



# The effect of human capital on countries' economic efficiency



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## HIGHLIGHTS

- Time-dependent conditional DEA estimators are applied on a sample of 123 countries.
- Countries' economic efficiency levels are estimated for the period of 1970–2011.
- The effect of human capital on countries' economic efficiency is examined.
- The results reveal a nonlinear relationship.

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## ABSTRACT

The paper applies time-dependent conditional frontier estimators in order to examine the effect of human capital on countries' economic efficiency levels. Specifically, time-dependent conditional full and partial efficiency measures are applied to a sample of 123 countries for the period of 1970–2011. The results from the nonparametric analysis reveal a nonlinear relationship between countries' human capital, technological change and efficiency levels.

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## 1. Introduction

The positive effect of human capital on countries' economic growth has been supported empirically from several studies (among others, Glaeser, 1994; Goetz and Hu, 1996; Bassanini and Scarpetta, 2002). However, as suggested by Kalaitzidakis et al. (2001) the impact of human capital accumulation on economic growth remains controversial. In their research they suggest the existence of a nonlinear relationship. They argue that the controversial results obtained are subject to the methodology adopted, the data used and the time period under examination. This paper contributes to this stream of research by adopting a frontier analysis approach to investigate the effect of human capital on country's economic efficiency levels. We apply the newly introduced time-dependent conditional frontier models (Mastromarco and Simar, 2014) for full and partial frontiers on a sample of 123 countries for

the period of 1970–2011. Furthermore, we examine the effect of human capital on countries' efficiency levels (technological catch-up) and on countries' technological change (shifts of the frontier). The nonparametric analysis adopted allows us to avoid the strong assumptions on the specification of the estimated production function and enables us to reveal any nonlinearities of the examined relationship.

## 2. Methodology

Following Mastromarco and Simar (2014) let  $X \in \mathbb{R}_+^p$  and  $Y \in \mathbb{R}_+^q$  be the input and output vectors, respectively. Let  $Z \in \mathbb{R}^d$  to be the vector of the environmental variable (human capital in our case). Then the attainable set can be characterized as:

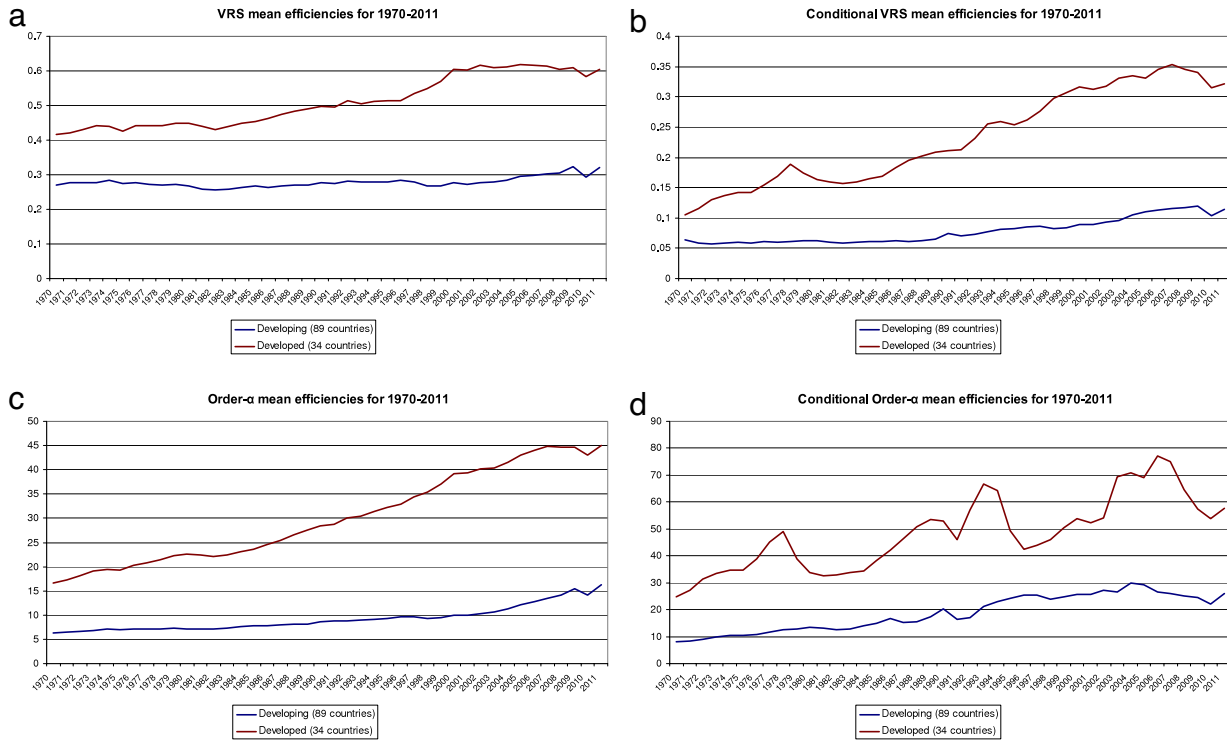
$$\Psi = \{(x, y) \in \mathbb{R}_+^{p+q} | x \text{ can produce } y\}, \quad (1)$$

according to Daraio and Simar (2005, 2007) this can also be defined as:

$$\Psi = \{(x, y) | H_{X,Y}(x, y) > 0\} \quad \text{where } H_{X,Y}(x, y) = \text{Prob}(X \leq x, Y \geq y). \quad (2)$$

