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Human capital effects on technical inefficiency:

A stochastic frontier analysis across sectors of the Greek economy

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Οι επιπτώσεις του ανθρώπινου κεφαλαίου στη τεχνική αποτελεσματικότητα: Ανάλυση σε κλάδους της ελληνικής οικονομίας με τη χρήση μιας στοχαστικής εν δυνάμει συνάρτησης παραγωγής

ΠΕΡΙΛΗΨΗ

Η κύρια συνεισφορά αυτής της μελέτης είναι η διερεύνηση των επιπτώσεων από τη χρήση του ανθρώπινου κεφαλαίου στην τεχνική αποτελεσματικότητα των κλάδων της ελληνικής οικονομίας[2]. Η διερεύνηση της υπόθεσης αυτής γίνεται με την ταυτόχρονη εκτίμηση μιας στοχαστικής εν δυνάμει συνάρτησης παραγωγής και ενός υποδείγματος τεχνικής αναποτελεσματικότητας σε ένα σύνολο στατιστικών δεδομένων που καλύπτει 15 μονοψήφιους κλάδους, για την περίοδο 2000-2005.

Τα οικονομετρικά αποτελέσματα δείχνουν ότι το ανθρώπινο κεφάλαιο συμβάλλει σημαντικά στη μείωση της αναποτελεσματικότητας των ελληνικών κλάδων. Ωστόσο, φαίνεται ότι οι αρνητικές επιπτώσεις του ανθρώπινου κεφαλαίου στην τεχνική αναποτελεσματικότητα εστιάζονται, κυρίως στον τομέα των υπηρεσιών της ελληνικής οικονομίας. Οι πιο αποτελεσματικοί κλάδοι προέρχονται, επίσης, από τον τομέα των υπηρεσιών και περιλαμβάνουν αυτούς της εκπαίδευσης, της χρηματοπιστωτικής διαμεσολάβησης και της ακίνητης περιουσίας, εκμίσθωσης και επιχειρηματικών δραστηριοτήτων, με μέση απόδοση άνω του 90%.

[2] Με τον όρο τεχνική αποτελεσματικότητα εννοείται η δυνατότητα μιας οικονομικής μονάδας να παράγει το μέγιστο δυνατό παραγόμενο προϊόν με τη χρήση των ελάχιστων δυνατών παραγωγικών πόρων.

Human capital effects on technical inefficiency:

A stochastic frontier analysis across sectors of the Greek economy

Sophia P. Dimelis[a] and Sotiris K. Papaioannou[b]

Abstract

In this paper we explore the hypothesis that human capital may have an impact on technical efficiency. A stochastic production frontier is simultaneously estimated with a technical inefficiency model using data from one digit industries of the Greek economy, for the period 2000-2005. The results indicate a significantly negative relationship between human capital and technical inefficiency. The most efficient industries of the Greek economy are those of education, financial intermediation and real estate, renting & business activities.

JEL classification: O15; O40; O47

Keywords: Human capital, Technical inefficiency, Greek economy

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1. Introduction

The literature on the relationship between economic growth and human capital has a long tradition, starting with Schultz (1962) who described how investment in human capital affects economic growth in the long run. The main theoretical argument is that investment in education and training makes more efficient the use of production inputs. A further theoretical argument is that the existence of a well trained labor force renders the adoption of new technologies easier, which, in turn, leads to increased productivity and higher rates of economic growth.

There has, also, been a large empirical literature exploring the impact of human capital on growth, with most of the existing studies having established a positive and measurable effect. However, a major shortcoming of most of the existing studies is the implicit assumption that all production units are efficient (Maudos et al. 1998). Non fulfillment of this assumption, however, would raise questions on the accuracy of these estimates.

The main contribution of this study is that we take account of the presence of inefficiency effects and that we explicitly explore the effects of human capital on technical inefficiency of Greek industries. To our knowledge, this study is one of the few in the relevant literature that studies the growth impact of human capital in the Greek economy. Greece constitutes an interesting case for examining the growth impact of human capital, since it has witnessed a rapid increase in its tertiary education rates, with more than 40% of total labor force having completed their tertiary studies.

With respect to policy making, the measurement of technical efficiency might be particularly useful in identifying ways to promote economic growth. A low level of technical efficiency would imply that higher economic growth could be achieved by efficiently producing more output with the same level of inputs. On the other hand, a highly efficient industry should lie more on technical progress and innovative activity in order to achieve higher economic growth.

We simultaneously estimate a stochastic production frontier and a technical inefficiency model across a panel dataset consisting of 15 one digit Greek industries, for the period 2000-2005. The econometric results indicate that human capital contributes significantly in reducing inefficiencies of Greek industries. However, it seems that the negative effects of human capital on technical inefficiency are, mainly concentrated in the service sector of the Greek economy. The most efficient industries are, also, from the service sector and include those of education, financial intermediation and real estate, renting & business activities with average efficiency scores above 90%.

The rest of this paper is organized as follows. Next section discusses the relevant theoretical and empirical literature. Section 3 introduces the econometric specification, while in section 4 the data are described and some descriptive statistics are presented. Section 5 provides the empirical results and, finally, section 6 concludes.

2. Theoretical background and related literature

The existing theories of economic growth which emphasize the role of human capital originate from the ideas of Schultz (1971) and Becker (1993). The main argument in these ideas is that investment in education and training makes more efficient the use of production inputs. A further argument is that the existence of a well trained labor force makes easier the absorption and adoption of new technologies, the use of which leads to increased productivity and higher rates of economic growth.

