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The effect of education on economic growth in Greece over the 1960–2000 period

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This paper examines the impact of education on economic growth in Greece over the period 1960–2000 by applying the model introduced by Mankiw, Romer, and Weil. The findings of the empirical analysis reveal that education had a positive and statistically significant effect on economic growth in Greece over the period 1960–2000. The econometric model explained up to 66% of the variation of the economic growth rate through the variation of the independent variables (physical capital, human capital, and labor). More specifically, when the coefficient of education is estimated using time lags, the contribution of the annual differences of human capital growth to the annual differences of GDP growth has been estimated from an annual 0.64% up to 0.81%.

Keywords: education; human capital; productivity; economic growth

1. Introduction

Education is widely recognized as the principal institutional mechanism of production, accumulation, and diffusion of human capital. Economic theory and empirical analysis stress the importance of human capital as a production factor that explains economic growth. According to the existing literature, there are three channels through which education can impact economic growth: (1) education increases human capital inherent in labor force, which enhances labor productivity and thus transitional growth towards a higher equilibrium level of output [(augmented neoclassical growth theories, Mankiw, Romer, and Weil [1992]), (2) education can increase the innovative power of an economy as well as knowledge on new technologies, products and processes that promote growth (theories of endogenous growth, Lucas [1988], Romer [1990]), and (3) education facilitates the diffusion and transmission of knowledge which is needed to understand and process new information and to implement new technologies successfully, also leading to economic growth (Nelson and Phelps 1966).

The purpose of this study is to estimate education's effect on the growth of the Greek economy over the period 1960–2000. This period has been of great importance for Greece since four major events took place, influencing the country's economic and political situation: (1) the association-for-entry agreement with the European Economic Community (EEC) (commencement of negotiations, September 1959 – validity of agreement connection, November 1962). (2) The dictatorship (April 1967–July 1974).

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(3) The accession to the EEC (the induction agreement came into force in January 1981). Greece, as an EEC member participated in all stages of European integration, including the single European Act and the signing of the Maastricht Treaty. (4) The accession to the European Monetary Union (EMU) and the adoption of the new euro-currency (January 2001).

During this period, policies with positive and non-positive results were planned and applied in the sectors of economy and education. After 2001, Greece as a member of the Eurozone entered a new era regarding its economy and education. Therefore, the results of this study could be useful for future comparative studies concerning the period after 2001. Additionally, this study aims at investigating whether the Mankiw, Romer, and Weil (1992) model can be applied, not only for interpreting cross-country differences as to the sources of economic growth, but also for examining the effect of certain sources of economic growth on a country, for a long time period.

The paper is organized as follows: First, the literature review follows. Section 3 explains the methodology and discusses the model, while Section 4 makes a brief reference to Greek economy and education and presents the sources and data. Section 5 portrays the empirical analysis and discusses the results. Finally, Section 6 summarizes the main findings and conclusions of the paper.

2. Literature review

Most studies assessing the role of education on economic growth usually employ standard sources-of-growth equations based on a dynamic Cobb–Douglas aggregate production function which can easily be extended to include human capital as a determinant of the economy's growth rate. The proxy of human capital is a key issue in the empirical growth models. There have been many studies on the impact of education on economic growth using different proxies of human capital. The most common proxies are school enrollment rates and the average number of schooling years. The following empirical studies expressing human capital stock used the average years of schooling as proxy for human capital. Benhabib and Spiegel (1994) found a positive impact of human capital on growth. An increase in the stock of human capital is associated with a 12–17% increase in GDP per capita growth. Hanushek and Kim (1995) showed that an extra year of male secondary schooling is associated with a 0.36% increase in GDP per capita growth rate. Barro (1997) used the average years of attainment for males aged 25 and over in secondary and higher schools at the start of each period and estimated the contribution of education on economic growth at a level of 1.2%.

De la Fuente and Domenech (2000) found that an increase in average education by one year would raise output per capita by 3%. Using the same method, Bassanini and Scarpetta (2001) concluded that each added year of schooling raises output per capita by 6%. Krueger and Lindahl (2001) obtained that higher education attainment has a positive effect on economic growth once measurement errors are taken into account with Lin (2003) noticing that education has had a positive and significant effect on growth in Taiwan over the period 1965–2000. On the same line, Lin (2006) showed that elementary education has played a remarkable role in Taiwan's economic development in the past four decades. The estimated effect reveals that one additional year of average education increases real output growth by approximately 0.40%, 0.29%, 0.29%, and 0.26%, for primary, junior-high, senior-high, and college education, respectively.

The following empirical studies expressing human capital flow, used school enrollment rates as proxy for human capital. Barro (1991) found that a percentage point increase in primary (secondary) school enrollment rates is associated with a 2.5% (3.0%) increase in GDP per capita growth rate. Murphy, Shleifer, and Vishny (1991) showed that percentage point increase in primary school enrollment rate is associated with a 2.2% increase in GDP per capita growth rate, while Levine and Renelt (1992) deduced that a percentage point increase in secondary school enrollment rate is associated with a between 2.5% and 3.7% increase in GDP per capita growth rate.