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**Fig. 1.** Countries' mean economic efficiencies estimates for 1970–2011. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Then  $\Psi_t \subset \mathfrak{R}_+^{p+q}$  having time  $T$  as a conditional variable and its distribution can be characterized as:

$$H_{X,Y}^t(x, y) = \text{Prob}(X \leq x, Y \geq y | T = t).$$

By introducing the additional conditional variable  $Z$  then the attainable set is defined as  $\Psi_t^z \subseteq \Psi_t \subset \mathfrak{R}_+^{p+q}$  and its distribution can be determined as:

$$H_{X,Y|Z}^t(x, y|z) = \text{Prob}(X \leq x, Y \geq y | Z = z, T = t). \quad (3)$$

The output oriented Farrell–Debreu technical efficiency can be defined as:

$$\lambda(x, y) = \sup\{\lambda | (x, \lambda y) \in \Psi\} = \sup\{\lambda | H_{X,Y}(x, \lambda y) > 0\}, \quad (4)$$

where  $H_{X,Y}(x, y) = S_{Y|X}(y|x)F_X(x)$ ,  $S_{Y|X}(y|x) = \text{Prob}(Y \geq y | X \leq x)$  and  $F_X(x)$  is the marginal cdf of  $X$ . Therefore we have:

$$\lambda(x, y) = \sup\{\lambda | S_{Y|X}(\lambda y|x) > 0\}. \quad (5)$$

Then a country's conditional output oriented economic efficiency level  $(x, y) \in \Psi_t^z$  at time  $t$  facing the effect of human capital  $z$  can be defined as:

$$\lambda_t(x, y|z) = \sup\{\lambda | S_{Y|X,Z}^t(\lambda y|x, z) > 0\}. \quad (6)$$

Similarly, following Daouia and Simar (2007) the order- $\alpha$  quantile efficiency measure (partial version of countries' economic efficiency level) for any  $\alpha \in (0, 1)$  can be expressed as:

$$\lambda_{t,\alpha}(x, y|z) = \sup\{\lambda | S_{Y|X,Z}^t(\lambda y|x, z) > 1 - \alpha\}, \quad (7)$$

where  $S_{Y|X,Z}^t(y|x, z) = \text{Prob}(Y \geq y | X \leq x, Z = z, T = t)$ . The estimation of countries' economic efficiency levels (the original and those conditional to time and human capital) are obtained via DEA estimators.<sup>1</sup>

<sup>1</sup> Here we use for the full frontiers the assumption of variable returns to scale (VRS) and for the robust frontiers we apply a median quartile ( $\alpha = 0.5$ ) rather than the extreme quartiles ( $\alpha = 0.9, \alpha = 0.95$ ). For in depth analysis and computational issues regarding the LP programs, bandwidth selection and smoothing techniques adopted see the works of (Daraio and Simar, 2005, 2007; Bădin et al., 2010; Mastromarco and Simar, 2014).

Finally, by following Bădin et al. (2012) we construct two ratios from the efficiencies calculated from the full and the partial frontiers as:

$$Q = \frac{\lambda_t(x, y|z)}{\lambda(x, y)}, \quad (8)$$

$$Q_\alpha = \frac{\lambda_{t,\alpha}(x, y|z)}{\lambda_\alpha(x, y)}. \quad (9)$$

Then by applying a nonparametric regression on the above ratios we can determine the effect of time and human capital on the boundary—swift of the frontier (for the case of full frontier- $Q$ ) and on the distributions of countries' efficiencies (for the case of partial frontier- $Q_\alpha$ ). For our analysis we are using local constant techniques and for bandwidth selection we apply the Least Squares Cross-Validation (LSCV) criterion as described in Hall et al. (2004) and Li and Racine (2007). An increasing regression line indicates a positive effect on countries' technological change (shift on the frontier) and on the distribution of their efficiencies (technological catch-up). However, the opposite indicates an unfavorable effect.

### 3. Empirical results

For our analysis we are using as inputs capital stock and labor force, whereas the output is GDP and the external variable affecting countries' production process is human capital. All the data have been extracted from Penn World Table v8.0 (Feenstra et al., 2013) and are covering 123 countries (see the Appendix for details) for the period of 1970–2011.

Fig. 1 provides diachronically countries' mean conditional and unconditional economic efficiency estimates both for the full and the partial frontiers.<sup>2</sup> As can be observed developed countries

<sup>2</sup> Due to length restrictions the detailed results and tables of all countries' efficiency estimates for conditional and unconditional frontiers cannot be presented. However, all the analytical results are available upon request.

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