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by

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Abstract

This paper investigates the effect of energy consumption on countries' economic efficiency. By using a sample of 18 EU countries for three census years (1980, 1990 and 2000) the paper employs conditional and unconditional robust nonparametric frontiers in order to establish such a relationship. By using probabilistic approaches it conditions the effect of energy consumption on the obtained countries' economic efficiencies. With the use of nonparametric regressions the paper calculates the effect of energy consumption. The results reveal that lower levels of energy consumption increase countries' economic efficiencies to a point where the effect of energy consumption on countries' economic efficiency is neutral.

Keywords: Energy consumption; economic growth; robust efficiency estimators; conditional nonparametric techniques.

JEL Classification: Q43, O13, C6, C67

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1. Introduction

The energy-growth relationship has been a popular topic for 'old' growth theory and a on going debate for 'new' growth theory (van Zon and Yetkiner, 2003). According to Moon and Son (1996) endogenous growth literature treats energy as physical resource in an indirect 'fashion' which links higher economic growth with an increased demand on energy. However several authors suggest that there is an ongoing debate among the energy economists whether energy consumption can stimulate economic growth and in which way (Gkali and El-Sakka, 2004; Wolde-Rufael, 2005; Chontanawat et al., 2008). According to Stern (1993) and Beaudreau (2005) energy is an essential factor of production. Moon and Sonn (1996) explain that energy consumption increases productivity of other productive inputs in the production process thus enhances economic growth. In contrast when energy increases the investment in physical capital is decreased because the increased energy use lowers the disposable income of the representative agent (p.194). Therefore, there is a dynamic effect between these two forces which have an effect on energy economic growth relationship. There have been many empirical studies explaining this dynamic relationship in aggregated energy consumption (Soytas and Sari 2006, 2007) and in disaggregated levels (Shiu and Lam, 2004; Zhou and Chau, 2006) but have presented mixed results. According to Yuan et al. (2008) the mixed results which are reported in the literature are due to the fact that different countries are in different developing stages. As such the developing process will have a different impact on the relationship between energy consumption and economic growth. In an extensive literature review Lee and Chang (2008) suggest that earlier studies have examined the energy consumption – income/ output relationship mostly based in the production side (aggregated production function). Furthermore they in the same lines with Stern (1993, 2000) and Oh and Lee (2004) emphasizing that studies are based on single countries or in small samples. As have been reported most of the studies, have used panel data techniques and time series techniques such as cointegration and vector error correction modeling in different countries for different time periods (Soytas and Sari, 2006). In contrast, with those studies this paper adopts a different approach for investigating the causal relationship between energy consumption and economic growth. For the first time (to our knowledge) this paper uses robust non-parametric frontiers (order-a) (Daouia and Simar, 2007) and its conditional form (Daraio and Simar, 2005, 2007a,b) in order to establish the effect of energy consumption on countries economic efficiency. By contributing to the existing literature this study provides a framework of how the new advances in efficiency analysis can be applied in order to for such a dynamic relationship to be investigated.

2. Literature review

Most of empirical studies examining the relationship between energy consumption and economic growth in an aggregated and disaggregated level have been inspired by the pioneered work by Kraft and Kraft (1978). By using data for a time period of 1947 -1974 for the United States they found a unidirectional causality from gross national product GNP to energy consumption. As such any energy policy innervations wouldn't affect GNP growth. However, Kraft and Kraft suggested that this outcome was due to the selected time period. Similarly, Schurr (1982) examining the period 1920 -1953 found that that in the United States the energy intensity of production was falling while the country's productivity was rising. However, for the time period of 1953 -1973 energy intensity was stable while evidence indicated that productivity continued to grow. Jorgenson (1984) emphasizes the fact that much research remains to be done until will be able to establish the relationship between energy utilization in productivity growth.

More recently, Lee and Chang (2008) examined the relationship between energy consumption and real GDP within a multivariate framework which included capital stock and labor as inputs for a sample of 16 Asian countries for the time period of 1971-2002. By applying panel unit root, heterogeneous panel cointegration and panel –based error correction models they found a long-run unidirectional causality running from energy consumption to economic growth. In addition Mishra et al. (2008) by testing for Granger causality and using panel cointegration techniques examined the relationship between energy consumption and GDP for the Pasific Island countries for the time period 1980-2005. Their evidence support that there is a positive impact between energy consumption and GDP. In addition many studies have used Granger causality tests in order to establish the link between energy and income (Abosedra and Baghestani, 1991; Akarca and Long, 1980; Bentzen and Engsted, 1993; Hwang and Gum, 1992; Yu and Choi, 1985; Yu and Hwang, 1984). However, the results reported are varying according to the country and the time period under examination. Erol and Yu (1987) support this view by providing mixed results of a sample of six countries. Similarly Stern (1993) found no evidence supporting that gross energy use causes GDP. However, recent studies by adopting new time series methodologies such as cointegration and vector error correction modelling couldn't establish a causal relationship between energy consumption and GDP growth. (Oh and Lee, 2004; Soytas and Sari, 2006, 2007; Stern, 1993, 2000). Furthermore, van Zon and Yetkiner (2003) reported that rising real energy prices tend to slow down growth. Smulders and de Nooij (2003) developed a growth model in which growth is driven by steady growth of energy inputs and endogenous technological change. They found that energy conversation policies studied reduce per capita income levels. They also found that in the long run energy policies which reduce energy tend to reduce long run growth. According to Lee and Chang (2008) different sample data, different techniques and different time periods have yield to inconsistent results of the energy – economic growth relationship.