Other relevant empirical studies include Liu and Armer (1993), who found that both primary and junior-high achievement variables add explanatory power to a Cobb–Douglas growth regression, but senior-high and college education did not exert any significant effects on growth. Englander and Gurney (1994) concluded that one percentage point increase in secondary school enrollment rate is associated with around 1.5% increase in productivity growth. Tallman and Wang (1994) showed that higher education exerts a greater effect on economic growth than do primary and secondary education with Gemmel (1996) demonstrating that 1% increase in tertiary human capital stock is associated with 1.1% increase in per capita GDP growth rate.

Likewise, Gylfason and Zoega (2001) estimated the human capital stock using both proxies obtaining a significant positive effect on growth, while Bils and Klenow (2000) maintained that initial enrollment 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. Petrakis and Stamatakis (2002) also asserted that primary and secondary education matter more for growth in less developed countries as opposed to more developed economies, where higher education becomes more important.

There are some empirical studies using complex specifications for human capital. Azariades and Drazen (1990) estimated human capital as a threshold variable, that is, the impact of human capital depends on human capital stock accumulated within a given time period. Aghion et al. (2005) found strong support for the hypothesis that investments in high brow education substantially enhance growth in the cases of states that are close to the technological frontier, while investments in low brow education significantly augment growth in the cases of states that are far from the technological frontier. Moreover, Portela, Alessie, and Teulings (2006) maintained that education has a moderate immediate effect on GDP of about 4.2–6.5%, but a huge long run effect of about 54–59%, which however takes many years to materialize, the half value time being 75–99 years. Finally, Easterlin (1981) dealt with the chicken–egg problem of the relationship between educational development and economic growth by examining historical data. His conclusion was that the spread of technology in modern economic growth depended on the learning potentials and motivation that were linked to the development of formal schooling or that the most likely causal link is from education to economic growth rather than the other way around.

In the case of Greece, there are some empirical studies which have investigated the effects of education on economic growth. More specifically, the following studies expressed human capital stock by using the average years of schooling as proxy for human capital. Bowles (1971) estimated the contribution of education on economic growth at 3% for the period 1951–1961, with Lianos and Milonas (1975) obtaining similar results for the period 1961–1971. Caramanis and Ioannides (1980) reckoned this contribution between 3% and 5%, while Psacharopoulos and Kazamias (1985),

employing data from sampling family budgets, estimated the contribution at the level of 2%. Dimakos (1996) calculated the input of education to economic growth for the periods 1961–1971 and 1971–1981 at 2.9% and 3.1%, respectively, and Magoula and Prodromidis (1999) showed that the relative contribution of secondary and higher education to growth in relation to the contribution of primary education has risen: from the 1960s to the 1980s, total contribution to economic growth has increased from a low 0.16% to a high 2.25%.

Others studies focusing on the Greek case used the school enrollment rates as proxy for human capital. Asteriou and Agiomirgianakis (2001) showed that growth rates of enrollments in primary and secondary education, as well as of public expenditure on education, positively affected the GDP per capita over the period 1960–1994. Finally, Benos and Karagiannis (2008) found that the number of students in lower and upper secondary education levels affected growth positively over the time period 1981–2003.

3. Methodology and model

One of the most cited relevant studies is that of Mankiw, Romer, and Weil (1992) (MRW model). This study showed that an augmented Solow growth model, when solved for the steady-state per capita income level, ends up to an equation that includes physical and human capital as the basic determinants of growth. The MRW model used the variable ‘secondary school enrollments’ as a proxy for human capital and explained almost 80% of the GDP per capita variation in a sample of 98 countries (including Greece) for the period 1960–1985. The model used in this paper has been formerly applied for determining how education affects the growth rate of a large number of countries (Durlauf and Quah 1999).

Among others, Bernanke and Gürkaynak (2001) have re-evaluated the model, by expanding the period of analysis concluding that MRW’s methodology applies broadly to almost any economic growth model that admits a balanced growth path. Furthermore, two of the most important empirical studies in the field of economic growth (i.e. Mankiw, Romer, and Weil (1992); Islam [1995]) were not without statistical problems. However, their value in determining the source of economic growth is not questioned (Edwards 2007). Nonneman and Vanhoudt (1996) propose an extension of the MRW model, by including R&D expenditures. In this way, they confirm the importance of human capital in achieving growth, but at a lower degree than that suggested by Mankiw, Romer, and Weil (1992). Their extended model now explains about 80% of the variation in the cumulative growth rates between OECD countries.

The MRW model has employed a Cobb–Douglas production function of the following form:

$$Y = K^\alpha H^\beta (AL)^{1-\alpha-\beta} \quad (1)$$

where Y = the product, K = the physical capital, L = labor, H = human capital, and A = the level of technology used. Labor and the level of technology used are considered to increase exogenously by rate n and g respectively. Considering decreasing returns to scale, that is $\alpha + \beta < 1$, we transform framework (1) and end up with an equation on income per worker of the following form:

$$\ln \frac{Y}{L} = \ln A + gt - \frac{\alpha + \beta}{1 - \alpha - \beta} \ln(n + g + \delta) + \frac{\alpha}{1 - \alpha - \beta} \ln(s_k) + \frac{\beta}{1 - \alpha - \beta} \ln(s_h) \quad (2)$$

where s_k = the ratio of investment to product, s_h = human capital investment, n , g , and δ = the growth rates of labor, technology, and capital amortization respectively, and t = time.

