7. The role of human capital in economic growth: evidence from Greek regions*

Nikos Benos and Stelios Karagiannis

7.1. INTRODUCTION

Human capital theory argues that there are positive educational externalities: that is, benefits of individually-acquired education are not restricted to the individual but spill over to higher levels of aggregation in the same industry, city, region or the macroeconomy as a whole. These externalities provide the economic justification for public funding of education.[1]

In the recent literature, attempts have been made to empirically test the relationship between human capital and economic growth, usually employing cross-sectional country data. These studies use measures of formal education as proxies for human capital, since investment in education plays a central role in human capital accumulation. They provide contrasting results regarding the impact of human capital on growth: effects are found to be positive, statistically insignificant or even negative in some cases (Pritchett, 2001; Barro and Sala-i-Martin, 2004).

The main cause of these puzzling results is probably that most studies use international data sets, but incorrectly impose equal returns to schooling (single coefficients) among sample countries (Temple, 1999; Krueger and Lindahl, 2001; Di Liberto, 2007). This problem arises when education quality is affected by educational institutions, which often differ across countries. In this context, one explanation for the estimated low returns to education in international data sets is that national statistics are dissimilar. Moreover, returns to education tend to be higher in countries with a better-educated labour force, as predicted by some growth models (Azariadis and Drazen, 1990). Another issue appears to be that acquisition of educational skills is not linked with productivity in some cases – that is, education is not only an investment but also a consumption good for the individual. Finally, in many countries (especially those which are less developed), the public sector employs most of the skilled labour force: this creates distortions in the estimation of returns to schooling, owing to measurement problems of public sector output, inefficiency and lack of innovative activities in this sector (Griliches, 1997).

In this paper, our objective is to estimate the impact of human capital on regional economic growth in Greece, and analyse the implications for economic policy. In order to control for the problems described above, we focus on a fairly homogeneous data set, which at the same time is relatively diverse in terms of human capital characteristics of the various regions. Furthermore, Greek regions are characterised by common institutions and, especially a homogeneous educational system.

Our approach features several important contributions. First, this study represents, to the best of our knowledge, the first attempt to provide a comprehensive set of estimates of the impact of human capital dynamics on growth of Greek regions (NUTS III level) for a fairly long period (1981–2003). Secondly, we define human capital more broadly than most of the literature, using various measures of education as well as healthcare. Thirdly, we investigate systematic growth differences between regions, which vary in terms of income level and location. Recent studies emphasise the presence of two income clubs in Greece based on: (a) access to the main transportation network (mostly the Athens-Thessaloniki highway), and (b) the highly developed tourist industry on the islands (Christopoulos, 2004; Prodromidis, 2006; Benos and Karagiannis, 2008). These two clubs are characterised by identical educational institutions together with significant differences in enrolment rates. This way, we allow for heterogeneity of the effect of human capital on growth across the two regional groups. Finally, we allow for human capital spillovers between neighbouring regions.

Our analysis is carried out using Random Effects (RE) and enhanced GMM (Arellano and Bond, 1991) estimators in order to handle endogeneity and unobserved heterogeneity problems. We find that the number of students in lower and upper secondary education levels affects growth positively. Additionally, a higher student/teacher ratio inhibits growth and the number of medical doctors fosters growth. Besides these, there is strong evidence of differential effects of the human capital variables between rich and poor regions. Finally, there are important human capital externalities across neighbouring regions.

The paper is organised as follows. In Section 7.2, we present a review of the theoretical and empirical literature on human capital and growth. Section 7.3 describes the data, while Section 7.4 presents the econometric framework and methodology. In Section 7.5, estimation results are analysed, while Section 7.6 offers policy considerations and concluding comments. An Appendix contains detailed information on our data and empirical results.

7.2. LITERATURE REVIEW

The theoretical literature on the relationship between human capital and economic growth provides different models. In the first group of models, growth is sustained by human capital accumulation – that is, human capital is a factor of production and its accumulation influences the growth process. In this type of model, human capital is a flow variable (Lucas, 1988). In the second category, economic growth depends on the existing human capital stock, which generates new knowledge (Romer, 1990) or facilitates the imitation and adoption of foreign technologies (Nelson and Phelps, 1966). In the third class of models, human capital is a threshold variable – that is, the impact of human capital depends on the human capital stock accumulated within a given time period (Azariadis and Drazen, 1990). Thus human capital matters as a stock and flow variable, because its accumulation is necessary to achieve the stock level, above which the impact of human capital strengthens. One implication of these models is the existence of multiple equilibria in the growth path, since the growth path comprises various phases.

Regarding empirics, the investigation of the growth impact of human capital uses measures of formal education, such as adult literacy rates, school enrolment rates and average years of schooling, as proxies for human capital. This follows from the fact that investment in education is central to human capital accumulation and can be measured more easily than other elements, such as on-the-job training, experience and learning-by-doing.

In one of the early studies that examined the role of human capital on growth, Barro (1991) found that primary and secondary enrolment rates have a positive growth effect, but this was not always true for adult literacy rates. Mankiw et al. (1992) estimated an elasticity of output of about one-third with respect to the average percentage of the working-age population in secondary school. Benhabib and Spiegel (1994) found that the human capital flow did not have a statistically significant growth effect, while the average stock had a positive, though not always significant, growth impact. Durlauf and Johnson (1995) identified different growth regimes for groups of countries characterised by different initial GDP per capita and human capital levels supporting models with multiple equilibria.

More recently, De la Fuente and Domenech (2000) and Bassanini and Scarpetta (2001) estimated a positive effect of schooling years on growth. Bils and Klenow (2000) concluded that initial enrolment rates explain less than one third of the variation in growth rates and half of this is due to the fact that anticipated increases in growth raise schooling. Pritchett (2001) estimated a negative growth impact of human capital growth. However, Krueger and Lindahl (2001) showed that higher education attainment has a positive effect on economic growth once measurement errors are taken into account. Also, they showed that linearity and parameter homogeneity are rejected by the data. Kalaitzidakis et al. (2001) found non-linear effects of human capital on growth. Papageorgiou (2003) concluded that the role of human capital in the creation and adoption of technology increases with country income. In a review of the empirical literature, Sianesi and Van Reenen (2002) pointed out that education implies indirect growth benefits in terms of physical capital, technology transfer, fertility and other dimensions of human capital (e.g. life expectancy, infant mortality).

Furthermore, some research has recently concentrated on the impact of human capital on regional growth. The idea is that knowledge produces spillovers: that is, firms learn from other firms and people get ideas from other people. Thus in regions with a high concentration of, and/or accessibility to, human capital, such as large cities, ideas disseminate quickly and human capital externalities are more likely to arise. Knowledge flows between different localities and regions imply spatial dependence among adjacent regions, which diminishes with distance (Grasjo, 2005; Andersson and Karlsson, 2007).

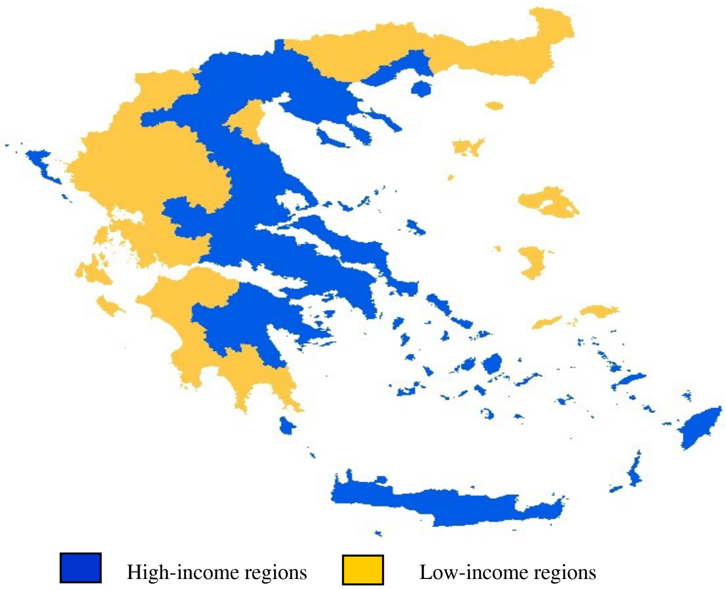
Finally, a number of recent papers examine the field of health as a human capital component, although several pioneering studies go back a few decades (Mushkin, 1962; Becker, 1964; Fuchs, 1966). In particular, health in the form of life expectancy has appeared in a number of cross-country empirics, which confirm the positive effect on the rate of growth (see Bloom and Canning, 2000, 2003). In addition, several papers include health indicators in growth regressions in an effort to incorporate direct or indirect effects on economic growth (see Barro and Lee, 1994; Barro and Sala-i-Martin, 1995; Barro, 1996; Caselli et al. 1996, Bloom and Sachs, 1998; Bloom and Williamson, 1998; Bloom et al., 1999).

7.3. DESCRIPTION OF THE DATA

We start our analysis with a brief description of the main regional educational and healthcare data used.[2] Our data include the number of students attending the two levels of secondary education[3] (upper and lower) together with the respective number of teachers at both levels.[4] Using these, we were able to construct the student/teacher ratio for the two levels of education. In addition, we include two healthcare indicators, namely the number of medical doctors and hospital beds available per region. All our variables span from 1981 through 2003 and cover the 51 regions of Greece (NUTS III level).

