

# **The Link between Educational Levels and Economic Growth: A Neoclassical Approach for the Case of Greece**

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## **Abstract:**

This study examines the link between educational levels and economic growth and estimates the potential impact of the different educational levels on economic growth in Greece over the period 1960 – 2009. During that period an educational expansion took place especially in secondary and mainly in higher education. The paper applies the Mankiw, Romer and Weil (1992) model and employs cointegration and error-correction models. The empirical analysis reveals that there is a long-run relationship between educational levels and gross domestic product. The overall results show that secondary and higher education have had a statistically significant positive impact on growth, while primary hadn't contributed to economic growth. The results also suggest that there is evidence of unidirectional long-run causality running from primary education to growth, bidirectional long-run causality between secondary and growth, long-run and short-run causality running from higher education to economic growth.

**Keywords:** education levels; human capital; economic growth; enrolment rates; Greece

**JEL classification:** O40; O41; O47; I21; I25

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## **1. Introduction**

The impact of human capital on economic growth is well-established in the economic literature. In neoclassical economics, the early work of Solow (1956) showed that economic growth could not only be explained by capital and labour increase. His aim was to determine the contributions of the factors of production (capital and labour) and the increase in technical progress to the growth rate as a whole. Mankiw, Romer and Weil (1992) (MRW thereafter), extended Solow's (1956) model by incorporating an explicit process of human capital accumulation. They 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. During the last three decades new growth theories or endogenous growth theories, accept education as one of the primary components of human capital and the effect of education on the economies has been pointed out, (Lucas 1988), (Romer 1990), etc. The purpose of this study is firstly, to examine the relationship between the levels of education and economic growth and secondly to estimate the effects of each level of education on the growth of the Greek economy over the period 1960-2009. The application of MRW (1992) model and a VAR analysis were used. During this period, a number of structural and functional reforms and adjustments, in both economy and education, were materialised, with varying success (Tsamadias and Prontzas, 2012). Three major events took place influencing the Greek economy and education: a. The association-for-entry agreement with the European Economic Community (EEC) (November, 1962). b. The accession to the European Economic Community. The induction agreement came into force in January 1981. c. The accession to the European Monetary Union (EMU) and the adoption of the new Eurocurrency (1 January, 2001).

The fact that different schooling levels of education may have different effects on growth has been addressed in a small set of recent papers. The motivation for this study comes from the necessity of identifying the potential impact of the different schooling levels on economic growth, in the period that an educational expansion took place especially in secondary and mainly in higher education. The results may improve the decisions of policymakers about education and its contribution to economic growth.

The rest of the paper is organized as follows. In section 2, provides a brief review of empirical literature. Section 3 discusses the methodology and explains sources and data. Section 4 reports the empirical results based on econometric analysis. Section 5 discusses the results. Finally, section 6 summarizes the main findings and conclusions of the study.

## **2. Review of Empirical Literature**

According to the existing literature, there is a large amount of evidence that human capital has a significant impact on economic growth. Although a few empirical studies focus on the impact of different education levels on economic growth. The main studies that have examined the impact of the educational levels on economic growth are presented below:

Liu and Armer (1993) found that both primary and junior-high achievement variables add explanatory power to economic growth in Taiwan, but senior-high and college education did not exert any significant effects on growth. Tallman and Wang (1994) showed that higher education has a greater positive impact on growth in relation to primary and secondary education for the case of Taiwan. Mingat and Tan (1996) for a sample of 113 countries found that higher education has a positive statistically significant impact only in the group of developed countries, while the primary has a positive effect in less developed and secondary a positive effect in developing. Gemmell (1996) for OECD countries concluded that primary education most affects the less developed countries, while secondary and higher education the developed ones. Mc Mahon (1998) examined the effect of the three levels of education on economic growth for a sample of Asian countries and concluded that primary and secondary level have a significantly positive effect on economic growth, while higher is negative. Abbas (2001) for the countries of Pakistan and Sri Lanka showed that the primary has a negative effect on economic growth, while secondary and higher education have a positive and statistically significant impact on economic growth in both countries. Petrakis και Stamatakis (2002) found that the growth effects of education depend on the level of development; low-income countries benefit from primary and secondary education while high-income developed countries benefit from higher education. Self and Grabowski (2004) for the case of India showed that except higher education the primary and secondary education had a strong causal impact on economic growth. Villa (2005) investigated the effect of the three levels of education on economic growth for Italy and found that the higher and secondary education has a positive effect on economic growth, while the primary has no significant effect. Gyimah, Paddison and Mitiku (2006) found that all levels of education have a positive and statistically significant impact on the growth of per-capita income in African countries. Lin (2006) for the case of Taiwan found that primary, secondary and tertiary, have a positive impact on economic growth. Chi (2008) showed that in China, higher education has a positive and larger impact on GDP growth than primary and secondary education.