The problem of establishing the role of energy in the production process and thus its causality relationship with GDP is a non ending academic debate over the last three decades. Berndt and Wood (1975, 1979) using a time series data for US economy have argued that energy and capital are compliments and energy and labour are substitutes. In the same lines Hudson and Jorgenson (1974) and Solow (1987) have also in favor of energy – capital complementarity. However Griffin and Gregory (1976) and Joregenson and Wilcoxen (1990) have obtained results proving that energy and capital are substitutes. In addition Smulders and de Nooij (2003) suggest that labour and energy inputs are gross complements and are being combined with specific complementary intermediate inputs which in turn are interpreted as capital in the production function.

As such in contrast with the rest of the studies analysing the relationship between energy consumption and economic growth, this paper for the first time uses nonparametric techniques in order to establish the effect of energy consumption on the economic efficiency of 18 EU countries for the period of three census years (1980,1990 and 2000). In our paper we model and we measure countries' economic efficiency by adopting robust non-parametric frontiers (order-a) as has been introduced by Daouia and Simar (2007). According to Daraio and Simar (2007a) the use of robust frontiers are more robust to extreme values and outliers and thus we can avoid one of the main disadvantages of traditional nonparametric measures which is their determinist nature. In addition robust frontiers are not suffering from dimensionality problems thus we can work with samples of small/ moderate sizes. According to Daraio and Simar (2007a) order-a frontiers (used in this study) are more robust to extremes than the order-m frontiers developed by Cazals et al. (2002). After measuring countries' economic efficiency levels we condition them to their energy consumption levels for the examined period by using conditional robust frontiers (Daraio and Simar, 2005, 2007b). The main advantage of robust ratios is that they can show us the impact of energy consumption on countries' economic efficiencies even if we have in our sample some extreme observations (caused by countries' heterogeneity). As such by treating energy consumption as an environmental factor which influences countries' process of economic activity we will be able to determine robust conditional measures (conditioned to energy consumption) and thus to evaluate if countries' energy consumption levels for the examined periods had any effect on their economic efficiencies.

3. Data

In the literature nonparametric techniques have been used to measure countries' environmental performance based on the production process (Färe et al., 1989a,b; Chung et al., 1997; Zaim and Taskin, 2000; Taskin and Zaim, 2000; Zaim et al., 2001; Zaim, 2004). However, non of the above studies have examined the energy-GDP relationship using non parametric techniques. Following Halkos and Tzeremes (2009a, b) we measure countries economic efficiency based in production of two inputs and one output. We use data for three census years 1980, 1990 and 2000 for 18 European countries[2]. The inputs used are Total Fixed Investment (TFI) (excluding stockbuilding) in volumes and Labour Force (LF) whereas the output used is the

[2] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Netherlands, Luxembourg, Norway, Spain, Portugal, Sweden, Switzerland, United Kingdom.

Gross Domestic Product (GDP) (market prices) in volumes. The inputs/ output used have been obtained from Economics Web Institute (EWI, 2009). The external variable used is Primary Energy Consumption (PEC). Primary energy comprises commercially traded fuels only. The energy consumption quantities have been obtained from BP Statistical Review of World Energy (2007). Table 1 provides the descriptive statistics of the inputs/ output used. As can be realised the energy consumption of the examined countries have been examined over the years. Furthermore, the descriptive statistics indicate that there are heterogeneities between the 18 countries. The heterogeneities reported in GDP, labour and total fixed investment makes the methodology adopted more appropriate since robust frontiers can accommodate samples with extreme values.

