Annex I and non-Annex I countries'productive performance revisited using a generalized directional distance function under a metafrontier framework: Is there any convergence-divergence pattern for technology gaps?

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Annex I and non-Annex I countries'productive performance revisited using a generalized directional distance function under a metafrontier framework: Is there any convergence-divergence pattern for technology gaps?

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Abstract

Countries rapid economic growth, energy consumption and anthropogenic emissions (GHGs) in the atmosphere are creating serious environmental problem on both global and local scales -. This is while compiled evidence about the relationship between climate change/global warming and the amount of GHG released is present (IEA, 2010). In advance, it is generally accepted that countries production processes, should seriously, take into account environmental sustainability principles and targets. In recent years, there have been a series of studies using a directional distance function dealing with environmental efficiency with the aim of measuring the ability of decision making units (i.e regions, firms, industries, countries) to produce more with less impact on the environment. A scarcity of empirical studies appears concerning the estimation of directional distance function under a metafrontier framework. In this paper we employ a balanced panel of 103 countries from 1995-2011 to shed light on the idiosyncratic performance of countries participating in two distinct different groups (Annex I and non-Annex I) using a generalized directional distance function independent of the direction vector length -. The non-parametric metafrontier framework - used in this study, as a first stage of analysis, is exploited to account for the heterogeneity between countries participating in our sample. In the second stage, a convergence-divergence hypothesis has been examined for the technology gaps estimated for each period. Our findings reveal significant patterns between countries' individual performance.

Key words: Metafrontier; Generalized Distance Function; Technology gaps; Annex-I countries

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1. Introduction

The Intergovernmental Panel on Climate Change (2007) has assessed that over the last 50 years, global warming has been caused due to anthropogenic greenhouse gas emissions (GHGs). The impact of GHGs on climate change has been the top agenda and considered the leading issue for many governments, organizations, economists, researchers and scholars since it threatens countries' sustainable development (Tol, 2009; Weitzman, 2009). The significance of this problem is apparent from cases such as the signing of the Kyoto Agreement in 1997 and subsequent efforts in Copenhagen and Cancun (2010), Durban and Doha (2011), Warsaw (2013) and latest in Paris (2015) to reach an international agreement aimed at reducing greenhouse gas emissions. In the face of climate change repercussions, many countries have devoted a large portion of their resources towards designing and implementing mitigation to achieve a satisfactory level of sustainable development while others (headed by U.S) criticizes insisting on a more voluntary orientation. Furthermore, it is true that Kyoto climate policies put more attention and emphasis on the reduction of global emissions to mitigate climate change (Yu-Ying et al., 2013).

The Kyoto protocol was negotiated in 1997 during the Third Conference of the Parties to the United Nations framework Convention of Climate Change. During its establishment put into discussion the reduction levels of GHGs, most notably CO_2 from fossil fuel combustion, for Annex I and non-Annex I countries in an international agreement framework (Den Elzen and Höhne, 2008). Moreover, in a world where economies are linked by international trade and capital flows emissions abatement of Annex I economies may have, possibly, effect on trade, carbon leakage, transfer and diffusion of energy efficient technologies on non-Annex I economies

(Den Elzen and De Moor, 2002). A further caveat, from the stance of economic theory, considers large economic adjustment costs to Annex I coutries (Böhringer, C., Vogt, C. 2003) or consider possible policies (i.w preferential tarrifs reductions) for their compesantion (Babiker et al. 2000). Furthermore, some studies report the fact that recent Kyoto modifications, including U.S decision, boil down climate policies as business as usual questioning its economic and enviromental impacts for the countries participated in this commitment (Böhringer and Vogt, 2003; 2004).

The level of ambitions for reducing emissions by developed (Annex I) and developing (non-AnnexI) countries under the Kyoto agreement was one of the most important aspects in current climate negotiations. Although there have been many attempts for the non-AnnexI group to ratify the agreement, several political, institutional and economic barriers appeared to hinder them (Calbick and Gunton, 2014)[1]. Thus, the clear distinction for countries participating as AnnexI and non-AnnexI gathers significant opportunity for engineers, economists, scholars and politicians to examine the negative impact of human activity, in terms of pollution equivalents, even at a country level through this perspective. This growing interest in incorporating undesirable outputs in the production function under the different technological regimes yields, on the one hand, numerous published articles (see Zhang and Choi, 2014) while, on the other hand, introduces several methods for asymmetrically handling the two types of outputs (i.e Tone, 2001; Cheng and Zervopoulos, 2014).

A common characteristic of these studies is that operates under the assumption of technological isolation (Tsekouras et al., 2016) examining a rather homogeneous

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[1] In article 2 of the Agreement technology transfer, financial support for the establishement of environmental friendly technologies and funding of technology express the important elements for the implementation of the agreement.

group (Feroz et al., 2009; Halkos and Tzeremes, 2014). It may also adopt a metafrontier production function in a "mechanistic" way creating groups according to specific criteria ignoring their technological status (Kounetas, 2015). The introduction of the metafrontier production function (Battese et al., 2004) allows technological heterogeneity to be incorporated in productive efficiency analysis and therefore relaxing restrictive technological isolation conditions. In the framework of technological heterogeneity, any positive influence of technological spillovers from domestic mitigation strategies onto productive performance may be eliminated, if the production units are locked-in, or if they exhibit path-dependence of the evolution of their productive performance (Tsekouras et al., 2016).

In this paper we extent a generalized efficiency measure of a directional distance function (Cheng and Zervopoulos, 2014) in a methodological framework which allows the co-examination of (i) efficiency differences in terms of productive performance for countries operating under two distinct technological regimes, (ii) any inter-linkages and flows between the two heterogeneous technologies and more specifically spillover effects on non-Annex I countries (iii) the convergence hypothesis for technology gaps for the examined set of countries. This analytical framework is applied to 103 countries over the 1995-2011 period revealing interesting patterns of productive performance which have not been traced by previous seminal papers on environmental efficiency.

This study unfolds as follows. Section 2 reviews the literature on directional distance functions in conjunction with the metafrontier analysis. Section 3 presents the methodology. Section 4 discusses the selection of input and output variables. Section 5 presents the outcomes of the empirical analysis. Section 6 concludes.

2. Review of the literature

In efficiency and productivity analysis, directional distance functions (hereafter DDF) have also become popular since most production processes generate undesirable output(s) as byproduct(s) (i.e. CO_2 emissions for firms or mortality rate for health systems). The main reason for this increased popularity is the ability of DDF to expand good outputs while reducing bad since the production process of every entity has not only an economic but also an environmental and social output (Färe and Grosskopf, 2000; Färe et al., 2005; Zhang et al., 2013). In this context, many empirical studies have used DDF to investigate the performance of individual DMUs. Extant studies apply DDF to measure energy efficiency (Zhang et al., 2013; Zhou et al., 2012), environmental efficiency (Kounetas, 2015; Kumar and Khanna, 2009; Caramero et al., 2008), sustainability performance (Zhang et al., 2013) and eco-efficiency (Oggioni et al., 2011; Picazo-Tadeo et al., 2012; Zhang et al., 2008; Färe et al. 2007; Kuosmanen and Kortelainenn, 2005)[2].

Focusing now on the methodological approaches that have been used to estimate the abovementioned indexes, the literature classifies three groups according to their framework. The first group contains transformations of conventional DEA models including hyperbolic distance functions (Färe et al., 1989) radial measures (Chambers et al., 1996) and non-radial measures. The second one concerns modifications on the slack-based measures (Tone, 2001) while the third group contains several modifications on the directional distance function (Chung et al., 1997).

Many studies have been recorded incorporating DDFs in order to mostly measure energy and environmental performance of different DMUs. As mentioned

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[2] Zhang and Choi (2014) present a comprehensive review of the literature on DDF related to environmental and energy studies.

above, radial nature of DDF stimulates researchers to develop non-radial measures. For instance, Färe and Grosskopf (2010) and Zhou et al. (2012) extended it in a non-radial model and Mahlberg and Sahoo (2011) proposed a non-radial Luenberger indicator. Extending the DDF, Zhang et al. (2013), Choi et al. (2012) and Zhou et al. (2006) developed several slack-based measures for environmental performance while Fukuyama and Weber (2009) proposed a slacks-based efficiency measure of efficiency combining the ideas of DDF and SBM. In addition, Zaim and Taskin (2000) and Cuesta et al. (2009) developed a hyperbolic efficiency measure while Fukuyama et al. (2011) and Barros et al. (2012) with DDFs proposed slacks-based measures and weighted Russell DDF. Sueyoshi et al. (2010) presented a Range-Adjusted measure model for US coal-fired power plants. Finally, Chang and Hu (2010), Färe and Grosskopf (2010) and Cheng and Zervopoulos (2014) put forth a generalized non-radial DDF while Zhang et al. (2014) presented a sequential generalized directional distance function.

On the other hand, very few studies have taken the potential technology heterogeneity into consideration. First, Oh (2010) using a Malmquist-Luenberg productivity index incorporated group heterogeneity while Kounetas (2015), Chiu et al. (2012) and Yu-Ying Lin et al. (2013) measured, not only technology gaps, but also environmental efficiency technology gaps exploiting the scarcity of similar studies under the presence of heterogeneity.

3. Methodology

Our methodological framework is developed in two interconnected stages. In the first stage, we present the theoretical and methodological underpinnings regarding the estimation of the generalized directional distance function and we discuss the expansion in a metafrontier framework presenting the theoretical base for its inclusion. In the second stage, we present the theory concerning the convergence hypothesis using a stochastic kernel approach.

3.1 Definitions, notation and technological gaps

The inputs $x=(x_1,...,x_m)\in\mathbb{R}_+^m$ are used to produce desirable outputs $y=(y_1,...,y_s)\in\mathbb{R}_+^s$ and undesirable outputs $b=(b_1,...,b_p)\in\mathbb{R}_+^p$ (i.e. CO2 emissions). In this context, the technology is described as follows:

$$T(x)=\{(y,b): x \text{ can produce } (y,b)\} \tag{1}$$

where $T\subset\mathbb{R}_+^m\times\mathbb{R}_+^s\times\mathbb{R}_+^p$, which represents the input - desirable output - undesirable output bundles that are technologically achievable.

The desirable outputs (y) are jointly produced with the undesirable outputs (b), modelled as follows:

$$\text{if } (y,b)\in T(x) \text{ and } b=0 \text{ then } y=0 \tag{2}$$

The assumptions that the technology satisfies are: (a) closedness, (b) free disposability of inputs and desirable outputs: $\forall\ (x,y)\in T,$ if $x'\geq x$ and $y'\leq y$ then $(x',y')\in T$, (c) weak disposability of undesirable outputs: $\forall\ (x,b)\in T\Rightarrow(x,\mu b)\in T\ \ \forall\ \mu\geq 1$, (d) no free lunch: if $(x,y,b)\in T$ and $x=0$ then $y=0$ and $b=0$, (e) doing nothing is feasible: $(0,0,0)\in T$, and (f) convexity (Färe et al., 1994).

The technology is described by the following directional distance function (DDF):

$$\vec{D}_T(x,y,b;g_x,g_y,g_b)=\sup\{\beta:(x-\beta g_x,y+\beta g_y,b+\beta g_b)\in T(x,y,b)\} \tag{3}$$

where β denotes inefficiency and the non-zero $g=(g_x,g_y,g_b)$ expresses the direction vector of the inputs, desirable outputs, and undesirable outputs, respectively. The expression (3) reflects simultaneous reduction in inputs, expansion of desirable outputs and contraction of undesirable outputs. Drawing on expression (3), the efficiency is defined as follows: $\frac{1-\beta}{1+\beta}$.

In this study, a generalized directional distance function (GDDF) is applied to measure environmental efficiency put forth by Cheng and Zervopoulos (2014). According to this generalized DDF, which is also based on expression (3) and satisfies the assumptions of the technology set, the efficiency is measured by the ratio: $\dfrac{1-\frac{1}{m}\sum_{i=1}^{m}\beta g_i / x_{io}}{1+\frac{1}{s+p}\left(\sum_{r=1}^{s}\beta g_r / y_{ro}+\sum_{t=1}^{p}\beta g_t / b_{to}\right)}$ where $\beta g_i / x_{io}$ expresses the proportion of the reduction in inputs, and $\beta g_r / y_{ro}$ and $\beta g_t / b_{to}$ indicate the proportion of the expansion and contraction of desirable and undesirable outputs, respectively. The efficiency measures obtained from this generalized DDF are units invariant, monotone, translation invariant provided that the Variable Returns to Scale (VRS) technology applies, and reference set invariant (Tone, 2001; Färe and Grosskopf, 2010). Unlike the conventional DDF, the generalized DDF that is used in this study yields efficiency scores independent of the length of the direction vector (*g*). Moreover, like the conventional DDF, this generalized DDF produces efficiency scores that are consistent with those obtained from radial models.