Both neoclassical, as well as endogenous growth theories have analyzed the impact of human capital on growth. Mankiw et al. (1992) extended the neoclassical model of Solow (1956) so as to include the saving rate on human capital and offered empirical evidence in favor of a significant growth contribution.

With respect to endogenous growth theories, a first group of models point to the existence of non-diminishing returns (Romer 1986; Lucas 1988), with the presence of human capital generating positive externalities. A form of human capital accumulation has been described in the model of learning by doing, which has become known from Arrow (1962). This model points out that the accumulation of human capital is the indirect effect of the accumulation of physical capital. More specifically, over the years, workers learn more efficient ways to use physical capital, leading to higher technical knowledge and elimination of diminishing returns[4] [5].

A second group of endogenous growth models focus on the results of innovation on long run economic growth. In Romer (1990), sustained growth is the result of the existence of one sector of the economy which generates new products and new ideas. In this model, human capital is the generator of innovation and, therefore, its existence is essential for long run economic growth. Nelson and Phelps (1966) have stressed that the ability of a country to absorb new technologies, as well

[4] Such models assume that there is a kind of interaction between physical and human capital, so that that the process of human capital accumulation follows that of physical capital accumulation (Lucas 1988).

[5] In this context, Lucas (1990) tried to interpret the lack of investment capital flows from more developed to less developed countries, in which the marginal productivity of capital is considered as, comparatively, higher. Its main argument is that lack of investment flows to poorer countries is due to comparatively lower stocks of human capital, which in turn lead to less efficient use of fixed capital. Therefore, taking this into account, it should be true that differences in investment returns between less and more developed countries should not be considered as too high.

as to innovate and produce new technologies, depends on the quality and quantity of its human capital.

Growth theories, based on human capital accumulation, also, argue that investment in human capital yields social benefits which are higher than their private returns. Mamuneas and Savvides (1999) have estimated the social return on human capital investment in Greece and showed that this is higher than its private return. This difference between social and private returns implies the existence of positive externalities from the presence of human capital.

There is an extensive literature which studies the growth impact of human capital. Mankiw et al. (1992) have established a significant contribution of human capital on growth of income per capita, into a neoclassical growth context. The cross country empirical findings of Benhabib and Spiegel (1994) and Barro (1998), also, emphasized the existence of a positive and significant impact of human capital on growth of countries. Bresnahan et al. (2002) pointed out that a well educated and trained labor force is essential in attracting and absorbing technology investments, which in turn lead to technological change and long run economic growth. Bassanini and Scarpetta (2001) studied the effect of human capital on growth and found a significant impact across a sample of OECD countries.

Kneller and Stevens (2006) utilized stochastic frontier analysis to investigate the effects of human capital on technical inefficiency across nine industries of 12 OECD countries, during the period 1973-1991. They showed that technical inefficiency is negatively associated with the existing levels of human capital. Maudos et al. (2010) used stochastic frontier analysis and data envelopment techniques to quantify the growth effects of human capital on OECD countries 1965-

1990. The results confirmed a positive growth effect of human capital across OECD countries through the channels of labor productivity growth and technical change.

3. Econometric specification

Farrell’s (1957) pioneering work on the definition of technical efficiency has led to the development of several methods that measure production efficiency. The main principle of all methods is that efficiency of production is determined by the distance of actual production from the best practice production frontier. Two main methodologies have been used for production frontier estimation and measurement of technical efficiency: non parametric methods like the data envelopment analysis (DEA) and stochastic frontier techniques (Seiford and Thrall 1990).

The main advantage of non parametric methods is that they do not impose any restrictions on production technology. However, the main disadvantage is that such methods are unable to disentangle inefficiency effects from white noise. In this way, the efficiency estimates may be biased if the production process is characterised by stochastic components.

On the other hand, the stochastic frontier methods, which are based on the work of Aigner et al. (1977) as well as of Meeusen and van den Broeck (1977), are able to distinguish the error component from the non negative component of inefficiency[6]. The main idea is the introduction of an additional error term (besides white noise) which can be used to model the inefficiency term. However, we should notice that the stochastic approach has the disadvantage that it assumes the same production technology across all production units. Furthermore, distributional assumptions are required for the error, as well as for the inefficiency term.

[6] Kumbhakar and Lovell (2000) provide a comprehensive overview on stochastic frontier analysis.

Earlier studies usually followed a two-stage estimation procedure, where the production frontier and the efficiency measures were estimated at the first stage by OLS and then the efficiency levels were regressed on a number of explanatory variables, assumed to influence efficiency. However, this two stage estimation procedure has several drawbacks. Kumbhakar and Lovell (2000) and Wang and Schmidt (2002) argue that if the vector of efficiency variables is correlated with the vector of production function parameters, then the coefficient estimates of the production function will be biased. Even in the case of no correlation between the production function and the efficiency variables, the technical efficiency levels are likely to be spuriously estimated, so that the estimated parameters of the technical efficiency equation will be biased. In this study, we follow the model specification proposed by Battese and Coelli (1995). In their setting, the technical inefficiency model is simultaneously estimated, at one stage, with the stochastic production frontier model.