Table 1 about here

4. Methodology

4.1Probabilistic approach to efficiency measurement

Daraio and Simar (2005) following extending the ideas of robust measurements introduced by Cazals et al. (2002) introduced a probabilistic approach of production process. Following the notation by Daraio and Simar (2007a) the production set Ψ defined as a set of p inputs and q outputs in a Euclidean space R_+^{p+q} as:

$$\Psi = \left\{ (x, y) \middle| x \in R_+^p, y \in R_+^q, (x, y) \quad is \quad feasible \right\} \qquad (1),$$

where x is the input vector y the output vector. Then the production process can be described by the joint probability measure of *(X,Y)* on $R_+^p x R_+^q$. Then the knowledge of the probability function $H_{XY}(.,.)$ can be defined as:

$$H_{XY}(x,y) = \Pr ob(X \le x, Y \ge y) \quad (2).$$

Then for the input oriented case the efficiency score $\theta(x,y)$ for $(x,y) \in \Psi$ can be defined as:

$$\theta(x,y) = \inf\{\theta | F_{X|Y}(\theta x|y) > 0\} = \inf\{\theta | H_{X|Y}(\theta x, y) > 0\} \quad (3).$$

A nonparametric estimator can be defined by replacing $F_{X|Y}(x|y)$ by its empirical version:

$$\hat{F}_{X|Y,n}(x|y) = \frac{\sum_{i=1}^{n} \Im(X_i \le x, Y_i \ge y)}{\sum_{i=1}^{n} \Im(Y_i \ge y)} \quad (4),$$

where $\Im$ is the indicator function. Under the free disposal assumption the FDH estimator of $\theta(x,y)$ developed by Deprins et al. (1984) coincides with the input efficiency score for a given point *(x,y)* (Cazals et al., 2002):

$$\hat{\theta}_{FDH}(x,y) = \inf\left\{\theta | (\theta x, y) \in \hat{\Psi}_{FDH}\right\} = \inf\left\{\theta | \hat{F}_{X|Y,n}(\theta x|y) > 0\right\} \quad (5).$$

4.2 The formulation of Order-a frontiers

Following Daouia and Simar (2007) an order- α nonparametric estimator can be calculated as:

$$\hat{\theta}_{a,n}(x,y) = \inf\left\{\theta | \hat{F}_{X|Y,n}(\theta x|y) > 1 - a\right\} \quad (6).$$

According to Daraio and Simar (2007a) order-α quantile frontiers benchmark the unit at *(x,y)* against the input level not exceed by (1-α) x 100% of the countries among the population of units producing output levels of at least y. When, $a \to 1$ then $\hat{\theta}_{a,n}(x,y) \to \hat{\theta}_{FDH}(x,y)$ (5). The estimator $\hat{\theta}_{a,n}(x,y)$ can take values >,< and = to 1. When $\hat{\theta}_{a,n}(x,y)$ have values greater than 1 then the countries *(x,y)* can increase its inputs by a factor $\theta_\alpha(x,y)$ to reach the same frontier. If $\theta_\alpha(x,y)=1$ then the countries is said to be efficient at the level $a \;\; x \;\; 100\%$ since it is dominated by countries producing more outputs than y with a probability *1-α*. If $\theta_a(x,y) < 1$, then the country *(x,y)* has to reduce its input to the level $\theta_a(x,y)x$ to reach the input efficient frontier of level $a \;\; x \;\; 100\%$.

4.3 Conditional Order-a frontiers

As has been described by Daraio and Simar (2005) different variables (exogenous to the production process) $Z \in \Re^r$ can be used to explain the efficiency variations of the production process. The idea is to condition the production process to a given value of $Z = z$. The joint distribution *(X,Y)* conditional on $Z = z$ defines the production process if $Z = z$. Then a nonparametric estimator $\theta_m(x,y|z)$ is provided by plugging the non parametric estimator:

$$\hat{F}_{X|Y,Z,n}(x|y,z) = \frac{\sum_{i=1}^{n} \Im(x_i \le x, y_i \ge y) K((z-z_i)/h)}{\sum_{i=1}^{n} \Im(y_i \ge y) K((z-z_i)/h)} \quad (7),$$

where K(.) is the kernel and *h* is the bandwidth of appropriate size. We have used kernel with compact support (Epanechnikov) as suggested by Daraio and Simar (2005). Furthermore, for the calculation of bandwidth we used the two stage data driven approach as proposed by Daraio and Simar (2006). As a first step we used the likelihood cross validation criterion based on K-NN method (Silverman, 1986). As a second step we take into account for the dimensionality of x and y, and the sparsity of points in larger dimensional spaces we expand the local bandwidths h_{Zi} by a factor $1 + n^{-1/(p+q)}$, increasing with (p + q) but decreasing with n. In the second step Similarly, following Daouia and Simar (2007) a conditional *order-a* nonparametric estimator can be obtained as:

$$\hat{\theta}_{a,n}(x, y|z) = \begin{cases} X_{(1)}^{y} & if \quad 0 \le 1 - a < l_1 \\ X_{k+1}^{y} & if \quad l_k \le 1 - a < l_{k+1} \\ & k = 1, \ldots, M_y - 1. \end{cases} \quad (8).$$