In the case where multiple technologies (e.g. *k* distinct technologies, where $k = 1,...,K$) are present, the input – desirable output – undesirable output sets are grouped into *k* technologically feasible sets (i.e. $T^1, T^2, ..., T^K$). The collection of all input-output feasible combinations of the operational units (e.g. countries) construct the smallest convex set that is known as metatechnology set, denoted by T^{meta} (Battese and Rao, 2002; Battese et al., 2004; O'Donnell et al., 2008). The metatechnology set is modelled as follows:

$$T^{meta}(x) = \{(y,b) : x \text{ can produce } (y,b)\} \tag{4}$$

and the group-specific technology set is described as follows:

$$T^{k}(x) = \{(y,b) : x \text{ used by operational units in group } k \text{ can produce } (y,b)\} \tag{5}$$

Hence, $T^{meta}(x) = \{T^1(x) \cup T^2(x) \cup ... \cup T^K\}$.

By introducing the generalized DDF (Cheng and Zervopoulos, 2014) into the metatechnology framework, we measure the metaefficiency and group-specific efficiency scores as follows:

$$\vec{D}_{T^{meta}}(x^k, y^k, b^k; g_x, g_y, g_b) = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \beta^{meta} g_i / x_{io}^k}{1 + \frac{1}{s+p}\left(\sum_{r=1}^{s} \beta^{meta} g_r / y_{ro}^k + \sum_{t=1}^{p} \beta^{meta} g_t / b_{to}^k\right)}$$

$$\begin{aligned}
s.t.\ & \sum_{k=1}^{K}\sum_{j=1}^{n} \lambda_j^k x_{ij}^k \le x_{io}^k - \beta^{meta} g_x & i = 1,\dots,m \\
& \sum_{k=1}^{K}\sum_{j=1}^{n} \lambda_j^k y_{rj}^k \ge y_{ro}^k + \beta^{meta} g_y & r = 1,\dots,s \\
& \sum_{k=1}^{K}\sum_{j=1}^{n} \lambda_j^k b_{tj}^k = b_{to}^k + \beta^{meta} g_b & b = 1,\dots,l \\
& \sum_{k=1}^{K}\sum_{j=1}^{n} \lambda_j^k = 1 \\
& \lambda_j^k \ge 0
\end{aligned} \tag{6}$$

$$\vec{D}_{T^k}(x^k, y^k, b^k; g_x, g_y, g_b) = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \beta^k g_i / x_{io}^k}{1 + \frac{1}{s+p}\left(\sum_{r=1}^{s} \beta^k g_r / y_{ro}^k + \sum_{t=1}^{p} \beta^k g_t / b_{to}^k\right)}$$

$$\begin{aligned}
s.t.\ & \sum_{j=1}^{n} v_j^k x_{ij}^k \le x_{io}^k - \beta^k g_x & i = 1,\dots,m \\
& \sum_{j=1}^{n} v_j^k y_{rj}^k \ge y_{ro}^k + \beta^k g_y & r = 1,\dots,s \\
& \sum_{j=1}^{n} v_j^k b_{tj}^k = b_{to}^k + \beta^k g_b & b = 1,\dots,l \\
& \sum_{j=1}^{n} v_j^k = 1 \\
& v_j^k \ge 0,\ k = 1,\dots,K
\end{aligned} \tag{7}$$

where λ_j^k and v_j^k represent the optimal weights assigned to inputs and outputs. In our case, $g_x = (1,1,1)$, $g_y = (1)$ and $g_b = (-1)$ as our data set consists of three inputs, one desirable output, and one undesirable output (see Fig.1).

Using programs (6) and (7), we can calculate the technology gap ratio (Battese et al., 2004) or the reciprocal relationship of the metatechnology ratio (MTR) (O'Donnell et al., 2008).

$$0<\mathrm{MTR}(x,y,b)=\frac{\mathrm{MTE}(x,y,b)}{\mathrm{TE}(x,y,b)}=\frac{\dfrac{1-\frac{1}{m}\sum_{i=1}^{m}\beta^{meta}g_i/x_{io}^{k}}{1+\frac{1}{s+p}\left(\sum_{r=1}^{s}\beta^{meta}g_r/y_{ro}^{k}+\sum_{t=1}^{p}\beta^{meta}g_t/b_{to}^{k}\right)}}{\dfrac{1-\frac{1}{m}\sum_{i=1}^{m}\beta^{k}g_i/x_{io}^{k}}{1+\frac{1}{s+p}\left(\sum_{r=1}^{s}\beta^{k}g_r/y_{ro}^{k}+\sum_{t=1}^{p}\beta^{k}g_t/b_{to}^{k}\right)}}\leq 1 \qquad (8)$$

where MTE expresses the technical efficiency of an operational unit with respect to the metatechnology, and TE represents the technical efficiency of an operational unit with respect to the *k* group frontier.

The metafrontier framework provides benchmarking for all operational units independently from the group-specific frontier that each unit belongs. As a result, drawing on the technology heterogeneity concept, we can attribute differences, captured by technology gaps, due to: (a) the structure of national markets, (b) national regulations and policies, (c) cultural profiles and legal and institutional frameworks (Halkos and Tzeremes, 2011), (d) available resource endowments, (e) economic infrastructure, (f) characteristics of the physical, social and economic environment in which production takes place (O'Donnell et al., 2008; Kounetas et al., 2009), and (g) knowledge characteristics and strategic orientation (Kontolaimou and Tsekouras, 2010). In this context, a value of the MTR closer to unity indicates smaller technology heterogeneity while a value closer to zero denotes greater technology heterogeneity.

In addition to the identification of technology heterogeneity, the metatechnology framework facilitates the measurement of technology gaps (TG). Chiu et al. (2012) defined the TG inefficiency as the distance between the individual frontier and the metafrontier. The TG is obtained as follows:

$$\mathrm{TG}(x,y,b)=\mathrm{TE}\times(1-\mathrm{MTR}(x,y,b)) \qquad (9)$$

We present a graphical analysis (please see Fig.1) of the world metafrontier and the two individual frontiers for the output-oriented framework. At a given input and output level, say x and y the observed country A under the non-Annex I technology consists of three components. First, the technical inefficiency (GDDF relative to the frontier) between points A and B, the metatechnical inefficiency between points A and C (MGDDF relative to the metafrontier) and the technology gap difference denoting as TG.

3.2 The Technology Gaps'Stochastic Convergence Hypothesis

Thus we can consider technology gap (TG)[3] as a continuous-time stochastic process $\{X(t),\ t \geq 0\}$ and assume that the each stochastic process is a continuous-time Markov chain with distribution function ϕ_t. Each ***X*** satisfies the Markovian property $\text{Prob}(X_{t+\tau} \in A | X_j,\ j \leq t;\ X = x) = \text{Prob}^{\tau}(x, A)$, with $A \subseteq E \subseteq$ where *E* is the space state of *X*, iP^{τ} called "stochastic kernel" and under certain conditions (Quah, 1997) satisfies the following equation $\phi_{t+\tau} = \int_E (x, A)\phi_t \mathrm{d}x$ that leads to $f_{t+\tau}(y) = \int_E f_{\tau}(y|x) f_t(x)\mathrm{d}x$ with $f_t(x)$ and $f_{\tau}(y|x)$, which are respectively the density function of ϕ_t and Prob^{τ}, if they exist.

The empirical estimate of the marginal probability density function (pdf) of x is given by:

$$\hat{f}(x) = \int_{-\infty}^{+\infty} \hat{f}(x, y)\mathrm{d}y = \frac{1}{n}\sum_{j=1}^{n} \frac{1}{h_x\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-x_j}{h_x}\right)^2} \int_{-\infty}^{+\infty} \frac{1}{h_y\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{y-y_j}{h_y}\right)^2} \mathrm{d}y$$

$$= \frac{1}{n}\sum_{j=1}^{n} \frac{1}{h_x\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-x_j}{h_x}\right)^2} \qquad (10)$$

where the joint distribution $f(x, y)$ is obtained using a product of Gaussian kernel *K* (Fotopoulos, 2006):

$$\hat{f}(x, y) = \frac{1}{n}\sum_{j=1}^{n} \frac{1}{h_x\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-x_j}{h_x}\right)^2} \frac{1}{h_y\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{y-y_j}{h_y}\right)^2}$$

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[3] For clarity and presentation reasons we consider TG as X.

$$= \frac{1}{n} \sum_{j=1}^{n} \frac{1}{h_x} K\left(\frac{x - x_j}{h_x} \right) \frac{1}{h_y} K\left(\frac{y - y_j}{h_y} \right) \qquad (11)$$

where h_x and h_y are bandwidths calculated with the direct plug method applied separately in each dimension. In this way, a nonparametric estimation of the stochastic kernel[4] is given by:

$$\hat{f}_\tau(y|x) = \frac{\hat{f}(y,x)}{\hat{f}(x)} \qquad (12)$$

The stochastic kernel may be interpreted as a transition matrix with a continuum of rows and columns. Let a time interval of length τ; the relationship among two distributions over τ can be written as:

$$f_{t+\tau}(y) = \int_{-\infty}^{+\infty} f_\tau(y|x) f_t(x) \mathrm{d}x \qquad (13)$$

Following the approach developed by Johnson (2000 and 2005) and Fotopoulos (2006), the long-run ergodic distribution is found as the solution to:

$$f_\infty(y) = \int_{-\infty}^{+\infty} f_\tau(y|x) f_\infty(x) \mathrm{d}x \qquad (14)$$

One possible way to face this problem is through a discretization of the time interval $[\alpha, b]$ by partitioning it in n non-overlapping subintervals, then is possible to estimate $f_\tau(z_j|x_i)$ with z_j, x_i midpoints of these subintervals. If $p_{ij} = f_\tau(z_j|x_i) \frac{b-a}{n}$ (≥ 0) are defined and n is sufficiently large (which leads to $\sum_{j=1}^{n} f_\tau(z_j|x) \frac{b-a}{n} \approx 1$) then the $n \times n$ matrix $\boldsymbol{P} = \{p_{ij}\}$ has the same structure as a transition probabilities matrix and $\{p_{ij}\}_{j=1}^{n}$ may be seen as the conditional probability mass function. The ergodic density can be evaluated as $f_\infty(y) = \psi \mid \frac{b-a}{n}$, where ψ is the rescaled (unit

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[4] In general, the characteristics of the kernel function and bandwidths influence the quality of the density estimation. Different kernel alternatives may be used (Silverman 1986, Wand and Jones 1995). Since the kernel estimator is not very sensitive to a choice of K, a Gaussian kernel has been used (Magrini 2007). Moreover, the Mean Integrated Squared Error (MISE) is minimized by a multivariate standard normal density over the class of product kernels (Pagan and Ullah 1999).

sum) left eigenvector corresponding to the unity eigenvalue (also the largest one) of the matrix ***P***.

4. Data Sources and Variable Definitions

To investigate the issues surrounding our main research question we have devised a unique dataset by employing and matching distinct, but complementary, information sources. The resulting dataset is a balanced panel consisting of 103 countries for the 1995-2011 period and our final panel dimension comprises of 1751 observations. We should note that our sample is affected by the events of the global financial crisis that manifested from August 2007 onwards but also covers the period before and after Kyoto's implementation. It is worth adding that the sample period was chosen purely on the basis of availability of key variables, some of which become unavailable after 1995.

For the estimation of productive efficiency with respect to each country frontier and the specific metafrontier as well, we employ a multi-input – single-desirable output- single-undesirable output data set. More specifically, we approximate the output variable (Y) by the Gross Value Added of each industry as the desirable output and CO2 emissions in metric tonnes (Mt) as the undesirable one. For the input side, we include the capital stock (K) in million Dollars, the labor input (L) which is captured by the total hours worked by employees, expenditure on intermediate inputs (M) in million Dollars and the total energy consumption (E) measured in million tons (Mt) of oil equivalent. Table 1 provides the definition, measurement and basic descriptive statistics for each variable.

As already mentioned, the data were drawn by combining several distinct sources of information. Data for Gross Value Added, total hours worked by employees and intermediate inputs were obtained from the World Bank database (World Bank Developing Indicators), Enerdata-Odyssey database was used to collect data on energy consumption and CO2. Finally, data on capital were acquired through OECD Structural Analysis and World Bank databases respectively. The deflators used to convert the current into constant 2005 prices are specific to each country. At this point, we should mention that the distinction in two specific frontiers (AnnexI and non-AnnexI) has been held following the distinction of Kyoto's protocol.