A more descriptive presentation of the model can be found in Appendix 1. Following the study of Mankiw, Romer, and Weil (1992), investment (as GDP percentage) is used as index for physical capital, and the percent share in secondary education is used as proxy of human capital. These variables do not constitute a stock but a kind of flow. In this way we control their contribution to production, taking into account that they contribute to the production of both physical and human capital. Proceeding to the framework (2) and taking the first differences in order to overcome the lack of time-series stationary, we end up to the following function:

$$\Delta \ln q_t = c_0 + \alpha \Delta \ln k_t + \beta \Delta \ln(n + g + \delta)_t + \gamma \Delta \ln h_t + \varepsilon_t \quad (3)$$

where q = output per worker, k = investment as percentage of GDP, h = the gross percentage of the enrolled in secondary education, and ε = the error term.

However, the most important proxy for human capital is education. Therefore, the fundamental concern evolves around the tracing of those proxies which can best depict the differences across countries, concerning their educational background as well as investment on school education.

The estimation of this variable is achieved by using the following function (World Bank 2009):

$$GSER^t = \frac{E^t}{P^t} \times 100 \quad (4)$$

where $GSER^t$ = Gross secondary enrollment ratio in school year t , E^t = Enrollment in the second level of education in school year t , P^t = Population in age-group which officially corresponds to the second level of education in school year t .

4. A brief reference on Greek economy and education during the period 1960–2000

As already mentioned in the introduction, the time period 1960–2000 was a remarkable one for Greece. During this ‘transition period’, a number of structural and functional reforms and adjustments, in both economy and education, were materialized, with varying success. Greece was transformed from a primary to a tertiary sector based economy and progressed rapidly in closing the income gap with the best performing economies. Economic growth was remarkable until the end of the 1970s. Indeed the average growth rate of GDP per worker was at 11.2% in the 1960s, 4.3% in the 1970s, 0.1% in the 1980s and 1.2% in the 1990s. The average growth rate was approximately 6% during the examined period. Greece, also achieved a satisfactory employment rate. The average unemployment rate was recorded at 5.1% during the 1960s, fell down to 2.2% in the 1970s and then increased to 7.1% in the 1980s and 9.7% in 1990s. On the other hand, the country suffered from high inflation, especially

during the period 1980–1995. More specifically, inflation rose from an annual average 2.1% in the 1960s to 14.3% in the 1970s and 19.5% in the 1980s, but later decreased to 9.1% in the 1990s and finally fell down to 2.5% in the year 2000. The fiscal deficit equaled 1.62% of GDP in the fiscal year 1960, 1.52% in 1970, 2.6% in 1980, 14% in 1990 and 3.7% in 2000. The 1980s and 1990s recorded high inflation and fiscal deficits rates with significant variation caused by exogenous factors (e.g. oil crisis) as well as the political cycle. At the same period the trade deficit varied from 7.6% in 1960 to 7.18% in 1970, 7.92% in 1980, 9.82% in 1990 and 13.5% in 2000. In this period, public debt increased significantly from 8.9% of the GDP in 1960, to 18.9% in 1970, 22% in 1980, 71% in 1990 and 102% in 2000.¹ The Greek economy, passed on to the twenty-first century, facing a number of unsolved problems: high fiscal deficits and public debt, trade deficits and mainly low competitiveness. The need for fiscal discipline was compelling as was the adoption of institutional, structural and functional reforms in order to adapt to the Eurozone environment.

Education in Greece constitutes a responsibility of the State and is offered for free by public educational institutions at all levels. The Greek educational system has always been a very centralized one. Social demand for education increased, during the period 1960–2000, and the public educational structures of all levels have at the same time expanded. In the case of higher education, at the beginning of the 1960s only seven universities operated in the country while in 2000 this number increased to 20 universities and 14 Technological Educational Institutions. Starting from the first half of the 1990s, a new system of post-secondary vocational training was adopted (through the operation of public and private centers).

Greek education, especially at the secondary level, has to a great extent been oriented towards general schooling. The period 1975–1977 stands out for the establishment of mandatory nine-year education (six year primary and three year secondary education). Technical and vocational education had not been well-developed until the mid-1970s. Since then, efforts have been made to reform and modernize educational structures of this level but progress has been slow. Educational qualifications in Greece are considered prerequisites for a successful professional career, both in the public and the private sector. The Greek educational system entered the twenty-first century facing a series of problems such as the low quality and low effectiveness of education at all levels, graduate unemployment, massive student exodus abroad, brain drain, misallocation of resources, regressive social transfers, reduced human capital investment.

4.1. Sources and data

Over the last 40 years, Greece has been spending about 3% of its GDP on education (see Figure 1), while in the years to come this rate is expected to increase and approach the EU average, which is estimated at 5% of GDP. Before any new financing takes place though, it is necessary and particularly useful to know what will be the contribution of these resources to the growth rate of the national income through the improvement of human capital. In other words, it would be useful to estimate the effect of education on the GDP growth rate.