3.1 Production frontier modelling

In this study, we will estimate a stochastic production frontier, across 15 one digit Greek industries, in which the output of an industry is a function of a set of inputs, inefficiency and random error. For each individual industry we assume a production technology of a Cobb-Douglas form:

$$Y_{it} = A\,e^{\lambda t}(L_{it})^{\alpha}(K_{it})^{\beta}\mathrm{e}^{(V_{it}-U_{it})} \qquad (1)$$

The subscripts of i and t denote industry and year respectively, Y measures value added, A is the level of technology, λ is the rate of technical change and t is a time trend which captures technical progress over time. V and U are the two components of the error structure, which compose the main feature of a stochastic frontier model.

The first one, V_{it} is a 'standard' random residual assumed to be independently and identically distributed as $N(0,\sigma_v^2)$ and independent of U_{it}. The later is a nonnegative random error, associated with technical inefficiency of production and assumed to be independently distributed of V_{it}. Thus, U_{it} has an asymmetric distribution equal to the upper half of the $N(0,\sigma_u^2)$ distribution[7].

L and K denote the labor and capital inputs, respectively. We measure labor input as full time equivalent workers, while K is the capital input in each industry, estimated by perpetual inventory method. The parameters α and β are the value added elasticities of labor (L) and capital (K), respectively. After taking a logarithmic transformation, value added in each industry can be expressed as a function of labor and capital[8]:

$$\ln(Y_{it}) = c + \lambda t + \alpha \ln(L_{it}) + \beta \ln(K_{it}) + V_{it} - U_{it} \qquad (2)$$

Following Battese and Coelli (1995), the technical inefficiency effects are assumed to be a function of a set of explanatory variables z_{it} and can be defined as:

$$U_{it} = z_{it}\,\delta + W_{it} \qquad (3)$$

where z_{it} is a vector of variables defined in section 3.2 and assumed to influence inefficiency, while δ is the vector of parameters to be estimated. The random variable W_{it} is defined by the truncation of the normal distribution.

All parameters included in the stochastic production frontier model (2) and the technical inefficiency model (3) along with the models' variances $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and

[7] Any deviations from the production frontier may result from factors which lie within the agents' control, such as technical and economic inefficiencies (Aigner et al. 1977). The frontier itself is stochastic and can vary randomly across industries or over time due to external shocks, measurement errors and other factors beyond the agents' control, all being captured by the stochastic error V_{it} (Schmidt and Sickles 1984).

[8] It should be noticed that instead of using the value added variable, we could have used the variable of gross output. In such case, we should have also used as explanatory variables those of intermediate inputs, which include energy, materials and other services required to produce final output. However, we considered that value added is a more appropriate variable to measure output, since any output of intermediate goods consumed within the same sector is also included in the variable of gross output.

γ= $\sigma_u^2/(\sigma_v^2+\sigma_u^2)$ are estimated by using maximum likelihood[9]. By applying likelihood ratio tests several hypotheses can be tested. Such an important hypothesis is whether γ=0. A rejection of the null hypothesis that γ=0, against the alternative that γ is positive, implies that deviations from the frontier are due to inefficiency effects.

Following the definition of inefficiency in (3), the technical efficiency level of industry *i* at time *t* results by taking:

$$TE_{it} = \exp(-U_{it}) \qquad (4)$$

However, the U_{it}'s defined in (1) are not observable since they are a portion of the estimated residuals $\varepsilon_{it} = V_{it} - U_{it}$. Battese and Coelli (1993) suggest to use as predictor of the technical efficiency level TE_{it} its conditional expectation given the random variable ε_{it}:

$$T\hat{E}_{it} = E\left[\exp(-U_{it}) \mid \varepsilon_{it}\right] = \left\{\exp\left[-\mu_{it} + \frac{1}{2}\bar{\sigma}^2\right]\right\} \cdot \left\{\Phi\left[\frac{\mu_{it}}{\bar{\sigma}} - \bar{\sigma}\right] / \Phi\left[\frac{\mu_{it}}{\bar{\sigma}}\right]\right\} \qquad (5)$$

where Φ(.) is the distribution function of the standard normal, $\varepsilon_{it} = V_{it} - U_{it}$, $\mu_{it} = (1-\gamma)\cdot\left[\delta + \sum_{j=1}^{n}\delta_j z_{j,it}\right] - \gamma\,\varepsilon_{it}$ and $\bar{\sigma}^2 = \gamma(1-\gamma)\sigma^2$. By replacing the unknown parameters in equation (5) with the maximum likelihood estimates, we obtain estimates of technical efficiency of industry *i* at time *t*.

3.2 Inefficiency variables

In this paper we use stochastic frontier analysis to get an insight into the causes of industry level inefficiencies and look at the impact of human capital. Though there is a debate with respect to the role of human capital in economic

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[9] The parameter σ^2 is the overall variance of the error term, σ_v^2 is the variance of V_{it}, while σ_u^2 is the variance of the inefficiency term U_{it}.

growth[10], we will evaluate its impact by testing the hypothesis that an increase in human capital results in higher levels of technical efficiency (Schultz 1962). The human capital variable included in equation (3) is measured as the share of hours worked by high skilled workers with tertiary education.

Equation (3) also includes two dummy variables to control for industry specific effects. Such variables indicate whether an industry is from the service sector of the economy and whether an industry is part either of the agriculture or the public sector. A further variable included in equation (3) is the investment intensity of each industry, defined as the ratio of gross fixed capital formation to total value added.

The parameters of the production function (2) as well as of the inefficiency model (3) are estimated simultaneously, at one stage, by maximum likelihood and using the computer program FRONTIER 4.1, as developed by Coelli (1996).