5. Empirical Results and Discussion

The presentation and discussion of the empirical results follows the two stage structure of the methodology section.The country specific efficiency scores with respect to the two groups are firstly presented and discussed.Subsequently, the metatechnology efficiency scores, the associated metatechnology ratios and technology gaps which arises in the context of the metafrontier have been used for the examination of our hypothesis. At the end, the results from the estimation of the stochastic kernel for the technology gaps has been presented.

5.1 Efficiency,Metatechnology ratios and Technology Gap Estimates

Productive efficiency scores with respect to the specific technology and the metatechnology, the associated metatechnology ratios and technological gaps are estimated for the 103 countries in each of the 17 years. GAMS is used to solve the linear problem of the generalized distance function expanding its use in also the metatechnology (Cheng and Zervopoulos, 2014). At this point, it is crucial to note that both the productive efficiency and technology gap estimations are grounded on a cross-section basis, estimated separately for each year in the sample denoting an individual production set. Therefore, the values of the estimated productive efficiency and technology gap for each country encompass two dynamic factors. First is the change of the distance from the (meta-) frontier, while the second is the movement outwards (technical change) or inwards (technical regress) of the metafrontier itself. Using this logic, the estimated time-series for efficiency and technology gaps reflect the diachronic evolution of productive performance of the examined country, considering any technological developments either in the industry-specific frontier or in the metatechnology.

Mean values of productive efficiency for each frontier, the metafrontier and the associated technology gaps are calculated in Table 3. The sample average of metatechnical efficiency is 0.827. This implies that countries operate at the average values of outputs and inputs have the potential to increase their GDP and simultaneously, decrease their CO2 emissions by about 17.3%. Furthermore, it is quite interesting to mention the slightly difference between AnnexI and non-AnnexI countries regarding their efficiency performance (0.886 against 0.847) with respect to their frontier but also the significant difference for their performance with respect to their metafrontier (0.878 against 0.799). The same holds for technology gaps with the corresponding values to be 0.029 for the AnnexI and 0.167 for the non-AnnexI. Furthermore, a Kruskal-Wallis test has been applied to examine the technology frontier differences between the AnnexI, non-AnnexI countries. The result shows that the value of this test is 203.17 and thus, the two groups have distinct technology frontiers with respect to their meta-efficiency productive performance.

Tables 4 and 5 display the estimated values of (i) the productive efficiency with respect to the specific technology and (ii) the technology gap with respect to the Global metatechnology for each country between 1995-2011. The distributions of the productive efficiency are also given in Fig.2 which shows kernel density estimates for the first period of the sample (1995), two middle periods (2000 and 2005), and the last (2011). Furthermore, the time evolution of metatechnology ratios for the two groups and the total sample are depicted in Fig.3.

We begin by looking at the estimated productive efficiency and technology gap values for Annex-I countries. From our results it is clear that countries like Germany, France, the Czech Republic, Ireland, Latvia, the Netherlands, New Zealand, Slovenia, Sweden Turkey, UK and USA exhibit the highest scores for productive efficiency constructing the Champions group, while Bulgaria, Belarus, Croatia and Hungary perform the worst (the laggards group). Furthermore, examining the efficiency scores with respect to the metatechnology, Canada, France, Ireland, Italy, Japan, Malta, Norway, Turkey, UK and USA present the smallest technology gaps and constitute, diachronically, the metafrontier. In contrast, a group of countries like Lithuania, Latvia, Poland, Portugal, Romania, Slovakia, and Ukraine perform worst among the remaining ones suggesting that significant knowledge spillover effects are not in operation within country-specific technologies. Latvia and New Zealand interestingly, though a champion under the AnnexI frontier, also maintain a large technology gap, suggesting some strong allocative inefficiencies.

Shifting attention towards to the non-AnnexI technological frontier given in Table 5, the sample average productive efficiency scores reveal that Armenia, China, Hong-Kong, Egypt, Mexico, Singapore and South Korea perform identically on average. However, it is quite interesting that only 4 of 66 (6.02%) of them diachronically define the metafrontier. Indonesia, Iran, Philippines and Singapore define the metafrontier more often than any other counterpart whilst Armenia, Georgia, MDA and Cambodia significantly underperform. The corresponding results accompanied from the significant low TGs scores for the specific group support the idea of significant knowledge incoming spillover barriers from the metatechnology (Tsekouras et al. 2016). Possible explanations arises from the specific nature of the agreement for non-Annex I countries (Böhringer and Vogt, 2003; 2004), the role of appropriability conditions (Castellaci, 2007), the degree of openness to foreign competition, mainly via globalization, the assymetric effect of technological opportunities and the size of the market (Los and Verspagen, 2006).

The time evolution of the productive efficiency scores, using the corresponding kernel densities, for the total sample, depicted in Fig.2c, reflect a process of continuous and quite significant divergence only for the 2011 period. This is reflected in the increased deviation of the distribution. The specific result provides valuable information for the impact of the Kyoto protocol on environmental performance since 2011 is only one year from its expiration. On the other hand, it is quite interesting the small but noticeable deterioration in 2005 year during the Kyoto transition period. The corresponding time evolution of the AnnexI (Fig.2a) reveals that, although the overall picture is quite similar to the one sketched for the total sample, a significant increase of the productive efficiency scores were especially significant during the period. Fig.2b offers the time evolution of the productive efficiency scores of the non-Annex I group. Notwithstanding this, the distribution remains almost steady with no apparent divergence or convergence processes in operation.

Finally, the box-plots of diachronic performance of metatechnology ratios provide more insight into the distribution among AnnexI, non-AnnexI and the total sample. In Fig.3c a box plot graph of the estimated metatechnology ratios of the total sample is depicted. It is evident that metatechnology ratios as well as their deviations are diachronically constant with no significant fluctuations. It is clear that Annex-I countries yield the best average and variance of metatechnology ratios compared with non-Annex-I and the total sample with a distribution skewed to the right (see Fig.3a). Moreover, the metatechnology ratios slightly decrease in the 2002-2005 period but exhibit a drastic increase over the 2005-2011. In contrast, Fig.3b mirrors a rather different, compared to the AnnexI case, pattern of the non-AnnexI metatechnology ratios performance. More specifically, it seems that between 1995 and 2001 technology gaps remain quite distant while for the 2002-2008 period a significant decrease has occurred. On the contrary, in the time window from 2009 to 2011, a considerable increase emerged. In the same direction, but more impressive, is the picture of the total sample metatechnology ratios distribution presented in Fig.3c.

5.2 Stochastic Kernel of Annex I and non-Annex I Technology Gaps

The non parametric methodology of stochastic kernel adopted in this study, refers to the "convergence literature", typified by the seminal papers by Barro and Sala-i-Martin (1991) and Mankiw et al. (1992) exploring beta-convergence.However, according to Quah (1993) stochastic Kernels describes the law of motion of a sequence of distribution and it serves to retrieve the evolution of the probability distribution of a random variable (usually GDP) along time allowing it to overcome the limitations of conventional convergence analysis focus on the dynamic properties of the series.Stochastic Kernel (Quah, 1996, 1997) resulted in the literature from the necessity to substitute discrete transition matrices. In this way, stochastic kernels can be achieved by estimating the density function of a distribution over a given period, lets say t+k, conditioned on the values corresponding to a previous period, t.

We examine the convergence-divergence hypothesis for technology gaps. The stochastic kernel in Fig.4 shows how countries' technological gaps in 1995 evolves into 2011.Thus, over the 17 years, a three peaks property appears. Each specific peak reflects a comparatively substantial number of observed transitions from a part of the distribution to another while having a constant point x-axis. We can understand the estimated distribution of technology gapsin 2011 at its initial level in 1995. A large portion of the probability mass is concentrated along the 45° diagonal while the existence of three peaks along the diagonal indicates the presence of individual convergence clubs for all the 103 countries. More specifically, there are two local maxima in both low and high technological gaps parts and a third in the middle part of relative ones.

Considering the corresponding contour plot in Fig.5, we notice that during the examined period, countries have a low probability of changing their relative position in one year in terms of technological gaps suggesting that the mobility is low. The three peaks phenomenon for technological gaps directly links productivity differentials and technology structure. This could be further explained in terms of factor accumulation deformations, factor prices change that acts as an inducement for the introduction of new technologies (Binswanger et al., 1978) and localized technological change (Antonelli, 2006; Mulder and DeGroot, 2012). Factor accumulation distortions (Easterly and Levine, 2001) of the examined countries in both physical and in terms of human capital could be important to facilitate the objective of the three clubs creation. For instance, physical capital investment may embody new energy saving technologies to help in catching up the frontier but this is not the case for all countries.

6. Conclusions

Addressing the problems arising from GHGs emissions released in the environment and climate change calls for a better understanding of the patterns of CO_2 emissions and country efficiency performance over time. The Kyoto Protocol which imposes emissions reduction targets on industrialized countires, has been celebrationg as a milestone in climate protection and mitigation for the world community. In this study, we apply a generalized efficiency measure of a directional distance function that allows the directional vector to be independent of the length, under a metafrontier framework. A particular, however, emphasis is on the construction of a best practice metafrontier production function that allows for the comparison of two individual frontiers (AnnexI and non-AnnexIcountries) with completely different technological regimes.

It has been found that, on average, countries of AnnexI group achieved highest values of productive efficiency and meta-efficiency performance compared with non-AnnexI group frontier. Among the countries, Canada, France, Ireland, Italy, Japan, Malta, Norway, Turkey, UK and USA seem to perform best in their frontier and metafrontier. In addition, only four countries, Indonesia, Iran, Philippines and Singapore, report the same for the non-AnnexI countries case.

Moreover, the results with respect to technological gaps report a rather enlarged differentiation for the two groups. The specific differentiation seems to acquire a timeless character with completely different behaviors in the two clusters. The significantly different behavior of the two clusters, in terms of technological gaps, could strongly depend on differences in local capabilities and on consequential technologically and environmental spillovers arising from the metafrontier production function. Causes of the different behavior of the two frontiers would benefit from further investigation.

The information yielded investigating the convergence hypothesis with respect to technological gaps reveals the significant role of spillovers and its inner-flows not only for each country but also for the two groups. Furthermore, it is related with general factors as different national policies, level of technology, the ambiguity of the role of internationalization and lax regulation.

Finally, it should be notes that the results of our study are dependent on the countires included and the variables used. Further research may be carried out to extent this study by covering a greater number of countries with a larger period of examination. Moreover, it is interesting to examine the possible drivers responsible for the different groups behavior with respect to their productive performance and technology gap characteristics.

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References

Antonelli, C., 2006.Localized technological change and factor markets: Constraints and inducements to innovation. *Structural Change and Economic Dynamics*, 17(2), 224-247.

Babiker, A., Reilly, M.J., Jacoby, D,H., 2000. The Kyoto Protocol and developing countries. *Energy Policy*, 28, 525-536.

Barros, C.P., Managi, S. R. Matousek, R., 2012,. The technical efficiency of the Japanese banks: non-radial directional performance measurement with undesirable outputs. *Omega*, 40, 1–8

Barro, R.J.,Sala-i-Martin, X.,1991.Convergence Across States and Regions. Brooking Papers on Economic Activity, 1990 (1), 107-182.

Battese, G. E., & Rao, D. P. 2002. Technology gap, efficiency, and a stochastic metafrontier function. *International Journal of Business and Economics*, *1*(2), 87-93.

Battese, G. E., Rao, D. P., & O'Donnell, C. J. 2004. A metafrontier production function for estimation of technical efficiencies and technology gaps for firms operating under different technologies. *Journal of Productivity Analysis*, *21*(1), 91 103.

Binswanger, H.P., Ruttan, V.W., Ben-Zion, U., Janvry, A. D., Evenson, R.E., 1978. Induced innovation; technology, institutions, and development.

Böhringer, C., Vogt, C. 2003. Economic and environmental impacts of the Kyoto Protocol. *Canadian Journal of Economics/Revue canadienne d'économique*, 36(2), 475-496.

Böhringer, C., Vogt, C. (2004). The dismantling of a breakthrough: the Kyoto Protocol as symbolic policy. *European Journal of Political Economy*, 20(3), 597-617.

Calbick, K.S., Gunton, T., 2014. Differences among OECD countries' GHG emissions: Causes and policy implications. *Energy Policy*, 67, 895–902.

Camarero, M., Picazo-Tadeo, A.J. C. Tamarit, C., 2008. Is the environmental performance of industrialized countries converging? A 'SURE' approach to testing for convergence. *Ecological Economics*, 66, 653–661

Camarero, M., Castillo, J., Picazo-Tadeo, A.J., and Tamarit, C., 2013. Is ecofficiency in greenhouse gas emissions converging among European Union countries. *Empirical Economics* , 47(1), 143-168.

Castellacci, F., 2007. Technological regimes and sectoral differences in productivity growth. *Industrial and Corporate Change*, *16*(6), 1105-1145.