The current study covers the period 1960–2000. The sources of the data on GDP per worker, population and investment will be the Penn World Table 6.1 and the World Development Indicators. From these sources we will retrieve the gross secondary

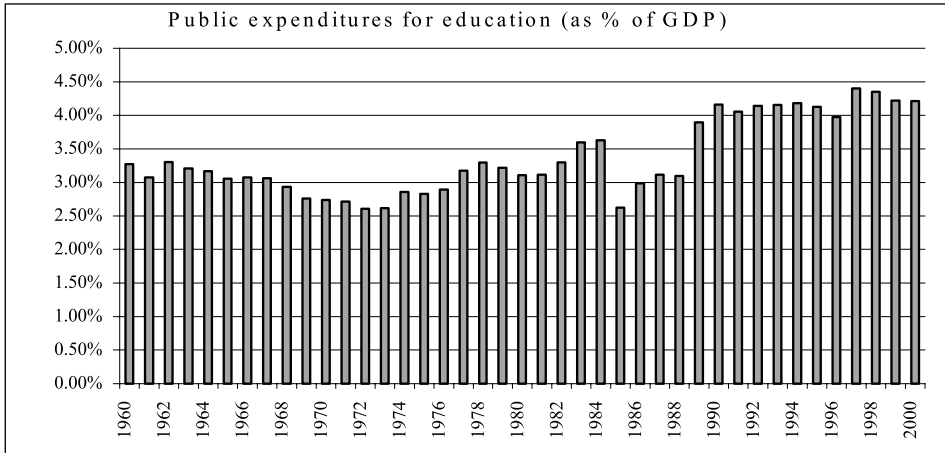


Figure 1. Public expenditure for education in Greece as percentage of GDP (1960–2000). Source: Own elaboration of data derived from National Accounts 1960–2000, National Statistical Service.

enrollment ratio (henceforth GSER). After a first data analysis, we notice that during 1960–2000 there has been a significant GDP increase, as well as a radical increase in the share of secondary education (Figure 2).

More specifically, over the last 40 years, Greece has more than tripled its income per worker, indicating an increase of 6.1%. The average level of education on a national level has taken a similar course. The milestone in the history of national education in Greece has been year 1975, when nine-year compulsory education has been constitutionally established.

During the examined period secondary education has shown significant development, with the percentage of enrolled students in secondary education increasing from 37% to 96%, exhibiting an average annual growth rate of 4% (Table 1). However,

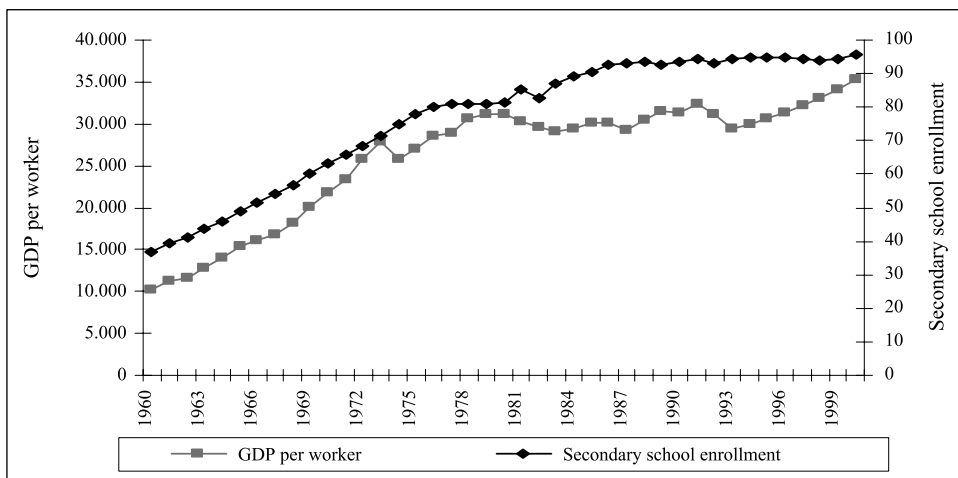


Figure 2. GDP per worker (USD, 1996 as base year) and GSER (1960–2000). Source: Own elaboration of data derived from Penn World Table 6.1 and World Bank Development Indicators.

Table 1. GDP, capital investments, and secondary education.

	GDP per worker (USD, 1996 as base year)	Capital investments as percentage of GDP (%)	GSER (%)	GDP per worker – average growth rate (%)	Capital investments as percentage of GDP – average growth rate (%)	GSER average growth rate (%)
1960	10,254	24.59	37.01	—	—	—
2000	35,243	23.51	96.04	—	—	—
1960–2000	26,093	25.85	77.10	6.12	0.21	4.02
1960–1970	15,320	29.77	49.23	11.23	3.86	7.03
1970–1980	27,488	31.49	75.16	4.35	–3.03	2.94
1980–1990	30,221	20.84	89.24	0.10	–1.47	1.51
1990–2000	31,887	20.91	94.33	1.24	1.49	0.33

Source: Data on GDP per worker and capital investment derived from Penn World Table 6.1; GSER derived from World Bank Development Indicators.

when this 40-year period splits to four 10-year periods, it becomes obvious that this increase shows no uniformity. The first 10-year period (1960s) registers the highest growth rate of enrolled students, while the 1990s the lowest. The population's participation in secondary education recorded its greater increase during the examined period (from 30% in 1960 it reached 97% in 2000). Furthermore, by examining such a long time period (40 years), we limit the variable bias, by allowing enough time for the effect of human capital on economic growth to take place. Meanwhile, GDP per worker shows its lowest growth rate during the 1980s. It is worth mentioning the significant fall of GDP growth rate in 1974 (Figure 3), compared to all previous and following years under study, due to the oil crisis. Finally, capital investments range at an average 25% of GDP during the entire given time period. The highest capital