4. Data and descriptive statistics

The empirical analysis of this paper is based on a panel of 15 one digit Greek industries (Agriculture, hunting & forestry, Fishing, Mining & quarrying, Manufacturing, Electricity, gas & water, Construction, Wholesale-retail trade & repairs, Hotels & restaurants, Transports, storage & communications, Financial intermediation, Real estate, renting & business activities, Public administration & defense, Education, Health, Other social services) for the period 2000-2005. The data regarding value added, employment, expressed in full time equivalent workers and gross fixed capital formation are based on the ISIC Rev. 3 industrial classification and were taken from OECD STAN Industrial Database (2011). The data for the human

[10] Mankiw et al. (1992) argue that human capital should enter the production function as a separate input. On the contrary, Benhabib and Spiegel (1994) and Pritchett (2001) argue that human capital influences growth indirectly through total factor productivity.

capital variable, proxied by the share of hours worked by high skilled workers with tertiary education were taken from the EU KLEMS Database (see Timmer et al. 2007).

Initial estimates of capital stocks in each industry for 2000 were taken from Skountzos and Stroblos (2011). In order to obtain capital stock series for the period 2001- 2005, we have applied the perpetual inventory method, by assuming a 5% depreciation rate (for more details see Bosworth and Kollintzas 2001) and using gross fixed capital formation data provided by the OECD STAN Industrial Database.

It should be noted at this point that the choice of period under examination was based on data availability, especially for the variable of human capital, for which the data are available only up to 2005. All value variables are expressed in 2000 constant prices. It should be made clear that the choice of industries and time period is dictated by the availability of data for all variables included in the econometric analysis. With this in mind, a brief analysis of stylized facts and descriptive statistics follows in Tables 1 to 3.

In Table 1, we can distinguish a substantial variation in value added per worker ratios (levels of labour productivity) across industries of the Greek economy. The most productive industries are those of electricity gas & water and transports, storage & communications, while the less productive industry is agriculture, hunting & forestry. In terms of capital deepening, the higher ratios are observed in real estate, renting & business activities and electricity gas & water and the lowest ones in construction and wholesale-retail trade & repairs. The industries of wholesale-retail trade & repairs as well as of real estate, renting and business activities have the highest value added shares in the Greek economy, while, fishing and mining & quarrying have the lowest value added shares. Furthermore, the industries of real estate, renting and business activities and transports, storage & communications show the highest investment intensity, while the financial intermediation industry displays the lowest ratio of investment to value added.

Table 1: Stylized facts of Greek industries

One digit industries (based on ISIC Rev. 3 classification system)	Value added per worker (in euros)*	Capital stock per worker (in euros)*	Value added share (% of total economy value added) **	Investment intensity (Gross fixed capital formation as % of value added)**
Agriculture, hunting & forestry	14,761.39	68,982.66	5.26	17.17
Fishing	28,376.78	101,263.79	0.43	25.42
Mining & quarrying	59,445.55	456,652.26	0.52	11.69
Manufacturing	32,777.07	79,117.84	10.28	16.20
Electricity, gas & water	133,809.32	1,356,064.08	2.43	25.08
Construction	30,042.32	25,826.27	6.75	25.08
Wholesale & retail trade, repairs	29,904.11	30,889.25	16.62	6.74
Hotels & restaurants	41,566.08	83,312.61	6.99	5.97
Transports, storage & communications	68,786.58	277,104.16	8.56	52.77
Financial intermediation	52,542.04	46,367.36	4.61	4.87
Real estate, renting & business activities	74,302.99	2,030,441.71	15.05	62.61
Public administration & defense	26,421.70	285,097.23	8.34	36.56
Education	34,541.84	54,537.88	5.45	9.96
Health	27,369.77	34,835.48	3.86	13.15
Other social services	33,899.89	93,198.80	4.16	25.66

Source: OECD STAN Industrial Database (2011).
*Values for 2005.
**Average for the period 2000-2005.

With respect to human capital, proxied by the share of hours worked by skilled high workers, we can observe that, except the industries of education and health, the industries of real estate, renting & business activities and financial intermediation display the highest shares of hours worked by high skilled workers in 2005 (Table 2). On the contrary, the industries of agriculture, hunting & forestry and fishing display the lowest shares of human capital across industries of the Greek economy. We can, also, distinguish an increase in the share of hours worked by skilled workers between 2000 and 2005 in most industries, with some exceptions existing in mining &

quarrying, electricity, gas & water and construction. The highest increase is observed in the industries of financial intermediation, health and public administration & defense. Finally, selected descriptive statistics for all variables included in the econometric estimation are shown in Table 3.

Table 2: Human capital in Greek industries
(% share of hours worked by persons with tertiary education)

	2000	2005
Agriculture, hunting & forestry	1.02%	1.43%
Fishing	1.02%	1.43%
Mining & quarrying	15.82%	14.06%
Manufacturing	10.38%	12.61%
Electricity, gas & water	15.82%	14.06%
Construction	5.43%	4.62%
Wholesale & retail trade, repairs	10.44%	11.54%
Hotels & restaurants	10.44%	11.54%
Transports, storage & communications	11.26%	13.31%
Financial intermediation	36.18%	42.65%
Real estate, renting & business activities	56.68%	58.29%
Public administration & defense	35.72%	41.92%
Education	82.41%	82.73%
Health	48.60%	54.13%
Other social services	14.73%	15.08%

Source: EU KLEMS Database (2007).

