence

In order to check for the conformity with theoretical relations, however, one needs to look at the total sample of regions. Figures 6 to 11 provide evidence from a cross-section perspective.

The left hand diagrams show how the region´s sample fits to hypothesis (a1), (b1), and (c1). As we have no measure for the stock of private and public capital, or the stock of human capital, to put in relation to income level, we need to constrain ourselves to a proxy for the level of accumulated stock. As such one could take the cumulative share of investment, or the average share of investment of past periods and relate it to income. With both proxies, the resulting patterns were practically identical. The Figures show the relationship between the attained per capita income in 1994, the end of the time series, and the average private investment rate in the data period. Equivalently, the relationship with the average rate of public investment, and with the average rate of enrolment in upper secondary education is shown. Figure 6 suggest, that in the European periphery, a high regional per capita income corresponds to high private investment rates. Similarly, regions with a high income level in 1994 had a high participation in schooling in the two past decades (Figure 10). In contrast, with respect to public investment, the behaviour of our regions seems to contradict theory at first view (Figure 8). High income regions had the lowest public investment rates in past periods, while public investment was rather high in less developed regions. However, given the generally long life time of public capital, public investment effected in that period certainly does not represent a region´s public capital stock. Much of the capital would have rather been accumulated in earlier periods. However, accumulation in that earlier period may have been weak, and hence, at the time when our analysis starts, poor regions may in fact have had a large deficit in public capital, in view of which they invested considerably. Actually, other studies (e.g. Tondl 1998) showed that poorer Southern regions faced particular deficits in public infrastructures in the eighties. In contrast, the lower investment in richer regions

Figure 6: Regional gross value-added per capita in 1994 and average private investment 1980-92 (share in GVA).

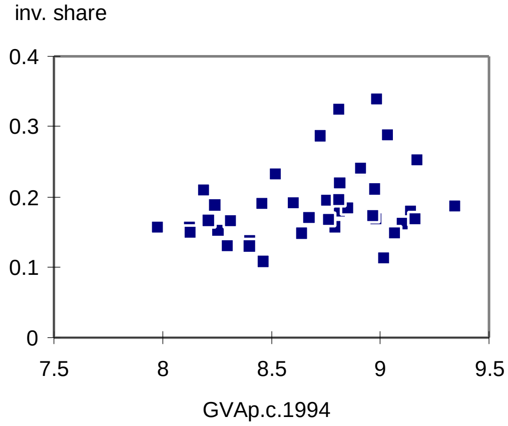


Figure 7: Average growth of GVAp.c.1981-93 and average private investment 1980-92 (share in GVA)

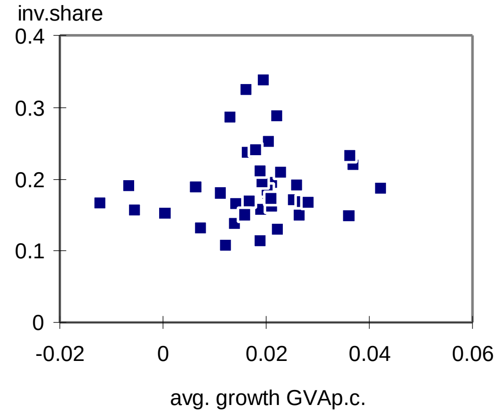


Figure 8: Regional GVAp.c. 1994 and average public investment 1976-92 (share of GVA)

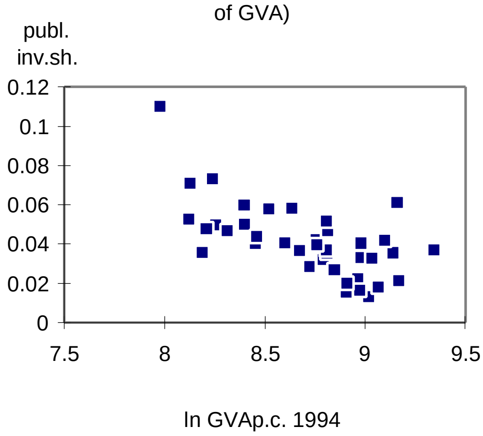


Figure 9: Average growth of GVAp.c. 1977-93 and average public investment 1976-92 (share in GVA)

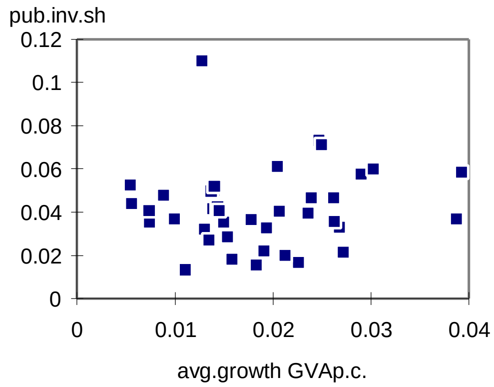


Figure 10: Regional GVAp.c. 1994 and average enrolment in upper secondary education 1971-91 (share in age group),

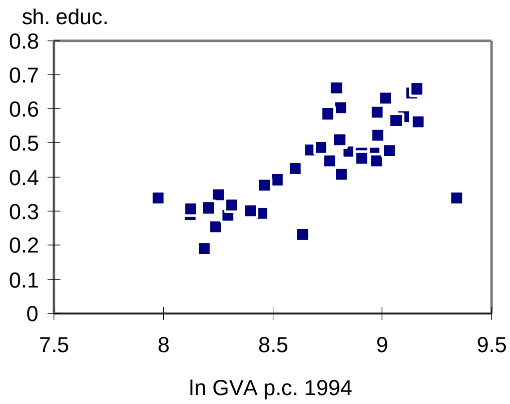
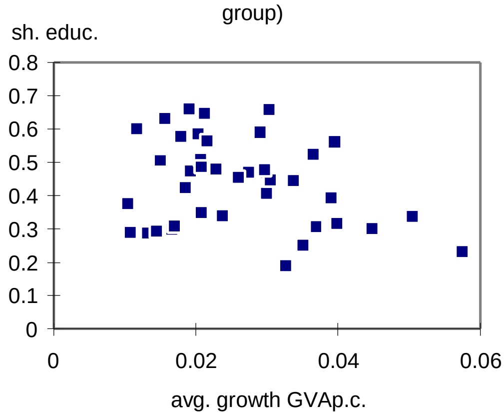


Figure 11: Average growth GVAp.c. 1975-94 and average enrolment in upper sec.education 1971-91 (share of age group)



shown in Figure 8 must be interpreted as a consequence of an already sufficiently high stock of public capital. Nevertheless, as shown in Figure 9, income growth - at least partly - tended to be higher in regions which had effected high public investment.

The right hand Figures wish to provide evidence for hypothesis (a2), (b2), and (c2). The view is on the cross-section dimension, regarding whether average income growth across regions varied with the typical investment rate of a region, i.e. her average rate. Figure 7 shows that the average income growth performance of a region was higher if the average private investment rate was high as well. However, one can note that the relation is only weak and contains a number of outliers. From Figure 9, one roughly can accept an equal causal relationship. Surprisingly, our region´s sample shows that higher average schooling did not lead to higher income growth.