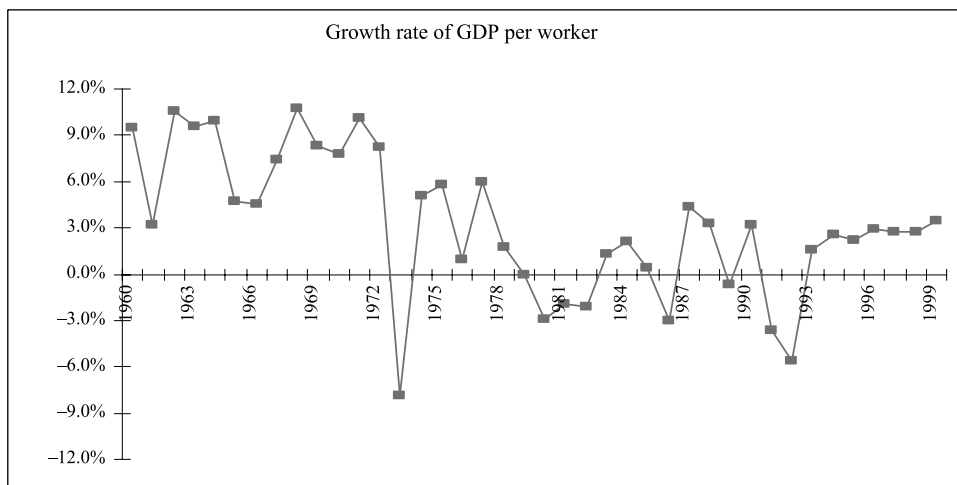


Figure 3. Growth rate of GDP per worker (USD, 1996 as base year) in Greece (1960–2000). Source: Own elaboration of data derived from Penn World Table 6.1.

investments (by average) are reported during the period 1970–1980 and the lowest during the following decade (1980–1990).

5. Empirical analysis and results

In order to assess education's effect on Greece's economic growth, function (3) is being estimated.² Following Mankiw, Romer, and Weil (1992) and considering that $g + \delta = 0.05$ remains constant during the whole period of study six cases are analyzed (Table 2). It should be noted that, according to Mankiw, Romer, and Weil (1992), g and δ are constant for all countries considering that technology (and, therefore, its rate, g) is a public good available to all countries. At the same time there are no available data to estimate depreciation rates for a specific country (for a further discussion, see Schütt 2003). Since $g + \delta$ are assumed to be constant, they have no influence on the estimated results from function (3) (see also Ikonen 1999). These assumptions can also apply in the case of Greece.

On the one hand, Greece has had access to EU knowledge and technology and has achieved a steady and constant GDP per capita increase. On these grounds, the hypothesis of constant growth rate of technology (g) and a constant growth rate of depreciation is not unrealistic. To the above, we must also add the lack of data for estimating these two variables. Therefore, the hypothesis that g and δ remain constant is considered necessary in order to estimate the MRW model for the case of the Greek economy. It should be also mentioned that all variables are stationary on 5% significant level (Table 3).

First, Case 1 is focused on. The human capital coefficient γ has been estimated at 0.64 and therefore has been proven positive and statistically significant. This nearly agrees with the results of Mankiw, Romer, and Weil (1992) as well as the other studies using the same framework, which estimated $\gamma = 0.66$ in a sample of 98 countries for the period 1960–1985. More specifically, Keller and Poutvaara (2005) using the Nonneman and Vanhoudt (1996) model (an extension of the MRW model, which includes R&D) confirm similar results regarding the contribution of human capital to GDP growth rate. However, the inexistence of R&D data for Greece for such a long period of time does not allow us to include this variable in our estimations.

Next, function (3) is estimated by taking one and two time lags (Cases 2 and 3, respectively). In these cases, estimations of education coefficients have been proven similar to that of Mankiw, Romer, and Weil (1992). Introducing time lags is necessary since a certain time intervenes between the enrollment of students in secondary education and their actual entry as workers in the productive process (Prontzas 2004). At this point two more parameters must be considered: (1) obligatory secondary education in Greece lasts three years, (2) despite the establishment of the nine-year obligatory education (six years of primary and three years of secondary education) in 1976, a significant rate of secondary education students' drop outs continued to be noted until the end of the 1980s (Ministry of Education 1995). Therefore, in the scope of this study, it seems that, in order to capture education's effect on productivity, the use of two time lags is sufficient.

Next, a dummy variable (D) is introduced in the pre-mentioned framework. This dummy equals zero for the time period 1960–2000, except for year 1974, when income has been greatly disturbed, in which case it equals 1. The same dummy is used in the following three cases (Cases 4, 5, and 6): coefficient (γ) on $\ln h$ increases ($\gamma = 0.73$) and reaches its highest point in the case of one time lag. On the contrary, the