Figure 7.1 presents the division of the 51 NUTS III Greek regions into two sub-groups, according to whether their average GDP per capita for 1981-2003 lies above or below the median. Tables 7A.3 and 7A.4[5] provide the descriptive statistics of our variables based on the division of our sample into high- and low-income regions.

According to our calculations, there are numerous income, education and healthcare disparities among the Greek regions. High-income regions enjoy higher levels of per capita GDP when compared to low ones (the means are 10,835 and 7,968 Euros respectively, over the period studied). They are characterised by different numbers of students attending lower secondary education (the means are around 591 and 584 students per 1000 of the relevant age group, respectively). On the other hand, low-income regions exhibit a greater proportion of students attending the upper level of education than high-income regions. Overall, participation rates[6] in the two levels of secondary education in Greece differ substantially across regions as well as through time. Our data reveal that rural regions present lower enrolment rates compared with urban ones.[7] The above findings are in line with previous studies specialised in this field of work.[8] Also, participation rates improved



Source: Our elaborations based on sources mentioned in Table 7A.1.

Figure 7.1. High- and low-income regions (NUTS III) in Greece (average GDP pc, 1981–2003)

during the period examined – especially in upper secondary education (from 35 per cent in 1981-94 to 60 per cent in the 1995–2003 period).

Healthcare variables reveal a greater inequality between the two sub-samples. The number of available hospital beds and, to a lesser extent, the number of medical doctors are greater in high-income than low-income regions (4.05 to 3.10 per 1000 people and 2.40 to 2.03 per 1000 people, respectively). Finally, public investment at regional level is included in our regressions in order to disentangle the effect of physical capital from the effect of human capital on growth (see Krueger and Lindahl, 2001).[9] We believe this is a good proxy for total investment at regional level. This is so, because public and private capital tend to behave similarly in Greek regions (Louri, 1989). Specifically, our proxy is based on the actual investment included in state budget expenditures at regional level[10]. As evident from the descriptive statistics, the regional allocation of public investment in Greece presents disparities across high-/low-income regions (2.3 per cent and 2.5 per cent respectively) as well as throughout the period examined (2.2 per cent of regional GDP for the 1981–91 period to 2.5 per cent for 1992–2003).[11]

7.4. THEORETICAL FRAMEWORK AND EMPIRICAL MODEL

As human capital is multidimensional (Bloom et al., 2004), we need a model of growth that includes its major components. While most studies identify human capital narrowly with education, they do not consider health to be a crucial aspect of human capital, and therefore a critical ingredient of economic growth. In particular, the population's health impinges on growth through productive efficiency, life expectancy, learning capacity, creativity, coping skills and inequality (Howitt, 2005). Also, an increase in survivorship raises the returns from education because educational costs come at earlier ages and returns at later ages (see Becker, 1964 and 1993; Meltzer, 1992; Ehrlich, 2000). In this paper we consider both education and health in the formation of human capital as complementarities exist between its different forms (Becker, 2007).

We study the role of human capital in the growth process, using the framework suggested (among others) by Mankiw et al. (1992), de la Fuente (2002), Bloom et al. (2004), Barro and Sala-i-Martin (2004). Thus, we specify an empirical model by augmenting a standard aggregate production function with a technological progress function. In this framework, we allow for regional fixed effects.

We therefore assume a Cobb–Douglas aggregate production function

$$Y_{it} = K_{Git}^{\theta_{KG}} \left(A_{it} L_{it}\right)^{\theta_l} S_{it}^{\theta_s} H_{it}^{\theta_h} \tag{7.1}$$

where Y_{it} denotes total output of region i ($i = 1, \ldots, 51$) during period t ($t = 1981, \ldots, 2003$), K_{Git} the public stock of physical capital, L_{it} is employment, S_{it} the stock of educational human capital, H_{it} is the stock of health human capital, and A_{it} a (labour-augmenting) TFP indicator. Also, we assume $\theta_{KG} + \theta_l + \theta_s + \theta_h = 1$, so we have a Solow-type model. Thus, we take a broader view of human capital than most of the literature by including education and health in the production function of our economies. Both forms of human capital are seen as production factors, the accumulation of which affects growth, i.e. human capital is a flow variable (Lucas, 1988). However, we allow for differential impact of the two components of human capital (education, heath) on output, hence on economic growth. Finally, incorporating A_{it}, we allow for permanent differences in the production functions of the various regions. The introduction of human capital in a broad sense, along with differential technical progress between regions, gives us the ability to obtain more accurate estimates of the model's parameters.

Now, equation (7.1) in per capita terms takes the form

$$\frac{Y_{it}}{L_{it}} = K_{Git}^{\theta_{KG}} A_{it}^{\theta_l} L_{it}^{\theta_l - 1} S_{it}^{\theta_s} H_{it}^{\theta_h} \tag{7.2}$$

Taking logs of (7.2)

$$\ln\left(\frac{Y_{it}}{L_{it}}\right) = \theta_{KG} \ln K_{Git} + \theta_l \ln A_{it} + \left(\theta_l - 1\right) \ln L_{it} + \theta_s \ln S_{it} + \theta_h \ln H_{it} \tag{7.3}$$

and then time differences, we get

$$\Delta\ln\left(\frac{Y_{it}}{L_{it}}\right) = \theta_{KG} \Delta\ln K_{Git} + \theta_l \Delta\ln A_{it} + \left(\theta_l - 1\right) \Delta\ln L_{it} + \theta_s \Delta\ln S_{it} + \theta_h \Delta\ln H_{it} \tag{7.4}$$

Before we estimate (7.4), we must specify the TFP growth term $\Delta\ln A_{it}$. We assume that the regional TFP variable (measured in logs) is the sum of two components:

$$\ln A_{it} = r_i + b_t \tag{7.5}$$

where r_i is a regional fixed effect, which captures regional features that affect productivity and are constant over time (e.g. location, climate etc.), and b_t is nationwide technical progress, which evolves at a constant rate g:

$$\Delta b_t = g \tag{7.6}$$

Thus, human capital does not influence technical progress. Therefore, the rate of change of regional TFP is:

$$\Delta \ln A_{it} = \Delta r_i + g \tag{7.7}$$

and after substitution of (7.7) and some rearrangements, equation (7.4) becomes

$$\Delta \ln\left(\frac{Y_{it}}{L_{it}}\right) = \theta_s \Delta \ln S_{it} + \theta_h \Delta \ln H_{it} + \theta_{KG} \Delta \ln K_{Git} + (\theta_l - 1)\Delta \ln L_{it} + \theta_l \Delta r_i + \theta_l g \tag{7.8}$$

Since we estimate a Solow-type model, we include initial GDP per capita in the empirical counterpart of (7.8) in order to control for convergence effects on growth. We expect the education, health and public investment parameters to be positive, while the labour force parameter should be negative.

Real per capita growth is thus related to an array of control variables, region-specific effects and technological progress effects common to all regions. For the first two terms, we use several human capital indicators and since it is generally accepted that human capital affects growth with time lags, we use lagged values of these indicators (Di Liberto, 2004, 2007; Midendorf, 2006).[12]

These indicators include the following: a) students at lower secondary education level; b) students at higher secondary education level; c) medical doctors; d) hospital beds.[13] The first two variables measure schooling and the other two capture the impact of health on growth (Malik, 2006; Ricci and Zachariadis, 2007). Additionally, we use the student-teacher ratio in the two levels of education as a measure of the quality of education provision. We also employ public investment per region regarding the third term in (7.8). Furthermore, we proxy employment growth by population growth in (7.8), because there are no available data on the former. Finally, following Andersson and Karlsson (2007) and Grasjo (2005) we include two variables in order to explore the possibility of spatial externalities in terms of human capital (see Section 7.5.3).

Regarding estimation methodology, OLS assume that the error in each time period is uncorrelated with the explanatory variables in the same period. However, a primary motivation for using panel data is to solve the problem of omitted variables, which are effectively part of the error term and cause bias in the coefficient estimates. In light of that, in the first part of our estimations, we assume that there is a time-constant unobserved effect, which we treat as a random variable drawn from a population together with the observed dependent and explanatory variables. The unobserved effect may represent region-specific technology, tastes, historical and cultural factors.

These characteristics are assumed to be correlated over time but uncorrelated with the observed explanatory variables, which is critical for the consistency of our estimates. We proceed with random effects estimation, which exploits the serial correlation in the error, due to the presence of the unobserved effect in every period. We apply GLS and compute robust standard errors of the coefficients.[14]

Furthermore, one of the most challenging problems in the empirical growth literature is the likely endogeneity of the right-hand-side variables. This is particularly true in the case of human capital variables, since education is highly income elastic and high-income economies dominated by the service sector require a well-educated workforce. In order to cope with this problem, in the second part of our estimations we use the GMM estimator of Arellano and Bond (1991), which calls for first differencing and using lags of the dependent and explanatory variables as instruments (Caselli et al., 1996). First differencing removes region-specific effects, which are a potential source of omitted variable bias (see above) and deals with series non-stationarity. Also, when choosing instruments, we allow the explanatory variables to be endogenous, which is the least restrictive assumption we can make. Thus, applying GMM we eliminate the inconsistency arising from the incorrect treatment of correlated region-specific effects and the endogeneity of explanatory variables. We are thus more confident about GMM compared with RE results and emphasise the former. At the same time, if the findings are similar, this is a signal of robustness.