4.3.3 Time series evidence

Admittedly, the above view focuses primarily on the cross-section behaviour. As a next step, therefore, we would like to look whether the theoretical relationships stated in 4.3.1 apply also with respect to time. The question is whether in the investment rate, or the participation in education, move together with a region´s per capita income. To examine this issue we effect cointegration tests with the procedure suggested by Engle and Granger (1987) for each region separately, checking variables pair-wise with income for cointegration. If a series is cointegrated with regional income we can be sure that there is a long-term relationship. If it is a positive relation, then an increase in the variable is associated with growth of per capita income.

In general, cointegration between two variables which are of the same order of integration is given if one can find a linear combination between them that is stationary. The cointegration test of Engle and Granger consists of estimating the cointegration relation by OLS and applying a unit root test on the obtained residuals. Variables of the same order of integration are cointegrated if the coefficient in the estimated cointegration equation is significant and if residuals are I(0).

Tables in the annex show the detailed results of these cointegration tests. The starting point of the tests are unit root tests on the variables. One can note that practically all variables are I(1).

The tests show a clear positive relationship between education and per capita income as well as between the public investment rate and income. In contrast, the relation between private investment shares and income is less clear.

With respect to the link between GVA p.c. and the rate of public investment, hypothesis (b2) suggests that we should observe a positive cointegration relation if public capital shows constant returns, at least together with other factors. Table I in the annex reports the results of cointegration test for public investment. One observes that for most regions GVA p.c. and the public investment share are cointegrated. However, there are clearly country specific characteristics.

For the Spanish regions, we generally find a positive and significant relation between public investment and GVA p.c. In Greek regions as well per capita income is positively related with public investment. Nevertheless, the coefficient in the cointegration equation is partly not significant for Greek regions because - as the series show - public investment acts with a delay of varying periods. The results for Southern Italian regions are quite different. Generally, we find a negative cointegration relation, which is significant for half of the regions. Per capita income has increased despite a decline in the public investment rate. This suggests diminishing marginal products of public investment in Southern Italy.

The cointegration tests for regional private investment and GVA p.c. show that in most cases the relationship between the two variables is not significant (see Table II in the annex). This applies particularly for Spanish and Greek regions. In Spanish regions, one observes that the low significance of the cointegration coefficient occurs because of a trend break in investment (decline in the first part of the period and increase thereafter) while income grew constantly over the whole period. As the cycles of both series are not fully synchronized - sometimes the investment trend runs ahead of income sometimes it shows a lag - one often finds a negative relation. There is also much evidence that income determines investment and not vice versa. For Greek regions, a look at the series shows that both variables are generally moving together. However, again, income movements are not fine-tuned with investment cycles. Investment series show much noise and precede income or lag behind. These facts lead to non-significant cointegration relationships. Finally, we find a clear negative cointegration relation between income and private investment in Southern Italian regions. The constant decline of investment did not impede ongoing growth of per capita income. This revokes the idea of diminishing marginal products of private capital in Southern Italy.

Regarding the results of cointegration tests between regional GVA p.c. and enrolment in upper secondary education (Table III in the annex), there is very strong evidence that both variables are positively related over time in our sample of regions. The rise of regional GVA p.c. over time was linked to an increase in education. In practically all regions of Spain, Greece, and Southern Italy the coefficient of education in the cointegration equation is positive. The relation is highly significant for Spanish and Southern Italian regions, however, not for Greek regions. We find that education sometimes would rather enter with a lag in the relationship. It is also the case that the serious decline of educational enrolment in Greece in the period following 1976 was not paired with a decline of per capita income in all regions. In some Spanish and Greek cases, the cointegration equation shows a rather high coefficient. This corresponds to a very large drop in education, which took place in some regions of Spain and Greece in a short period after 1976 and was immediately recovered thereafter.

The intention of our exploratory data analysis was to make sure that we can expect causality from the selected explanatory variables and to obtain a first idea of the type of relationship, across regions on the one hand, and over time on the other hand. The actual estimation with the panel data procedure will combine both elements.

5. Estimation of the determinants of income and growth in a panel data model

5.1 The traditional cross-section model

The analysis of the impact of growth determinants (in the process of income convergence) was initiated with cross-country convergence analyses.

The original model for income convergence analysis was developed by Barro and Sala-i-Martin in the framework of neo-classical growth theory (see Barro and Sala-i-Martin 1995: 80-82, 383-86):

Regarding per capita income of a set of economies *i* at the beginning of a period of time of length T, $y_{i,t0}$, and income at the end of the period, $y_{i,t}$, cross-section growth analysis uses the following basic equation to estimate the speed of income convergence β :

$$(\ln y_{i,t} - \ln y_{i,t0})/T = a - (1-e^{-\beta T})/T \ \ln y_{i,t0} + u_{i,t} \qquad (6)$$

The left hand term refers to the average growth rate of per capita income y_i in period T . It is negatively related to the initial per capita income $y_{i,t0}$. The coefficient $(1-e^{-\beta T})/T$ declines over time, reflecting the dynamics in a neo-classical growth model. β is the speed of convergence, indicating the rate at which the economy converges towards its steady state income. The intercept *a* represents the common steady state: $a = x + (1-e^{-ß}) (\ln y_i^* + x (t - T)$, where x is the exogenous growth of technology, corresponding to steady state growth, and y_i^* is the steady state income.

If different steady state incomes across economies are assumed, i.e. in the case of conditional convergence, the equation becomes:

$$(\ln y_{i,t} - \ln y_{i,t0})/T = a - (1-e^{-\beta T})/T \ \ln y_{i,t0} + \mathbf{X}_{i,t0} + u_{i,t} \qquad 0 < \beta \qquad (7)$$

where $\mathbf{X}_{i,t0}$ is a set of variables which determine the general level of growth and hence the steady state (conditional variables or growth determinants). In practice, for $\mathbf{X}_{i,t0}$ either stock variables at the beginning of the period are considered, as e.g. the level of education in the working population, or flow variables in the period T, e.g. the average rate of investment. The specification assumes that residuals are i.i.d., namely that the mean of errors $\bar{u}_{i,t}$ is zero, $s^2_{ui,t}$ is constant and that errors show no systematic correlation. We shall see below that these conditions are likely to be violated.

In regional growth analysis, one should also consider the possibility of spatial correlation patterns. It is very likely that a region´s growth is influenced by that of neighbouring regions. Fingleton (1995) suggests to use a spatially autocorrelated errors model to cope with this issue. The use of country dummy variables is an alternative approximate method to absorb spatial correlation.