Table 2. Secondary education effect on Δ GDP growth.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
c_0	0.015 ^a (2.247633)	0.012 ^a (1.969813)	0.0123 (1.803167)	0.014 ^a (2.346940)	0.012 ^a (2.151065)	0.012 ^a (1.927481)
$\Delta \ln k_t$	0.317 ^a (5.057134)	0.335 ^a (5.825684)	0.327 ^a (5.413100)	0.253 ^a (3.901513)	0.277 ^a (4.722744)	0.267 ^a (4.307027)
$\Delta \ln(n + g + \delta)_t$	-0.005 (-0.421565)	0.004 (0.415580)	-0.007 (-0.627987)	-0.006 (-0.616953)	0.003 (0.362941)	-0.009 (-0.848119)
$\Delta \ln h_t$	0.643 ^a (3.274637)			0.731 ^a (3.878396)		
$\Delta \ln h_t(-1)$		0.761 ^a (4.282297)			0.822 ^a (4.896782)	
$\Delta \ln h_t(-2)$			0.736 ^a (3.784213)			0.808 ^a (4.367982)
Dum				-0.077 ^a (-2.347061)	-0.074 ^a (-2.457592)	-0.075 ^a (-2.372263)
R^2	0.54	0.61	0.58	0.60	0.66	0.64
Adjusted R^2	0.50	0.57	0.54	0.56	0.63	0.60
Observations	39	39	38	39	39	38

^aThe coefficient is significantly different from 0 at the 5% significance level.
Note: The dependent variable is $\Delta \ln q_t$ (1960–2000), t -statistics in parenthesis.

Table 3. Result of unit root test.

	Without including trend or intercept in equation		Including intercept in equation		Including trend and intercept in equation	
	ADF test statistic	5% Critical value	ADF test statistic	5% Critical value	ADF test statistic	5% Critical value
$\Delta \log q_t$	-2.096552	-1.9498	-3.094097	-2.9399	-3.617079	-3.5312
$\Delta \log k_t$	-4.481869	-1.9498	-4.430557	-2.9399	-4.356840	-3.5312
$\Delta \log(n + g + \delta)_t$	-7.116748	-1.9501	-7.042764	-2.9422	-6.897859	-3.5348
$\Delta \log h_t$	-2.092543	-1.9498	-3.766127	-2.9399	-3.593659	-3.5312

Note: The critical values signify that all variables are stationary on 5% significant level. MacKinnon critical values have been used for rejection of hypothesis of a unit root.

Table 4. Granger Causality Test – two-period lag.

Null hypothesis	Obs	F-statistic	Probability
$\Delta \log h_t$ does not Granger Cause $\Delta \log q_t$	38	2.92667	0.06759
$\Delta \log q_t$ does not Granger Cause $\Delta \log h_t$	38	0.88945	0.42050

Note: The *F*-statistics indicate that $\Delta \ln h_t$ does Granger Cause to $\Delta \ln q_t$ on 10% significant level, while $\Delta \ln q_t$ does not Granger Cause to $\Delta \ln h_t$. The results are based on a two-period lag time.

coefficient on investment ($\ln k_t$) decreases compared to Cases 1, 2, and 3 when the dummy has not been used. Introducing the dummy also increased R^2 . The coefficient on $\ln(n + g + \delta)$ is of negative value, almost in all cases, but is not statistically significant. Results become more robust when we add the dummy variable, and we capture an exogenous effect in the GDP growth rate, which occurred in 1974 due to the international petroleum crisis.

Through this framework, it seems that the educational process has had a significant positive effect on Greece's economic growth during these 40 years of study (1960–2000). Moreover, up to 63% of the total variance of $\Delta \ln \text{GDP}$ is explained by the total variance of the independent variables (investments, human capital, labor). The human capital coefficient is estimated to be twice the investment coefficient. The results show that for every 1% increase of the annual differences in human capital, the annual differences of GDP growth raise by 0.64%. This positive effect is also valid and intensifies for time lags $t = -1$ and $t = -2$ to 0.76% and 0.81% respectively.

In order to improve the validity of the results and verify any causality between education and economic growth, we apply the Granger Causality test. The results (Table 4) lead to the conclusion that education's growth rate ($\Delta \log h_t$) is causally related to GDP per worker growth rate ($\Delta \log q_t$), at 10% significant level, which means that secondary education actually affects economic growth. On the other hand, GDP growth rate has no causal relation to secondary education growth rate.

6. Concluding remarks

According to the existing literature, there is a large amount of evidence that human capital and, therefore, education have a significant impact on economic growth. This

paper has analyzed the effect of education on economic growth (in terms of GDP per worker) in Greece during the transition period 1960–2000. This period has been most crucial as significant economic, social, and political changes of strategic nature have taken place in the country. In order to estimate education's contribution to economic growth the paper used the methodology and model of Mankiw, Romer, and Weil (1992) and the percentage of enrollments in secondary education as proxy for human capital.

The econometric model explained up to 66% of the variation of economic growth rate through the variation of physical capital, human capital, and labor. More specifically the contribution of the annual differences of human capital growth to the annual differences of GDP growth has been estimated from an annual 0.64% up to 0.81%, when the coefficient of education is estimated using time lags. By testing for Granger Causality we confirmed that it is education that affects the economic growth rate (and not vice versa). It, thus, becomes obvious that during this 40-year period of study (1960–2000) Greece's economic growth has been positively affected by education.

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Notes

1. AMECO database (European Commission) and Bank of Greece.
2. In all examined cases the Serial Correlation LM test and the White Heteroskedasticity test have been run. They have both verified that there is no first- and second-class correlation problem as well as no heteroskedasticity problem in the error terms, respectively.