7.5. EMPIRICAL RESULTS

7.5.1. Full Sample

Full sample estimations reveal that students at lower-secondary level and higher-secondary level exert a positive, albeit small, effect on growth in most cases (Table 7A.5, cols. 1–8). Furthermore, the student-teacher ratios in lower and upper secondary education, which are measures of education quality, exert a negative influence on growth in most cases as well – that is, the higher the number of students relative to teachers, the lower is human capital accumulation and growth. These findings accord with the fact that controlling for labour force quality reduces the impact of schooling on growth (Sianesi and Van Reenen, 2002). Overall, the results concur with our theoretical underpinnings and previous empirical evidence (Barro, 1991; Sianesi and Van Reenen, 2002).

Regarding healthcare indicators, we use the number of medical doctors, as it reflects the quality of health services. This is expected to boost productivity and growth.[14] The evidence confirms our intuition showing a positive impact on regional growth (Table 7A.5, cols. 2, 4, 6 and 8).[16, 17] Overall, the evidence supports the case for public funding of education and health care in Greece as a growth-enhancing policy.

Public investment does not have a statistically significant growth impact in most cases. This is possibly because it represents a small proportion of GDP in most regions and is inefficiently allocated in accordance with the electoral cycle theory (see Labrinidis et al., 2005).

The estimated parameter of initial income indicates conditional convergence of Greek NUTS III regions at an annual rate of approximately 17 per cent (Table 7A.5, cols. 5–8).[18] This is in line with our Solow-type model, where an economy is in the process of transitional growth towards its steady state. The above convergence speed is similar in magnitude to those found by Caselli et al. (1996) and differs from results commonly found in work on convergence.[19, 20] Hence Greek regions are mostly near their steady states and differences in GDP per capita are due to differences in their steady-state levels. In this framework, areas with high growth are those which experienced repeated shifts in their steady state during the period covered by our sample. Finally, population growth exerts a negative influence on per capita income growth in accordance with theory and previous evidence (Eckey et al., 2006).[21]

7.5.2. Convergence Clubs

As mentioned in Section 7.2, there is a strong case, both theoretically and empirically, for different effects of human capital on growth among regions which vary in terms of income. Consequently, we split regions into low-income and high-income according to whether their average GDP per capita is below or above the median for our sample period (1981–2003).[22, 23] First, we estimate the same equations as before for the two sub-samples.

According to Tables 7A.6–7A.7, for the rich and poor regions respectively, we see that lower secondary education students have a positive impact on growth in the former (Table 7A.6, cols. 1, 5–6), while they are not statistically significant in the latter (Table 7A.7). Furthermore, there are positive growth returns to upper secondary education in the high-income regions (Table 7A.6, cols. 3–4, 7–8), while they are mostly insignificant in the low-income ones (Table 7A.7, cols. 3–4, 7–8). These differences among the income groups explain the very weak growth influence of both variables in the full sample estimation and agree with previous work (Durlauf and Johnson, 1995).

Also, we identify a strong negative effect on per capita growth of the student-teacher ratio at both the lower secondary and upper secondary education levels in the rich regions (Table 7A.6, cols. 1, 5–8). In poor regions, this impact appears mostly insignificant (Table 7A.7, cols. 1–8), implying a weak effect of this variable in the full sample. Besides these, the number of medical doctors boosts regional growth in both sub-samples (Tables 7A.6–7A.7, cols. 2, 4, 6, 8). However, it seems that the effect of healthcare on regional growth is stronger in low-income areas.

In addition, we estimate regressions, which include interaction terms for our education and health indicators in order to check the robustness of the previous results. In particular, we interact a binary variable that indicates rich and poor areas with the education and health variables. Our findings confirm the stronger impact of lower secondary education students and the student-teacher ratio in lower secondary education on growth in high-income regions relative to the poor areas (Table 7A.11, cols. 1–2, 5).

Thus, our evidence suggests parameter heterogeneity regarding the effect of human capital on growth – confirming previous studies. From a policy perspective the evidence presented above implies that it is optimal to direct public spending on education mostly towards rich regions if the aim is growth maximization.[24] Also, conditional convergence seems to hold in both sub-samples, as was the case for the whole sample. Finally, public investment does not have a growth impact and population growth affects per capita income growth negatively as before.

7.5.3. Spatial Externalities

Next, we proceed to examine whether there is dependence of regional growth on human capital in neighbouring regions – that is, human capital externalities among regions. We construct three types of variables to capture these effects. The first type includes students of both the region in question and its neighbouring regions (*Regional Students*). It replaces the students of the region in question in the regressions. The second type corresponds to the students of the neighbouring regions only (*Extra-Regional Students*). It is used in the equations in addition to the student variables used in the previous section. The third type refers to two variables: they add the number of university medical doctors and hospital beds, when direct access to a university hospital is available, to the medical doctors and hospital beds at the regional level used in the original estimations creating *University Medical Doctors* and *University Hospital Beds* respectively.

Looking at Table 7A.8, *Regional Students* of lower secondary (see cols. 9–10) and upper secondary education (see cols. 11–12) have a much stronger impact on growth than the original student variables (Table 7A.5). This is in line with the evidence which shows that students of neighbouring regions (*Extra-Regional Students*) have a positive effect on growth (Table 7A.8, cols.

13–14). Lower and upper secondary school students continue to affect growth positively (Table 7A.8, cols. 2, 6, 10, 12–13). Regarding healthcare variables, *University Medical Doctors* affect growth positively and *University Hospital Beds* do not influence the growth process as before (Table 7A.8, cols. 7–8, 15–16). Thus, there is quite strong evidence of spatial externalities, in the sense that regions seem to be affected by the performance of their neighbours in terms of education and health status. This is in accordance with recent findings for Sweden (Andersson et al., 2008). The results do not change when we incorporate public investment in the regressions, which continues to be statistically insignificant (Table 7A.11, cols. 5–7).

When estimating the same equations in the two sub-samples of rich and poor regions, the findings are somewhat different. We observe that the positive impact of *Regional Students* (both lower and upper secondary levels) on growth is stronger in the wealthy regions compared to the lagging ones (Tables 7A.9–7A.10, cols. 9–12). The same pattern is true for the *Extra-Regional Students* at both education levels (Tables 7A.9–7A.10, cols. 13–14). Besides these, students of lower and upper secondary level education continue to exert a positive growth influence in all but one case in rich regions (Table 7A.9, cols. 2, 6, 10, 12–13), while their effect is not statistically significant in poor regions in most cases (Table 7A.10, cols. 2, 4–6, 10, 12–14). Furthermore, *University Medical Doctors* and *University Hospital Beds* do not affect growth in the affluent regions, contrary to the results for the former variable in the full sample, while they have a positive growth impact in poor regions (Tables 7A.9–7A.10, cols. 7–8, 15–16). At this point we should note that *Medical Doctors* are significant in high-income regions (see Table 7A.6, cols. 2, 4, 6 and 8) but *University Medical Doctors* are not. This seemingly awkward result can be explained by the fact that since university hospitals are mainly hosted in rich regions, their effect is captured by *Medical Doctors*. Consequently, there is no additional impact of *University Medical Doctors* to be estimated in these regions.

These findings are consistent with the evidence obtained when we use interaction terms to estimate the differential impact of *Regional Students, Extra-Regional Students and University Medical Doctors* on growth between high- and low-income areas (Table 7A.11, cols. 5–7). For example, *Regional Students* in upper secondary education boost growth in rich regions more strongly than in poor ones. Also, *University Medical Doctors* have a larger growth impact in poor areas compared to rich ones. Thus, we continue to find evidence of parameter heterogeneity regarding human capital variables in Greek regions when we take into account spatial externalities. Also, in both sub-samples conditional convergence holds and population growth is detrimental to per capita output growth, as is true for the whole sample.

As a result, evidence presented in this section emphasizes the need for larger public funding of education and health in both high- and low-income regions in order to realize the benefits arising from spatial externalities of human capital accumulation on regional growth. Additionally, the results underline that healthcare is a more important growth determinant in poor than in rich regions. On the contrary, education seems to matter more for growth in wealthy than lagging regions. In light of these findings, policy makers should direct a larger share of the funding for human capital accumulation towards healthcare in poor regions and education in rich ones.[25]

7.6. CONCLUSIONS

This chapter examined the social returns to human capital at regional level in Greece using education and healthcare indicators. We estimated the effect of these variables for all regions and separately for poor and rich ones, allowing for spatial heterogeneity of rates of return to human capital. Overall, we found that there are differences between the two regional clubs. In particular, our results show a positive impact of education on growth in high-income regions, while the evidence is much weaker for low-income regions. On the contrary, health is more important for growth in poor than rich regions. Also, there are important human capital externalities across neighbouring regions. Thus, the findings imply the need for larger public spending on education and healthcare in all areas as a growth-enhancing policy. However, the policy makers should direct a larger share of human capital expenditure on education in wealthy regions and health in lagging regions.