According to Daraio and Simar (2007a, 2007b) the global influence of *Z* on the production process can be obtained by comparing the conditional *order-a* frontiers to their unconditional equivalents. In a univariate case of *Z* a scatter-plot of the ratios $Q_{a,z} = \dfrac{\hat{\theta}_a(x, y|z)}{\hat{\theta}_a(x, y)}$ against *Z* and its smoothed nonparametric regression line would indicate the global effect of *Z* o the production process. If the smoothed nonparametric regression is increasing it indicates that *Z* is unfavourable to efficiency and when this regression is decreasing then is favourable to efficiency. Finally, we use a nonparametric regression estimator introduced by Nadaraya (1964) and Watson (1964):

$$\hat{g}(z) = \frac{\sum_{i=1}^{n} K(\frac{z - Z_i}{h})Q}{\sum_{i=1}^{n} K(\frac{z - Z_i}{h})} \quad (9).$$

4.4 Decomposition of conditional efficiency

We decompose the conditional efficiency obtained as suggested by Daraio and Simar (2006). The conditional efficiency $CE^{z}(x, y)$ obtained for every country can be decomposed in to three main indicators. The first indicator is the indicator of unconditional efficiency $UE(x, y)$ or countries' internal efficiency. The second is the externality index $EI^{z}(x, y)$ or the level of Z owned by the country. It is the expected value of the ratios $Q_{a,z}$ given the value of z owned by the country. It is given by the nonparametric fitted value of $Q_{a,z}$ obtained by some appropriate nonparametric regression of $Q_{a,z}$ on Z:

$$\hat{E}\left(Q_{a,z} \middle| Z = z\right) = \frac{\sum_{i=1}^{n} Q_{a,zi} K\left((z - z_i)/h\right)}{\sum_{i=1}^{n} K\left((z - z_i)/h\right)} \tag{10}$$

Where $K(.)$ is the Kernel and h an appropriate bandwidth. Finally, the third indicator is the individual index $II^z(x, y)$ and can be defined as:

$$Q_{a,z} / \hat{E}\left(Q_{a,z} \middle| Z = z\right) \tag{11}$$

The individual index measures country's intensity in catching the opportunities or threats by the external factor.

The formulation of the three index can be defined as:

$$CE(x, y) = UE(x, y) * EI^z(x, y) * II^z(x, y) \tag{12}$$

The decomposition of conditional efficiency give us the possibility for analysing individual and localized effects of external factors (in our case energy consumption) and interpret them together with their global influence on countries' economic efficiency.

4. Empirical results

The analysis has been conducted in two stages for 1980, 1990 and 2000. As such the conditional and unconditional measures have been obtained. The value of α used in our analysis was 0.9. With values of α greater than 0.9 the efficiency scores of order-a frontiers quickly converge to the estimates obtained by FDH frontier (see equation 5). According to Daraio and Simar (2007a) when the order-a values are close to the FDH we do not have the existence of outliers. Table 2 provides the results obtained from our analysis. For the year 1980 we realize the countries with higher economic efficiency are Belgium, Greece, Italy, Spain and Portugal. The lowest efficiency scores have been observed for Luxemburg, Iceland and Ireland. When we took into account the effect of energy consumption for that year then countries' economic efficiency scores have changed (for some cases). For instance Finland has increased its economic efficiency performance from 0.64 to 0.74. Furthermore, Spain has dramatically increased its economic performance from 1 to 2.85[3]. Similarly, France has also been increased its economic efficiency from 0.61 to 1. In contrast with Greece which under the influence of energy consumption its economic efficiency has been decreased from 1 to 0.85. The same stands for Netherlands which had a decrease from 0.63 to 0.31.

Table 2 about here

Continuing in the same way our analysis for 1990 we realise that in some cases the effect of energy consumption caused an increase of countries' economic efficiencies and in some cases caused even a decrease of their economic efficiencies. However as have been also reported for year 1980 when examine countries efficiencies of 1990, we realise that in some cases energy consumption hadn't any effect on countries economic efficiency performances. For instance Germany in both years is reported to have the same economic efficiency score regardless the effect of energy consumption. The same goes for Iceland, Belgium and Ireland. Lee and Chang (2008) suggest that the findings of no causality in either direction is called 'neutrality hypotheses' and signifies no effect of energy consumption on countries growth. In addition for the year of 1990 we can observe for the case of Austria a high increased of its economic efficiency (from 0.27 to 0.77). The same goes for Denmark which had

[3] As has been explained previously efficiency scores for robust frontiers can take values greater than 1 (Daouia and Simar, 2007; Daraio and Simar, 2007a,b)

an increase of its efficiency from 0.54 to 1.However, the highest decreases of countries economic efficiencies have been reported for Sweden (from 0.85 to 0.23) and the United Kingdom (from 0.72 to 0.39). Finally, when looking the results obtained for the year 2000 we can realise that in some cases countries' efficiency scores haven't been affected by the countries' energy consumption levels (Belgium, Germany, Iceland, Ireland, Italy and Spain). Again for some cases we observe an increase of their economic efficiency scores (Austria, Denmark, Finland, France, and Portugal) and for some we observe a decrease (Netherlands, Luxembourg, Norway, Sweden, Switzerland and the United Kingdom). As can be realised the effect of energy consumption on countries' economic efficiency is change over the years under examination and among the countries themselves. Even though our sample contains phenomenically same countries (EU members) we observe that the effect of energy consumption in some cases changes rapidly even if we examine the same country (see for instance the case of Austria, Sweden, Finland and the United Kingdom). In fact this phenomenon explains the dynamics between energy demand and economic growth which have a counteracting relationship (Monn and Sonn, 1996).