Pereira and Aubyn (2009) showed that in Portugal primary and secondary education have a positive impact on GDP, while higher has a small negative effect. Loening, Bhaskara and Singh (2010) for the case of Guatemala found that primary education is more important than secondary and tertiary education. Shaihani, et al. (2011) for the case of Malaysia concluded that in the short run only secondary education has a positive and statistically significant coefficient, while the primary and tertiary exhibit negative and statistically significant results. On the contrary only the higher education has a positive and statistically significant effect in the long run. In the case of Greece, Asteriou and Agiomirgianakis (2001) used the Lucas (1988) model and showed that the growth of enrolment rates in primary, secondary and higher education positively affected the GDP in Greece for the period 1960-1994.

### 3. Methodology and Model

The empirical analysis of this paper uses the methodology of neoclassical theory. Following MRW's (1992) augmented neoclassical model we assumed a Cobb-Douglas production function with constant returns to scale and decreasing returns to capital, augmented with the exogenous level of technological progress and human capital. The principal assumptions of their model included country specific constant rates (steady state) of investment in human and physical capital. The Cobb-Douglas production function of MRW model has been given in the following form:

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

where  $Y$  represents aggregate output,  $K$  is the physical capital,  $H$  is human capital and  $A$  is a technical efficiency index and  $L$  is labour. One assumes that  $L$  and  $A$  grow at constant and exogenous rates  $n$  and  $g$ , respectively. Considering decreasing returns to scale, that is  $\alpha + \beta < 1$ , transform equation (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  $\delta$ : the growth rates of labour, technology and depreciation rate of capital respectively and  $t$ : time.

The proxy of human capital is a key issue in the empirical growth model, as it would improve the performance of the growth model. Many researchers tried to approach human capital using proxies, as flow or as stock (Sianesi and Reenen, 2003). The proxy of human capital that was used in this study is the gross enrolment rates (flow) for the three educational levels (primary, secondary and higher). The estimation of this variable is achieved by using the following function (World Bank 2012):

$$GHER^t = \frac{E^t}{P^t} * 100 \quad (3)$$

where  $GHER^t$ =Gross Enrolment Ratio in school year  $t$  for each educational level,  $E^t$  = Enrolment for each level of education in school year  $t$ ,  $P^t$  = Population in age-group which officially corresponds to each level of education in school year  $t$ . This proxy is reported as quantitative measurement of human capital. The quality of education cannot be taken into account. Given the availability of the data, it is not possible to consider wider definition of human capital investment compassing on-the-job training,

experience and learning-by doing, the number of repeaters and dropouts in each grade and ignoring its depreciation.

### **3.1. Data and Sources**

Data on Gross Domestic Product (GDP), physical capital investments and employment series are annual and were taken from the AMECO database. GDP per worker measured at 2005 constant prices, investments is the gross capital formation as percentage of GDP at 2005 constant prices for the total economy and employment is civilian domestic employment. For the rate of population growth the growth rate of labour force is used. It should be noted that according to MRW, the growth rates of technology and depreciation rate of capital remain constant for all countries, assuming that  $g+\delta=0.05$ , considering that technology (and therefore its rate,  $g$ ) is a public good available to all countries. These assumptions also apply to Greece. Data for constructing human capital proxy were taken from the Hellenic Statistical Authority (HSA) database<sup>1</sup>. All variables are expressed in logarithmic form.

During the period 1960-2009 Greek GDP per worker indicates a significant increase as well as a radical increase in the share of secondary and higher education. The primary education is represented by a very small (almost stable), negative slope over the whole period (Figure 1).