Many studies do not estimate the convergence coefficient β, but use a specification where the term $(1 - e^{-\beta T})/T$ is replaced by a coefficient b:

$$\ln y_{i,t} - \ln y_{i,t0} = a - b \ln y_{i,t0} + \mathbf{X}_{i,t0} + u_{i,t} \qquad 0 < b \qquad (8)$$

In this case, the speed of convergence β can be recovered from the estimated coefficient b from the formula:

$$\beta = - \ln (1-b) \;\; / \; T \qquad (9)$$

5.2 The panel data model

Only recently, panel data estimation theories (see e.g. Hsiao 1986, Baltagi 1996) have become influential in growth estimation. The assumption that economy-specific, time invariant fixed effects exist, which are responsible for individual steady state income positions, was adopted in several growth analyses (Islam 1995, Canova and Marcet 1995, Tondl 1999). This idea is convincing if one considers that a number of unobservable individual factors must exist, in addition to those which can be captured by the conditional variables in $\mathbf{X}_{i,t.}$ Panel data theory suggests that in the presence of fixed effects the cross-section error term $u_{i,t}$ can be decomposed into $u_{i,t} = e_{i,t} + h_i$, where h_i is a fix individual component and $e_{i,t}$ is the remaining random error component. Hence, conventional cross-section estimates which neglects h_i can be assumed to suffer from an omitted variable bias. Empirical evidence shows that this bias is not negligible.

In the panel data specification of a fixed effects model the growth equation becomes:

$$\ln y_{i,t} - \ln y_{i,t-1} = - c \ln y_{i,t-1} + \mathbf{X}_{i,t-1}\, \delta + \eta_i + \xi_t + \varepsilon_{i,t} \qquad 0 < c \qquad (10)$$

As one can note, panel data estimation uses several observations in time. The observations may be given for some interval in time T, or one may be able to work with annual data. Consequently, panel data estimates are derived from a much richer set of information than cross-section analyses.

The individual fixed effect η_i, which is constant over all observations, replaces the common intercept. Thus the fixed effect η_i represents the individual steady state income. $\mathbf{X}_{i,t-1}$ is a row vector of growth determinants and δ the coefficient vector. ξ_t is a time-specific effect, ruling in period t. It is most useful to include a time-specific effect in order to capture aggregate shocks which may be present in a particular period. The error term $\varepsilon_{i,t} \sim N(0,\sigma^2)$ is a random disturbance.

The equation for growth in (10) can be rewritten as a dynamic panel data model with per capita income as the dependent variable:

$$\ln y_{i,t} = d \ln y_{i,t-1} + \mathbf{X}_{i,t-1}\, \delta + \eta_i + \xi_t + \varepsilon_{i,t} \qquad 0< d \qquad (11)$$

where d = 1 + c.

Hence, one can estimate the impact of growth factors either in a model with income as the dependent variable, or in one with growth as the dependent. Both specifications are equivalent.

We follow this specification and thus estimate how per capita income is explained by its past level on the one hand, and a set of growth determining variables on the other hand.

5.3 Estimation procedure

The specification in equation (11) constitutes a dynamic panel data model, where the dependent variable is partly explained by its past value. The model involves two econometric problems, as discussed e.g. in Hsiao (1986: 73-75), Islam (1995: 1137-38), Pesaran/Smith (1995), or Baltagi (1996: 126), which are generally not accounted for in the empirical growth literature:

(a) As the right hand side of equation (11) contains a lag of the dependent variable, the problem of a correlation of error terms arises with the common estimation procedure of fixed effects models, i.e. the LSDV. Such static panel data estimation methods lead to biased estimates with dynamic panel data models.

(b) A number of variables contained in $\mathbf{X}_{i,t-1}$ must be considered as endogenous, they are determined simultaneously with growth. Investment is a typical example for an endogenous variable. The causal relation runs in both directions. The instrumental variable estimation, necessary in this case, is hardly applied in empirical growth studies.

With respect to problem (a), one should note that LSDV estimation is effected by applying OLS on a transformed series, where the individual time series mean is subtracted from each observation to sweep out the individual effects and avoid the dummy variable trap: $\ln(y_{i,t} - \bar{y}_i) = d \ln(y_{i,t-1} - \bar{y}_i) + \ldots + (h_i - h_i) + e_{i,t} - \bar{e}_i$, with $\bar{y}_i = \sum_{t=1}^{T} y_{i,t} / T$. One can easily see that the error $(e_{i,t} - \bar{e}_i)$ from estimating $(y_{i,t} - \bar{y}_i)$ is correlated with the autoregressive term $(y_{i,t-1} - \bar{y}_i)$ (Hsiao 1995: 73-75). Nickel (1981) shows that the bias approaches zero if T goes to infinity. However, this is typically not the case in regional growth regression analysis. For a small number of observations in time, the bias of the LSDV estimator cannot be ignored. To cope with this problem, Anderson/Hsiao (1981) proposed an instrumental variable estimation procedure:

Starting from the model in equation (11), in a first step, first differences of the series are taken in order to remove the individual fixed effects:

$$(y_{i,t} - y_{it-1}) = d\,(y_{i,t-1} - y_{i,t-2}) + (x_{i,t-1} - x_{i,\,t-2})\,\delta + (\eta_i - \eta_i) + (\xi_t - \xi_{t-1}) + (\varepsilon_{i,t} - \varepsilon_{i,t-1}) \qquad (12)$$

We see that now there appears the problem that the errors ($\varepsilon_{i,t}$ - $\varepsilon_{i,t-1}$) are correlated with ($y_{i,t-1}$-$y_{i,t-2}$). Anderson/Hsiao recommend to use a lag of the variable, either the lagged observation $y_{i,t-2}$ or the lagged difference ($y_{i,t-2}$ - $y_{i,t-3}$) as instrument for ($y_{i,t-1}$ - $y_{i,t-2}$). Those are correlated with the explanatory variable, but not with the error term. This estimator suggested by Anderson/Hsiao is a consistent estimator for a dynamic panel data model.

However, as Arellano and Bond (1991) show, the Anderson/Hsiao estimator is not necessarily an efficient estimator since it does not make use of all available moment restrictions. These authors argue that additional instruments can be gained if using all possible orthogonality conditions E($y_{i,t-2}$, $\varepsilon_{i,t}$ - $\varepsilon_{i,t-1}$) = 0, E($y_{i,t-3}$, $\varepsilon_{i,t}$ - $\varepsilon_{i,t-1}$) = 0, etc., meaning that if the lagged observation $y_{i,t-2}$ is not correlated with the error $\varepsilon_{i,t}$ - $\varepsilon_{i,t-1}$, any further lag $y_{i,t-3}$, $y_{i,t-4}$, etc. is not correlated with the error term $\varepsilon_{i,t}$ - $\varepsilon_{i,t-1}$ neither and thus is a valid instrument. As a consequence, they suggest to take all available lags as instruments and demonstrate in a Monte Carlo simulation that this estimation procedure improves significantly estimation efficiency.