Figure 1 about here

In an aggregative way figure illustrates the density of the conditional and unconditional efficiency scores of the 18 EU countries. As can be realised for the year 1980 countries' energy consumption seem to have a positive effect on their economic efficiencies concentrating their economic efficiency levels around unity. However, when looking the year of 1990, we realise that the effect of energy consumption had rather a negative/ neutral effect forcing countries' economic efficiency scores away from unity (left asymmetry, i.e. the median is greater than the mean). The same can be observed for year 2000. Again a left asymmetry of countries' economic efficiency scores is observed indicating that the effect of energy consumption is neutral and in some cases negative. According to Monn and Son (1996) the increased energy use lowers the disposal income of the representative agents, thus a decrease on investment of physical capital is observed which in turn has a negative effect on countries' economic efficiencies.

Table 3 about here

In order to analyse further the effect of energy consumption on countries' economic efficiencies we decompose the conditional efficiency as have been proposed by Daraio and Simar (2006). Table 3 provides the results of the conditional efficiency decomposition in its components (see equation 12). The index Q_a is the ratio of $\frac{\hat{\theta}_a(x, y|z)}{\hat{\theta}_a(x, y)}$ and can take values >,<,=1. As such when Q_a is equal 1 indicates that energy consumption has a neutral effect on country's economic efficiency. However, when the values are greater than 1 then the effect is positive and when are lower than 1 the effects are negative. As can be observed for 1980 for the majority of countries (Austria, Belgium, Denmark, Germany, Iceland, Ireland, Italy, Portugal, Sweden and Spain) the energy consumption had a neutral effect on their economic efficiency. In addition the externality index (EI) when takes values above 1 means that the country works at a energy level with an expected $Q_a > 1$. The opposite occurs when EI takes values below1. As can be realised for the year 1980 the countries with EI greater than unity are reported to be Belgium, France, Iceland, Italy, Netherlands, Luxembourg, Spain, Sweden and the United Kingdom. However, in some cases the effect of the energy consumption is not (as expected) positive. For instance Belgium is reported to have EI=1.14 but a $Q_a = 1$. In the case of Netherlands the value of the externality index is 1.12 but the value of Q_a is 0.5 indicating a negative effect of energy consumption on country's economic efficiency. This is maybe to differentiations of energy prices among the observed countries or to different consumption patterns and various sources of energy (Soytas and Sari, 2007). Finally, the individual index (II_{80}) analyses how the country performed in respect to the expected value of its performance. For instance if individual index is greater than 1 then the effect of energy consumption on the efficiency score of the country under consideration is higher with respect to its expected value. In contrast, if II <1 we are considering a country for which the environmental externality (energy consumption) is lower then what expected for its level of energy consumption. As such countries with the expected higher influence (relative to their energy consumption) are reported to be Austria, Denmark, Finland, France, Germany, Ireland, Spain, Portugal and Switzerland. However, this expected influence is not reflected on their economic efficiency scores. If continue our analysis in the same fashion for year 1990 we realise that five countries have been positively influenced by their energy consumption, six of them have been negatively influenced and seven of them had a neutral effect of energy consumption on their economic efficiency. In addition when looking the year 2000 we realise that five countries have increased their economic efficiency as a result of their energy consumption, whereas six of them have reduce their economic efficiency scores. Finally, energy consumption appeared to have a neutral effect on seven countries' economic efficiencies. Again the disparities and differentiations of energy prices, energy consumption patterns, macroeconomic policies and economic process appeared to be a major obstacle for identifying a global effect of causality between energy consumption and economic efficiency.

Figure 2 about here

As described previously figure 2 illustrates the effect of energy consumption on countries' economic efficiency for the years 1980, 1990 and 2000 (subfigures 2a,b,c additionally). For instance subfigure 2a examines the influence of energy consumption on countries' economic performance for the period of 1980. It represents a scatter plot of the ratios $\hat{\theta}_n(x, y|z)/\hat{\theta}_n(x, y)$ against countries' energy consumption levels and its smoothed nonparametric regression line in order to define this influence. As the regression line is almost flat it specifies that energy consumption has a rather neutral effect to the countries' economic efficiencies. Accordingly for the year 1990 we realise at lower levels of energy consumption the effect is negative to the countries' economic efficiency levels bust when the energy consumption increases again we realise that the effect is neutral. Finally, for the year 2000 we realise that in lower levels of energy consumption the effect is negative but as the energy consumption increases countries' economic efficiencies are also increasing to a point where the effect of energy consumption on countries' economic efficiency is neutral. As such our findings fully support previous studies by Lee and Chang (2008) and Moon and Son (1996) which mention the difficulties and the dynamic nature of the energy consumption-economic growth relationship.