Table 3: Descriptive statistics of variables

Variable	Definition	Obs.	Mean	Std. Dev.	Min	Max
Y*	Gross value added	90	22.54	1.04	20.14	24.02
K*	Capital stock	90	23.71	1.34	21.26	27.04
L*	Employment (in full time equivalent workers)	90	12.02	1.18	9.39	13.71
INV	Investment intensity (Gross fixed capital formation, % of value added)	90	22.59	17.16	2.58	66.22
HUM	Human capital (% of hours worked by high skilled persons – with tertiary education)	90	24.41	23.33	0.97	83.30

*Variables in logs.

5. Empirical results

5.1 Econometric estimates

Table 4 presents the maximum likelihood estimates of the stochastic production frontier and the inefficiency model for the panel of 15 one digit industries in the period 2000-2005. The estimated production function includes the inputs of labor (L) and physical capital (K), as well as a time trend (t) to proxy for technological progress. The technical inefficiency equation is simultaneously estimated using as regressors the share of hours worked by high skilled persons (H) and a time trend to account for the existence of any time specific effects on technical inefficiency.

From the reported results in column 1 of Table 4, we can distinguish a significantly positive effect of physical capital (K) and labour (L) on output, a result which is plausible and compares well with the results of the relevant literature. The coefficient on time trend (t) appears to be negative but not statistically significant. To determine whether deviations from the estimated frontier are due to inefficiency effects, we test the null hypothesis that $\gamma=0$, against the alternative that $\gamma>0$. As it is evident, the parameter γ is significantly different from zero and this implies that inefficiency effects are present and that we should proceed with the estimation of parameters related to the sources of inefficiency. With respect to the impact of human capital (H) on technical inefficiency, the results indicate that a rise in the share of hours worked by high skilled persons contributes significantly in reducing inefficiencies in Greek industries.

In column 2, we have included as an additional regressor in the technical inefficiency equation, the variable of investment intensity (INV) in each industry. However, its impact although positive, does not seem to be significant. Furthermore, the influence of human capital remains significantly negative, as we can see from the reported results.

Table 4: Maximum likelihood estimates

Production Function								
	(1)		(2)		(3)		(4)	
	coef.	t-stat	coef.	t-stat	coef.	t-stat	coef.	t-stat
c	9.59*	18.27	15.50*	10.65	10.48*	15.08	9.18*	8.37
K[†]	0.22*	43.40	0.22*	14.25	0.22*	9.42	0.21*	6.40
L	0.65*	15.46	0.61*	12.37	0.59*	17.36	0.74*	34.04
t	0.02	1.10	0.03	1.34	0.03	1.44	-0.01	-0.47
Inefficiency Function								
c	0.21	0.80	0.18	0.75	0.33	0.79	0.51	1.22
t	0.00	-0.05	0.03	0.97	0.02	0.25	-0.04	-0.94
H	-0.05*	-2.60	-0.03*	-2.15	-0.003	-0.27	-0.01*	-5.82
INV			0.00	1.37				
d1					-0.93**	-1.78		
d2							0.60*	8.38
σ^2	0.27*	4.23	0.09*	5.63	0.25*	2.05	0.06*	6.12
γ	0.78*	5.37	0.97*	37.40	0.89*	11.11	0.04	0.06
Log likelihood	-21.62		6.59		-17.56		0.73	
Observations	90		90		90		90	

[†] See table 3 for the definitions of variables.
* Significant at 5% level of significance.
** Significant at 10% level of significance.

In column 3, we have included in the technical inefficiency equation a dummy variable (*d1*) indicating whether an industry belongs to the services sector of the economy. As we can see from the figures reported in Table 2, the most intensive users of human capital are the industries of the service sector of the Greek economy. It would be interesting, therefore, to estimate the impact of human capital on technical inefficiency, after isolating unobserved heterogeneity related to the diffusion of human capital across industries of the Greek economy. As we can see from the reported results in column 3, the estimate of the dummy coefficient, *d1*, is significantly negative, while the impact of human capital becomes statistically insignificant. This finding strongly implies that any negative effects of human capital on technical inefficiency are, mainly present in the service sector of the Greek economy.

In the fourth column, we estimate the same model, by having included in the technical inefficiency equation a dummy variable (*d2*) indicating whether an industry belongs to the agriculture or the public sector of the economy. As we can see from the reported results, the estimate of this dummy coefficient is positive and statistically significant, indicating the presence of higher inefficiency effects in the agriculture and public sector part of the Greek economy. The impact of human capital, however, remains negative and statistically significant.

5.2 Efficiency scores across industries

As explained in section 3.1, we can obtain the predictions of technical efficiency by using the conditional expectation defined in equation (4). Table 5 presents efficiency measures for each industry of the Greek economy, for the period 2000-2005.

There exist significant disparities in the levels of technical efficiency across industries of the Greek economy. It seems that the most efficient industries are those of education, financial intermediation, real estate, renting & business activities and health, with average efficiency scores above 90%, for the period 2000-2005. On the other hand, the least efficient industries are those of agriculture, hunting & forestry, with an average efficiency score at 47.5% and fishing, with an average efficiency score close to 55%. These efficiency scores confirm the econometric evidence presented in columns 3 and 4 of Table 4 that the most efficient industries are form the service sector and that the least efficient ones come from the agriculture and public sector part of the Greek economy.