The second problem in estimating our model, problem (b), arises from the endogeneity of explanatory variables included in $\mathbf{X}_{i,t-1}$. This creates a second correlation problem. Due to the endogeneity of $\mathbf{X}_i$, an error correlation would exist in the fixed effects OLS estimation with the transformed series, as $(e_{i,t} - \bar{e}_i)$ is correlated with $(x_{i,t-1} - \bar{x}_i)$. In addition, an error correlation appears also in the Anderson/Hsiao estimation specification in first differences, where $(e_{i,t} - e_{i,t-1})$ is now correlated with $(x_{i,t-1} - x_{i,t-2})$. Again, this problem can be cured by the use of instruments. Following the Anderson/Hsiao concept, lagged observations, $x_{i,t-2}$ or ($x_{i,t-2}$ - $x_{i,t-3}$), can be used as instruments, and in the Arellano/ Bond approach all lagged observations of the variables should be used as instruments.

To summarize, one has to apply an instrumental variable estimation procedure in order to obtain consistent estimates in a dynamic panel data model, and for the case that endogenous variables are investigated.

For our analysis, we shall employ two estimation procedures: the GMM procedure suggested by Arellano/Bond (1991) and the Anderson/ Hsiao (1981) estimator, which will be described now in more detail.

As mentioned above, the original instrumental variable estimator was proposed by Anderson/Hsiao (AH). For the dynamic panel data model with a set of explanatory variables ($X_{i,t}$) and a lagged dependent variable the AH estimator is defined as:

$$\theta_{AH} = (Z'X)^{-1} Z\, Y \qquad (13)$$

The panel consists of economies i = 1,...,N over period t = 1, ..., T. X includes K explanatory variables.

We take $y_{i,t-2}$ as instrument for the lagged dependent variable in differences ($y_{i,t-1}$ -$y_{i,t-2}$). $x_{i,t-2}$ is taken as instrument for the regressors in differences ($x_{i,t-1}$ - $x_{i,t-2}$). (This means that one will loose the first two observations of the panel to construct instruments and the estimation starts for t=3).

To introduce a more simple notation we define $\Delta y_{i,t} = y_{i,t} - y_{i,t-1}$ in equation (12). Y is the N(T-2) x 1 vector of dependent variables, X the N(T-2) x K matrix of regressors and Z the K x N(T-2) matrix of instruments. We take the AH estimator with instruments in levels, for which empirical performance has shown to be superior to instruments in differences (Arellano and Bond 1991).

.

$$Y = \begin{bmatrix} Y_1 \\ \cdot \\ \cdot \\ Y_N \end{bmatrix} \qquad X = \begin{bmatrix} X_1 \\ \cdot \\ \cdot \\ X_N \end{bmatrix} \qquad Z = \begin{bmatrix} Z_1 \\ \cdot \\ \cdot \\ Z_N \end{bmatrix} \qquad (14)$$

$$Y_i = \begin{bmatrix} \Delta y_{i,3} \\ \cdot \\ \cdot \\ \Delta y_{i,T} \end{bmatrix} \qquad X_i = \begin{bmatrix} \Delta y_{i,2} & \Delta x_{i,2} \\ \cdot & \cdot \\ \cdot & \cdot \\ \Delta y_{i,T-1} & \Delta x_{i,T-1} \end{bmatrix} \qquad Z_i = \begin{bmatrix} y_{i,1} & x_{i,1} \\ \cdot & \cdot \\ \cdot & \cdot \\ y_{i,T-2} & y_{i,T-2} \end{bmatrix} \qquad (15)$$

The GMM estimator suggested subsequently by Arellano and Bond (1991) uses all available lags - in levels - of the dependent variable and of the regressors as instruments. It exploits all possible moment restrictions: $E(y_{i,t-2}, \varepsilon_{i,t} - \varepsilon_{i,t-1}) = 0$, $E(y_{i,t-3}, \varepsilon_{i,t} - \varepsilon_{i,t-1}) = 0$, etc. (see Arellano /Bond 1991: 279). The authors show that this construction permits a considerable gain in efficiency. The standard deviation of the estimated coefficients is considerably smaller than with the Anderson/Hsiao estimator (Arellano/Bond 1991: 285).
Arellano/Bond define the GMM estimator as:

$$\theta_{GMM} = (X'Z^* A_N Z^{*\prime}X)^{-1} X'Z^* A_N Z^{*\prime}Y \qquad (16)$$

where the instrument matrix Z_i^* is a block diagonal matrix with s=1, ..., T-2 blocks of the form: $(y_{i1} \ldots y_{is}\ x_{i1} \ldots x_{is})$

$Z_i^* =$

$$\begin{pmatrix} y_{i1} & x_{i1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & \cdots & 0 & 0 & \cdots & 0 \\ 0 & 0 & y_{i1} & y_{i2} & x_{i1} & x_{i2} & 0 & 0 & 0 & 0 & 0 & 0 & & 0 & & 0 & 0 & & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & y_{i1} & y_{i2} & y_{i3} & x_{i1} & x_{i2} & x_{i3} & \ddots & 0 & & 0 & 0 & & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & y_{i1} & \cdots & y_{is} & x_{i1} & \cdots & x_{is} \end{pmatrix} \qquad (17)$$

(compare Arellano/Bond 1991: 290). Note that here the instrument for $(y_{i,t-1} - y_{i,t-2})$ is $y_{i,t-3}$ and not $y_{i,t-2}$ as with the Anderson-Hsiao estimator.
One can use a one-step or a two-step GMM estimator. The one-step estimator, GMM1, assumes that errors are i.i.d., i.e. homoscedasticity of errors across units and over time, while

the two-step estimator, GMM2, allows for heteroscedasticity of errors. Both estimators differ in their weighting matrix A_N.
If errors can be assumed to be i.i.d., there is an optimal, one-step GMM estimator with the weighting matrix A_N given by:

$$A_N = \left(\frac{1}{N} \sum_{i}^{N} Z_i *' \; H Z_i * \right)^{-1} \tag{18}$$

where H is a (T-2) square matrix with twos in the main diagonal, minus ones in the sub-diagonals and zeroes otherwise. In this case, GMM1 is consistent and efficient.

If the restriction on the error term is relaxed, i.e. if heteroscedasticity is allowed, the weighting matrix is calculated in two steps. The final weighting matrix of the two-step estimator uses the covariance of the one-step consistent estimation instead of the matrix *H* from above. The two-step estimator is only available for $N \to \infty$, with T fixed. For finite N, the number of instruments may exceed the number of units. This is the case with our panel, where N=40, T=18, and K= 6. Therefore, we can not apply a two-step estimation but will use the one-step GMM estimator. Further, we shall also use various restricted GMM estimation procedures, i.e. restrict the number of lags used in the instrument matrix.