Cheng, G., Zervopoulos, P., 2014. Estimating the technical efficiency of health care systems: A cross-country comparison using the directional distance function. *European Journal of Operational Research, 238* (3), 899-910.

Chambers, F.G., Chung, Y., Fare, R., 1996. Benefit and distance functions. *Journal of Economic Theory*, 70, 407–419

Chiu, C.R., Liou, J.L., Wu, P.I., Fang, C.L. 2012. Decomposition of the environmental inefficiency of the meta-frontier with undesirable output. *Energy Economics* 34, 1392-1399.

Cuesta, R. A., Lovell, C. K., & Zofío, J. L. (2009). Environmental efficiency measurement with translog distance functions: A parametric approach. *Ecological Economics*, 68(8), 2232-2242.

Den Elzen, M., Höhne, N. 2008. Reductions of greenhouse gas emissions in Annex I and non-Annex I countries for meeting concentration stabilisation targets. Climatic Change, 91(3), 249-274.

Den Elzen, M. G., De Moor, A. P. 2002. Analyzing the Kyoto Protocol under the Marrakesh Accords: economic efficiency and environmental effectiveness. Ecological Economics, 43(2), 141-158.

Easterly, W., Levine R., 2001. What have we learned from a decade of empirical research on growth? It's Not Factor Accumulation: Stylized Facts and Growth Models. *World Bank Economic Review*, 15 (2), 177-219.

Färe, R, S. Grosskopf, C. Pasurka 2007. Environmental production functions and environmental directional distance functions. *Energy* 32 ,1055-1066.

Färe, R.,and S. Grosskopf 2010. Directional distance functions and slacks-based measures of efficiency. *European Journal of Operational Research,* 200 320-322.

Färe, R., Grosskopf, S., Dong-Woon N., Weber, W., 2005. Characteristics of a polluting technology:theory and practice. *Journal of Econometrics,* 126, 469-492.

Färe, R., and Grosskopf, S, 2000, Theory and Application of Directional Distance Functions. *Journal of Productivity Analysis*, 13, 93-103.

Färe, R., Grosskopf, S., Lovell, C. (1994). Production frontiers. Cambridge University Press: Cambridge.

Feroz, E. H., Raab, R. L., Ulleberg, G. T., & Alsharif, K. 2009. Global warming and *environmental production efficiency ranking of the Kyoto Protocol nations. Journal of environmental management*, 90(2), 1178-1183.

Fotopoulos, G., 2006. Nonparametric Analysis of Regional Income Dynamics: the case of Greece. *Economic Letters*, 91, 450-457.

Fukuyama, H., Weber, W.L., 2009.A directional slacks-based measure of technical efficiency. Socio-Economic Planning Science, 43, 274–287

Fukuyama,H., Yoshida, Y., Managi, S., 2011. Modal choice between air and rail: a social efficiency benchmarking analysis that considers CO_2 emissions. *Environment and Economic Policy Studies*,13,89-102.

IEA (2010). Carbon Dioxide Emissions from Fuel Combustion. Highlights. International Energy Agency. OCDE.

Johnson, A.P., 2000. A nonparametric analysis of income convergence across the US states. Econ. Lett. 69, 219-223.

Johnson, A.P., 2005. A continuous state space approach to "Convergence by Parts. *Economic Letters,* 86 (3), 317-321.

Halkos, G. E., Tzeremes, G.N., 2014. Measuring the effect of Kyoto protocol agreement on countries' environmental efficiency in CO2 emissions: an application of conditional full frontiers. *Journal of Productivity Analysis* 41 (3), 367-382.

Halkos, G. E., Tzeremes, G.N., 2011 Modelling the effect of national culture on multinational banks performance: a conditional robust nonparametric frontier analysis. Economic Modeling , 28, 515–525

IPCC Climate Change 2007. In: Pachauri, R.K., Reisinger, A. (Eds.), Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team. IPCC, Geneva, Switzerland.

Kontolaimou, A., Kounetas, K., Mourtos, I., & Tsekouras, K. 2012. Technology gaps in European banking: Put the blame on inputs or outputs? *Economic Modelling*, 29(5), 1798-1808.

Kounetas, K. 2015. Heterogeneous technologies, strategic groups and environmental efficiency technology gaps for European countries. *Energy Policy*, 83, 277-287.

Kumar, S., Khanna, N., 2009. Measurement of environmental efficiency and productivity: a cross-country analysis. Environment and Development Economics, 14 (4),473–495.

Kuosmanen, T and Kortelainen, M., 2005. Measuring Eco-efficiency of Production with Data Envelopment Analysis. *Journal of Industrial Ecology*, 9 (4) 59-72.

Los, B., Verspagen, B., 2006. The evolution of productivity gaps and specialization patterns. *Metroeconomica*, *57(4)*, 464-493

Mahlberg, B. Sahoo, B. K., Luptacik, M., 2011. Alternative measures of environmental technology structure in DEA: An application. *European Journal of Operational Research*, 215(3), 750-762.

Mankiw, N.G., D. Romer, D., D.N. Weil, D.N., 1992. A contribution to the empirics of economic growth. *Quarterly Journal of Economics*, 107 (2), 407–437.

Mulder, P., De Groot, L.F.H., 2012.Structural change and convergence of energy intensity across OECD countries, 1970-2005. Energ. Econ. 34, 1910-1921.

O’Donnell, C. J., Rao, D. P., & Battese, G. E. 2008. Metafrontier frameworks for the study of firm-level efficiencies and technology ratios. *Empirical Economics*, *34*(2), 231-255.

Oggioni, G., Riccardi, R., & Toninelli, R. (2011). Eco-efficiency of the world cement industry: a data envelopment analysis. *Energy Policy*, 39(5), 2842-2854.

Oh, Dong-hyun 2010. A metafrontier approach for measuring an environmentally sensitive productivity growth index. *Energy Economics* 32 (1), 146-157.

Quah, D.T., 1997. Empirics for Growth and Distribution: Stratification, Polarization, and Convergence Clubs. *Journal of Economic Growth*, 2, 27-59.

Quah, D.T., 1993. Galton's Fallacy and the Convergence Hypothesis. *Scandinavian Journal of Economics*, 95, 427-443.

Quah, D.T., 1996. Convergence empirics across economies with (some) capital mobility. *Journal of Economic Growth*, 1, 95-124.Sueyoshi, T., Goto, M. 2010. Should the US clean air act include CO 2 emission control?: Examination by data envelopment analysis. *Energy Policy*, 38(10), 5902-5911.

Tol R., 2009. The economic effects of climate change. *Journal of Economic Perspectives,* 23:29-51.

Tone, K. 2001. A slacks-based measure of efficiency in data envelopment analysis. *European Journal of Operational Research* 130, 498-509.

Tsekouras, K., Chatzistamoulou, N., Kounetas, K., Broadstock, D. C. 2016. Spillovers, path dependence and the productive performance of European transportation sectors in the presence of technology heterogeneity. *Technological Forecasting and Social Change*, 102, 261-274.

Yu-Ying Lin, E., Chen Ping-Yu., Chen, Chi-Chung 2013.Measuring the environmental efficiency of countries: A directional distance function metafrontier approach. *Journal of Environmental Management* 119, 134-142.

Weitzman, M.L., (2009) On modeling and interpreting the economics of catastrophic climate change. *The Review of Economics and Statistics,* 91 (1) 1-19

Taskin, F., & Zaim, O. (2001). The role of international trade on environmental efficiency: a DEA approach. *Economic Modelling*, 18(1), 1-17.

Zhou,P., B.W. Ang, H. Wang 2012. Energy and CO2 emission performance in electricity generation: a non-radial directional distance function approach. *European Journal of Operational Research*, 221, 625–635

Zhang, N., P. Zhou, Choi Yongrok 2013. Energy efficiency, CO2 emission performance and technology gaps in fossil fuel electricity generation in Korea: a meta-frontier non-radial directional distance function analysis. *Energy Policy*, 56, 653–662

APPENDIX A

Table 1: Variables, units of measurement and sources

Variable	Units of measurement	Source
Output (Y)	million $	World Bank
Capital (K)	million $	OECD STAN, World Bank
Labor (L)	million hours worked by employees	World Bank
CO_2 emissions (CO_2)	million $	Enerdata - Odyssey
Energy consumption (E)	million tons of oil equivalent	Enerdata - Odyssey

All the values are in constant 2005 prices.

Table 2: Descriptive statistics by type of agreement and variable

	TOTAL	Annex-I	Non-Annex-I
Y	203,81	125,16	14,64
	(143,1)	(185,41)	(18,87)
K	1575,85	745,14	55,48
	(4561,07)	(658.1)	(98,49)
L	24.05	12.83	3.91
	(84.06)	(24.17)	(4.97)
CO_2	231,441	168,15	89,25
	(731,35)	(125,17)	(63,25)
E	93,125	65,47	22,01
	(281,76)	(58,62)	(17,32)

Note 1: *Numbers indicate the mean value while parentheses correspond to the standard deviation*

Table 3: Average descriptive statistics for technical, metatechnical efficiency and technology gaps for the individual groups

	Technical Efficiency	Meta-technical Efficiency	Technology Gap
Annex-I	0.886	0.878	0.029
	(0.102)	(0.107)	(0.011)
Non-Annex-I I	0.849	0.799	0.167
	(0.125)	(0.122)	(0.103)
ALL	0.869	0.827	0.077
	(0.118)	(0.122)	(0.032)

Table 4: Productive Efficiency scores and Technology gap values for the Annex I countries to the Kyoto convention for 1995-2011