## **4. Empirical Analysis**

This section concentrates on the effect of primary, secondary, higher education and investments in physical capital on economic growth using a VAR methodology. We estimate three different VAR models. Each model includes the variables of economic growth, investments and one of the three educational levels. Using education data by levels may be preferable for a number of reasons<sup>2</sup>. First, the order of integration is checked and then cointegration tests are used in order to check the existence of long run relationship between variables. Second, the causality tests based on vector error correction approach were applied and third, in order to investigate the dynamic relationships between the variables of the models the impulse response functions and variance decomposition are plotted and calculated respectively.

### **4.1 Stationarity test**

Initially, the stationarity of the variables GDP, investments and education is checked. The stationarity of the data set is examined using Augmented Dickey-Fuller (ADF) (1981), Phillip-Perron (PP) (1988) and Perron (1997) structural break tests. We test for the presence of unit roots and identify the order of integration for each variable in levels and first differences. The variables are specified including intercept and including both intercept and trend. Unit root test results are given in Table 1.

The results in Table 2 show that physical capital investments ( $k$ ) and educational levels ( $h_1, h_2, h_3$ ) have unit root or integrated of order one in their level and become stationary in their first differences, at least at the 5% level of significance. The labor growth rate ( $ngd$ ) appears to be an  $I(0)$  process. The unit root tests give mixed results on the issue of whether or not GDP per worker ( $q$ ) is stationary. The combined results from all the tests suggest that the GDP per worker under consideration follows an  $I(1)$  process.

## 4.2 Cointegration test

Stationary tests show that the variables of GDP, physical capital investments and primary, secondary, higher education integrated of order one. So it is checked if these variables are cointegrated. The variable ( $ng\delta$ ) was taken as exogenous in the model<sup>3</sup>. In order to account for influences on the GDP, two dummy variables are added to the VAR models. The first dummy variable involves the year 1974, when the international oil crisis took place and GDP had a significant fall. The second dummy variable involves the year 2001, when Greece became a member of the Euro zone. Akaike information criterion is used to select the optimal lag length. The cointegration test was conducted by using the reduced rank procedure developed by Johansen (1988) and Johansen and Juselius (1990). This cointegration method recommends two statistics to check the long run relationship: the Trace and maximum Eigenvalue tests. The results of the cointegration tests are presented in the tables 2, 3, and 4.

The null hypothesis is no cointegration. The null hypothesis of one co-integrating vector in the Trace test could be rejected at 5% and could not be rejected at 5% for more than one co-integrating vectors, which implies that there is only one cointegrating vector in all the cases. The finding of one co-integrating vector was further supported by the results of the maximum Eigenvalue test. Thus, the results lead to the conclusion that the GDP, investments and each of the three educational levels are cointegrated and there is a long-run relationship between them. The estimated cointegration relationships are presented in the following table 5:

From the above-estimated equations it can be concluded that in the long run the coefficients of secondary and higher education are positive and statistically significant at the one-percent level. The elasticity of GDP with respect to secondary and higher education is 0.55 and 0.52 respectively. This means that a one percent increase in secondary and higher education will foster economic growth by about 0.55 and 0.52 percent respectively. The elasticity of GDP with respect to primary education is -2.81. So the primary education has had a negative effect on economic growth. Also, it can be concluded that in the long run, physical capital investments have had a significant positive effect on economic growth in all the equations.

## 4.3 Error Correction Models

Having verified that the variables are cointegrated, the vector error-correction models (VECM thereafter) can be applied. For the VECMs including primary and secondary education the Akaike information criterion identified no lags and one lag for the VECM with higher education. So, there is not a short run but only a long run relationship between the variables which included in the VECMs with primary and secondary education. The VECMs pass all the standard diagnostic tests for residual serial correlation, normality and heteroscedasticity. The results<sup>4</sup> of the VECMs showed that the first dummy variable has a negative and statistically significant influence on GDP. The second dummy has no influence on GDP as the coefficient is not statistically significant. The t statistic on the coefficient of the lagged error-correction term represents the long-run causal relationship and the F-statistic on the explanatory variables represents the short-run causal effect (Narayan and Smyth 2006). More specifically, the Wald-test applied to the joint significance of the sum of the lags of

each explanatory variable and the t-test of the lagged error-correction term will imply statistically the Granger exogeneity or endogeneity of the dependent variable. The non-significance of ECT is referred to as long-run non-causality, which is equivalent to saying that the variable is weakly exogenous with respect to long-run parameters. The absence of short-run causality is established from the non-significance of the sums of the lags of each explanatory variable. Finally, the non-significance of all the explanatory variables, including the ECT term in the VECM, indicates the econometric strong-exogeneity of the dependent variable that is the absence of Granger-causality (Hondroyannis and Papapetrou 2002).