Arellano/Bond (1991) suggest several specification tests to test the validity of the assumed moment restrictions. The first test statistic tests for the autocorrelation of error terms. The GMM estimator depends on the assumption that there is no second order serial correlation of error terms. Let $\upsilon_{i,t}$ be the first difference of the error term, so that $\upsilon_{i,t} = \varepsilon_{i,t} - \varepsilon_{i,t-1}$, $\upsilon_{i,t-1} = = \varepsilon_{i,t-1} - \varepsilon_{i,t-2}$, $\upsilon_{i,t-2} = \varepsilon_{i,t-2} - \varepsilon_{i,t-3}$, etc. The hypothesis of no second order serial correlation is:

$H_0 : E\,(\upsilon_{i,t}\ \upsilon_{i,t-2}) = 0$,

and the alternative hypothesis $H_1 : E\,(\upsilon_{i,t}\ \upsilon_{i,t-2}) \neq 0$ (19)

The test statistic *m2* for second order serial correlation is given by:

$$m2 = \hat{u}'_{-2}\, \hat{u}_* / \hat{u}^{1/2} \quad \tilde{a} \;\; N(0,1) \tag{20}$$

$\hat{u}_{-2}$ is the vector of residuals lagged twice, and $\hat{u}_*$ is a vector of residuals adjusted to match the length of the twice lagged residuals (Arellano/Bond 1991: 281). The test statistic is asymptotically normal distributed. H_0, the hypothesis of no second order correlation is rejected if the value of *m2* exceeds the critical value (1%, 5%,..) of the standard normal distribution.

The *m2* statistic would tell us also about remaining spatial error correlation, which regional economists may argue to be present even in a fixed effects model.

The second type of test recommended by Arellano/Bond (1991) is a test statistic on the validity of instruments. Remember that a central requirement for an instrument was not to be correlated with error terms. If that was the case, a moment restriction would be violated. Arellano/Bond (1991) use a Sargan test (1958) for overidentifying restrictions. The null hypothesis of no correlation between instruments and errors is:

$H_0 : E\,(Z_i' u_i) = 0$

The test statistic for the one-step GMM estimator is:

$$s1 = \frac{1}{\hat{s}^2} u'Z \left(\sum_{i=1}^{N} Z_i' \; H_i \; Z_i \right)^{-1} Z'u \qquad (21)$$

where υ are the residuals of the one-step estimation and $\hat{s}^2$ is their variance. The test statistic is c^2 - distributed with p - k degrees of freedom, p is the number of columns in the instrument matrix, k is the number of variables. The null hypothesis will be rejected if the statistic *s1* exceeds the critical value of the c^2 - distribution with p - k degrees of freedom. The Sargan test for the one-step GMM estimator is only valid if the residuals are indeed i.i.d.

Finally, we are in a position to specify the econometric model for our estimation of income determinants in EU Southern regions. To write down the estimation specification in a more simple notation let us drop the subscript i and t. Δ shall denote the variable in first differences and (-1), (-2), etc. denote the lag of the variable for 1, 2 periods etc. The set of variables is denoted: LGDP indicates gross value-added per capita in logarithms, PUB indicates public investment as a share of regional gross value-added, PRIV indicates the respective share of private investment, EDU indicates the average rate of enrolment in upper secondary education over the past four periods, AGRI is the share of employment in agriculture in total employment, PARTI is the participation rate, i.e. the number of employees as a fraction of total population.

Recalling equation (10) and (12) we can now write the specification for estimation as follows:

$$\Delta\ \text{LGDP} = \Delta\ \text{LGDP}(-1) + \Delta\ \text{PUB}(-1) + \Delta\ \text{PRIV}(-1) + \Delta\ \text{EDU} + \Delta\ \text{AGRI}(-1) + \Delta\ \text{PARTI} + \text{COUNTRY} + \text{TIME} \qquad (22)$$

The specification includes dummy variables for each period TIME and a dummy variable for each country COUNTRY, considering the fact that relationships between variables often show a strong country characteristic.

Estimation then was effected on the following specifications concerning the matrix of instruments:

regressors:	ΔLGDP(-1)	ΔPUB(-1)	ΔPRIV(-1)	ΔEDU	ΔAGRI(-1)	ΔPARTI
instruments: (in levels)						
(a2)	LGDP(-2)	PUB(-2)	PRIV(-2)	--	--	--
(b)	all lags	PUB(-3)	PRIV(-3)	--	--	--
(c1)	all lags	all lags	PRIV(-3)	--	--	--
(c2)	all lags	max 5 lags	PRIV(-3)	--	--	--
(d1)	all lags	PUB(-3)	all lags	--	--	--
(d2)	all lags	PUB(-3)	max 5 lags	--	--	--
(e)	all lags	PUB(-3)	PRIV(-3)	all lags	--	--
(f)	all lags	all lags	all lags	--	--	--

(23)

As a reference case, a fixed effects estimation was effected in a specification with the variables in levels (case (a1)), which contains no instruments. Specification (a2) is an AH estimator and uses lags t-2 as instruments, specifications (b) to (f) are for estimation with GMM 1 and use instruments at various lag lengths. Note that instruments are always in levels. For our purpose, this feature of the estimation procedure is rather convenient since the levels of variables, which determine the whole growth path, enter into the estimation.

For estimation, a Gauss programme written by Arellano and Bond, kindly provided to the authors, was used. Standard econometric software does not provide the option for GMM estimation with panel data.

6. Results

Table 1 shows the results of the estimations according to the specifications indicated in (23). Column (a1) shows the results from a fixed effects estimation with the variables in levels, the commonly applied estimation method if using panel data methods in growth regressions. As explained before, the LSDV estimator is no consistent estimator in this context. (The high R^2 value of 0.95 misleading in this case. One can note that particularly the coefficient of potentially endogenous variables as public and private investment is much lower than in the other specifications and insignificant.

The other results (columns (a2) - (f)), refer to the estimation of the model in first differences and variables in levels as instruments. In the GMM specification the full number of past levels of the variables is used as instruments. In general, the results of the estimation must be interpreted economically such that the estimated parameters show the effect of private/public investment, or enrolment in education, on per capita income. Note that the transformation of the model in differences is only a technical procedure in the estimation process. The estimated parameters still refer to the relationship stated in the original model, i.e. they show the relation between investment and income e.g. Therefore one can also directly compare the estimated parameters of the fixed effects estimation done with the variables in levels and those of the AH or GMM estimation in differences.

In summary, the GMM estimates yield the following results: All results indicate that a region´s per capita income position is determined to a very large extent by its past income position. In all specifications the coefficient on lagged income lies around 0.60. Further, per capita income is always positively related with the rate of participation, with a coefficient in the range of 0.30-0.46. Among the set of growth factors considered, enrolment in secondary education has a significant and robust positive impact on per capita income levels. The coefficient ranges from around 0.2 to over 0.3. The impact of the two investment categories is quite different. Both coefficients are positive, however, that of public investment is 3-5 times as large as that of private investment, and only the coefficient of public investment can be accepted as sufficiently significant. It ranges between 0.3-0.45. The insignificant coefficient of private investment is between 0.02-0.09. The significance of agricultural employment changes between specifications. Income is negatively related to agricultural employment by a factor of around 0.2.

The results of the specification tests are reported at the bottom of the columns with the coefficient estimates. The values of the *m2* test statistic for second order serial correlation are below the critical value (1.96 for 5%, and 2.58 for 1%) in each specification. This indicates that the estimation errors are indeed i.i.d., hence GMM1 is an optimal, consistent estimator in our context.