Country		AUS	AUT	BEL	BUL	BLR	CAN	CHE	CYP	CRO	CZE	DEN	ESP	EST	FIN	FRA	GER	GRC	HUN	IRL	ICE	ITA
1995	**TE**	0.927	0.884	0.924	0.730	0.705	1.000	1.000	0.917	0.778	0.773	0.863	0.955	0.764	0.861	1.000	1.000	0.812	0.766	1.000	1.000	1.000
	TG	0.000	0.000	0.000	0.011	0.017	0.000	0.000	0.007	0.010	0.000	0.009	0.000	0.009	0.018	0.000	0.004	0.002	0.000	0.000	0.000	0.000
1996	**TE**	0.926	0.880	0.917	0.720	0.706	1.000	1.000	0.913	0.772	0.774	0.862	1.000	0.770	0.860	1.000	1.000	0.811	0.764	1.000	1.000	1.000
	TG	0.000	0.000	0.000	0.011	0.013	0.000	0.000	0.008	0.009	0.001	0.008	0.014	0.012	0.015	0.000	0.004	0.002	0.000	0.000	0.000	0.000
1997	**TE**	0.930	0.876	0.918	0.718	0.709	1.000	1.000	0.912	0.774	0.771	0.861	0.948	0.776	0.860	1.000	1.000	0.813	0.764	1.000	1.000	1.000
	TG	0.000	0.000	0.000	0.019	0.023	0.000	0.076	0.015	0.012	0.009	0.010	0.001	0.023	0.019	0.000	0.006	0.005	0.000	0.000	0.000	0.000
1998	**TE**	0.932	0.883	0.917	0.720	0.712	1.000	1.000	0.914	0.779	0.773	0.862	0.950	0.779	0.866	1.000	1.000	0.813	0.767	1.000	1.000	1.000
	TG	0.000	0.000	0.000	0.023	0.029	0.000	0.000	0.026	0.015	0.029	0.013	0.001	0.025	0.022	0.000	0.008	0.004	0.000	0.000	0.000	0.000
1999	**TE**	0.932	0.886	0.919	0.723	0.713	1.000	1.000	0.915	0.781	0.776	0.862	0.945	0.778	0.866	1.000	1.000	0.815	0.766	1.000	1.000	1.000
	TG	0.000	0.000	0.000	0.024	0.032	0.000	0.000	0.025	0.015	0.022	0.005	0.000	0.018	0.022	0.000	0.008	0.007	0.000	0.000	0.000	0.000
2000	**TE**	0.923	0.886	0.916	0.727	0.714	1.000	1.000	0.917	0.779	0.779	0.863	0.937	0.791	0.867	1.000	1.000	0.817	0.766	1.000	0.989	1.000
	TG	0.000	0.000	0.000	0.026	0.036	0.000	0.000	0.026	0.016	0.037	0.003	0.001	0.029	0.023	0.000	0.009	0.006	0.001	0.000	0.000	0.000
2001	**TE**	0.928	0.881	0.910	0.729	0.716	1.000	1.000	0.925	0.791	0.781	0.860	0.939	0.797	0.866	1.000	1.000	0.820	0.769	1.000	1.000	1.000
	TG	0.000	0.000	0.000	0.028	0.039	0.000	0.000	0.024	0.016	0.027	0.004	0.002	0.035	0.024	0.000	0.009	0.008	0.000	0.000	0.000	0.000
2002	**TE**	0.927	0.882	0.910	0.731	0.719	1.000	1.000	0.923	0.792	0.782	0.859	0.935	0.800	0.866	1.000	1.000	0.820	0.772	1.000	1.000	1.000
	TG	0.000	0.000	0.000	0.031	0.043	0.000	0.000	0.027	0.018	0.031	0.011	0.000	0.038	0.027	0.000	0.010	0.004	0.000	0.000	0.000	0.000
2003	**TE**	0.928	0.877	0.907	0.732	0.722	0.986	1.000	0.918	0.796	0.784	0.858	0.941	0.804	0.866	1.000	1.000	0.823	0.774	1.000	1.000	1.000
	TG	0.000	0.000	0.000	0.030	0.033	0.000	0.000	0.025	0.017	0.032	0.010	0.001	0.034	0.026	0.000	0.009	0.008	0.000	0.000	0.000	0.000
2004	**TE**	0.924	0.873	0.904	0.733	0.726	0.977	1.000	0.915	0.796	0.786	0.858	0.930	0.807	0.866	1.000	1.000	0.821	0.777	1.000	1.000	1.000
	TG	0.000	0.000	0.000	0.036	0.036	0.000	0.000	0.025	0.021	0.023	0.010	0.001	0.042	0.032	0.000	0.012	0.021	0.000	0.000	0.000	0.000
2005	**TE**	0.919	0.872	0.901	0.734	0.730	0.970	1.000	0.910	0.799	0.790	0.859	0.927	0.811	0.867	1.000	1.000	0.818	0.781	1.000	1.000	1.000
	TG	0.000	0.000	0.000	0.032	0.024	0.000	0.000	0.022	0.019	0.020	0.005	0.000	0.029	0.029	0.000	0.009	0.017	0.000	0.000	0.000	0.000
2006	**TE**	0.921	0.880	0.906	0.737	0.736	0.963	1.000	0.911	0.807	0.798	0.864	0.930	0.813	0.874	1.000	1.000	0.826	0.786	1.000	1.000	1.000
	TG	0.000	0.000	0.000	0.038	0.024	0.000	0.000	0.022	0.024	0.023	0.011	0.000	0.030	0.036	0.000	0.010	0.012	0.000	0.000	0.000	0.000
2007	**TE**	0.922	0.888	0.911	0.739	0.742	0.949	1.000	0.913	0.811	0.805	0.866	0.924	0.821	0.884	1.000	1.000	0.832	0.788	1.000	1.000	0.988
	TG	0.000	0.000	0.000	0.033	0.015	0.000	0.000	0.017	0.022	0.017	0.006	0.000	0.022	0.036	0.000	0.009	0.009	0.000	0.000	0.000	0.000
2008	**TE**	0.919	0.895	0.916	0.744	0.750	0.945	1.000	0.924	0.819	0.811	0.870	0.940	0.817	0.888	1.000	1.000	0.836	0.797	1.000	1.000	0.990
	TG	0.000	0.001	0.002	0.024	0.012	0.000	0.000	0.017	0.022	0.025	0.005	0.001	0.025	0.033	0.000	0.013	0.007	0.000	0.000	0.001	0.000
2009	**TE**	0.923	0.891	0.912	0.742	0.753	0.936	1.000	0.932	0.817	0.809	0.866	0.959	0.817	0.879	1.000	1.000	0.834	0.794	1.000	1.000	0.983
	TG	0.000	0.001	0.005	0.023	0.014	0.000	0.000	0.021	0.022	0.025	0.011	0.002	0.018	0.036	0.000	0.018	0.001	0.000	0.000	0.001	0.000
2010	**TE**	0.923	0.892	0.913	0.745	0.757	0.928	1.000	0.936	0.819	0.812	0.870	1.000	0.828	0.882	1.000	1.000	0.832	0.794	1.000	1.000	0.988
	TG	0.006	0.001	0.011	0.029	0.020	0.000	0.000	0.024	0.026	0.026	0.016	0.041	0.020	0.057	0.000	0.030	0.000	0.000	0.000	0.003	0.000
2011	**TE**	0.919	0.895	0.914	0.747	0.758	0.916	1.000	0.936	0.822	0.812	0.865	0.974	0.823	0.878	1.000	1.000	0.828	0.791	1.000	1.000	0.983
	TG	0.003	0.011	0.039	0.032	0.022	0.001	0.000	0.027	0.040	0.026	0.021	0.021	0.021	0.066	0.000	0.042	0.000	0.000	0.000	0.005	0.000
	Mean TE	**0.925**	**0.884**	**0.913**	**0.732**	**0.728**	**0.975**	**1.000**	**0.919**	**0.796**	**0.789**	**0.863**	**0.949**	**0.800**	**0.870**	**1.000**	**1.000**	**0.822**	**0.777**	**1.000**	**0.999**	**0.996**
	Mean TG	**0.001**	**0.001**	**0.003**	**0.026**	**0.025**	**0.000**	**0.004**	**0.021**	**0.019**	**0.022**	**0.009**	**0.005**	**0.025**	**0.031**	**0.000**	**0.012**	**0.007**	**0.000**	**0.000**	**0.001**	**0.000**

		JAP	LTU	LUX	LAT	MAL	NLD	NOR	NZL	POL	POR	ROM	SVK	SVN	SWE	TUR	UKR	UK	USA	Mean	St.Dev

	TE	1.000	0.739	1.000	0.736	1.000	0.938	1.000	0.823	0.758	0.794	0.711	0.762	0.795	0.851	1.000	0.699	1.000	1.000	**0.879**	**0.111**
1995	**TG**	0.000	0.261	0.000	0.264	0.000	0.062	0.000	0.177	0.242	0.206	0.289	0.238	0.205	0.149	0.000	0.301	0.000	0.000	**0.064**	**0.104**
	TE	0.997	0.989	1.000	1.000	1.000	1.000	0.987	1.000	0.998	0.998	0.978	0.992	1.000	1.000	1.000	1.000	1.000	1.000	**0.939**	**0.095**
1996	**TG**	0.000	0.257	0.000	0.261	0.000	0.067	0.000	0.182	0.240	0.207	0.288	0.236	0.199	0.152	0.000	0.305	0.000	0.000	**0.064**	**0.104**
	TE	0.996	0.989	1.000	1.000	1.000	1.000	0.986	1.000	0.997	0.998	0.979	0.990	1.000	1.000	1.000	1.000	1.000	1.000	**0.938**	**0.094**
1997	**TG**	0.000	0.253	0.000	0.260	0.000	0.068	0.000	0.182	0.236	0.208	0.289	0.233	0.193	0.150	0.000	0.306	0.000	0.000	**0.067**	**0.102**
	TE	0.994	0.980	0.998	1.000	1.000	1.000	0.973	1.000	0.996	0.997	0.966	0.976	1.000	1.000	1.000	0.999	1.000	1.000	**0.937**	**0.092**
1998	**TG**	0.000	0.247	0.000	0.257	0.000	0.064	0.000	0.180	0.234	0.205	0.289	0.228	0.190	0.145	0.000	0.306	0.000	0.000	**0.065**	**0.101**
	TE	0.989	0.968	0.987	1.000	1.000	1.000	0.963	1.000	0.995	0.996	0.957	0.967	1.000	1.000	1.000	0.999	1.000	1.000	**0.936**	**0.091**
1999	**TG**	0.000	0.247	0.000	0.255	0.000	0.047	0.000	0.176	0.227	0.203	0.288	0.227	0.188	0.141	0.000	0.306	0.000	0.000	**0.064**	**0.100**
	TE	0.996	0.975	0.987	1.000	1.000	1.000	0.955	1.000	0.996	0.995	0.954	0.966	1.000	1.000	1.000	0.999	1.000	1.000	**0.936**	**0.090**
2000	**TG**	0.000	0.242	0.000	0.248	0.000	0.050	0.000	0.181	0.223	0.204	0.288	0.226	0.187	0.141	0.000	0.304	0.000	0.000	**0.064**	**0.099**
	TE	0.995	0.980	0.977	1.000	1.000	1.000	0.958	1.000	0.996	0.994	0.948	0.972	1.000	1.000	1.000	0.998	1.000	1.000	**0.937**	**0.088**
2001	**TG**	0.000	0.231	0.000	0.243	0.000	0.056	0.000	0.181	0.221	0.205	0.285	0.223	0.183	0.147	0.000	0.302	0.000	0.000	**0.064**	**0.098**
	TE	0.989	0.970	0.964	1.000	1.000	1.000	0.950	1.000	0.995	0.994	0.945	0.956	1.000	1.000	1.000	0.999	1.000	1.000	**0.935**	**0.087**
2002	**TG**	0.000	0.229	0.000	0.241	0.000	0.068	0.000	0.180	0.217	0.206	0.278	0.219	0.182	0.140	0.000	0.301	0.000	0.000	**0.064**	**0.096**
	TE	0.986	0.962	0.957	1.000	1.000	1.000	0.946	1.000	0.995	0.993	0.939	0.953	1.000	1.000	1.000	0.999	1.000	1.000	**0.935**	**0.086**
2003	**TG**	0.000	0.221	0.000	0.237	0.000	0.071	0.000	0.181	0.213	0.209	0.276	0.217	0.179	0.131	0.000	0.299	0.000	0.000	**0.063**	**0.095**
	TE	0.990	0.985	0.958	1.000	1.000	1.000	0.957	1.000	0.994	0.994	0.942	0.964	1.000	1.000	1.000	1.000	1.000	1.000	**0.935**	**0.086**
2004	**TG**	0.000	0.215	0.000	0.235	0.000	0.074	0.000	0.186	0.211	0.211	0.272	0.215	0.177	0.122	0.000	0.295	0.000	0.000	**0.063**	**0.094**

	TE	0.991	0.987	0.940	1.000	0.999	1.000	0.960	1.000	0.992	0.993	0.942	0.965	1.000	1.000	1.000	1.000	1.000	1.000	**0.935**	**0.085**
2005	**TG**	0.000	0.208	0.000	0.229	0.000	0.069	0.000	0.188	0.211	0.211	0.269	0.210	0.173	0.000	0.000	0.295	0.000	0.000	**0.058**	**0.093**
	TE	0.994	0.991	0.957	1.000	0.998	1.000	0.972	1.000	0.992	0.994	0.957	0.974	1.000	1.000	1.000	1.000	1.000	1.000	**0.938**	**0.083**
2006	**TG**	0.000	0.200	0.000	0.224	0.000	0.058	0.000	0.187	0.206	0.208	0.263	0.202	0.167	0.000	0.000	0.291	0.000	0.000	**0.057**	**0.091**
	TE	0.995	0.991	0.957	1.000	0.998	1.000	0.971	1.000	0.989	0.993	0.956	0.973	1.000	1.000	1.000	1.000	1.000	1.000	**0.939**	**0.081**
2007	**TG**	0.000	0.192	0.000	0.217	0.000	0.058	0.000	0.183	0.202	0.202	0.258	0.190	0.161	0.000	0.000	0.287	0.000	0.000	**0.055**	**0.089**
	TE	0.997	0.994	0.982	1.000	0.998	1.000	0.979	1.000	0.990	0.994	0.972	0.984	1.000	1.000	1.000	1.000	1.000	1.000	**0.942**	**0.079**
2008	**TG**	0.000	0.185	0.000	0.219	0.000	0.047	0.000	0.180	0.190	0.197	0.249	0.181	0.153	0.000	0.000	0.284	0.000	0.000	**0.053**	**0.087**
	TE	0.997	0.996	0.972	1.000	0.998	1.000	0.975	1.000	0.993	0.993	0.970	0.977	1.000	1.000	1.000	0.998	1.000	1.000	**0.941**	**0.079**
2009	**TG**	0.000	0.198	0.005	0.218	0.000	0.059	0.000	0.174	0.181	0.194	0.251	0.181	0.157	0.000	0.000	0.290	0.000	0.000	**0.054**	**0.087**
	TE	0.994	0.993	0.961	1.000	0.999	1.000	0.977	1.000	0.990	0.990	0.970	0.976	1.000	1.000	1.000	0.997	1.000	1.000	**0.943**	**0.078**
2010	**TG**	0.000	0.191	0.009	0.214	0.000	0.059	0.000	0.176	0.178	0.191	0.252	0.175	0.153	0.000	0.000	0.289	0.000	0.000	**0.056**	**0.085**
	TE	0.991	0.989	0.952	1.000	0.995	1.000	0.976	1.000	0.992	0.983	0.961	0.973	1.000	1.000	1.000	0.993	1.000	1.000	**0.940**	**0.078**
2011	**TG**	0.000	0.190	0.020	0.200	0.000	0.057	0.000	0.182	0.176	0.194	0.251	0.177	0.155	0.000	0.000	0.286	0.000	0.000	**0.058**	**0.083**
	Mean TE	**0.993**	**0.984**	**0.972**	**1.000**	**0.999**	**1.000**	**0.968**	**1.000**	**0.994**	**0.994**	**0.959**	**0.972**	**1.000**	**1.000**	**1.000**	**0.999**	**1.000**	**1.000**		
	Mean TG	**0.000**	**0.222**	**0.002**	**0.237**	**0.000**	**0.061**	**0.000**	**0.181**	**0.212**	**0.204**	**0.273**	**0.210**	**0.177**	**0.083**	**0.000**	**0.297**	**0.000**	**0.000**		