To conclude with some possible research extensions, we could employ alternative estimation methods as a check for the robustness of the results (i.e. spatial econometrics). We might also use other measures of human capital, taking more comprehensive account of its quality, additional stages of education (higher education) and other forms of education (job training) when data become available. These are left for future work.

APPENDIX

Table 7A.1. Description of variables

Dependent variable	Description	Source
GDP per capita	in Euros, at 2000 constant prices;	National Statistical Service of Greece, Quarterly Regional and Satellite Accounts Section
Explanatory variable		
Public investment	Investment of the state budget at regional level (NUTS 3) as a % of regional GDP. The variable is constructed by extracting payments for services rendered from total regional state budget expenditures.	National Statistical Service of Greece, Public Sector Survey Section
Students; Lower secondary level	Number of students attending the lower secondary level of education at regional level (NUTS 3). The variable is denoted per 1000 children aged 10 to 14 years of age.	National Statistical Service of Greece, Social Accounts Section
Students; Upper secondary level	Number of students attending the upper secondary level of education at regional level (NUTS 3). The variable is denoted per 1000 children aged 15 to 19 years of age.	National Statistical Service of Greece, Social Accounts Section
Student–teacher ratio; Lower secondary level	The number of students divided by the number of teachers at the lower secondary level of education at regional level (NUTS 3). Teachers are denoted per 1000 inhabitants at regional level.	National Statistical Service of Greece, Social Accounts Section
Student–teacher ratio; Upper secondary level	The number of students divided by the number of teachers at the upper secondary level of education at regional level (NUTS 3). Teachers are denoted per 1000 at regional level.	National Statistical Service of Greece, Social Accounts Section

Medical doctors	Number of medical doctors per 1000 inhabitants at regional level (NUTS 3).	National Statistical Service of Greece, Social Accounts Section
Hospital beds	Number of hospital beds per 1000 inhabitants at regional level (NUTS 3).	National Statistical Service of Greece, Social Accounts Section
Regional students; Lower secondary level	Number of students attending the lower secondary level of education at regional level (NUTS 3), including students at the same level of education from neighbouring regions.	National Statistical Service of Greece, Social Accounts Section
Regional students; Upper secondary level	Number of students attending the upper secondary level of education at regional level (NUTS 3), including students at the same level of education from neighbouring regions.	National Statistical Service of Greece, Social Accounts Section
Extra-regional students; Lower secondary level	Number of students attending the lower secondary level of education from neighbouring regions only (NUTS 3).	National Statistical Service of Greece, Social Accounts Section
Extra-regional students; Upper secondary level	Number of students attending the upper secondary level of education from neighbouring regions only (NUTS 3).	National Statistical Service of Greece, Social Accounts Section
University medical doctors	Number of university medical doctors per 1000 inhabitants at regional level (NUTS 3). The number of university medical doctors (when direct access to the respective university hospital is available) is added to medical doctors at regional level (NUTS 3).	National Statistical Service of Greece, Social Accounts Section
University hospital beds	Number of university hospital beds per 1000 inhabitants at regional level (NUTS 3). The number of university hospital beds (when direct access to the respective university hospital is available) is added to hospital beds at regional level (NUTS 3).	National Statistical Service of Greece, Social Accounts Section

Table 7A.2. Descriptive statistics: Greek regions, 1981–2003 (NUTS III)

	Obs.	Mean	St. dev.	Min	Max
GDP per capita	1173	9373.0	2796.8	5272.6	33490.7
GDP pc growth	1173	0.016	0.069	–0.349	0.521
Population growth	1173	0.003	0.010	–0.121	0.060
Public investment	1169	0.024	0.015	0.001	0.123
Students; Lower secondary level	1168	587.2	71.8	300.8	995.8
Student; Upper secondary level	1168	393.0	124.9	140.2	775.9
Student– teacher ratio; Lower secondary level	1168	1168	207.8	41.7	80.0
Student–teacher ratio; Upper secondary level	1168	1170	180.2	32.2	87.5
Medical doctors	1173	1173	2.211	1.152	0.47
Hospital beds	1173	1173	3.569	1.964	0.51

Table 7A.3. Descriptive statistics: low-income regions, 1981–2003 (NUTS III)

	Obs.	Mean	St. dev.	Min	Max
GDP per capita	598	7967.7	1435.9	5272.6	16509.5
GDP pc growth	572	0.016	0.071	–0.256	0.400
Population growth	572	0.003	0.009	–0.072	0.060
Public investment	597	0.025	0.012	0.001	0.104
Students; Lower secondary level	595	583.8	80.7	300.8	995.8
Student; Upper secondary level	596	394.8	123.7	151.1	700.1
Student–teacher ratio; Lower secondary level	595	205.8	40.7	95.4	365.7
Student–teacher ratio; Upper secondary level	596	177.1	28.6	107.9	271.9
Medical doctors	598	2.03	1.04	0.47	7.11
Hospital beds	598	3.10	1.25	1.03	8.12

Table 7A.4. Descriptive statistics: high-income regions, 1981–2003 (NUTS III)

	Obs.	Mean	St. dev.	Min	Max
GDP per capita	575	10834.6	3103.1	6377.4	33490.7
GDP pc growth	550	0.016	0.067	–0.349	0.521
Population growth	550	0.004	0.012	–0.121	0.040
Public investment	572	0.023	0.018	0.001	0.123
Students; Lower secondary level	573	590.7	61.2	380.9	755.2
Student; Upper secondary level	574	391.2	126.2	140.2	775.9
Student–teacher ratio; Lower secondary level	573	209.9	42.7	80.0	342.7
Student–teacher ratio; Upper secondary level	574	183.6	35.3	87.5	505.1
Medical doctors	575	2.40	1.23	0.75	6.83
Hospital beds	575	4.05	2.41	0.51	15.88

Table 7A.5. Panel data estimates: education and healthcare variables (all regions)

Explanatory Variables [4]	Random effect estimates (1)	(2)	(3)	(4)	Arellano-Bond estimates (5)	(6)	(7)	(8)
Students; Lower secondary level	0.001** (2.51)	0.148** (2.24)	–	–	0.001*** (3.55)	0.001 (1.41)	–	–
Student–teacher ratio; Lower secondary level	–0.062*** (–5.75)	–0.024** (–2.14)	–	–	–0.018 (–0.64)	–0.003 (0.13)	–	–
Student; Upper secondary level	–	–	0.001*** (5.80)	0.001** (1.51)	–	–	0.001*** (3.12)	0.001*** (3.88)
Student–teacher ratio; Upper secondary level	–	–	–0.033*** (–2.66)	–0.018** (–1.49)	–	–	–0.020 (–0.85)	–0.011*** (–0.50)
Medical doctors	–	0.024*** (4.59)	–	0.010*** (2.97)	–	0.092*** (4.52)	–	0.092*** (4.61)
GDP initial [1]	–0.005 (–0.06)	–0.016 (–1.52)	–0.004 (–0.45)	–0.016 (–1.51)	–0.185*** (–6.31)	–0.166*** (–5.81)	–0.182*** (–6.23)	–0.158*** (–5.58)
Public investment	0.002 (0.69)	–0.007* (–1.73)	0.001 (0.49)	–0.005 (–1.33)	0.005 (0.78)	0.002 (0.31)	–0.007 (1.16)	0.003 (0.51)
Population growth	–1.147*** (–5.77)	–1.303*** (–6.73)	–1.124*** (–5.69)	–1.297*** (–6.66)	–1.411*** (–5.68)	–1.545*** (–6.56)	–1.421*** (–5.78)	–1.555*** (–6.68)
Obs.	1070	1019	1070	1020	1019	968	1019	968
R^2	0.066	0.075	0.084	0.079	–	–	–	–
Sargan test (p-value) [2]	–	–	–	–	0.104	0.116	0.121	0.138
Autocovariance test of order 2 (p-value) [3]	–	–	–	–	0.302	0.128	0.670	0.312

Notes:

Dependent variable GDP per capita growth in region i (i = 1, …, 51) in period t (t = 1981, …, 2003). z-statistics in parentheses; *, **, *** denote 10%, 5% and 1% significance respectively.
[1] Initial per capita GDP in region i in period t– 1.
[2] The null hypothesis is that the instruments used are not correlated with the residuals.
[3] The null hypothesis is that the errors in the first-differenced regression exhibit no second order serial correlation.
[4] See Table 7A.1 for the definition of the variables used. Explanatory variables lagged 2 periods and Medical Doctors lagged 3 periods. All the explanatory variables were used as instruments.