From the Wald test statistics we can conclude that all explanatory variables are significant. Wald tests for the significance of time and country dummies were also effected and showed that their inclusion is highly relevant. Finally, the Sargan test statistics indicate that we have included appropriate instruments. Note that with instrumental variable estimation the usual concept of the coefficient of determination R^2 is not applicable.

The table of results shows that the significance of coefficients increases if moving away from the Anderson-Hsiao estimator to GMM estimation. In columns (c), (d) and (e) a restricted GMM estimator is used where in addition to GDP all lags for the variable public investment (c1), private investment (d1), and education (e) are used. Using all lags improves the significance of coefficients on past income, public investment and private investment in relation to the results of the AH-estimation. The standard error of coefficients is much smaller.

The different specification of instruments in both estimators, the AH estimator uses the variable with value t-2, the GMM with value t-3 changes distinctly the coefficient of public and private investment. One could say that closer investment rates as in the AH-estimator have a higher impact on income levels. On the other hand, it is arguable that t-2 is not an appropriate instrument for the variable in differences (t-1 - t-2) as there would still remain some endogeneity. Hence, the results of column (b) provide a less biased estimate for the impact of investment rates. The positive contribution of *public* investment is in line with the results of the exploratory analysis, where cointegration tests showed a positive relation, and the cross-section evidence, in most cases, indicated higher growth when public investment was high in a region. Since the relationship of income with public investment goes back for years, the coefficient becomes more significant with a GMM estimator using all lags. Moreover, as all public investment over a long period is considered in the instrument matrix, the variable becomes a good indicator for the public capital stock, and a capital stock should be positively related with income. The coefficient of *private* investment is positive, but it is significantly lower than that of public investment. From the first cross-section analysis we had expected a positive relation. The smaller size of the coefficient was also discernible from the cross-section evidence. One can explain the low significance of the estimated coefficient in the panel in recalling the results from the cointegration tests.

It is somewhat puzzling that the impact of private investment on income should be much smaller than that of public investment. One interpretation could be that public capital is still relatively scarce in Southern regions. Any additional investment has a high rate of return. In contrast, there could be already abundant private capital - consider e.g. the artificially high investment rates in the South of Italy over a considerable period - which yields a relatively low rate of return and reveals dynamics of neoclassical growth.

With education, significance does not improve if taking instruments - in the GMM procedure all lags. Our educational measure, which takes the past years enrolment average, seems to be a quite good measure for human capital, that rules out endogeneity.

Table 1: Determinants of regional per capita income
Results from a panel data model

Dependent variable: LGDP
Time period: 1978-92
No. of regions: 40 (535 observations)

	fixed effects (a1)		**AH (a2)**		**GMM (b)**		**GMM (c1)**		**GMM (c2)**	
regressors										
LGDP(-1)	**0.79**	45.1	**0.567**	3.2	**0.606**	12.9	**0.620**	17.8	**0.587**	15.7
	(0.017)		(0.176)		(0.046)		(0.034)		(0.037)	
PUB(-1)	**0.022**	0.25	**0.621**	0.8	**0.474**	1.7	**0.318**	1.6	**0.254**	1.1
	(0.091)		(0.722)		(0.279)		(0.194)		(0.224)	
PRIV(-1)	**-0.03**	0.74	**0.171**	1.5	**0.024**	0.26	**0.057**	0.6	**0.062**	0.7
	(0.035)		(0.110)		(0.092)		(0.086)		(0.092)	
EDU	**0.25**	7.88	**0.500**	4.7	**0.300**	3.3	**0.372**	3.7	**0.356**	3.0
	(0.032)				(0.091)		(0.098)		(0.117)	
AGRI(-1)	**-0.07**	1.62	**-0.091**	0.5	**-0.205**	1.6	**-0.273**	2.8	**-0.287**	2.3
	(0.047)		(0.181)		(0.129)		(0.096)		(0.124)	
PARTI	**0.18**	3.31	**0.385**	2.5	**0.465**	3.6	**0.346**	2.9	**0.412**	3.3
	(0.057)		(0.151)		(0.128)		(0.117)		(0.123)	
m2			-1.723		-1.701		-1.755		-1.794	
Wald test			114 (6)		408 (6)		565 (6)		478 (6)	
Sargan test					191	(134)	347	(268)	312	(202)

	GMM (d1)		**GMM (d2)**		**GMM (e)**		**GMM (f)**	
regressors								
LGDP(-1)	**0.661**	16.8	**0.604**	15.9	**0.645**	16.1	**0.655**	22.9
	(0.039)		(0.037)		(0.040)		(0.028)	
PUB(-1)	**0.451**	2.0	**0.344**	1.6	**0.389**	1.7	**0.293**	1.7
	(0.226)		(0.217)		(0.222)		(0.168)	
PRIV(-1)	**0.093**	1.3	**0.079**	1.0	**0.049**	0.6	**0.089**	1.3
	(0.073)		(0.078)		(0.076)		(0.067)	
EDU	**0.187**	2.2	**0.239**	2.6	**0.191**	1.9	**0.187**	2.2
	(0.086)		(0.091)		(0.102)		(0.085)	
AGRI(-1)	**-0.094**	0.8	**-0.148**	1.2	**-0.121**	1.3	**-0.193**	2.4
	(0.116)		(0.122)		(0.096)		(0.080)	
PARTI	**0.328**	2.4	**0.426**	3.0	**0.404**	4.0	**0.300**	2.3
	(0.137)		(0.140)		(0.101)		(0.126)	
m2	-1.694		-1.736		-1.684		-1.756	
Wald test	790 (6)		510 (6)		524 (6)		822 (6)	
Sargan test	337	(268)	285	(202)	324	(283)	432	(360)

Notes to table 1:

Estimation is effected with the variables in first differences and with instruments in levels, except for fixed effects estimation. GMM refers to one-step, restricted GMM estimation as specified before. AH refers to the Anderson-Hsiao estimation procedure, instruments used are the variable values for t-2 in levels. The estimations include time dummies and country dummies of which the coefficients are not reported.

EDU indicates average enrolment in upper secondary education in period t-5 to t-1.

Standard errors robust to serial correlation are reported in parenthesis, t-values to the right of the coefficient. Test statistics : The Sargan test is a statistic for instrument validity. The m2 test statistic is a test for the lack of second-order serial correlation of the errors (Arellano/Bond 1991: 282). Wald test is for joint significance of variables. With the Sargan test and the Wald test, degrees of freedom are indicated in parenthesis.

Finally in column (f) the results of our preferred estimate is reported. Here income and investments are instrumented with all lags, for the other variables no instruments are taken. Following these results, per capita income in the periphery is strongly determined by a region´s past income. Education and public capital are important factors determining the income level. In lower income regions in the periphery, agricultural restructuring has not yet taken place. Richer regions in the periphery have a high participation rate (labour does not show decreasing returns in the periphery). One can follow that a lower participation in the form of high unemployment coincides with a lower per capita income growth.

From the coefficient of per capita income one can recover the convergence coefficient β (see equation (9)). The implied speed of convergence is 18 percent per annum. It indicates that peripheral regions converge towards their individual steady state incomes at a rate of 18 percent. Canova and Marcet (1995) found a very similar rate of convergence. It means that a region is fairly close to its steady state income and would reach it in about 3 years if growth factors did not change.