Table 5: Productive Efficiency scores and Technology gap values for the non-AnnexI countries to the convention for 1995-2011

		ALB	ANG	ARG	ARM	AZR	BNG	BAH	BOL	BRA	CHL	CHN	CAM	COL	CRI	DOM	ECU	EGY	ETH	GEO	GHA	HK	IDN
1995	TE	0.956	0.682	0.780	1.000	0.700	0.703	1.000	0.775	1.000	1.000	1.000	0.738	0.751	0.956	0.776	0.739	1.000	1.000	0.878	0.720	1.000	0.767
	TG	0.000	0.001	0.027	0.303	0.023	0.095	0.039	0.095	0.000	0.075	0.254	0.312	0.032	0.000	0.067	0.027	0.000	0.000	0.211	0.066	0.054	0.000
1996	TE	0.967	0.684	0.786	1.000	0.700	0.705	1.000	0.785	1.000	1.000	1.000	0.737	0.749	0.988	0.780	0.738	1.000	1.000	0.844	0.718	1.000	0.750
	TG	0.000	0.000	0.032	0.301	0.024	0.105	0.042	0.106	0.000	0.073	0.252	0.311	0.034	0.000	0.072	0.027	0.000	0.000	0.213	0.170	0.052	0.000
1997	TE	0.987	0.685	0.794	1.000	0.701	0.711	1.000	0.767	0.749	0.991	1.000	1.000	0.752	1.000	0.765	0.750	1.000	0.703	0.839	0.714	1.000	0.737
	TG	0.000	0.000	0.033	0.300	0.027	0.126	0.050	0.089	0.005	0.000	0.244	0.311	0.035	0.000	0.060	0.046	0.000	0.022	0.218	0.165	0.048	0.000
1998	TE	0.995	0.684	0.799	1.000	0.703	1.000	1.000	0.770	0.746	0.932	1.000	1.000	0.754	1.000	0.757	0.743	1.000	0.682	0.848	0.712	1.000	0.700
	TG	0.000	0.000	0.036	0.298	0.029	0.132	0.324	0.096	0.005	0.000	0.197	0.311	0.040	0.000	0.055	0.039	0.000	0.018	0.222	0.172	0.045	0.000
1999	TE	1.000	0.684	0.791	1.000	0.704	1.000	1.000	0.769	0.743	0.865	1.000	1.000	0.749	1.000	0.776	0.753	1.000	0.696	0.866	0.714	1.000	0.697
	TG	0.151	0.001	0.035	0.296	0.030	0.137	0.324	0.096	0.005	0.000	0.139	0.310	0.040	0.000	0.074	0.052	0.000	0.023	0.220	0.185	0.048	0.000
2000	TE	1.000	0.683	0.785	1.000	0.704	1.000	1.000	0.768	0.742	0.864	1.000	1.000	0.743	1.000	0.767	0.751	1.000	0.677	0.847	0.712	1.000	0.698
	TG	0.271	0.001	0.034	0.295	0.029	0.138	0.324	0.096	0.006	0.000	0.138	0.309	0.036	0.000	0.070	0.053	0.000	0.013	0.219	0.172	0.047	0.000
2001	TE	1.000	0.683	0.779	1.000	0.704	0.716	1.000	0.788	0.743	0.910	1.000	1.000	0.742	1.000	0.765	0.733	1.000	0.773	0.835	0.712	1.000	0.702
	TG	0.000	0.003	0.037	0.293	0.029	0.130	0.056	0.111	0.007	0.000	0.184	0.308	0.037	0.000	0.060	0.032	0.000	0.021	0.217	0.156	0.047	0.000
2002	TE	1.000	0.685	0.776	1.000	0.704	0.714	1.000	0.778	0.742	0.860	1.000	1.000	0.742	1.000	0.772	0.726	1.000	0.733	0.894	0.714	1.000	0.707
	TG	0.258	0.007	0.038	0.284	0.027	0.110	0.055	0.104	0.007	0.000	0.139	0.306	0.037	0.000	0.069	0.027	0.000	0.013	0.216	0.208	0.050	0.000
2003	TE	1.000	0.684	0.780	1.000	0.703	0.717	1.000	0.765	0.741	0.922	1.000	1.000	0.739	1.000	0.780	0.725	1.000	0.716	0.889	0.717	1.000	0.709
	TG	0.255	0.001	0.040	0.264	0.022	0.079	0.058	0.091	0.006	0.000	0.197	0.304	0.032	0.000	0.077	0.025	0.000	0.027	0.211	0.189	0.053	0.000
2004	TE	1.000	0.685	0.778	1.000	0.703	0.699	1.000	0.770	0.740	0.902	1.000	1.000	0.737	1.000	0.781	0.721	1.000	0.729	0.893	0.718	1.000	0.708
	TG	0.253	0.008	0.038	0.212	0.024	0.077	0.034	0.097	0.006	0.000	0.179	0.302	0.032	0.000	0.078	0.022	0.249	0.012	0.208	0.203	0.055	0.000
2005	TE	1.000	0.687	0.781	1.000	0.719	0.698	1.000	0.764	0.739	0.893	1.000	1.000	0.734	1.000	0.796	0.724	1.000	1.000	0.874	0.738	1.000	0.709
	TG	0.250	0.005	0.038	0.179	0.030	0.084	0.031	0.093	0.006	0.000	0.168	0.300	0.028	0.000	0.091	0.024	0.256	0.000	0.205	0.181	0.078	0.000
2006	TE	1.000	0.691	0.782	1.000	0.809	0.680	1.000	0.747	0.739	0.830	1.000	1.000	0.737	1.000	0.801	0.725	1.000	1.000	0.862	0.713	1.000	0.709
	TG	0.234	0.007	0.033	0.141	0.116	0.114	0.006	0.075	0.006	0.000	0.108	0.296	0.022	0.000	0.092	0.021	0.252	0.000	0.203	0.166	0.047	0.000
2007	TE	1.000	0.697	0.791	1.000	1.000	0.680	1.000	0.761	0.742	0.785	1.000	0.799	0.738	1.000	0.817	0.728	1.000	1.000	0.885	0.713	1.000	0.710
	TG	0.232	0.004	0.032	0.120	0.208	0.142	0.004	0.086	0.006	0.047	0.049	0.291	0.015	0.000	0.102	0.024	0.253	0.000	0.199	0.179	0.045	0.000
2008	TE	1.000	0.701	0.797	1.000	1.000	0.681	1.000	0.764	0.744	0.790	1.000	0.861	0.739	1.000	0.823	0.734	1.000	1.000	0.907	0.719	1.000	0.716
	TG	0.231	0.001	0.031	0.166	0.136	0.169	0.004	0.085	0.006	0.023	0.052	0.287	0.010	0.000	0.104	0.023	0.240	0.000	0.198	0.191	0.050	0.000
2009	TE	1.000	0.700	0.802	1.000	1.000	0.685	0.960	0.773	0.745	0.773	1.000	0.732	0.737	1.000	0.852	0.732	1.000	1.000	0.900	0.815	1.000	0.730
	TG	0.050	0.000	0.034	0.263	0.000	0.160	0.008	0.094	0.006	0.051	0.030	0.284	0.010	0.000	0.133	0.024	0.148	0.000	0.199	0.189	0.079	0.000
2010	TE	1.000	0.699	0.808	1.000	1.000	0.680	0.928	0.769	0.747	0.748	1.000	0.730	0.732	1.000	0.855	0.728	1.000	1.000	0.919	0.721	1.000	0.726
	TG	0.219	0.001	0.032	0.263	0.000	0.147	0.001	0.090	0.008	0.059	0.004	0.280	0.007	0.020	0.133	0.019	0.229	0.000	0.199	0.199	0.045	0.000
2011	TE	1.000	1.000	0.813	1.000	1.000	0.682	0.917	0.767	1.000	0.744	1.000	0.789	0.734	1.000	0.854	0.731	1.000	1.000	0.941	0.754	1.000	0.725
	TG	0.000	0.280	0.021	0.261	0.097	0.145	0.001	0.088	0.000	0.000	0.003	0.000	0.004	0.010	0.133	0.021	0.243	0.000	0.199	0.187	0.000	0.000
	Mean TE	**0.994**	**0.707**	**0.790**	**1.000**	**0.797**	**0.750**	**0.989**	**0.769**	**0.788**	**0.871**	**1.000**	**0.905**	**0.742**	**0.997**	**0.795**	**0.734**	**1.000**	**0.865**	**0.878**	**0.725**	**1.000**	**0.718**
	Mean TG	**0.141**	**0.019**	**0.034**	**0.249**	**0.050**	**0.123**	**0.080**	**0.094**	**0.005**	**0.019**	**0.137**	**0.284**	**0.027**	**0.002**	**0.086**	**0.030**	**0.110**	**0.009**	**0.209**	**0.175**	**0.050**	**0.000**