Table 5: Efficiency scores

INDUSTRY	2000	2005	Average 2000-2005
Education	94.39%	94.71%	94.55%
Financial intermediation	94.92%	93.80%	94.36%
Real estate, renting & business activities	94.01%	92.65%	93.33%
Health	91.18%	91.05%	91.12%
Electricity, gas & water	86.72%	90.62%	88.67%
Transports, storage & communications	81.56%	90.27%	85.91%
Hotels & restaurants	84.50%	86.58%	85.54%
Wholesale & retail trade, repairs	83.16%	87.44%	85.30%
Construction	85.58%	83.76%	84.67%
Manufacturing	81.91%	83.44%	82.68%
Other social services	81.89%	80.67%	81.28%
Public administration & defense	82.13%	79.30%	80.72%
Mining & quarrying	74.75%	75.69%	75.22%
Fishing	55.37%	54.19%	54.78%
Agriculture, hunting & forestry	47.96%	47.31%	47.64%

* Industries are sorted in descending order according to their average efficiency scores.

We can, also, observe a significant increase in the levels of technical efficiency of the industries of transports, storage & communications (from 81.5% in 2000 to 90.3% in 2005), wholesale, retail trade & repairs (from 83.2% to 87.4%) and electricity, gas & water (from 86.7% to 90.6%). We can, also, see some reductions in technical efficiency levels, the highest ones observed in the industries of public administration & defense and construction.

5.3 Contribution of human capital to efficiency

The predicted technical efficiencies in equation (4) are gross measures which include the impact of human capital along with the impact of the other factors considered in the technical inefficiency equation (3). An interesting question that arises is whether we can decompose these predicted efficiencies by factor. Such attempts can be found in the microeconomic literature (Gathon and Pestieau 1995; Coelli et al. 1999). Based on these ideas, we wish to calculate to which extent human capital contributes to the improvement of technical efficiency across industries of the Greek economy.

First we need to evaluate the efficiency levels after we clear out the influences from the human capital factor. To obtain such measures of net technical efficiency (net of human capital influences), we replace the term $\sum_{j=1}^{n} \delta_j z_{j,it}$ in equation (5) with $\min\left[\sum_{j=1}^{n} \delta_j z_{j,it} - \delta_H H\right]$ and recalculate efficiency predictions (Coelli et al. 1999). These predictions may be interpreted as net efficiency scores because they involve predictions of efficiency when all industries are assumed to face identical effects of human capital (Coelli et al. 1999). The differences between gross and net efficiency scores represent the contribution of human capital to efficiency for each country.

We calculate the contribution of human capital on technical efficiency of each industry and the results are presented in Table 6. These results show that human capital has contributed positively in the increase of technical efficiency levels of all industries of the Greek economy. The highest contribution is observed in the industries of public administration & defense (more than 20.7%), health (16.1%), education (15.4%) and real estate, renting & business activities (10.4%). In general, the highest contributions of human capital are observed in the service industries, while the lowest ones in agriculture, hunting & forestry, fishing and construction.

Table 6: Contribution of human capital to efficiency (average 2000-2005)

	GROSS EFFICIENCY	NET EFFICIENCY	CONTRIBUTION OF HUMAN CAPITAL
Public administration & defense*	80.28%	59.60%	20.68%
Health	90.72%	74.63%	16.09%
Education	94.58%	79.14%	15.44%
Real estate, renting & business activities	93.46%	83.10%	10.37%
Mining & quarrying	73.07%	64.84%	8.23%
Other social services	82.27%	75.69%	6.58%
Manufacturing	80.95%	75.97%	4.98%
Financial intermediation	93.82%	89.00%	4.83%
Transports, storage & communications	86.61%	83.09%	3.52%
Electricity, gas & water	88.91%	85.41%	3.50%
Hotels & restaurants	85.56%	82.16%	3.40%
Wholesale & retail trade, repairs	86.23%	83.04%	3.19%
Construction	85.14%	83.59%	1.55%
Fishing	54.20%	53.68%	0.52%
Agriculture, hunting & forestry	47.11%	46.65%	0.46%

* Industries are sorted in descending order according to the average contribution of human capital.

5.4 Discussion

The empirical results of this study provide us with strong evidence that there exist significant benefits from higher levels of human capital, associated with increased levels of technical efficiency. In particular, the econometric results show that a rise in the share of hours worked by high skilled persons contributes significantly in reducing inefficiencies in Greek industries. However, as we saw from the econometric results of Table 4 the impact of human capital on technical inefficiency is statistically insignificant outside the service industries of the Greek economy. This finding strongly implies that any negative effects of human capital on technical inefficiency are, mainly present in the service sector of the Greek economy.

It is important to note at this point that the figures reported in Table 2 show that the most intensive users of human capital are the industries of the service sector of the Greek economy. Furthermore, the highest levels of technical efficiency are observed in several service industries, like education, financial intermediation, real estate, renting & business activities and health, with average efficiency scores above 90%. On the other hand, the least efficient industries are those of agriculture, hunting & forestry, fishing, mining & quarrying and public administration & defense.

The highest contributions of human capital are, also, observed in the service industries. Overall, this evidence confirms that human capital has contributed positively in the increase of technical efficiency levels of Greek industries, the most efficient of which are service industries.

The empirical evidence provided in this paper is in line with results of previous studies, having established a significant impact of human capital on GDP per capita growth. We further add to this literature by providing evidence in favour of a positive impact of human capital on technical efficiency, which is stronger in the service sector of the economy. Furthermore, the positive association between human capital and higher efficiency suggests that higher productivity, at the industry level, is likely to be achieved through investment in skills and training. This is an important observation for policy making, given the willingness to achieve higher rates of output growth and converge with other developed countries of Europe

6. Conclusion

In this paper we explored the idea that human capital may have a contribution in reducing technical inefficiency. A stochastic production frontier was simultaneously estimated with a technical inefficiency model using panel data from one digit industries of the Greek economy, for the period 2000-2005.