Our results of the impact of private investment suggest that this factor is no essential variable in the growth process of Europe´s peripheral regions, as we find no significant coefficient for the investment rate. However, - if any - investment rather has a positive contribution. This result is similar to the conclusion of Bacchetta (1994), who found a weak, but positive relationship for investment and growth for regions of 6 EU countries (among them Spain). Bacchetta reported a coefficient of investment of 0.09 (t-value 0.97). On the other hand, Paci and Pigliaru (1995: 12) showed that investment was negatively, but not significantly related with Italian region´s growth. Their estimated coefficient obtained in an OLS regression for 20 Italian regions for the period 1970-89 was -0.01 (t-value -0.34). Consequently, we can conclude from our estimates that for Europe´s peripheral regions, in general, private investment has a weak, but positive impact on growth, but investment rates artificially boosted by generous incentives had obviously no big impact on growth.

Further, the results show a relatively high, positive impact of public investment in the growth process. These findings are similar to those of Aschauer (1989), whenever of a much smaller order. Aschauer found that the impact of public capital in the production function reached 0.39 percent and hence was higher than that of private investment. Munnell (1990) found an equally high impact of public capital on output productivity growth. Aschauer´s results were not uncritisized, in particular he did not account for the endogeneity of public capital and did not consider the non-stationarity of time series.

It is interesting to investigate the reasons of the high contribution of public investment further. Evidently, public investment boosts income in the less developed regions of the EU. However, it does so because it becomes an important prerequisite and stimulus for private investment. Another set of cointegration tests (not reported), which look at the relation between public investment and private investment, shows that both factors are positively related in the majority of regions. (In theory, one could have also observed a crowding out of private investment by public.) Therefore, public investment must be considered as an important complement for private capital accumulation in the less developed regions of the EU.

With respect to human capital, our results confirm the perception of its importance found in the literature. Our estimates are in a very similar order to those of de la Fuente (1996b), who estimated that human capital (defined as percent of employed persons who received secondary education) had a positive and significant impact on the growth of Spanish regions in the period 1964-91. His coefficient of human capital ranges between 0.15-0.18. According to our estimation, that relation is valid for the peripheral regions in general.

It is noteworthy that, according to our estimation, in the EU objective 1 regions both education and a high degree of employment are the most important and significant factors determining income. This is a clear indicator that structural policies must focus on the human factor in a broad sense.

7. Conclusions

This paper has shown that the EU´s peripheral regions are quite differently endowed with the typical growth factors, public and private capital, and educational attainments. Given that these regions are subject to a common regional development strategy under the EU´s objective 1 policy, it is a clear deficit that so far no empirical studies investigated the growth factors of that group of regions.

The assessment of their impact requires an appropriate econometric framework, which on the one hand accounts for an unobservable region-specific long-term growth determinant and, on the other hand, for the endogeneity of factors explaining growth. In general, these requirements are not met by estimation methods applied in empirical growth studies. A GMM estimation procedure accounts for these problems and turns out to deliver more significant and more efficient estimates than alternative estimators.

The results show that commonly a region is for a long time haunted by its past development gap. Present development gaps show a strong coincidence with weak past incomes. Next, it clearly matters if a region has a high unemployment level and poor education standards. Both reduce potential income levels. Surprisingly, there is a positive impact of public investment on income, which is three times as high as that of private investment. In addition, the latter shows a low level of significance. One explanation could be that since there is commonly insufficient public capital in poor regions, public investment has a fairly high rate of return. On the other hand, the weak impact of private investment may partly reflect its abundance due to high investment aids and its inefficient allocation. However, investment series also show a high degree of fluctuation, which explains the low significance of private investment. Finally, the negative impact of a high employment in agriculture shows that regions, which have not diversified into non-traditional activities, will not be in a position to develop.

At present, EU regional policy in objective 1 regions highly emphasized private investment aids (30-40% of structural funds allocations; an equivalent share is spent on infrastructure), while relatively few resources are spent in employment and education policies (20% of structural funds). In contrast, our results suggest that policies which focus on the human factor (employment, education), should receive highest priority. With respect to the intensive financing of infrastructures and rising critical voices, our results show that spending is highly justified, the more since it acts as a complement to private investment, as we could show. With respect to the Community´s long tradition to provide generous investment aid in less developed areas, we think that it is overdue to cut excessive levels of investment assistance as it only creates artificially high investment, which is not efficiently allocated. Nevertheless, there will remain a few poor, disadvantaged regions with insufficient private capital without investment aid. A well-designed mix of regional policies is the essential investment into a region´s future development.

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Annex

Table I -III

Table I: Cointegration test: Regional GVA p.c. and public investment share

PUB = regional public investment as share of GVA, series GVA p.c. taken in logarithms.
Columns 1 and 2 indicate the order of integration of the series which results from ADF unit root tests.
Cointegration tests according to Engle/ Granger (1987). ** coefficient not significant, *significant only at 10%.

	order of integration of variables		**estimated cointegration equation GVA p.c. = a + *r* PUB**		stationarity of residuals: results of ADF test on residuals
region code	GVA p.c.	PUB	**a**	***r***	
Spain					
es11	I(1)	I(1)	8.10	9.55	I(0)
es12	I(1)	I(1)	8.40	6.65	I(0)
es13	I(1)	I(1)	8.57	3.67	I(1)
es21	I(1)	I(1)	8.66	7.78	I(0)
es22	I(1)	I(1)		**	
es23	I(1)	I(1)	9.02	-1.26	I(1)
es24	I(1)	I(1)		**	
es3	I(1)	I(1)	8.53	24.34	I(0)
es41	I(1)	I(0)	8.29	6.83	I(1)
es42	I(1)	I(1)	8.13	7.36	I(0)
es43	I(1)	I(1)	7.82	6.42	I(0)
es51	I(1)	I(1)	8.40	15.9	I(0)
es52	I(1)	I(1)	8.42	8.56	I(0)
es53	I(1)	I(1)	8.49	14.06	I(1)
es61	I(1)	I(1)	8.14	6.22	I(0)
es62	I(1)	I(1)	8.50	4.49	I(0)
es7	I(1)	I(0)		**	
Greece					
gr11	I(1)	I(1)	7.98	2.05**	I(0)
gr12	I(1)	I(0)	8.36	-1.96**	I(1)
gr13	I(1)	I(1)	8.00	0.81	I(1)
gr14	I(1)	I(1)	7.93	4.95	I(0)
gr21	I(1)	I(1)	7.85	0.93**	I(0)
gr22	I(1)	I(1)	7.92	4.09	I(0)
gr23	I(1)	I(1)	8.17	-1.20*	I(0)
gr24	I(1)	I(1)	8.44	0.79**	I(0)
gr25	I(1)	I(1)	8.19	0.70**	I(0)
gr3	I(1)	I(0)	8.22	3.23*	I(1)
gr41	I(1)	I(1)	7.71	2.81	I(0)
gr42	I(1)	I(1)	7.75	9.07	I(0)
gr43	I(1)	I(1)	7.61	9.01	I(0)
Mezzogiorno					
itabr	I(1)	I(1)	9.40	-21.07	I(0)
itmol	I(1)	I(1)	9.33	-16.84	I(0)
itcam	I(1)	I(0)	8.86	-6.94**	I(1)
itpul	I(1)	I(1)	9.09	-19.09	I(0)
itbas	I(1)	I(1)	8.95	-5.60	I(0)
itcal	I(1)	I(1)	8.44	4.64**	I(1)
itsic	I(1)	I(1)	9.08	-17.06*	I(1)
itsar	I(1)	I(0)	8.89	-2.22**	I(1)