5. Conclusions

As has been highlighted by several scholars (van Zon and Yetkiner, 2003; Stern, 1993, 2000; Beaudreau, 2005; Smulders and de Nooij, 2003) the energy-economic growth relationship is an ongoing debate among the energy economists. As such any measures and techniques adopted must be critically evaluated and applied before establishing the causality of such a dynamic relationship. To our knowledge for the first time conditional and unconditional measures have been used in order to establish and quantifying such a dynamic (in nature) relationship. In contrast with well known studies employing advanced panel and time series techniques in aggregated and disaggregated level (Soytas and Sari 2006, 2007; Shiu and Lam, 2004; Zhou and Chau, 2006; Lee and Chang, 2008; Yuan et al., 2008; Stern, 1993 2000; Oh and Lee, 2004, among others) this study uses order–a frontiers as introduced by Daouia and Simar (2007). The results reveal that lower levels of energy consumption have a negative effect on countries economic efficiency. This finding comes along with the view by Smulders and Nooij (2003) suggesting that cuts in energy can have a seriously affect on GDP and economic growth. Furthermore, the results reveal that when the energy consumption values increase significantly can have a negative effect on countries' economic efficiencies. However, from a point onwards the effect of energy consumption on countries' economic efficiency is neutral. Lee and Chang (2008) suggest that this finding is in the favour of the 'neutrality hypothesis' whereas the negative effect on countries' economic efficiencies may be as a result of a decrease of disposable income of the representative agent due to increase in energy prices of the countries under examination (Moon and Sonn, 1996).

As a limitation of the research provided may be the fact that we are examining only three census years and having a sample of only 18 EU countries. In fact this must be a direction for a future research; however, our intension was to highlight the dynamics of the energy-economic growth relationship using the new advances in nonparametric techniques. In contrast with the studies mentioned previously this technique (especially with the decomposition of conditional efficiency) can provide us with useful information of the insides and the structure of the energy consumption – economic growth relationship in such a way that we will be able to overcome the problems of countries' dissimilarities.

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Table 1:Descriptive statistics of the variables used

1980	TFI	LF	GDP	PEC (Z)
Mean	13423871.86	8344072.37	61756199.68	74.93
Min	4702.11	106200.00	19049.96	1.69
Max	227849000.00	27869000.00	1051041000.00	355.70
Std	53533264.46	9674664.08	246987437.27	92.48
1990	**TFI**	**LF**	**GDP**	**PEC (Z)**
Mean	15842238.71	9021364.75	77165072.44	80.40
Min	5127.70	127169.00	27190.00	1.68
Max	266044000.00	30362250.00	1310659000.00	349.76
Std	62485421.53	10375898.39	307974969.47	93.95
2000	**TFI**	**LF**	**GDP**	**PEC (Z)**
Mean	16922534.63	9749469.21	89065833.42	89.30
Min	9633.40	141453.39	53114.44	2.44
Max	278879112.60	38249711.50	1505184559.00	330.46
Std	65448038.21	11562275.19	353602547.00	95.15

Table 2: Conditional and unconditional efficiency scores

Countries	$\theta_a^{80}(x,y)$	$\theta_a^{80}(x,y\|z)$	$\theta_a^{90}(x,y)$	$\theta_a^{90}(x,y\|z)$	$\theta_a^{00}(x,y)$	$\theta_a^{00}(x,y\|z)$
Austria	0.77	0.77	0.27	0.77	0.33	0.86
Belgium	1.00	1.00	1.00	1.00	1.00	1.00
Denmark	0.62	0.62	0.54	1.00	0.67	1.14
Finland	0.64	0.74	0.90	0.95	0.56	0.72
France	0.61	1.00	0.61	1.00	0.56	1.00
Germany	0.70	0.70	0.66	0.66	0.84	0.84
Greece	1.00	0.85	1.00	1.00	1.00	1.00
Iceland	0.04	0.04	0.05	0.05	0.06	0.06
Ireland	0.07	0.07	0.06	0.06	0.07	0.07
Italy	1.00	1.00	1.00	1.00	1.00	1.00
Netherlands	0.63	0.31	0.69	0.30	0.71	0.47
Luxembourg	0.06	0.06	0.06	0.05	0.07	0.05
Norway	0.58	0.45	0.47	0.43	0.54	0.38
Spain	1.00	2.85	1.00	1.00	1.00	1.00
Portugal	1.00	1.00	1.00	1.12	1.00	1.08
Sweden	0.21	0.21	0.85	0.23	0.57	0.19
Switzerland	0.57	0.57	0.64	0.58	0.59	0.57
United Kingdom	0.47	0.35	0.72	0.39	0.59	0.50
Mean	0.61	0.70	0.64	0.64	0.62	0.66
Min	0.04	0.04	0.05	0.05	0.06	0.05
Max	1.00	2.85	1.00	1.12	1.00	1.14
Std	0.33	0.63	0.34	0.39	0.33	0.38