Table 7A.6. Panel data estimates: education and healthcare variables (high-income regions)

Explanatory Variables [4]	Random effect estimates (1)	(2)	(3)	(4)	Arellano-Bond estimates (5)	(6)	(7)	(8)
Students; Lower secondary level	0.001** (2.33)	0.001 (0.46)	–	–	0.001*** (3.47)	0.001** (2.36)	-	-
Student–teacher ratio; Lower secondary level	–0.051*** (–3.59)	–0.021 (–1.41)	–	–	–0.003** (–0.09)	–0.018** (–2.11)	-	-
Student; Upper secondary level	–	–	0.001*** (4.30)	0.001** (2.04)	–	–	0.001*** (3.45)	0.001*** (3.93)
Student–teacher ratio; Upper secondary level	–	–	–0.021** (–1.25)	–0.012** (–0.73)	–	–	-0.055** (-2.05)	-0.049** (-1.88)
Medical doctors	–	0.018** (2.45)	–	0.005** (0.53)	–	0.058** (2.05)	-	0.055** (0.50)
GDP Initial [1]	–0.001 (–0.00)	–0.012 (0–.74)	–0.018 (–1.12)	–0.022 (–1.37)	–0.133*** (–3.20)	–0.128*** (–3.03)	-0.133*** (-3.21)	-0.118*** (-2.82)
Public Investment	–0.001 (–0.29)	–0.009 (–2.45)	–0.002 (–0.48)	–0.007 (–1.20)	0.008 (0.95)	0.002 (0.24)	0.008 (1.08)	0.001 (0.06)
Population Growth	–1.066*** (–4.31)	–1.143*** (–4.64)	–1.085*** (–4.50)	–1.125*** (–4.64)	–1.413*** (–4.83)	–1.474*** (–5.12)	-1.366*** (-4.70)	-1.409*** (-4.94)
Obs.	524	499	524	499	499	474	499	474
R^2	0.067	0.068	0.086	0.068	–	–	-	-
Sargan test (p-value)[2]	–	–	–	–	0.062	0.074	0.099	0.106
Autocovariance test of order 2 (p-value)[3]	–	–	–	–	0.176	0.122	0.146	0.144

Notes:

Dependent variable GDP per capita growth in region i (i = 1, …, 25) for high-income regions and i (i =1, …, 26) for low-income regions; in period t (t =1981, …, 2003). z-statistics in parentheses; *, **, *** denote 10%, 5% and 1% significance respectively.

[1] Initial per capita GDP in region i in period t – 1.

[2] The null hypothesis is that the instruments used are not correlated with the residuals.

[3] The null hypothesis is that the errors in the first-differenced regression exhibit no second order serial correlation.

[4] See Table 7A.1 for the definition of the variables used. Explanatory variables lagged 2 periods and Medical Doctors lagged 3 periods. All the explanatory variables were used as instruments.

Table 7A.7. Panel data estimates: education and healthcare variables (low-income regions)

Explanatory Variables [4]	Random effect estimates (1)	(2)	(3)	(4)	Arellano-Bond estimates (5)	(6)	(7)	(8)
Students; Lower secondary level	0.001 (1.51)	–0.001 (–0.83)	–	–	0.001 (0.97)	–0.001 (–0.81)	–	–
Student–teacher ratio; Lower secondary level	–0.080*** (–4.64)	–0.023 (–1.24)	–	–	–0.046 (–1.19)	–0.003 (–0.10)	–	–
Student; Upper secondary level	–	–	0.001*** (4.08)	0.001 (0.82)	–	–	0.001 (1.27)	0.029 (0.72)
Student–teacher ratio; Upper secondary level	–	–	–0.042** (–2.14)	–0.014 (–0.76)	–	–	–0.039 (–1.11)	–0.020 (–0.63)
Medical doctors	–	0.028*** (3.66)	–	0.026*** (2.92)	–	0.089*** (3.71)	–	0.087*** (3.64)
GDP Initial [1]	–0.032 (–1.21)	–0.047** (–1.87)	–0.031 (–1.21)	–0.049** (–1.96)	–0.245*** (–6.07)	–0.215*** (–5.65)	–0.244*** (–6.05)	–0.211*** (–5.55)
Public Investment	–0.001 (–0.25)	–0.001 (–0.19)	0.007 (1.02)	–0.001 (–0.19)	–0.001 (–0.04)	0.001 (0.06)	0.003 (0.36)	0.003 (0.39)
Population Growth	–1.367*** (–4.02)	–1.547*** (–4.78)	–1.210*** (–3.51)	–1.502*** (–4.52)	–1.548*** (–3.77)	–1.702*** (–4.49)	–1.560*** (–3.80)	–1.632*** (–4.32)
Obs.	546	520	546	520	520	494	520	494
R^2	0.070	0.092	0.084	0.095	–	–	–	–
Sargan test (p-value) [2]	–	–	–	–	0.129	0.280	0.123	0.330
Autocovariance test of order 2 (p-value) [3]	–	–	–	–	0.302	0.314	0.620	0.524

Notes:

Dependent variable GDP per capita growth in region i (i = 1, …, 25) for high-income regions and i (i =1, …, 26) for low-income regions; in period t (t =1981, …, 2003). z-statistics in parentheses; *, **, *** denote 10%, 5% and 1% significance respectively.

[1] Initial per capita GDP in region i in period $t-1$.

[2] The null hypothesis is that the instruments used are not correlated with the residuals.

[3] The null hypothesis is that the errors in the first-differenced regression exhibit no second order serial correlation.

[4] See Table 7A.1 for the definition of the variables used. Explanatory variables lagged 2 periods and Medical Doctors lagged 3 periods. All the explanatory variables were used as instruments.

Table 7A.8. Panel data estimates: regional and extra-regional education and healthcare variables (all regions)

	Random effect estimates							
Explanatory Variables [4]	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Regional students Lower secondary level	–0.005 (–1.61)	–0.011*** (–3.32)	–	–	–	–	–	–
Regional students Upper secondary level	–	–	0.003 (1.07)	0.002 (0.79)	–	–	–	–
Extra-regional students; Lower secondary level	–	–	–	–	–0.003 (–0.83)	–	–	–
Extra-regional students; Upper secondary level	–	–	–	–	–	–0.003 (–0.85)	–	–
Students; Lower secondary level	–	–	–	0.000 (1.24)	–0.026 (–1.51)	–	–	–
Students; Upper secondary level	–	0.000*** (7.16)	–	–	–	0.045*** (5.66)	–	–
University medical doctors	–	–	–	–	–	–	0.016 (3.19)	–
University hospital beds	–	–	–	–	–	–	–	0.002 (0.45)
GDP Initial [1]	–0.003 (–0.39)	–0.003 (–0.35)	–0.009 (–0.95)	–0.010 (–0.99)	–0.003 (–0.29)	–0.004 (–0.45)	–0.015 (–1.62)	–0.011 (–1.17)
Population Growth	–1.168*** (–5.73)	–1.231*** (–6.17)	–1.045*** (–5.12)	–1.075*** (–5.24)	–1.220*** (–5.39)	–1.123*** (–5.56)	–1.233*** (–6.43)	–1.210*** (–6.29)
Obs.	1071	1071	1071	1071	903	903	1020	1020
R^2	0.031	0.080	0.051	0.040	0.035	0.079	0.064	0.043
Sargan test (p-value) [2]	–	–	–	–	–	–	–	–
Autocovariance test of order 2 (p-value) [3]	–	–	–	–	–	–	–	–

Table 7A.8. Continued

	Arellano-Bond estimates							
Explanatory Variables [4]	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Regional students Lower secondary level	0.253***	0.236***	–	–	–	–	–	–
	(4.79)	(4.41)						
Regional students Upper secondary level	–	–	0.092***	0.783***	–		–	–
			(4.03)	(3.37)				
Extra-regional students; Lower secondary level	–	–	–	–	0.295***	–	–	–
					(3.88)			
Extra-regional students; Upper secondary level	–	–	–	–	–	0.086**	–	–
						(2.27)		
Students; Lower secondary level	–	–	–	0.155***	0.086**		–	–
				(3.43)	(1.39)			
Students; Upper secondary level	–	0.047**	–	–	–	0.001**	-	-
		(2.34)				(0.02)		
University medical doctors	–	–	–	–	–	–	0.106***	-
							(3.99)	
University hospital beds	–	–	–	–	–	–	-	0.038
								(1.26)
GDP Initial [1]	–0.186***	–0.182***	–0.174***	–0.176***	–0.187***	–0.167***	-0.168***	-0.163***
	(–6.40)	(–6.28)	(–6.01)	(–6.10)	(–5.92)	(–5.29)	(-5.93)	(-1.26)
Population Growth	–1.37***	–1.369***	–1.389**	–1.350***	–1.482***	–1.493***	-1.629***	-1.147***
	(–5.60)	(–5.60)	(–5.70)	(–5.53)	(–5.56)	(–5.60)	(-6.96)	(-6.35)
Obs.	1020	1020	1020	1020	860	860	969	969
R^2	–	–	–	–	–	–	-	-
Sargan Test (p-value) [2]	0.656	0.722	0.632	0.740	0.629	0.832	0.680	0.741
Autocovariance test of order 2 (p-value) [3]	0.530	0.563	0.788	0.707	0.621	0.813	0.941	0.799

Notes:

Dependent variable GDP per capita growth in region *i* (*i* = 1, …, 51) in period *t* (*t* = 1981, …, 2003). *z*-statistics in parentheses; *, **, *** denote 10%, 5% and 1% significance respectively.

[1] Initial per capita GDP in region *i* in period *t*– 1.

[2] The null hypothesis is that the instruments used are not correlated with the residuals.

[3] The null hypothesis is that the errors in the first-differenced regression exhibit no second order serial correlation.