References

- Aghion, P., L. Boustany, C. Hoxby, and J. Vandenbusschex. 2005. Exploiting states mistakes to identify the causal impact of higher education on growth. Working Paper, Department of Economics, Harvard University.
- Asteriou, D., and G. Agiomirgianakis. 2001. Human capital and economic growth, Time series evidence from Greece. *Journal of Policy Modeling* 23: 481–9.
- Azariades, C., and A. Drazen. 1990. Threshold externalities in economic development. *Quarterly Journal of Economics* 103: 501–26.
- Barro, R. 1991. Economic growth in a cross section of countries. *Quarterly Journal of Economics* 106: 407–43.
- Barro, R. 1997. *Determinants of economic growth: A cross-country empirical study*. Cambridge, MA: MIT press.
- Bassanini, A., and S. Scarpetta. 2001. The driving forces of economic growth: Panel data evidence for the OECD countries. *OECD Economic Studies* 33: 9–56.
- 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, no. 1: 52–69.
- Bernanke, B., and R. Gürkaynak. 2001. Is growth exogenous? Taking Mankiw, Romer, and Weil seriously. *NBER Macroeconomics Annual* 16: 11–57.
- Bils, M., and P. Klenow. 2000. Does schooling cause growth? *American Economic Review* 90, no. 5: 1160–83.

- Bowles, S. 1971. Growth effects of changes in labor quality and quantity, Greece 1951–1961. In *Studies in development planning*, ed. H. Chenery, 371–85. Cambridge: Harvard University Press.
- Caramanis, M., and J. Ioannides. 1980. Sources of growth and the contribution of education, sex and age structure to the growth rate of the Greek economy. *Greek Economic Review* 2: 143–62.
- De la Fuente, A., and R. Domenech. 2000. Human Capital in Growth Regressions: How Much Difference Does Data Quality Make? [mimeo]. Universidad Autonoma de Barcelona.
- Dimakos, G. 1996. Education – Productivity, social and economic development of Greece. PhD thesis, Department of Economics, National and Kapodistrian University of Athens.
- Durlauf, S., and D. Quah. 1999. The new empirics of economic growth. In *Handbook of macroeconomics*, ed. J. Taylor and M. Woodford, 1st ed., chap. 4, 235–308. Amsterdam: Elsevier.
- Easterlin, R. 1981. Why isn't the whole world Developed? *Journal of Economic History* 41: 1–19.
- Edwards, T. 2007. Returns to education and the Mankiw-Romer-Weil result. *Economics Bulletin* 15: 1–8.
- Englander, S., and A. Gurney. 1994. OECD productivity growth: Medium-term trends. *OECD Economic Studies*, no. 22.
- Gemmell, N. 1996. Evaluating the impacts of human capital stock and accumulation on economic growth: Some new evidence. *Oxford Bulletin of Economics and Statistics* 58: 9–28.
- Gylfason, T., and G. Zoega. 2001. Education, social equality and economic growth: A view of the landscape. Working paper, University of Iceland.
- Hanushek, E., and D. Kim. 1995. Schooling, labor force quality, and economic growth. NBER Working Paper 5399.
- Ikonen, P. 1999. Further testing of the human-capital augmented Solow model. Discussion Paper, Government Institute for Economic Research, Helsinki.
- Islam, N. 1995. Growth empirics: A panel data approach. *Quarterly Journal of Economics* 110: 1127–70.
- Keller, K., and Poutvaara, P. 2005. Growth in OECD countries and elsewhere: How much do education and R&D explain? *Economics Bulletin* 15: 1–11.
- Krueger, A., and M. Lindahl. 2001. Education for growth: Why and for whom? *Journal of Economic Literature* 39, no. 4: 1101–36.
- Levine, R., and D. Renelt. 1992. A sensitivity analysis of cross-country growth regressions. *American Economic Review* 82: 942–63.
- Lianos, T., and A. Milonas. 1975. The contribution of production input to the Greek growth rate, 1961–1971 [in Greek]. Athens: Centre for Planning and Economic Research.
- Lin, T. 2003. Education, technical progress, and economic growth: The case of Taiwan. *Economics of Education Review* 22: 213–20.
- Lin, T. 2006. Alternative measure for education variable in an empirical economic growth model: Is primary education less important? *Economics Bulletin* 15: 1–6.
- Liu, C., and M. Armer. 1993. Education's effect on economic growth in Taiwan. *Comparative Education Review* 37, no. 3: 304–21.
- Lucas, E. 1988. On the mechanics of economic development. *Journal of Monetary Economics* 22: 3–42.
- Magoula, T., and K. Prodromidis. 1999. Education and economic growth in Greece. Discussion Paper No. 99, Athens University of Economics and Business.
- Mankiw, G., D. Romer, and D. Weil. 1992. A contribution to the empirics of economic growth. *Quarterly Journal of Economics* 107: 407–37.
- Ministry of Education. 1995. *Educational policy review*. Background report to OECD on education. Athens: Organization of Textbooks Publishing.
- Murphy, M., A. Shleifer, and R. Vishny. 1991. The allocation of talent: Implications for growth. *Quarterly Journal of Economics* 106: 503–30.
- Nelson, R., and E. Phelps. 1966. Investment in human, technological diffusion, and economic growth. *American Economic Review Papers and Proceedings* 56: 69–75.
- Nonneman, W., and P. Vanhoudt. 1996. A further augmentation of the Solow model and the empirics of economic growth for OECD countries. *Quarterly Journal of Economics* 111: 943–53.