Table 3: Decomposition of the conditional efficiencies scores

Countries	**Qa_{80}**	**EI_{80}**	**II_{80}**	**Qa_{90}**	**EI_{90}**	**II_{90}**	**Qa_{00}**	**EI_{00}**	**II_{00}**
Austria	1.00	0.97	1.03	2.81	1.22	2.30	2.63	1.19	2.21
Belgium	1.00	1.14	0.88	1.00	0.99	1.01	1.00	1.01	0.99
Denmark	1.00	0.98	1.03	1.85	1.29	1.44	1.70	1.25	1.36
Finland	1.17	0.97	1.21	1.06	1.35	0.79	1.28	1.25	1.02
France	1.63	1.13	1.44	1.65	1.08	1.52	1.77	1.18	1.50
Germany	1.00	0.99	1.01	1.00	1.04	0.96	1.00	1.21	0.82
Greece	0.85	0.98	0.86	1.00	1.36	0.74	1.00	1.15	0.87
Iceland	1.00	1.01	0.99	1.00	0.94	1.06	1.00	0.98	1.02
Ireland	1.00	0.99	1.01	1.00	1.14	0.88	1.00	1.20	0.83
Italy	1.00	1.20	0.83	1.00	0.96	1.05	1.00	1.06	0.94
Netherlands	0.50	1.12	0.44	0.43	1.02	0.42	0.66	1.01	0.65
Luxembourg	0.92	1.11	0.83	0.74	1.04	0.71	0.68	1.02	0.67
Norway	0.77	1.00	0.77	0.91	1.12	0.82	0.70	1.09	0.64
Spain	2.85	1.13	2.51	1.00	1.02	0.98	1.00	1.01	0.99
Portugal	1.00	0.99	1.01	1.12	1.28	0.88	1.08	1.36	0.79
Sweden	1.00	1.11	0.90	0.27	1.06	0.26	0.33	1.05	0.31
Switzerland	1.00	0.97	1.03	0.90	1.20	0.75	0.96	1.22	0.79
United Kingdom	0.75	1.09	0.68	0.54	1.09	0.49	0.85	1.16	0.73
Mean	1.08	1.05	1.03	1.07	1.12	0.95	1.09	1.13	0.95
Min	0.50	0.97	0.44	0.27	0.94	0.26	0.33	0.98	0.31
Max	2.85	1.20	2.51	2.81	1.36	2.30	2.63	1.36	2.21
Std	0.49	0.08	0.43	0.57	0.13	0.46	0.51	0.11	0.41