		IND	**IRN**	**IRQ**	**ISR**	**JOR**	**KAZ**	**KEN**	**KGZ**	**KHM**	**KUW**	**LKA**	**MAR**	**MDA**	**MEX**	**FYR**	**MOZ**	**MYS**	**NIG**	**OMA**	**PAK**	**PER**	**PHIL**
1995	TE	1.000	0.819	0.686	0.870	0.793	0.700	0.711	1.000	1.000	1.000	1.000	0.693	0.766	1.000	1.000	1.000	0.757	0.681	1.000	0.710	0.747	0.699
	TG	0.062	0.000	0.029	0.000	0.034	0.086	0.000	0.034	0.304	0.000	0.000	0.007	0.085	0.181	0.000	0.024	0.006	0.156	0.023	0.027	0.012	0.000
1996	TE	1.000	0.821	0.694	0.880	0.781	0.700	0.711	1.000	1.000	1.000	1.000	0.696	0.774	1.000	1.000	1.000	0.758	0.680	1.000	0.713	0.745	0.700
	TG	0.015	0.000	0.030	0.000	0.048	0.076	0.000	0.045	0.303	0.000	0.000	0.009	0.095	0.153	0.000	0.026	0.006	0.154	0.028	0.031	0.013	0.000
1997	TE	1.000	0.812	0.695	0.877	0.782	0.701	0.710	1.000	1.000	1.000	0.887	0.692	0.829	1.000	1.000	1.000	0.759	0.681	1.000	0.705	0.743	0.701
	TG	0.012	0.000	0.025	0.002	0.055	0.083	0.003	0.045	0.304	0.014	0.168	0.008	0.155	0.156	0.000	0.024	0.007	0.152	0.019	0.023	0.014	0.000
1998	TE	1.000	0.803	0.709	0.920	0.797	0.699	0.702	1.000	1.000	1.000	1.000	0.696	0.867	1.000	1.000	1.000	0.747	0.684	1.000	0.703	0.750	0.700
	TG	0.010	0.000	0.020	0.008	0.102	0.101	0.005	0.035	0.304	0.049	0.000	0.012	0.193	0.147	0.000	0.018	0.012	0.154	0.018	0.031	0.013	0.000
1999	TE	1.000	0.802	0.867	1.000	0.788	0.701	0.702	1.000	1.000	1.000	1.000	0.695	0.902	1.000	1.000	1.000	0.754	0.680	1.000	0.707	0.750	0.699
	TG	0.011	0.000	0.025	0.176	0.170	0.091	0.005	0.035	0.303	0.086	0.171	0.013	0.224	0.176	0.000	0.025	0.007	0.154	0.024	0.033	0.012	0.000
2000	TE	1.000	0.798	0.861	1.000	0.783	0.704	0.701	1.000	1.000	1.000	0.834	0.690	0.921	1.000	1.000	1.000	0.756	0.678	1.000	0.709	0.746	0.700
	TG	0.012	0.000	0.027	0.175	0.170	0.086	0.007	0.036	0.296	0.103	0.162	0.007	0.240	0.000	0.000	0.026	0.004	0.172	0.025	0.032	0.013	0.000
2001	TE	1.000	0.799	0.885	0.994	0.770	0.709	0.706	1.000	1.000	1.000	0.773	0.695	0.907	1.000	1.000	1.000	0.758	0.687	1.000	0.712	0.747	0.699
	TG	0.016	0.000	0.034	0.197	0.171	0.072	0.011	0.040	0.254	0.120	0.096	0.011	0.226	0.179	0.000	0.030	0.015	0.156	0.029	0.028	0.013	0.000
2002	TE	1.000	0.831	0.813	0.963	0.766	0.715	0.710	1.000	1.000	1.000	0.762	0.696	0.890	1.000	1.000	1.000	0.764	0.726	1.000	0.717	0.747	0.699
	TG	0.012	0.000	0.071	0.138	0.151	0.068	0.014	0.047	0.263	0.132	0.085	0.012	0.211	0.189	0.000	0.035	0.066	0.162	0.036	0.031	0.013	0.000
2003	TE	1.000	0.856	0.683	0.892	0.765	0.719	0.768	1.000	1.000	1.000	0.896	0.698	0.922	1.000	1.000	1.000	0.767	0.749	1.000	0.715	0.754	0.700
	TG	0.035	0.000	0.097	0.000	0.084	0.065	0.016	0.047	0.000	0.086	0.219	0.013	0.233	0.192	0.000	0.038	0.091	0.170	0.033	0.031	0.014	0.000
2004	TE	1.000	0.848	0.796	0.878	0.749	0.718	0.735	1.000	1.000	1.000	0.751	0.694	0.926	1.000	1.000	1.000	0.767	0.787	0.978	0.720	0.739	0.700
	TG	0.022	0.000	0.093	0.119	0.069	0.046	0.015	0.043	0.000	0.087	0.075	0.009	0.234	0.196	0.000	0.036	0.131	0.159	0.040	0.022	0.014	0.000
2005	TE	1.000	0.847	0.751	0.883	0.749	0.725	0.713	1.000	1.000	1.000	0.787	0.691	0.934	1.000	1.000	1.000	0.772	1.000	0.956	0.728	0.736	0.701
	TG	0.012	0.000	0.093	0.061	0.066	0.043	0.017	0.030	0.000	0.047	0.112	0.006	0.238	0.199	0.000	0.038	0.284	0.147	0.049	0.018	0.014	0.000
2006	TE	1.000	0.863	0.820	0.855	0.768	0.725	0.710	1.000	1.000	1.000	0.763	0.693	0.945	1.000	1.000	1.000	0.770	1.000	0.842	0.727	0.733	0.701
	TG	0.020	0.000	0.103	0.134	0.037	0.057	0.012	0.038	0.000	0.051	0.075	0.007	0.243	0.198	0.000	0.030	0.000	0.040	0.048	0.011	0.012	0.000
2007	TE	1.000	0.906	0.864	0.864	0.784	0.728	0.711	1.000	1.000	1.000	0.761	0.695	0.989	1.000	1.000	1.000	0.773	1.000	0.870	0.731	0.730	0.702
	TG	0.022	0.000	0.135	0.174	0.037	0.069	0.009	0.035	0.000	0.040	0.071	0.007	0.274	0.199	0.000	0.026	0.000	0.054	0.052	0.008	0.011	0.000
2008	TE	1.000	0.904	0.891	0.929	0.802	0.726	0.709	1.000	1.000	1.000	0.849	0.696	1.000	1.000	1.000	1.000	0.776	1.000	0.901	0.731	0.734	0.702
	TG	0.029	0.000	0.128	0.194	0.105	0.082	0.005	0.042	0.000	0.040	0.147	0.006	0.279	0.198	0.000	0.024	0.000	0.065	0.051	0.007	0.008	0.000
2009	TE	1.000	0.973	0.934	1.000	0.805	0.725	0.708	1.000	1.000	0.933	0.767	0.699	0.985	1.000	1.000	1.000	0.772	1.000	0.906	0.763	0.735	0.702
	TG	0.045	0.000	0.187	0.204	0.163	0.083	0.002	0.042	0.000	0.009	0.061	0.007	0.266	0.210	0.000	0.023	0.000	0.069	0.088	0.008	0.008	0.000
2010	TE	1.000	0.964	0.919	0.889	0.805	0.722	0.708	1.000	1.000	0.935	0.766	0.698	0.995	1.000	1.000	1.000	0.766	1.000	0.904	0.750	0.731	0.702
	TG	0.040	0.000	0.178	0.190	0.067	0.084	0.000	0.042	0.000	0.015	0.049	0.007	0.269	0.203	0.000	0.022	0.000	0.069	0.072	0.003	0.005	0.000
2011	TE	1.000	0.924	0.933	0.891	0.802	0.722	0.706	1.000	1.000	0.934	1.000	0.698	0.983	1.000	1.000	1.000	0.762	1.000	0.901	0.751	0.738	0.700
	TG	0.034	0.000	0.149	0.174	0.074	0.083	0.002	0.028	0.000	0.018	0.000	0.302	0.258	0.193	0.000	0.021	0.000	0.071	0.072	0.005	0.004	0.000
	Mean TE	**1.000**	**0.857**	**0.812**	**0.917**	**0.782**	**0.714**	**0.713**	**1.000**	**1.000**	**0.988**	**0.858**	**0.695**	**0.914**	**1.000**	**1.000**	**1.000**	**0.763**	**0.825**	**0.956**	**0.723**	**0.741**	**0.700**
	Mean TG	**0.024**	**0.000**	**0.084**	**0.114**	**0.094**	**0.075**	**0.007**	**0.039**	**0.137**	**0.053**	**0.088**	**0.026**	**0.219**	**0.175**	**0.000**	**0.027**	**0.037**	**0.124**	**0.041**	**0.021**	**0.011**	**0.000**

		QAT	**SAU**	**SUD**	**SEN**	**SGP**	**SKO**	**SYR**	**THA**	**TJK**	**TKM**	**TTO**	**TUN**	**TZA**	**URU**	**UZB**	**VEN**	**VIET**	**YEM**	**ZAF**	**ZAM**	**Mean**	**St.Dev**
1995	TE	1.000	1.000	1.000	0.803	0.884	0.700	0.723	0.863	0.716	1.000	0.751	0.728	1.000	0.690	0.785	0.698	0.748	0.848	0.972	0.956	**0.850**	**0.128**
	TG	0.054	0.147	0.041	0.166	0.000	0.000	0.014	0.193	0.008	0.176	0.051	0.016	0.000	0.000	0.032	0.032	0.064	0.131	0.224	0.028	**0.065**	**0.084**
1996	TE	1.000	1.000	1.000	0.788	0.853	0.702	0.726	0.868	0.716	1.000	0.746	0.730	1.000	0.691	0.778	0.695	0.771	0.863	0.962	0.776	**0.848**	**0.128**
	TG	0.049	0.132	0.025	0.144	0.000	0.000	0.016	0.200	0.008	0.136	0.044	0.000	0.236	0.001	0.031	0.027	0.086	0.149	0.049	0.038	**0.066**	**0.084**
1997	TE	1.000	1.000	1.000	0.787	0.857	0.698	0.720	0.862	0.715	1.000	0.748	1.000	1.000	0.691	0.778	0.686	0.761	0.846	0.895	0.951	**0.847**	**0.127**
	TG	0.044	0.131	0.030	0.115	0.000	0.002	0.013	0.176	0.018	0.083	0.050	0.000	0.222	0.002	0.029	0.014	0.075	0.135	0.185	0.105	**0.070**	**0.084**
1998	TE	1.000	1.000	1.000	0.782	0.856	0.697	0.717	0.859	0.717	1.000	0.744	1.000	1.000	0.697	0.770	0.687	0.764	0.828	0.939	0.815	**0.851**	**0.129**
	TG	0.034	0.126	0.046	0.032	0.000	0.003	0.013	0.192	0.020	0.000	0.048	0.000	0.196	0.013	0.023	0.015	0.081	0.119	0.252	0.061	**0.071**	**0.090**
1999	TE	1.000	1.000	1.000	0.776	0.892	0.693	0.718	1.000	0.715	1.000	0.761	1.000	1.000	0.723	0.760	0.683	0.757	0.836	1.000	0.748	**0.858**	**0.131**
	TG	0.043	0.119	0.074	0.049	0.000	0.002	0.014	0.304	0.018	0.000	0.066	0.000	0.229	0.048	0.023	0.009	0.074	0.130	0.000	0.000	**0.080**	**0.094**
2000	TE	1.000	1.000	1.000	0.771	0.907	0.689	0.718	1.000	0.717	1.000	0.753	1.000	1.000	0.722	0.760	0.680	0.756	0.836	1.000	1.000	**0.858**	**0.132**
	TG	0.051	0.114	0.074	0.057	0.000	0.000	0.015	0.302	0.019	0.000	0.061	0.000	0.230	0.048	0.024	0.005	0.073	0.132	0.000	0.000	**0.079**	**0.096**
2001	TE	1.000	1.000	1.000	0.758	0.877	0.689	0.720	1.000	0.716	1.000	0.741	1.000	1.000	0.745	0.764	0.681	0.756	0.876	1.000	1.000	**0.855**	**0.130**
	TG	0.068	0.099	0.063	0.052	0.000	0.001	0.018	0.000	0.017	0.000	0.041	0.000	0.000	0.075	0.031	0.006	0.074	0.172	0.000	0.000	**0.065**	**0.080**
2002	TE	1.000	0.987	1.000	0.746	0.892	0.689	0.722	1.000	0.712	1.000	0.736	1.000	1.000	0.754	0.756	0.682	0.764	0.908	1.000	1.000	**0.855**	**0.129**
	TG	0.080	0.087	0.070	0.082	0.000	0.001	0.019	0.000	0.014	0.000	0.036	0.000	0.000	0.086	0.032	0.006	0.084	0.201	0.000	0.000	**0.070**	**0.082**
2003	TE	1.000	0.992	1.000	0.744	0.975	0.688	0.725	1.000	0.709	1.000	0.741	1.000	1.000	0.764	0.745	0.683	0.760	0.905	1.000	1.000	**0.858**	**0.130**
	TG	0.091	0.083	0.124	0.061	0.000	0.000	0.021	0.000	0.009	0.000	0.040	0.000	0.000	0.094	0.029	0.007	0.079	0.198	0.000	0.000	**0.066**	**0.080**
2004	TE	1.000	0.973	1.000	0.739	0.996	0.689	0.725	1.000	0.709	1.000	0.739	1.000	1.000	0.785	0.756	0.682	0.748	0.909	1.000	1.000	**0.856**	**0.129**
	TG	0.088	0.077	0.125	0.061	0.000	0.001	0.020	0.000	0.009	0.000	0.037	0.000	0.238	0.118	0.031	0.006	0.067	0.201	0.000	0.000	**0.072**	**0.081**
2005	TE	1.000	0.966	1.000	0.735	0.996	0.692	0.725	1.000	0.715	1.000	0.743	0.759	1.000	0.810	0.768	0.684	0.736	0.923	1.000	1.000	**0.861**	**0.128**
	TG	0.087	0.073	0.115	0.062	0.000	0.001	0.020	0.000	0.011	0.000	0.039	0.029	0.235	0.138	0.036	0.007	0.053	0.210	0.000	0.000	**0.072**	**0.084**
2006	TE	1.000	0.938	1.000	0.738	0.968	0.698	0.726	1.000	0.725	1.000	0.743	0.752	0.895	0.860	0.773	0.684	0.723	0.926	1.000	1.000	**0.858**	**0.124**
	TG	0.065	0.076	0.089	0.060	0.000	0.004	0.018	0.000	0.018	0.000	0.038	0.013	0.168	0.182	0.030	0.005	0.036	0.206	0.000	0.000	**0.063**	**0.077**
2007	TE	1.000	0.926	1.000	0.735	1.000	0.707	0.727	1.000	0.740	1.000	0.750	0.774	0.902	0.930	0.784	0.684	0.716	0.949	1.000	1.000	**0.864**	**0.125**
	TG	0.058	0.072	0.000	0.060	0.000	0.007	0.017	0.291	0.027	0.000	0.040	0.040	0.166	0.236	0.032	0.005	0.025	0.221	0.000	0.000	**0.071**	**0.087**
2008	TE	1.000	0.928	1.000	0.736	1.000	0.717	0.727	1.000	0.759	1.000	0.750	0.859	0.882	1.000	0.827	0.685	0.714	0.954	1.000	1.000	**0.873**	**0.123**
	TG	0.057	0.073	0.000	0.061	0.000	0.013	0.017	0.000	0.039	0.000	0.038	0.069	0.149	0.125	0.077	0.004	0.022	0.220	0.000	0.000	**0.068**	**0.080**
2009	TE	1.000	0.924	1.000	0.726	0.953	0.725	0.726	1.000	0.767	1.000	0.751	0.974	0.882	1.000	0.821	0.686	0.713	0.949	1.000	1.000	**0.874**	**0.122**
	TG	0.060	0.060	0.030	0.067	0.000	0.015	0.017	0.000	0.043	0.000	0.036	0.050	0.147	0.000	0.079	0.004	0.022	0.216	0.000	0.000	**0.064**	**0.079**
2010	TE	1.000	0.918	1.000	0.719	1.000	0.725	0.728	1.000	0.770	1.000	0.746	0.815	0.911	1.000	0.760	0.685	0.713	0.925	1.000	1.000	**0.867**	**0.124**
	TG	0.061	0.052	0.000	0.072	0.000	0.017	0.019	0.000	0.043	0.000	0.032	0.000	0.159	0.000	0.018	0.004	0.022	0.194	0.000	0.000	**0.062**	**0.082**
2011	TE	1.000	0.921	1.000	0.726	0.880	0.723	0.725	1.000	0.772	1.000	0.745	0.951	0.912	1.000	0.754	0.685	0.708	0.905	1.000	1.000	**0.880**	**0.121**
	TG	0.063	0.062	0.008	0.047	0.000	0.019	0.018	0.000	0.042	0.000	0.034	0.000	0.154	0.000	0.015	0.003	0.022	0.178	0.000	0.000		
	Mean TE	**1.000**	**0.969**	**1.000**	**0.753**	**0.929**	**0.701**	**0.723**	**0.968**	**0.729**	**1.000**	**0.746**	**0.903**	**0.964**	**0.815**	**0.773**	**0.685**	**0.742**	**0.893**	**0.986**	**0.956**		
	Mean TG	**0.062**	**0.093**	**0.054**	**0.073**	**0.000**	**0.005**	**0.017**	**0.098**	**0.021**	**0.023**	**0.043**	**0.013**	**0.149**	**0.069**	**0.034**	**0.009**	**0.056**	**0.177**	**0.042**	**0.014**		