[4] See Table 7A.1 for the definition of the variables used. Explanatory variables lagged 2 periods and Doctors University & Beds University lagged 3 periods. All the explanatory variables were used as instruments.

Table 7A.9. Panel data estimates: regional and extra-regional education and healthcare variables (high-income regions)

Explanatory Variables [4]	Random effect estimates							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Regional students Lower secondary level	–0.004 (–0.89)	–0.010** (–2.08)	–	–	–	–	–	–
Regional students Upper secondary level	–	–	0.004 (1.08)	0.003 (0.85)	–	–	–	–
Extra-regional students; Lower secondary level	–	–	–	–	–0.001 (–0.32)	–	–	–
Extra-regional students; Upper secondary level	–	–	–	–	–	–0.002 (–0.50)	–	–
Students; Lower secondary level	–	–	–	0.037 (1.35)	–0.039 (–1.28)	–	–	–
Students; Upper secondary level	–	0.045*** (5.04)	–	–	–	0.048*** (4.35)	–	–
University medical doctors	–	–	–	–	–	–	0.008 (1.11)	–
University hospital beds	–	–	–	–	–	–	–	0.004 (0.54)
GDP Initial [1]	–0.007 (–0.49)	–0.009 (–0.66)	–0.014 (–0.98)	–0.013 (–0.87)	–0.005 –0.32	–0.011 (–0.72)	–0.018 (–1.18)	–0.011 (–0.77)
Population Growth	–1.08*** (–4.36)	–1.254*** (–5.10)	–0.984*** (–3.96)	–1.064*** (–4.17)	–1.117*** –4.33	–1.125*** (–4.73)	–1.125*** (–4.66)	–1.082*** (–4.50)
Obs.	525	525	525	525	462	462	500	500
R^2	0.039	0.087	0.051	0.055	0.039	0.089	0.054	0.047
Sargan Test (p-value) [2]	–	–	–	–	–	–	–	–
Autocovariance test of order 2 (p-value) [3]	–	–	–	–	–	–	–	–

Table 7A.9. Continued

	Arellano-Bond estimates							
Explanatory Variables [4]	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Regional students Lower secondary level	0.345*** (4.19)	0.293*** (3.45)	–	–	–	–	–	–
Regional students Upper secondary level	–	–	0.113*** (3.71)	0.089*** (2.83)	–		–	–
Extra-regional students; Lower secondary level	–	–	–	–	0.309*** (2.81)	–	–	–
Extra-regional students; Upper secondary level	–	–	–	–	–	0.475** (2.43)	–	–
Students; Lower secondary level	–	–	–	0.184*** (2.65)	0.007** (1.19)		–	–
Students; Upper secondary level	–	0.068** (2.44)	–	–	–	–0.086** (2.27)_	–	–
University medical doctors	–	–	–	–	–	–	0.052 (1.42)	–
University Hospital Beds	–	–	–	–	–	–	–	0.004 (0.11)
GDP Initial [1]	–0.130*** (–3.15)	–0.122*** (–2.96)	–0.114*** (–2.77)	–0.119*** (–2.89)	–0.150*** (–3.43)	–0.127*** (–2.91)	–0.116*** (–2.79)	–0.117*** (–2.81)
Population Growth	–1.35*** (–4.69)	–1.393*** (–4.82)	–1.348*** (–4.69)	–1.385*** (–4.81)	–1.368*** (–4.52)	–1.369*** (–4.52)	–1.428*** (–4.98)	–1.349*** (–4.79)
Obs.	500	500	500	500	440	440	475	475
R^2	–	–	–	–	–	–	–	–
Sargan Test (p-value) [2]	0.872	0.541	0.911	0.852	0.853	0.832	0.734	0.741
Autocovariance test of order 2 (p-value) [3]	0.946	0.827	0.761	0.2808	0.762	0.813	0.638	0.622

Notes:

Dependent variable GDP per capita growth in region i (i = 1, …, 25) in period t (t = 1981, …, 2003). z-statistics in parentheses; *, **, *** denote 10%, 5% and 1% significance respectively.
[1] Initial per capita GDP in region i in period t– 1.
[2] The null hypothesis is that the instruments used are not correlated with the residuals.
[3] The null hypothesis is that the errors in the first-differenced regression exhibit no second order serial correlation.
[4] See Table 7A.1 for the definition of the variables used. Explanatory variables lagged 2 periods and Doctors University & Beds University lagged 3 periods. All the explanatory variables were used as instruments.

Table 7A.10. Panel data estimates: regional and extra-regional education and healthcare variables (low-income regions)

Explanatory Variables [4]	Random effect estimates (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Regional students Lower secondary level	0.005 (1.27)	0.011 (2.51)	–	–	–	–	–	–
Regional students Upper secondary level	–	–	0.002 (0.61)	0.015 (0.37)	–	–	–	–
Extra-regional students; Lower secondary level	–	–	–	–	–0.004 (–0.79)	–	–	–
Extra-regional students; Upper secondary level	–	–	–	–	–	–0.003 (–0.59)	–	–
Students; Lower secondary level	–	–	–	0.019 (0.95)	0.026 (1.18)	–	–	–
Students; Upper secondary level	–	0.051*** (5.25)	–	–	–	0.045*** (3.79)	–	–
University medical doctors	–	–	–	–	–	–	0.025*** (3.43)	–
University Hospital Beds	–	–	–	–	–	–	–	0.001 (0.15)
GDP Initial [1]	–0.299 (–1.14)	–0.039 (–1.52)	–0.382 (–1.46)	–0.043 (–1.62)	–0.040 (–1.20)	–0.047 (–1.48)	–0.022 (–0.87)	–0.035 (–1.34)
Population Growth	–1.26*** (–3.61)	–1.171*** (–3.42)	–1.102*** (–3.14)	–1.094 (–3.12)	–1.32 (–3.18)	–1.199*** (–2.92)	–1.153*** (–3.43)	–1.154*** (–3.40)
Obs.	546	546	546	546	441	441	546	546
R^2	0.025	0.080	0.032	0.032	0.029	0.070	0.072	0.026
Sargan Test (p-value) [2]	–	–	–	–	–	–	–	–
Autocovariance test of order 2 (p-value) [3]	–	–	–	–	–	–	–	–

Table 7A.10. Continued

	Arellano-Bond estimates							
Explanatory Variables [4]	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Regional students Lower secondary level	0.150**	0.148**	–	–	–	–	–	–
	(2.38)	(2.32)						
Regional students Upper secondary level	–	–	0.057*	0.054*	–		–	–
			(1.77)	(1.67)				
Extra-regional students; Lower secondary level	–	–	–	–	0.266***	–	–	–
					(2.98)			
Extra-regional students; Upper secondary level	–	–	–	–	–	0.080*	–	–
						(1.67)		
Students; Lower secondary level	–	–	–	0.042	0.020		–	–
				(0.81)	(0.30)			
Students; Upper secondary level	–	0.014	–	–	–	–0.033	–	–
		(0.53)				(–0.84)		
University medical doctors	–	–	–	–	–	–	0.094***	–
							(3.00)	
University hospital beds	–	–	–	–	–	–	–	0.071***
								(0.01)
GDP Initial [1]	–0.024***	–0.248***	–0241***	–0.241***	–0.237***	–0.022***	–0.224***	–0.219***
	(–6.20)	(–6.17)	(–6.04)	(–6.05)	(–5.30)	(–4.99)	(–5.92)	(–5.69)
Population Growth	–1.443***	–1.419***	–1.456***	–1.416***	–1.861***	–1.898***	–1.771***	–1.657***
	(3.58)	(–3.50)	(–3.62)	(–3.50)	(3.85)	(–3.92)	(–4.75)	(–4.40)
Obs.	520	520	520	520	420	420	494	494
R^2	–	–	–		–	–	–	–
Sargan test (p-value) [2]	0.810	0.781	0.881	0.970	0.997	0.747	0.897	0.789
Autocovariance test of order 2 (p-value) [3]	0.982	0.954	0.854	0.910	0.781	0.968	0.741	0.822

Notes:

Dependent variable GDP per capita growth in region i (i = 1, …, 26) in period t (t = 1981, …, 2003). z-statistics in parentheses; *, **, *** denote 10%, 5% and 1% significance respectively.

[1] Initial per capita GDP in region i in period t– 1.

[2] The null hypothesis is that the instruments used are not correlated with the residuals.

[3] The null hypothesis is that the errors in the first-differenced regression exhibit no second order serial correlation.

[4] See Table 7A.1 for the definition of the variables used. Explanatory variables lagged 2 periods and Doctors University & Beds University lagged 3 periods. All the explanatory variables were used as instruments.