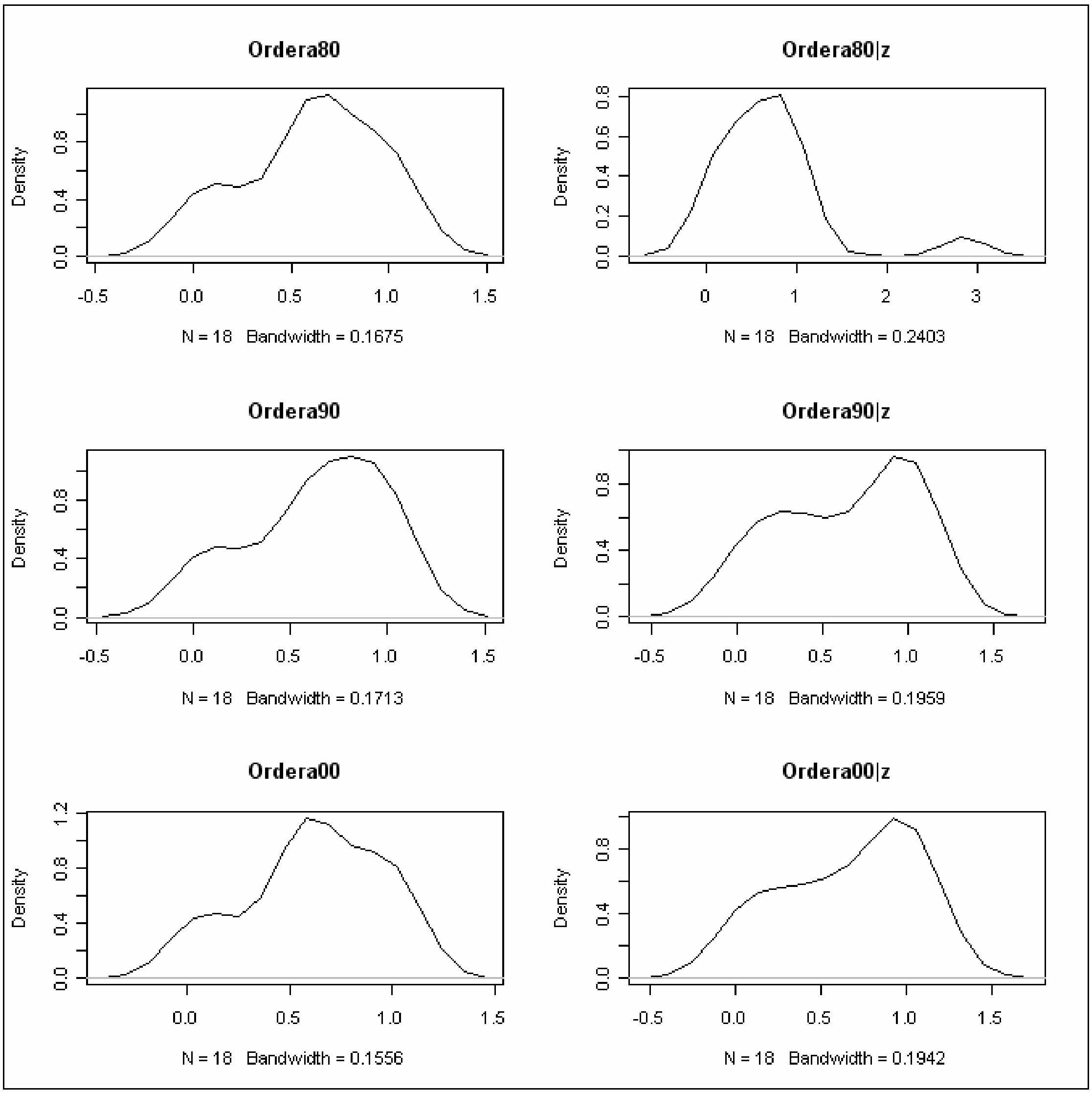
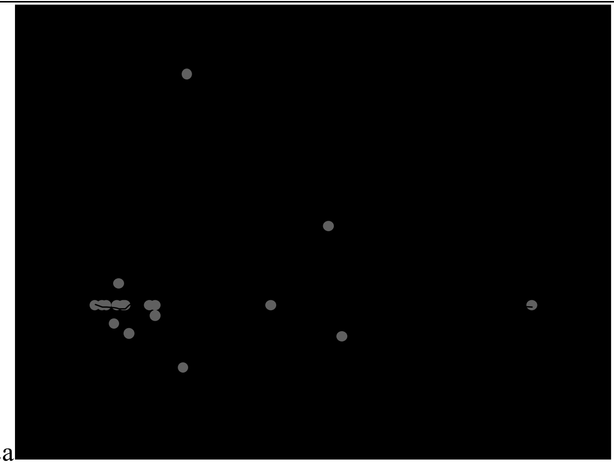
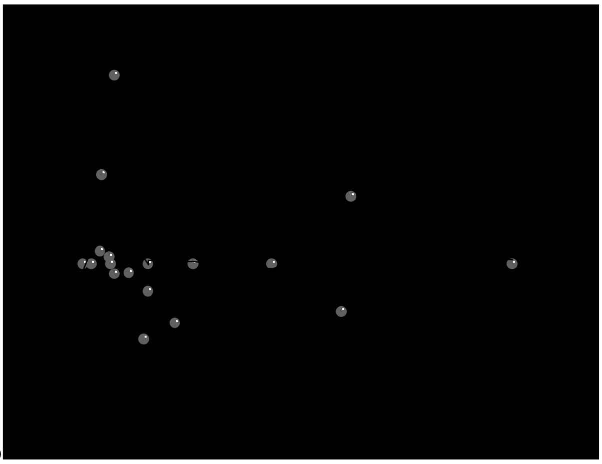


Figure 1: Kernel density functions of Conditional and Unconditional Order-a frontiers using Gaussian Kernel and the appropriate bandwidth (Silverman, 1986)

Figure 2: The Global effect of energy consumption on countries' economic efficiencies



2a



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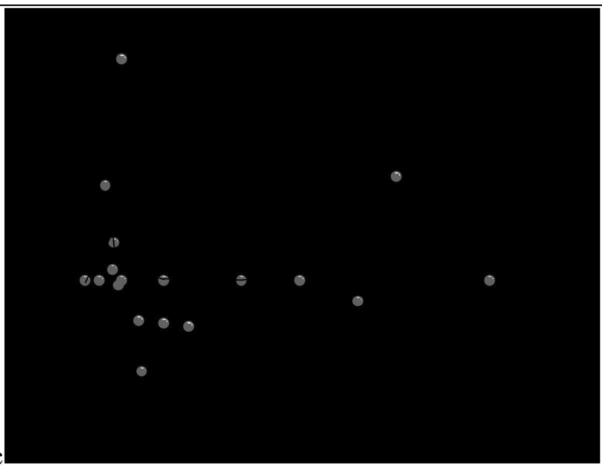

2c