Appendix B

Figure 1: Meta-frontier, individual frontiers, for the single output-single output case.

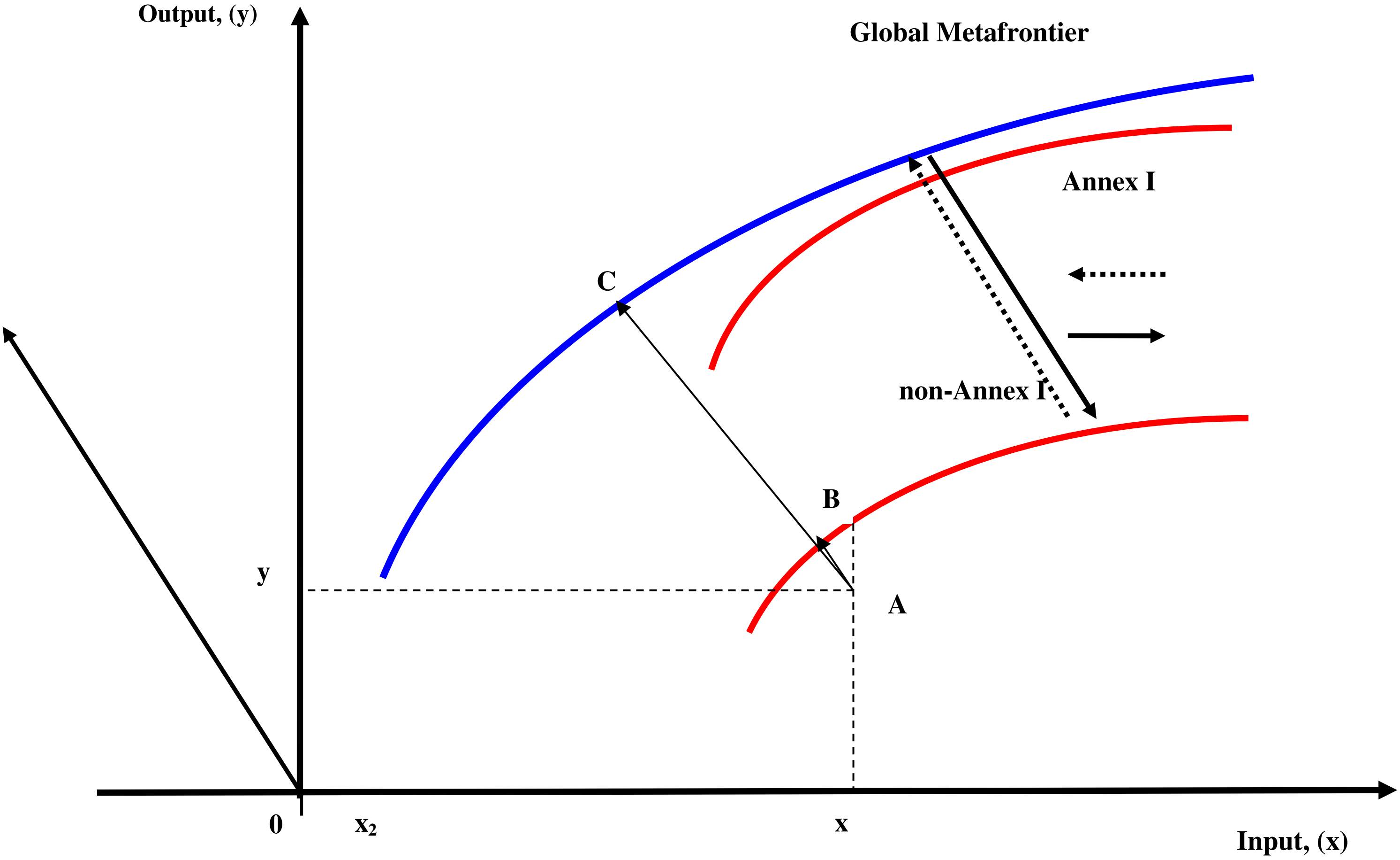

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Figure 2: Kernel densities of the productive efficiency for Annex-I, non-Annex-I and total countries group in 1995, 2000, 2005 & 2011

Fig. 2a

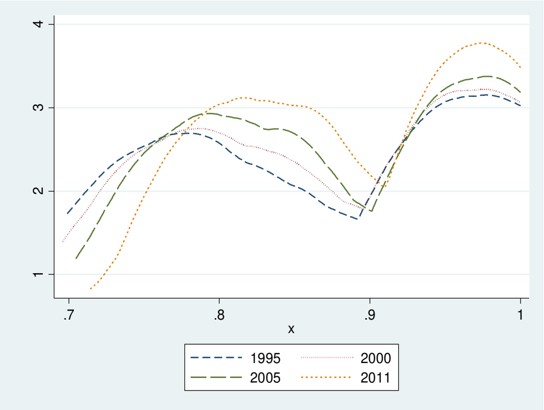

Fig. 2b

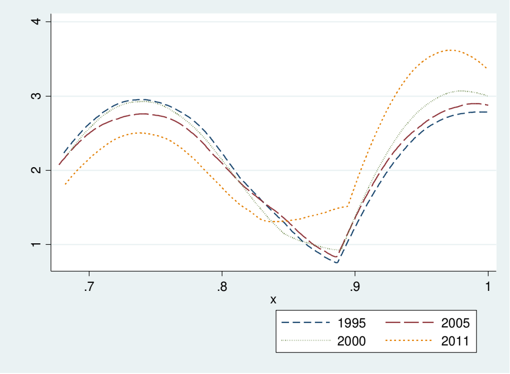

Fig. 2c

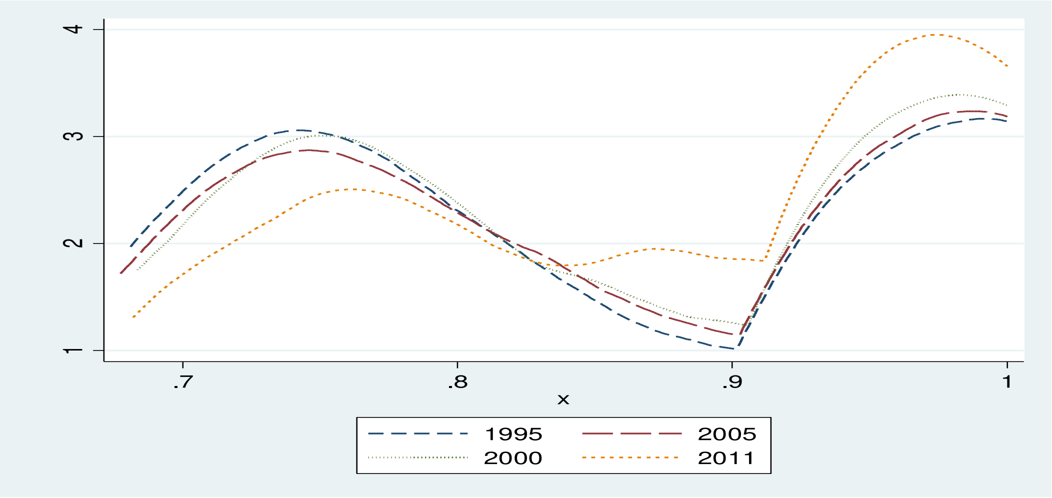

Figure 3: Box-plot of Metatecnology ratios for Annex-I, non-Annex-I and total countries group

Fig. 3a

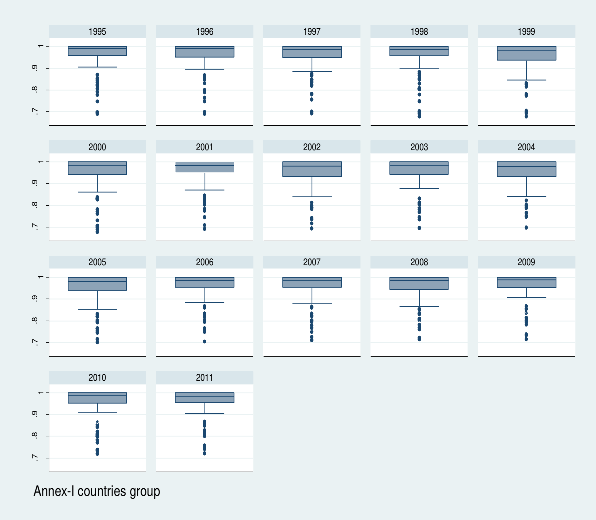

Fig. 3b

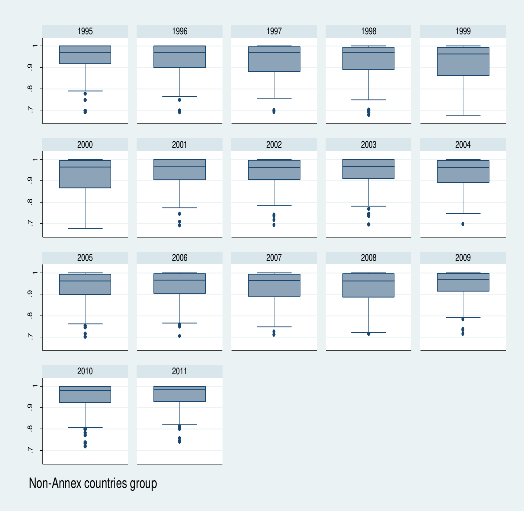

Fig. 3c

Figure 4: Stochastic kernel of the distribution of Technology gaps.

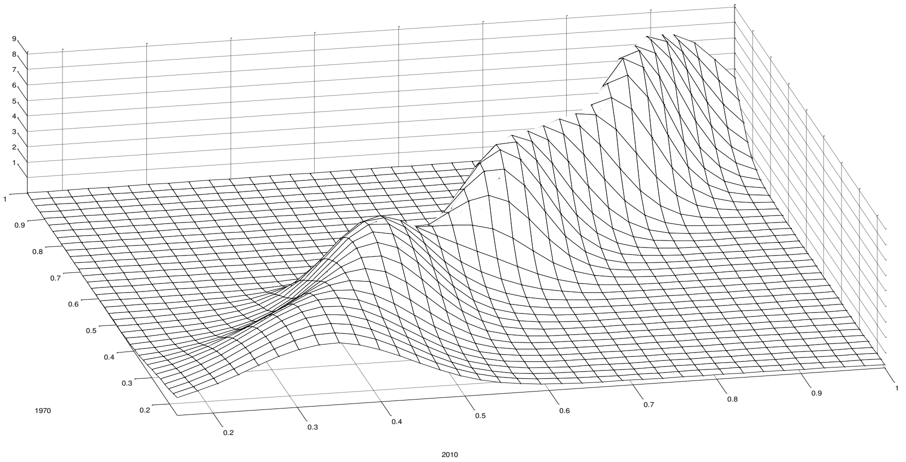

Figure 5: Contour plot of the distribution of Technology gaps.