Table 7A.11. Panel data estimates: robustness analysis (Arellano-Bond estimates)

Explanatory Variables [4]	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Students; Lower secondary level	0.001 (1.33)	-0.001 (-1.28)	-	-	-0.013 (-0.45)	0.036 (1.07)	-
Students; Upper secondary level	-	-	0.001* (1.84)	0.001** (1.92)	-	-	-
Student–teacher ratio; Lower secondary level	-0.022 (-0.56)	0.222 (1.29)	-	-	-	-	-
Student–teacher ratio; Upper secondary level	-	-	-0.017 (-0.49)	0.003 (0.10)	-	-	-
Medical doctors	-	0.085*** (4.59)	-	0.114*** (4.83)	-	-	-
Students; Lower secondary level * Income	0.250** (2.55)	0.229** (6.14)	-	-	0.100** (1.82)	0.159*** (3.71)	-
Students; Upper secondary level * Income	-	-	0.027 (0.89)	0.049 (1.38)	-	-	-
Student–teacher ratio; Lower secondary level * Income	0.016 (0.28)	-0.072*** (-2.77)	-	-	-	-	-
Student–teacher ratio; Upper secondary level * Income	-	-	-0.004 (-0.11)	-0.022 (-0.51)	-	-	-
Medical doctors * Income	-	-0.012 (-0.67)	-	0.057* (1.77)	-	-	-
Regional students; Upper secondary level	-	-	-	-	0.113** (14.94)	-	-
Extra-regional students; Lower secondary level	-	-	-	-	-	0.190** (2.59)	-
University medical doctors	-	-	-	-	-	-	0.094*** (10.37)
Regional students; Upper secondary level * Income	-	-	-	-	0.046*** (3.76)	-	-
Extra-regional students; Lower level * Income	-	-	-	-	-	0.017 (0.18)	-
University medical doctors * Income	-	-	-	-	-	-	-0.030*** (-3.85)
GDP Initial [1]	-0.187*** (-6.34)	-0.144*** (-11.36)	-0.180*** (-6.13)	-0.158*** (-5.56)	-0.071*** (-6.42)	-0.191*** (-6.00)	-0.161*** (-5.80)
Public Investment	0.006 (0.87)	0.001 (0.11)	-0.007 (-1.06)	-0.003 (-0.54)	0.004 (1.00)	0.003 (-0.79)	-0.004 (-1.28)
Population Growth	-1.445*** (-5.81)	-1.506*** (-6.01)	-1.419*** (-5.73)	-1.516*** (-6.45)	-1.372*** (-21.2)	-1.504*** (-5.70)	-1.559*** (-6.84)
Obs.	1019	968	1019	968	968	859	968
Sargan test (p-value) [2]	0.610	0.115	0.712	0.773	0.804	1.000	1.000
Autocovariance test of order 2 (p-value) [3]	0.807	0.509	0.720	0.244	0.941	0.608	0.540

Notes:

Dependent variable GDP per capita growth in region i (i = 1, …, 26) in period t (t = 1981, …, 2003). z-statistics in parentheses; *, **, *** denote 10%, 5% and 1% significance respectively.

[1] Initial per capita GDP in region i in period t– 1.

[2] The null hypothesis is that the instruments used are not correlated with the residuals.

[3] The null hypothesis is that the errors in the first-differenced regression exhibit no second order serial correlation.

[4] See Table 7A.1 for the definition of the variables used. Explanatory variables lagged 2 periods and Doctors University & Beds University lagged 3 periods. All the explanatory variables were used as instruments.

INCOME is a binary variable taking the value of 1 if observation belongs to high-income regions.

NOTES

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1. A commonly used definition of human capital includes the set of knowledge, skills, competencies and abilities embodied in individuals and acquired through education, training and experience (Bassetti, 2007).
2. Detailed definitions of the variables are available in the Appendix (Table 7A.1).
3. We do not include data on the number of primary education students since there is no significant variation across regions, thus we would not be able to identify a distinct growth impact of such variables on regional growth.
4. The use of enrolment rates as a human capital variable is justified by the notion that current investment in human capital will be reflected in the future stock of human capital (Bassetti, 2007). We would have been keen to use human capital stock in our estimations (i.e. average years of schooling) but unfortunately it is not available for Greek regions (NUTS 3 level). In addition, such data depend on arbitrary assumptions about depreciation and rely on inaccurate measures of benchmark stocks and investment flows (Barro and Sala-i-Martin, 2004). Studies that consider school enrolment rates include Barro (1991), Mankiw et al. (1992) and Levine and Renelt (1992).
5. Tables 7A.2–7A.4 provide all descriptive statistics (see Appendix).
6. Nine years of education (primary and lower secondary) has been compulsory in Greece since 1976 (Hellenic Constitution, Article 16, Paragraph 3).
7. Rural regions present enrolment rates of approximately 60–65 per cent over the whole period in lower secondary education and include prefectures such as Rodopi, Xanthi, Grevena, Euritania and Rethimno. The same regions exhibit enrolment rates around 30–40 per cent at the beginning of our sample period. In contrast, urban regions such as Athens, Thessaloniki and Achaia present enrolment rates of around 90–95 per cent.
8. See Kanelopoulos, Mauromaras and Mitrakos (2003), Paleocrassas et al. (1997), Paleocrassas (1996) and Kanelopoulos (1994).
9. Here we should note that data on regional private investment (NUTS 3 level) are not available for Greece.
10. Please note that this is the second attempt for the computation of such a variable in the relevant literature on Greek regions; the initial one was by Labrinidis et al. (2005).
11. According to Labrinidis et al. (2005) regional public investment disparities in Greece are positively associated with the national elections and the infrastructure capital stock, and negatively associated with population size and regional product per capita.
12. The unavailability of average years of schooling as a measure of human capital, combined with the relatively short time span, led us to use 2-year lags in our estimations. We tried longer lags (3–5 years) and the results were essentially the same. Our final choice was dictated by the need to maintain a sufficient number of observations.
13. For detailed definitions of the variables see Table 7A.1.
14. Spatial autocorrelation might be an issue in this context. However, island prefectures constitute almost 30 per cent of Greek regions and mainland Greece is dominated by a mountain range (Pindos). As a result, labour and capital mobility between Greek regions are

quite limited, and the location of economic activity is mostly stable over time, which limits spatial autocorrelation. Nevertheless, spatial externalities are partially taken into account in Section 7.5.3.

15. The correlations between students (lower and upper secondary level) and medical doctors are 0.13 and 0.57 respectively and thus do not influence our results.
16. We also tried using hospital beds per 1000 population, but it was not significant. We think this is because it is a measure of the quantity of health services, in contrast with doctors who measure better the quality of services provided.
17. We do not use variables employed in cross-country studies, like life expectancy and infant mortality, since there are no such data at regional level in Greece.
18. The relevant specification tests provided no evidence of misspecification of our models.
19. Caselli et al. (1996) showed that their estimation methodology, which is very similar to ours, implies consistent estimates of convergence in contrast with most empirical growth literature.
20. The presence of business cycles possibly induces upward bias in the convergence coefficient. However, in our case regional business cycles are likely to be correlated, so this effect is rather weak. Also, previous work with the same dataset with 5-year averages indicated that findings are not sensitive to the time span employed in the estimation (Benos and Karagiannis, 2008).
21. Furthermore, we include in our model a number of geographical dummies (North/South, East/West, and islands/mainland) in order to capture spatial effects across groups of Greek regions. Our estimations exhibit a positive sign regarding mainland regions, meaning that these regions enjoy a positive growth differential with respect to islands. This might be explained by the insufficient public infrastructure and problematic connection of the islands with the mainland, especially during the non-tourist period of the year.
22. See Figure 7.1 (Section 7.3) for the spatial allocation of the two income groups. The *high-income group* includes: (a) the mainland regions with access to the main transportation network (from Athens to Thessaloniki), and (b) the island regions with highly developed tourist industry (Crete, Corfu, Cyclades, Dodecanese). The *low-income group* includes most regions of Thrace, Western Macedonia, Epirus, Peloponnese, North Aegean and Eptanisa.
23. Our spatial division of Greek regions concurs with the findings of recent studies. Christopoulos (2004) reports similar evidence on the spatial segregation of Greek regions and states that such regional divergence exists due to employment and output differentials. Prodromidis (2006) traces the same effects at NUTS 4 (post code) level and argues that access to the Athens-Thessaloniki transportation network acts as an income corridor between Greek regions. Finally, Benos and Karagiannis (2008) present similar findings arguing that two convergence clubs exist in the Greek economy.
24. However, one must always keep in mind that economic growth is only one of the government objectives along with e.g. stabilization, income equality, and external balance. In light of that, higher funding on education in rich regions relative to poor ones may not be desirable, because it will increase spatial income inequality.
25. However, we should point here that policy makers should also take into account the overall characteristics of every region, such as geographic location, when designing specific growth promoting policies.

REFERENCES

Andersson, M., U. Grasjo and C. Karlsson (2008), 'Human Capital and Productivity in a Spatial Economic System – Relating the Extent of Spatial Dependence to Localities Position', *Annals of Economics and Statistics* [forthcoming].

Andersson, M. and C. Karlsson (2007), 'Knowledge in Regional Economic Growth – The Role of Knowledge Accessibility', *Industry and Innovation*, **14**(2), 129–49.

Arellano, A. and T.M. jr. Fullerton (2005), 'Educational Attainment and Regional Economic Performance in Mexico', *International Advances in Economic Research,* **11**(2), 231–42.

Arellano, M. and S. Bond (1991), 'Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations', *The Review of Economic Studies,* **58**(2), 277–97.

Azariadis, C. and A. Drazen (1990), 'Threshold Externalities in Economic Development', *Quarterly Journal of Economics*, **105**, 501–26.