Table 6 results show that the error-correction term is negative and statistically significant only for the GDP equation and indicates the significance of the long-run causal effect at the one percent level. Therefore, GDP is not weakly exogenous variable. These results imply that in the long run there is a unidirectional Granger causality running from primary education to GDP. Table 7 results show that the error-correction term is negative and statistically significant for GDP and secondary education equations and indicates the significance of the long-run causal effect at the one percent level. Therefore, GDP and secondary education are not weakly exogenous variables. These results imply that in the long run, there is a bidirectional Granger causality running between secondary education and GDP. Table 8 results show that the error-correction term is negative and statistically significant only for the GDP equation and indicates the significance of the long-run causal effect at the one percent level. Therefore, GDP is not a weak exogenous variable. In the long run, there is a unidirectional Granger causality running from higher education to GDP. In the short-run dynamics, the Wald tests indicate that there is a unidirectional Granger causality running from higher education to GDP. Finally, the significance levels associated with the Wald tests of joint significance of the sum of the lags of the explanatory variable and the error-correction term provide more information on the impact of higher education on economic growth and vice versa. So, only for GDP we can reject the hypothesis of strong exogeneity.

#### **4.4 Impulse Response Functions**

In order to study the dynamic properties of the VAR models, impulse response functions analysis (IRF thereafter) is employed over ten years by using the Cholesky decomposition. The IRF derived from the unrestricted VARs are presented in figures 2, 3 and 4<sup>5</sup>.

From the three figures, it becomes apparent that one standard deviation shock of primary education has had a negative impact on economic growth, while a one standard deviation shock to secondary education and higher education has had a positive impact on economic growth. The response of economic growth to higher education is significantly bigger than secondary education. Also a one standard deviation shock to physical capital investments has had a positive impact on economic growth in all the figures.

#### **4.5 Variance Decomposition Analysis**

The variance decomposition (VDC thereafter) is estimated for each variable in the VAR models for a period of ten years. The VDC estimation results are presented in tables 9<sup>6</sup>.

As the years pass primary, secondary and higher education gradually affect more the variation of economic growth. More precisely, 0.92, 0.35 and 21.01 percent of economic growth forecast error variance in a ten years period is explained by disturbances of primary, secondary and higher education, respectively. Higher education innovation explains much more than primary and secondary the variation of economic growth. Also, as the years pass physical capital investments affect the variation of economic growth in all figures. The overall results from VDC seem to be in agreement with those of IRF, providing evidence in favour of the importance of secondary and mainly of higher education to explain variation in economic growth.

## **5. Discussion of the results**

The existence of a positive impact of secondary and higher education on economic growth is consistent with most of the previous studies mentioned above. Specifically, it is in line with the studies, such as Tallman and Wang (1994), Lin (2006), Loening, Bhaskara and Singh (2010), Abbas (2001), Shaihani et al. (2011), Villa (2005), Chi (2008), Gyimah, Paddison and Mitiku (2006) and Asteriou and Agiomirgianakis (2001). The findings of a negative impact of primary education on economic growth are consistent with less of the previous studies mentioned above. In fact, the results are in line with studies such as Abbas (2001), Villa (2005) and Shaihani et al. (2011). As Romer (2001) noted, primary education might not show short run results in the economy, but has indirectly long term effects on it. As primary is the first and basic level of education it is very important for the other two levels of education. The overall results are consistent with the research of Gemmell (1996), Mingat and Tan (1996) and Petrakis and Stamatakis (2002), who concluded that primary education affects more in less developed countries, while growth in more developed countries depends mainly on higher and secondary education.

## **6. Concluding remarks**

The study analyses and estimates the effect of the three level of education on economic growth in Greece during the time period 1960–2009. In order to estimate the contribution of education to economic growth, the paper uses the neoclassical model of MRW (1992) and the enrolments rates as proxy of human capital. The empirical analysis reveals that in the long run the elasticity of GDP with respect to primary, secondary and higher education is -2.81, 0.55 and 0.52, respectively. The results also suggest that there is evidence of unidirectional long-run causality running from primary education to growth, bidirectional long-run causality between secondary and growth, long-run and short-run causality running from higher education to economic growth. These results are supported from the generalized impulse response functions and the generalized variance decomposition analysis. Overall the conclusion of the study indicates that secondary and higher education have had a positive contribution to economic growth.