The results provided us with strong evidence in favor of a negative impact of human capital in reducing inefficiencies at the industry level. Further econometric evidence shows that the negative impact of human capital on technical inefficiency is, mainly concentrated in the service sector of the Greek economy. The most efficient industries of the Greek economy are those of education, financial intermediation and real estate, renting & business activities.

References

Aigner, D., Lovell, K., Schmidt, P., 1977, Formulation and estimation of stochastic frontier production function models, *Journal of Econometrics*, 6, 21-37.

Arrow, K. 1962, The economic implications of learning by doing, *Review of Economic Studies*, 29, 155-173.

Barro, R., 1998, Human capital and growth in cross country growth regressions, mimeo, Harvard University.

Bassanini, A., Scarpetta, S., 2001, Does human capital matter for growth in OECD Countries? Evidence from pooled mean group estimates, OECD Economics Department Working Paper no. 282.

Battese, G., Coelli, T., 1993, Frontier production function, technical efficiency and panel data: with application to paddy farmers in India, *Journal of Productivity Analysis*, 3, 153-169.

Battese, G., Coelli, T., 1995, A model for technical inefficiency effects in a stochastic frontier production function for panel data, *Empirical Economics*, 20, 325-332.

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

Benhabib, J., Spiegel, M., 1994, The role of human capital in economic development: Evidence from aggregate cross country data, *Journal of Monetary Economics*, 34, 143-173.

Bosworth, B., Kollintzas, T., 2001, Economic growth in Greece: Past performance and future prospects, in R. Bryant, N. Garganas and G. Tavlas (eds.) Greece's Economic Performance and Prospects', Bank of Greece and the Brookings Institution.

Bresnahan, T., Brynjolfsson, E., Hitt, L., 2002, Information technology, workplace organisation and the demand for skilled labor: Firm-level evidence, *Quarterly Journal of Economics*, 117, 339-76.

Coelli, T., 1996, A guide to DEA Version 2.1: A data envelopment analysis (computer) program, CEPA Working Paper 96/8, Department of Econometrics, University of New England, Australia.

Coelli, T., Perelman, S., Romano, E., 1999, Accounting for environmental influences in stochastic frontier models: With application to international airlines, *Journal of Productivity Analysis,* 11, 251-73.

Farrell, M, 1957, The measurement of productive efficiency, *Journal of the Royal Statistical Society, A, General*, 120, 253-281.

Gathon, H., Pestieau, P., 1995, Decomposing efficiency into its managerial and its regulatory components: The case of European railways, *European Journal of Operational Research,* 80, 500-07.

Kneller, R., Stevens, P., 2006, Frontier technology and absorptive capacity: Evidence from OECD manufacturing industries, *Oxford Bulletin of Economics and Statistics,* 68, 1-21.

Kumbhakar, S., Lovell, K., 2000, *Stochastic Frontier Analysis,* Cambridge: Cambridge University Press.

Lucas, R., 1988, On the mechanics of economic development, *Journal of Monetary Economics*, 22, 3-42.

Lucas, R., 1990, Why doesn't capital flow from rich to poor countries?, *American Economic Review*, 80, 92-96.

Mamuneas T., Savvides, A., 1999, Economic development and the return to human capital, University of Cyprus Working Paper.

Mankiw, G., Romer, P., Weil, D., 1992, A contribution to the empirics of economic growth, *Quarterly Journal of Economics*, 107, 407-437.

Maudos, J., Pastor, J., Serrano, L., 1998. Convergence in OECD countries: Technical change, efficiency and productivity, Instituto Valenciano de Investigaciones Económicas Working Paper no. 98-21

Maudos, J., Pastor, J., Serrano, L., 2010, Human capital in OECD countries: Technical change, efficiency and productivity, *International Review of Applied Economics*, 17, 419-435.

Meeusen, W., Van den Broeck, J., 1977, Efficiency estimation from Cobb-Douglas production functions with composed error, *International Economic Review*, 18, 435-444.

Nelson, R. Phelps, E., 1966, Investment in humans, technological diffusion and economic growth, *American Economic Review: Papers and Proceedings*, 61: 69-75.

OECD, 2011, STAN Industrial Database, Paris: OECD.

Pritchett, L., 2001, Where has all the education gone?, *World Bank Economic Review*, 15: 367-391.

Romer, P., 1986, Increasing returns and long-run growth, *Journal of Political Economy*, 94, 1002-1037.

Romer, P., 1990, Endogenous technical change, *Journal of Political Economy*, 98, 71-102.

Schmidt, P., Sickles, R., 1984, Production frontiers and panel data, *Journal of Business and Economic Statistics*, 2, 367-74.

Schultz, T., 1962, Reflections on investment in man, *Journal of Political Economy*, 70, 1-8.

Schultz, T., 1971, *Investment in Human Capital: The Role of Education and of Research*. New York: Free Press.

Seiford, L., Thrall, R., 1990, Recent developments in DEA: The mathematical programming approach to frontier analysis, *Journal of Econometrics*, 46, 7-38.

Skountzos, T., Stroblos, N., 2011, Sectoral capital-output ratios and capital intensity in the Greek economy, in S. Balfoussias, P. Hatzipanayotou, C. Kanellopoulos (eds.) 'Essays in Economics: Applied Studies on the Greek economy'; Athens: Centre of Planning and Economic Research.