- Petrakis, P., and D. Stamatakis. 2002. Growth and educational levels: A comparative analysis. *Economics of Education Review* 21: 513–21.
- Portela, M., R. Alessie, and C. Teulings. 2006. Measurement error in education and growth regressions. IZA Discussion Paper 1165, Center for Economic Studies & Ifo Institute for Economic Research.
- Prontzas, P. 2004. Education and economic growth: The case of Greece (1960–2000) [in Greek]. Master's diss., Department of Economics, National and Kapodistrian University of Athens.
- Psacharopoulos, G., and A. Kazamias. 1985. *Education and development in Greece: A social and economic review of higher education* [in Greek]. Athens: National Center for Social Research (NCSR).
- Romer, P. 1990. Endogenous technological change. *Journal of Political Economy* 98: S71–S102.
- Schütt, F. 2003. *The importance of human capital for economic growth*. Materialien des Wissenschaftsschwerpunktes. Bremen: Institute for World Economics and International Management.
- Tallman, E., and P. Wang. 1994. Human capital and endogenous growth: Evidence from Taiwan. *Journal of Monetary Economics* 34: 101–24.
- World Bank. 2009. Education statistics – Definitions. <http://www.worldbank.org>

Appendix 1

The model Mankiw, Romer, and Weil (1992) is derived from a constant returns to scale Cobb–Douglas production function. Output at time t is given by:

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

where Y , K , H , and L are respectively output, physical capital, human capital labor, and labor. $A(t)$ is the level of technology used (technological and economic efficiency). α and β are the partial elasticities of output with respect to physical capital and human capital and $0 < \alpha + \beta < 1$. Labor and the level of technology used are considered to increase exogenously by rate n and g , respectively. Therefore:

$$L(t) = L(0)e^{nt} \tag{A2}$$

$$A(t) = A(0)e^{gt} \tag{A3}$$

$$\text{so } A(t)L(t) = A(0)L(0)e^{(n+g)t} \tag{A4}$$

with $A(t)L(t)$ = the number of effective unit of labor which increases with a rate of $n + g$. So output is produced using physical capital, human capital and effective labor.

We define the output, physical capital, and human capital per unit of effective labor, respectively $y = \frac{Y(t)}{A(t)L(t)}$, $k = \frac{K(t)}{A(t)L(t)}$, and $h = \frac{H(t)}{A(t)L(t)}$. When diving equation (A1) by $A(t)L(t)$, we end up with

$$\begin{aligned} \frac{Y(t)}{A(t)L(t)} &= K(t)^\alpha H(t)^\beta \frac{(A(t)L(t))^{1-\alpha-\beta}}{A(t)L(t)} = K(t)^\alpha H(t)^\beta (A(t)L(t))^{-\alpha} \\ (A(t)L(t))^{-\beta} &\Rightarrow y = k^\alpha h^\beta \end{aligned} \tag{A5}$$

Assuming now that a constant fraction of output (S_K) is invested on physical capital, the law of motion for physical capital is:

$$\dot{K} = s_k Y - \delta_k K \tag{A6}$$

where δ_k is the annual depreciation rate of the physical capital and $\dot{K} \frac{dK}{dt}$. In order to find the evolution of physical capital per unit of effective labor over time, we take the first derivative of $k = \frac{K(t)}{A(t)L(t)}$ with respect to t and the result is:

$$\frac{\dot{k}}{k} = \frac{\dot{K}}{K} - \frac{\dot{A}}{A} - \frac{\dot{L}}{L} \tag{A7}$$

By using equations (A4) and (A5) and defining the exogenous annual growth rate of technological progress as $g = \frac{\dot{A}}{A}$ and the exogenous annual growth rate of the labor force as, $n = \frac{\dot{L}}{L}$, we end up with:

$$\begin{aligned}
 k^* &= \frac{K}{AL} \left(\frac{s_K Y - \delta_k K}{K} - n - g \right) = \frac{s_K Y - \delta_k K}{AL} - k(n + g) = s_K y - \delta_K k - k(n + g) \\
 &\Rightarrow k^* = s_K k^\alpha h^\beta - \delta k - k(n + g) = s_K k^\alpha h^\beta - (\delta_k + n + g)k \quad (A8)
 \end{aligned}$$

Following a similar methodology and assuming that S_H is the investment in human capital as a fraction of output, we conclude that:

$$\dot{H} = s_H Y - \delta_H H \quad (A9)$$

where δ_H is the annual depreciation rate of the human capital and $\dot{H} = \frac{dH}{dt}$. Using these formulas we find that the evolution of human capital per unit of effective labor is:

$$h^* = s_H k^\alpha h^\beta - (\delta_H + n + g)h \quad (A10)$$

Assuming that human capital depreciates at the same rate as physical capital, we conclude to these functions:

$$k^* = s_k y - (n + g + \delta)k \quad (A11)$$

$$h^* = s_h y - (n + g + \delta)h \quad (A12)$$

Using these functions (A11) and (A12) and taking logarithms, we transform framework (A1) and end up with an equation on income per worker of the following form:

$$\ln \frac{Y}{L} = \ln A + gt - \frac{\alpha + \beta}{1 - \alpha - \beta} \ln(n + g + \delta) + \frac{\alpha}{1 - \alpha - \beta} \ln(s_k) + \frac{\beta}{1 - \alpha - \beta} \ln(s_h) \quad (A13)$$