## **Endnotes**

<sup>1</sup> After 2009 there are no statistical data available from Hellenic Statistical Authority database for the calculation of the variable of human capital.

<sup>2</sup> For more details please refer to Loening, Bhaskara and Singh (2010). Effects of schooling levels on economic growth: time-series evidence from Guatemala.

<sup>3</sup> The MRW model assumes exogenous rates of  $n, g, d$ .

<sup>4</sup> The results of VECMs are available from the authors upon request.

<sup>5</sup> The overall results of IRFs are available from the author upon request.

<sup>6</sup> The overall results of VDCs are available from the author upon request.

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## Appendix 1

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

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

where  $Y$ ,  $K$ ,  $H$  and  $L$  are respectively output, physical capital, human capital labor and labour.  $A(t)$  is the level of technology used (technological and economic efficiency).  $\alpha$  and  $\beta$  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 :

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

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

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

with  $A(t)L(t)$  is 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 labour 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

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

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

$$\dot{K} = s_K Y - \delta_K K \quad (\text{A6})$$

where  $\delta_K$  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:

$$\frac{\dot{k}}{k} = \frac{\dot{K}}{K} - \frac{\dot{A}}{A} - \frac{\dot{L}}{L} \quad (\text{A7})$$

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:

$$\dot{k} = \frac{K}{AL} \left( \frac{s_K Y - \delta_K K}{K} - n - g \right) = \frac{s_K Y - \delta_K K}{AL} - k(n + g) = s_K y - \delta_K k - k(n + g)$$

$$\Rightarrow k^* = s_K k^\alpha h^\beta - \delta k - k(n + g) = s_K k^\alpha h^\beta - (\delta_K + n + g)k \quad (\text{A8})$$

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

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

where  $\delta_H$  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:

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

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

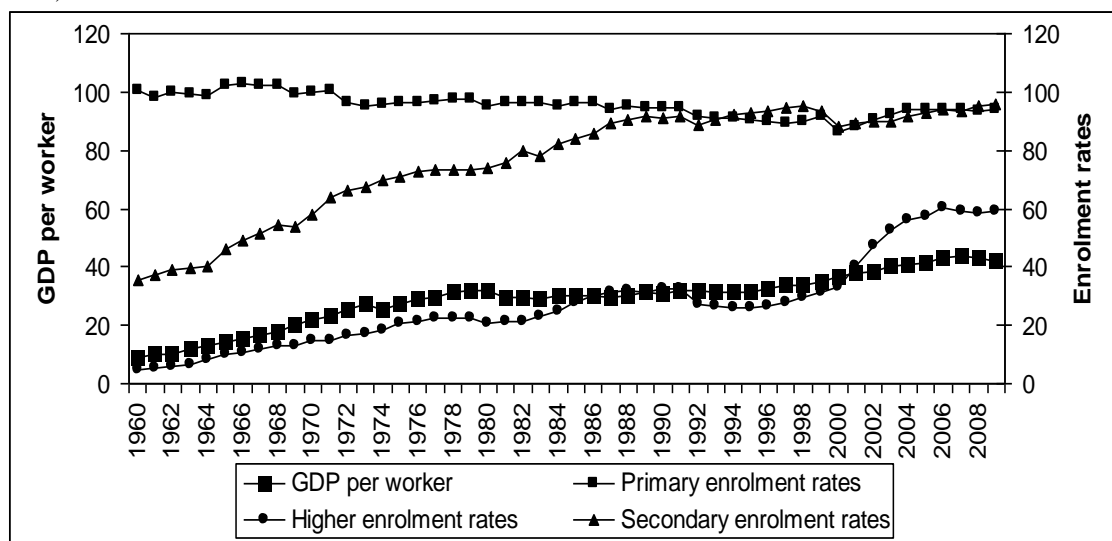
$$k^* = s_k y - (n + g + \delta)k \quad (\text{A11})$$

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

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:

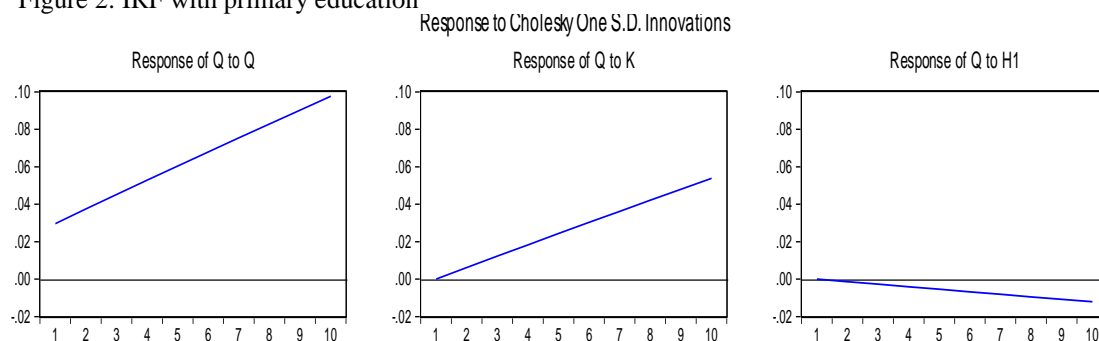
$$\ln \frac{Y}{L} = \ln A + gt - \frac{\alpha + \beta}{1 - \alpha - \beta} \ln(n + g + \delta) + \frac{\alpha}{1 - \alpha - \beta} \ln(s_k) + \frac{\beta}{1 - \alpha - \beta} \ln(s_h) \quad (\text{A13})$$

Figure 1: GDP per worker (2005 as base year) and Primary, Secondary, Higher enrolment rates (1960-2009)



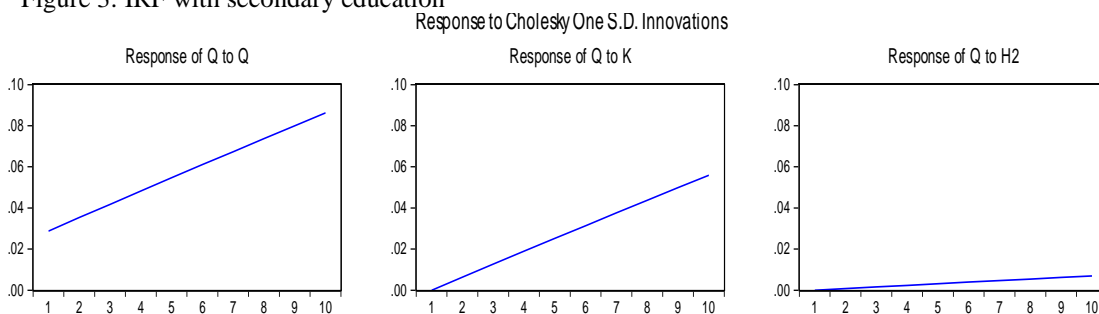
Source: AMECO database and Hellenic Statistical Authority (EL.STAT.)

Figure 2: IRF with primary education



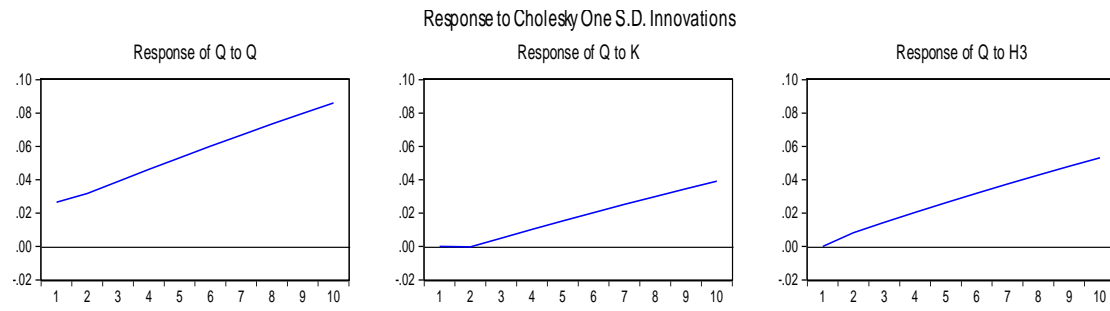
The variables of the first VAR order as following: GDP per worker, physical capital investments and primary education (Q, K and H1)

Figure 3: IRF with secondary education



The variables of the second VAR order as following: GDP per worker, physical capital investments and secondary education (Q, K and H2).