Table II: Cointegration test: Regional GVA p.c. and private investment share

PRIV = regional private investment as share of GVA, series GVA p.c. taken in logarithms.
Columns 1 and 2 indicate the order of integration of the series which results from ADF unit root tests.
Cointegration tests according to Engle/ Granger (1987). ** coefficient not significant, * significant only at 5 %.

	order of integration of variables		**estimated cointegration equation GVA p.c. = a + q PRIV**		stationarity of residuals: results of ADF test on residuals
region code	GVA p.c.	PUB	**a**	**q**	
Spain					
es11	I(1)	I(1)	8.84	-2.27*	I(0)
es12	I(1)	I(1)	8.57	0.27**	I(1)
es13	I(1)	I(1)	8.71	-0.12**	I(1)
es21	I(1)	I(1)			
es22	I(1)	I(1)	9.03	-0.64**	I(1)
es23	I(1)	I(1)	8.48	2.34	I(1)
es24	I(1)	I(1)	9.30	-2.00	I(1)
es3	I(1)	I(1)	8.66	1.55	I(1)
es41	I(1)	I(0)	8.78	-1.05**	I(1)
es42	I(1)	I(1)	8.66	-0.80**	I(1)
es43	I(1)	I(1)	8.48	-1.29	I(1)
es51	I(1)	I(1)	8.56	1.72**	I(1)
es52	I(1)	I(1)	8.56	0.48**	I(1)
es53	I(1)	I(1)	8.85	-0.25**	I(1)
es61	I(1)	I(1)	8.30	0.45**	I(1)
es62	I(1)	I(1)	8.31	1.77	I(1)
es7	I(1)	I(1)	8.37	0.92**	I(1)
Greece					
gr11	I(1)	I(0)	8.45	-1.23	I(0)
gr12	I(1)	I(1)	8.50	-1.48*	I(0)
gr13	I(1)	I(1)	8.50	-2.04	I(0)
gr14	I(1)	I(0)	8.33	-0.89**	I(1)
gr21	I(1)	I(1)	8.02	-0.14**	I(1)
gr22	I(1)	I(0)	8.20	-0.06**	I(1)
gr23	I(1)	I(1)	8.10	0.09**	I(1)
gr24	I(1)	I(0)	8.47	0.17**	I(1)
gr25	I(1)	I(0)	8.25	0.03**	I(1)
gr3	I(1)	I(0)	8.33	0.27**	I(1)
gr41	I(1)	I(0)	8.00	-0.13**	I(1)
gr42	I(1)	I(1)	8.71	-2.31	I(1)
gr43	I(1)	I(0)	8.46	-1.71	I(1)
Mezzogiorno					
itabr	I(1)	I(1)	10.13	-4.55	I(0)
itmol	I(1)	I(1)	9.25	-1.43	I(1)
itcam	I(1)	I(1)	10.14	-5.14	I(0)
itpul	I(1)	I(1)	9.61	-3.65	I(0)
itbas	I(1)	I(1)	8.94	-0.76	I(0)
itcal	I(1)	I(1)	9.27	-2.37	I(0)
itsic	I(1)	I(1)	9.71	-3.91	I(0)
itsar	I(1)	I(1)	9.31	-1.51	I(0)

Table III: Cointegration test: Regional GVA p.c. and education

EDU = enrolment in upper secondary education as share of age group 15-19, series GVA p.c. taken in logarithms. Columns 1 and 2 indicate the order of integration of the series which results from ADF unit root tests. Cointegration tests according to Engle/ Granger (1987). ** coefficient not significant.

	order of integration of variables		**estimated cointegration equation GVA p.c. = a + e EDU**		stationarity of residuals: results of ADF test on residuals
region code	GVA p.c.	EDU	**a**	**e**	
Spain					
es11	I(1)	I(1)	8.04	0.75	I(0)
es12	I(1)	I(1)	8.14	0.68	I(0)
es13	I(1)	I(1)	8.45	0.38	I(0)
es21	I(1)	I(1)	8.43	0.74	I(0)
es22	I(1)	I(1)	8.54	0.57	I(0)
es23	I(1)	I(1)	8.18	1.09	I(0)
es24	I(1)	I(1)	8.15	0.93	I(0)
es3	I(1)	I(1)	8.45	0.62	I(0)
es41	I(1)	I(1)	8.16	0.66	I(0)
es42	I(1)	I(1)	7.87	1.40	I(0)
es43	I(1)	I(1)	7.46	1.73	I(0)
es51	I(1)	I(1)	8.34	0.82	I(0)
es52	I(1)	I(1)	8.27	0.78	I(0)
es53	I(1)	I(1)	7.84	1.99	I(0)
es61	I(1)	I(1)	8.02	0.80	I(0)
es62	I(1)	I(1)	8.40	0.50	I(0)
es7	I(1)	I(1)	7.98	1.14	I(0)
Greece					
gr11	I(1)	I(1)	6.97	4.42	I(0)
gr12	I(1)	I(1)	7.58	2.21	I(0)
gr13	I(1)	I(1)	7.53	2.41	I(0)
gr14	I(1)	I(1)	7.87	0.78**	I(1)
gr21	I(1)	I(1)	7.26	1.95	I(0)
gr22	I(1)	I(1)	6.68	4.30	I(0)
gr23	I(1)	I(1)	8.04	0.20**	I(1)
gr24	I(1)	I(1)	8.16	1.02**	I(1)
gr25	I(1)	I(1)	7.89	1.01**	I(1)
gr3	I(1)	I(1)	7.99	0.95	I(0)
gr41	I(1)	I(1)	7.41	1.49**	I(1)
gr42	I(1)	I(1)	7.00	5.18	I(0)
gr43	I(1)	I(1)	1.71	-0.52**	I(1)
Mezzogiorno					
itabr	I(1)	I(1)	7.95	1.64	I(0)
itmol	I(1)	I(1)	7.86	1.60	I(0)
itcam	I(1)	I(1)	7.84	1.81	I(0)
itpul	I(1)	I(1)	7.99	1.64	I(0)
itbas	I(1)	I(1)	8.22	0.79	I(0)
itcal	I(1)	I(1)	7.86	1.38	I(0)
itsic	I(1)	I(1)	7.92	1.68	I(0)
itsar	I(1)	I(1)	8.32	0.96	I(0)