Barro, R.J. (1991), 'Economic Growth in a Cross Section of Countries', *Quarterly Journal of Economics*, **106**(425), 407–43.

Barro, R.J. (1996), 'Determinants of Economic Growth: A Cross Country Empirical Study', *NBER Working Paper*, no. 5698.

Barro, R.J. and J-W. Lee (1993), 'International Comparisons of Educational Attainment', *Journal of Monetary Economics*, **23**(3), 363–94.

Barro, R.J and X. Sala-i-Martin (1991), 'Convergence Across States and Regions', *Brookings Papers on Economic Activity*, 1, 107-182.

Barro, R.J and X. Sala-i-Martin (1992), 'Convergence', *Journal of Political Economy* **100**(2), 223–51.

Barro, R.J and X. Sala-i-Martin (1996), *Economic Growth*, New York: McGraw Hill, Inc.

Barro, R.J and X. Sala-i-Martin (2004), *Economic Growth*, Cambridge, MA: MIT Press.

Bassanini, A. and S. Scarpetta S. (2001), 'The Driving Forces of Economic Growth: Panel Data Evidence for the OECD Countries', *OECD Economic Studies,* **33**, 9–56.

Bassetti, T. (2007), 'Human Capital and Economic Growth: A Selective Survey', *PRIN 2005 Working Paper,* no. 018.

Becker, G.S. (2007), 'Health as Human Capital: Synthesis and Extensions', *Oxford Economic Papers,* **59**(3), 379–410.

Becker, G.S. (1993), *Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education*, Chicago: University of Chicago Press.

Becker, G.S. (1964), *Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education*, New York: National Bureau of Economic Research.

Benhabib, J. and M. Spiegel (1994), 'The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country Data', *Journal of Monetary Economics,* **34**, 143–74.

Benos, N. and S. Karagiannis (2008), 'Convergence and Economic Performance in Greece: Evidence at Regional and Prefecture Level', *Review of Urban and Regional Development Studies*, **20**(1), 52–69.

Bils, M. and P.J. Klenow (2000), 'Does Schooling Cause Growth?', *American Economic Review*, **90**(5), 1160–83.

Bloom, D.E. and D. Canning (2000), 'Health as Human Capital and its Impact on Economic Performance', *The Geneva Papers on Risk and Insurance,* **28**(2), 304–15.

Bloom, D.E. and D. Canning (2000), 'Health and the Wealth of Nations', *Science*, **287**(5456), 1207–9.

Bloom, D.E, D. Canning and J. Sevilla (2004), 'The Effect of Health on Economic Growth: A Production Function Approach', *World Development*, **32**(1), 1–13.

Bloom, D.E, and J. Sachs (1998), 'Geography, Demography, and Economic Growth in Africa', *Brookings Papers on Economic Activity*, **2**, 207–295.

Bloom, D.E, and J. Williamson (1998), 'Demographic Transitions and Economic Miracles in Emerging Asia', *World Bank Economic Review*, **12**(3), 419–55.

Bloom, D.E, B. Bloom, J. Cohen and J. Sachs (1999). 'Investing in the World Health Organization', *Science*, **284**, 911.

Caselli, F., G. Esquivel and F. Lefort (1996), 'Reopening the Convergence Debate: A New Look at Cross-Country Growth Empirics', *Journal of Economic Growth*, **1**(3), 363–89.

Christopoulos, D. (2004), 'The Relationship Between Output and Unemployment: Evidence From Greek Regions', *Papers in Regional Science*, **83**(3), 611–20.

De la Fuente, A. (2002), 'On the Sources of Convergence: A Close Look at the Spanish Regions', *European Economic Review*, **46**(3), 569–99.

De la Fuente, A. and R. Domenech (2000), *Human Capital in Growth Regressions: How Much Difference Does Data Quality Make?*, Universidad Autonoma de Barcelona, mimeo.

Di Liberto, A. (2007), 'Education and Italian Regional Development', *Economics of Education Review,* **27**(1), 94–107.

Di Liberto, A. (2004), 'Convergence Clubs, and the Role of Human Capital in Spanish Regional Growth', in H. Folmer and J. Surinach (eds), *Knowledge and Regional Economic Development*, Cheltenham, UK: Edward Elgar.

Durlauf, S.N and P.A. Johnson (1995), 'Multiple Regimes and Cross-Country Growth Behaviour', *Journal of Applied Econometrics*, **10**(4), 365–84.

Eckey, H-F, C. Dreger and M. Turck (2006), 'European Regional Convergence in a Human Capital Augmented Solow Model', *University of Kassel Working Paper*, no. 88.

Ehrlich, I. (2000), 'Uncertain Lifetime, Life Protection, and the Value of Life Saving', *Journal of Health Economics*, **19**(3), 341–67.

Fuchs, J. (1966), 'The Contribution of Health Services to the American Economy', *Milbank Memorial Fund Quarterly*, **44**(4), 65-102.

Grasjo, U. (2005), 'Human Capital, Rand and Regional Exports', *Working Paper Series in Economics and Institutions of Innovation*, no. 50, Royal Institute of Technology, CESIS.

Griliches, Z. (1997), 'Education, Human Capital and Growth: A Personal Perspective', *Journal of Labour Economics*, **5**(1), 330–44.

Kalaitzidakis, P., T. Mamuneas, A. Savvides and T. Stengos (2001), 'Measures of Human Capital and Nonlinearities in Economic Growth', *Journal of Economic Growth*, **6**(3), 229-254.

Howitt, P. (2005), 'Health, Human Capital, and Economic Growth: A Schumpeterian Perspective', in G. López-Casasnovas, B. Rivera and L. Currais (eds), *Health and Economic Growth: Findings and Policy Implications,* Cambridge, MA: MIT Press, 19–40.

Kanelopoulos, K., (1994), *Greek Education in the 2000 Horizon*, Reports No. 10, KEPE, Athens. [in Greek]

Kanelopoulos, K., K. Mauromaras and Th. Mitrakos (2003), *Education and the Labour Market*, Studies No. 50, KEPE, Athens. [in Greek]

Krueger, A.B. and M. Lindahl (2001), 'Education for Growth: Why and For Whom?' *Journal of Economic Literature*, **39**(4), 1101–36.

Lambrinidis, M., Y. Psycharris and A. Rovolis (2005), 'Regional Allocation of Public Infrastructure Investment: The Case of Greece', *Regional Studies*, 39(9), 1231–44.

Levine R. and D. Renelt (1992), 'A Sensitivity Analysis of Cross-Country Growth Regressions', *American Economic Review*, **82**(4), 942–63.

Louri, H. (1989), 'Regional Policy and Investment Behaviour: The Case of Greece, 1971–1982', *Regional Studies*, **23**(3), 231–39.

Lucas, R.E. (1988), 'On The Mechanics of Economic Development', *Journal of Monetary Economics*, **22**(1), 3–42.

Malik, G. (2006), 'An Examination of the Relationship Between Health and Economic Growth', *ICRIER Working Paper.*

Mankiw, N., D. Romer and D. Weil (1992), 'A Contribution to the Empirics of Economic Growth', *Quarterly Journal of Economics,* **107**(2), 407–37.

Meltzer, D.O. (1992), *Mortality Decline, the Demographic transition, and Economic Growth,* Dissertation, University of Chicago, December.

Middendorf, T., (2006), 'Human Capital and Economic Growth in OECD Countries', *Jahrbucher Fur Nationalokonomie Und Statistik,* **226**(6), 670–86.

Mushkin, S.J., (1962), 'Health as an Investment', *Journal of Political Economy,* **70**, supplement, 129–57.

Nelson, R.R. and S.E. Phelps (1966), 'Investment in Humans, Technological Diffusion, and Economic Growth', *American Economic Review*, **56**(1–2), 69–75.

Paleocrassas, S. (1996), *Student Dropouts in Gymnasium and Their Needs for Professional Education and Training*, Pedagogical Institute, OEEK. [in Greek]

Paleocrassas, S., P. Rousseas and V. Vretakou (1997), 'Greek Lower Secondary School Dropouts: Results from a National Survey', *European Educational Research Association Bulletin*, **3**(1), 12–18.

Papageorgiou, C. (2003), 'Distinguishing Between the Effects of Primary and Post-Primary Education on Economic Growth', *Review of Development Economics*, **7**(4), 622–35.

Pritchett, L. (2001), 'Where Has all the Education Gone?', *World Bank Economic Review,* **15**(3), 367–91.

Prodromidis, P.I. (2006), *A Regional Analysis of Declared Incomes in Greece*, Studies No. 63, KEPE, Athens.

Ricci, F. and M. Zachariadis (2007), 'Determinants of Public Health Outcomes: A Macroeconomic Perspective', *Computing in Economics and Finance Working Papers*.

Romer, P.M. (1990), 'Endogenous Technological Change', *Journal of Political Economy*, **98**(5), 71–102.

Sianesi, B. and J. Van Reenen (2002), 'The Returns to Education: A Review of the Empirical Macroeconomic Literature', *IFS Working Paper*, no. 02/05.

Temple, J. (1999), 'The New Growth Evidence', *Journal of Economic Literature*, **37**(1), 112–56.