Figure 4: IRF with higher education



The variables of the third VAR order as following: GDP per worker, physical capital investments and higher education (Q, K and H3).

Table 1: Results of unit root tests

Note: \*\*\*, \*\* indicates the rejection of the null hypothesis of non stationarity (ADF) and (PP) at 1% and 5% level of significance respectively. For ADF and PP tests MacKinnon (1996) critical values have been used for rejection of hypothesis of a unit root.

Variables (in levels & first differences)	ADF test		PP test		Perron test	
	With intercept in equation	With intercept and trend in equation	With intercept in equation	With intercept and trend in equation	With intercept in equation	With intercept and trend in equation
$q_t$	-6.001***	-3.554**	-5.161***	-3.226	-3.992	-4.037
$\Delta q_t$	-4.298***	-5.185***	-4.331***	-5.319***	-7.610***	-7.510***
$k_t$	-1.506	-2.512	-1.535	-2.576	-3.192	-2.959
$\Delta k_t$	-6.754***	-6.759***	-6.761***	-6.767***	-7.488***	-7.396***
$(ngd)_t$	-5.342***	-6.111***	-5.303***	-6.112***	-7.639***	-8.230***
$\Delta(ngd)_t$	-7.630***	-7.582***	-21.21***	-22.32***	-12.59***	-12.52***
$h1_t$	-1.767	-2.349	-1.665	-2.411	-3.796	-4.132
$\Delta h1_t$	-8.028***	-7.945***	-8.028***	-7.945***	-8.662***	-8.679***
$h2_t$	-5.013***	-2.022	-5.154***	-2.066	-2.415	-3.669
$\Delta h2_t$	-4.903***	-6.393***	-5.028***	-6.393***	-7.560***	-7.465***
$h3_t$	-2.225	-3.753**	-2.329	-2.582	-3.978	-4.152
$\Delta h3_t$	-3.543**	-3.744**	-3.523**	-3.753**	-4.869	-4.8207

For structural break test critical values are those reported in Perron (1989).

Table 2: Cointegration test: GDP per worker, physical capital investments and primary education

Series: q k h1					
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5 Percent Critical Value	Max-Eigen Statistic	5 Percent Critical Value
None*	0.737	76.294	24.275	65.534	17.797
At most 1	0.188	10.759	12.320	10.222	11.224
At most 2	0.010	0.536	4.129	0.536	4.129

Note: <sup>a</sup> Trace and Maximum Eigen test statistics are compared with the critical values from Johansen and Juselius (1990). \*Trace and Max-Eigen tests indicate 1 cointegrating equation at the 5% level. <sup>b</sup> Lags interval: 0 to 0

Table 3: Cointegration test: GDP per worker, physical capital investments and secondary education

Series: q k h2					
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5 Percent Critical Value	Max-Eigen Statistic	5 Percent Critical Value
None*	0.769	93.422	35.192	71.991	22.299
At most 1	0.263	21.430	20.261	14.980	15.892
At most 2	0.123	6.450	9.164	6.450	9.164

Note: <sup>a</sup> Trace and Maximum Eigen test statistics are compared with the critical values from Johansen and Juselius (1990). \*Trace and Max-Eigen tests indicate 1 cointegrating equation at the 5% level. <sup>b</sup> Lags interval: 0 to 0

Table 4: Cointegration test: GDP per worker, physical capital investments and higher education

Series: q k h3					
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5 Percent Critical Value	Max-Eigen Statistic	5 Percent Critical Value
None*	0.633	60.227	35.192	48.183	22.299
At most 1	0.178	12.043	20.261	9.463	15.892
At most 2	0.052	2.579	9.164	2.579	9.164

Note: <sup>a</sup> Trace and Maximum Eigen test statistics are compared with the critical values from Johansen and Juselius (1990). \*Trace and Max-Eigen tests indicate 1 cointegrating equation at the 5% level. <sup>b</sup> Lags interval: 1 to 1

Table 5: Long Run Relationships

Levels of Education	k	h
Primary	3.85 (0.50)***	-2.81 (0.42)***
Secondary	2.10 (0.28)***	0.55 (0.22)***
Higher	2.52 (0.43)***	0.52 (0.15)***

Note: The standards errors are presented in parentheses. The asterisks indicate significance at the 1% level.