Solow, R., 1956, A contribution to the theory of economic growth, *Quarterly Journal of Economics*, 70, 65-94.

Timmer, M., O' Mahony, M., Van Ark, B., 2007, The EU KLEMS Growth and productivity accounts: An overview, University of Groningen & University of Birmingham.

Wang, H., Schmidt, P., 2002, One-step and two-step estimation of the effects of exogenous variables on technical efficiency levels, *Journal of Productivity Analysis*, 18, 129–44.

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No 93 Y. Panagopoulos, I. Reziti, and Ar. Spiliotis, "Monetary and Banking Policy Transmission Through Interest Rates: An Empirical Application to the USA, Canada, U.K. and European Union". Athens, 2007.

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No 86 P. I. Prodromídis, " Functional Economies or Administrative Units in Greece: What Difference Does It Make for Policy?" Athens, 2006. Published in: *Review of Urban & Regional Development Studies*, vol. 18.2, 2006, pp. 144-164.

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No 83 G. C. Kostelenos, “La Banque Nationale de Grèce et ses Statistiques Monétaires (1841-1940)". Athènes, 2006. Published in: *Mesurer la monnaie. Banques centrales et construction de l’ autorité monétaire (XIXe-XXe siècle)*, Paris: Edition Albin Michel, 2005, 69-86.

No 82 P. Baltzakis, “The Need for Industrial Policy and its Modern Form”. Athens, 2006 (in Greek).

No 81 St. Karagiannis, “A Study of the Diachronic Evolution of the EU’s Structural Indicators Using Factorial Analysis”. Athens, 2006.

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No 79 Y. Panagopoulos and A. Spiliotis, “An Empirical Approach to the Greek Money Supply”. Athens, 2005.

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No 77 I. A. Venetis, E. Emmanuilidi, “The Fatness in Equity Returns. The Case of Athens, Stock Exchange”. Athens, 2005.

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Athens, 2002. Published under the title "The contribution of remittances to growth: a dynamic approach and empirical analysis" in: *Journal of Economic Studies*, December 2005.

No 73 N. Glytsos, "A Model of Remittance Determination Applied to Middle East and North Africa Countries". Athens, 2002.

No 72 Th. Simos, "Forecasting Quarterly GDP Using a System of Stochastic Differential Equations". Athens, 2002.

No 71 C. N. Kanellopoulos and K. G. Mavromaras, "Male-Female Labour Market Participation and Wage Differentials in Greece". Athens, 2000. Published in: *Labour*, vol. 16, no. 4, 2002, 771-801.

No 70 St. Balfoussias and R. De Santis, "The Economic Impact of The Cap Reform on the Greek Economy: Quantifying the Effects of Inflexible Agricultural Structures". Athens, 1999.

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No 59 St. Makrydakis, “Testing the Intertemporal Approach to Current Account Determination: Evidence from Greece”. Athens, 1996. Published in: *Empirical Economics*, vol. 24, no. 2, 1999, pp. 183-209.

No 58 Chr. Kollias and St. Makrydakis, “The Causal Relationship Between Tax Revenues and Government Spending in Greece: 1950-1990”. Athens, 1996. Published in: *The Cyprus Journal of Economics*, vol. 8, no. 2, 1995, pp. 120-135.

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No 53 N. Glytsos, “Remitting Behavior of “Temporary” and “Permanent” Migrants: The Case of Greeks in Germany and Australia”. Athens, 1996. Published in: *Labour*, vol. II, no. 3, 1997, pp. 409-435.

No 52 V. Stavrinos and V. Droucopoulos, ‘Output Expectations, Productivity Trends and Employment: The Case of Greek Manufacturing”. Athens, 1996. Published in: *European Research Studies*, vol. 1, no. 2, 1998, pp. 93-122.

No 51 A. Balfoussias and V. Stavrinos, "The Greek Military Sector and Macroeconomic Effects of Military Spending in Greece". Athens, 1996. Published in N.P. Gleditsch, O. Bjerkholt, A. Cappelen, R.P. Smith and J.P.

Dunne: *In the Peace Dividend*, Amsterdam: North-Holland, 1996, pp. 191-214.

No 50 J. Henley, "Restructuring Large Scale State Enterprises in the Republics of Azerbaijan, Kazakhstan, the Kyrgyz Republic and Uzbekistan: The Challenge for Technical Assistance". Athens, 1995.

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No 48 G. Kouretas and L. Zarangas, "A Cointegration Analysis of the Official and Parallel Foreign Exchange Markets for Dollars in Greece". Athens, 1995. Published in: *International Journal of Finance and Economics*, vol. 3, 1998, pp. 261-276.

No 47 St. Makrydakis, E. Tzavalis and A. Balfoussias, "Policy Regime Changes and the Long-Run Sustainability of Fiscal Policy: An Application to Greece". Athens, 1995. Published in: *Economic Modelling*, vol. 16 no. 1, 1999, pp. 71-86.

No 46 N. Christodoulakis and S. Kalyvitis, "Likely Effects of CSF 1994-1999 on the Greek Economy: An ex ante Assessment Using an Annual Four-Sector Macroeconometric Model". Athens, 1995.

No 45 St. Thomadakis and V. Droucopoulos, "Dynamic Effects in Greek Manufacturing: The Changing Shares of SMEs, 1983-1990". Athens, 1995. Published in: *Review of Industrial Organization*, vol. 11, no. 1, 1996, pp. 69-78.

No 44 P. Mourdoukoutas, "Japanese Investment in Greece". Athens, 1995 (in Greek).

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