Table 6: Causality test for primary education based on VECM

Variables	Long-Run Causality
	ECT
DQ	- 0.028*** [-6.97]
DK	-0.005 [-0.43]
DH1	0.001 [0.01]

Note: The asterisks of the lagged ECTs are distributed as t-statistics and indicate rejection of the null hypothesis that the estimated coefficient is equal to zero (weak exogeneity) and no causality. The asterisks indicate significance at the 1% level.

Table 7: Causality test for secondary education based on VECM

Variables	Long-Run Causality
	ECT
DQ	- 0.051*** [-7.35]
DK	-0.015 [-0.66]
DH2	-0.025*** [-3.82]

Note: The asterisks of the lagged ECTs are distributed as t-statistics and indicate rejection of the null hypothesis that the estimated coefficient is equal to zero (weak exogeneity) and no causality. The asterisks indicate significance at the 1% level.

Table 8: Summary of causality test for higher education based on VECM

Variables	Short-run dynamics non-causality			Weak exogeneity	Tests of Granger non-causality (joint short run dynamics and ECT)			Test for strong exogeneity
	DQ	DK	DH3	ECT	DQ and ECT	DK and ECT	DH3and ECT	All variables and ECT
DQ	-	3.19 (0.08)	4.09** (0.04)	- 0.032*** [-4.34]	-	25.45*** (0.00)	30.80*** (0.00)	37.59*** (0.00)
DK	0.83 (0.35)	-	2.71 (0.10)	0.026 [1.03]	1.30 (0.52)	-	3.04 (0.21)	4.17 (0.24)
DH3	0.01 (0.99)	0.01 (0.90)	-	-0.013 [-0.83]	0.89 (0.63)	0.76 (0.68)	-	0.89 (0.82)

Note: The Wald test statistics reported are distributed as a chi-square distribution with degrees of freedom the number of restrictions. The p-values are presented in parentheses. In the short-run dynamics, asterisks indicate rejection of the null hypothesis that there is a short-run non-causal relationship between the two variables. The asterisks of the lagged ECTs are distributed as t-statistics and indicate rejection of the null hypothesis that the estimated coefficient is equal to zero (weak exogeneity). The t-statistics are presented in brackets. Finally, in the tests for Granger non-causality and strong exogeneity, asterisks denote rejection of the null hypothesis of Granger non-causality and strong exogeneity respectively. The asterisks indicate the following levels of significance: \*\*5% and \*\*\*1%.



**Table 9: Variance Decomposition**

Periods	Variance Decomposition of Q				Variance Decomposition of Q				Variance Decomposition of Q			
	S.E.	Q	K	H1	S.E.	Q	K	H2	S.E.	Q	K	H3
1	0.02	100.00	0.00	0.00	0.02	100.00	0.00	0.00	0.02	100.00	0.00	0.00
2	0.04	98.28	1.62	0.08	0.04	98.06	1.90	0.02	0.04	96.13	0.01	3.85
3	0.06	95.63	4.15	0.21	0.06	94.93	4.98	0.07	0.05	91.35	0.71	7.93
4	0.08	92.82	6.83	0.34	0.08	91.54	8.32	0.12	0.07	86.57	2.11	11.30
5	0.10	90.17	9.34	0.47	0.10	88.28	11.53	0.17	0.09	82.33	3.69	13.97
6	0.13	87.80	11.61	0.58	0.12	85.31	14.45	0.22	0.12	78.72	5.21	16.06
7	0.15	85.69	13.61	0.68	0.14	82.67	17.06	0.26	0.14	75.68	6.60	17.71
8	0.18	83.85	15.36	0.77	0.16	80.34	19.36	0.29	0.17	73.13	7.82	19.04
9	0.20	82.23	16.91	0.85	0.19	78.28	21.38	0.32	0.19	70.97	8.90	20.12
10	0.23	80.80	18.27	0.92	0.21	76.46	23.17	0.35	0.22	69.13	9.85	21.01

The variables of the three VARs order as following: GDP per worker, physical capital investments and primary, secondary, higher education (Q, K and H1, H2, H3 respectively).