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Environmental performance and quality of governance: A non-parametric analysis of the NUTS 1-regions in France, Germany and the UK

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Abstract

This paper applies nonparametric estimators to examine the effect of regional quality of government on the environmental performance in the NUTS 1-regions in France, Germany and the UK. The most comprehensive existing regional measure on governance is used, gauging the partiality, corruption and effectiveness of government services in each region. By utilizing regional level measures of three pollutants (CO_2, CH_4 and N_2O) the effect of governance on environmental efficiency is analyzed. The empirical analysis suggests that there is a nonlinear relationship between regions' governance quality levels and their environmental performance. It appears that the effect of regional quality of governance is positive up to a certain level, then turning slightly negative. This suggests that higher governance quality will not always result in increased environmental efficiency.

Keywords: *Quality of governance, Environmental performance, Regions, Nonparametric analysis.*

JEL Classification: C14; H23; R11; Q58.

1. Introduction

A burgeoning literature has in the last decades studied how the design of governance affects environmental outcomes, focusing on the role of constitutions, legal systems, degree of democratization and other institutional features of countries mode of governance. Besides the attention on the formal design of government institutions there has also been a wide concern among scholars and policymakers that quality of government – the extent to which the state is infested by corruption and partiality – has an impact on environmental outcomes since this affect the formulation and implementation of environmental policies (e.g. Damania et al. 2004; López & Mitra 2000).

While the massive number of empirical studies on this topic certainly has not reached a consensus, the majority of this research largely contends that there are negative effects from corruption on different measures of environmental performance. However, we have identified a gap in this body of research and argue that it is problematic that an absolute majority of these studies only use national-level variables as empirical measures of governance and environmental outcomes.

Although exceptions exist, as some recent studies focus on one subnational unit or different units within a country (e.g. Golden and Min 2013; Halkos and Tzeremes 2013a), few studies have, to date, analyzed regional differences across countries in a comparative perspective. Barrett and colleagues (2006) argue that the debate on whether or not corruption has a negative impact on environmental performance has been limited by the focus on countries as the unit of analysis: "Researchers employing the conventional model [of corruption and environmental outcomes] have thus far focused on national-level political corruption, which is understandable. Data availability sharply limits analysts' ability to study these phenomena at smaller scales. //… [Yet] given all the possible subnational variation in resource characteristics and quality of governance, a single measure of corruption at the national level seems highly unlikely to capture whatever true relationship(s) might exist between corruption and resource outcomes" (p. 1359).

We pick up this point and focus in this article, in contrast to previous studies on corruption and the environment, on regions as this limit the risk of ecological fallacies when making inferences only based on national values. To account for the role of economic development we focus in this study on environmental efficiency, broadly understood as the relationship between desirable economic output and undesirable ecological output (i.e. pollution). The aim of our article is more specifically to examine the effect of French, German and U.K. NUTS level 1 regions' governance quality on their environmental efficiency levels.

Recently Halkos and Tzeremes (2013a) introduced an application of the model proposed by Färe and Grosskopf (2004) based on the probabilistic characterization of a directional distance function (Simar and Vanhems, 2012). In our case we apply the same approach in order to measure the effect of government quality on regions environmental performance. More precisely we apply nonparametric estimators to examine the effect of regional quality of government on the environmental performance in 36 regions. We use the European Quality of Government Index (EQI), the most comprehensive existing measure on subnational governance. The index gauges the partiality, corruption and effectiveness of government services in each region. By utilizing regional level measures of three pollutants (CO_2, CH_4 and N_2O) we construct sub-national environmental efficiency indicators and analyze the effect of governance on environmental performance.

The article proceeds as follows: The following section reviews the theoretical arguments and empirical findings regarding the impact from governance on environmental outcomes. After describing our datasets in section 3 we discuss the statistical methods employed in section 4. We then present the empirical results in section 5. We conclude by discussing the implications of our study and outlining a future research agenda.

2. Literature review

Several veins of research have focused on the impact from different institutional designs of governance on environmental outcomes. One literature examines the effect from the degrees of democracy in a country and constitutional arrangements on environmental measures (see Fredriksson and Wollscheid 2007 as well as Li and Reuveny 2006 for useful reviews). Other authors have studied the role played by different legal systems (see for example Meiners and Yandle 1998) and the composition and size of government (e.g. Bernauer and Koubi 2012) on environmental outcomes.

Also, there has been a wide focus on bad governance and the presence of bribery and corruption within government, the issue at focus in this article.[1] Corruption and low quality of government was anecdotally mentioned as being present where the environment is deteriorating in some early studies (e.g. Carter 1997; Hafner 1998; Sapru 1998; Lippe 1999) and described as “a major culprit in environmental degradation” (Desai 1998:300). Since then a large body of research has emerged that investigates the effect from corruption on environmental outcomes.

Bad governance in general and in particular the presence of corrupt government institutions is described in the theoretical literature to have a negative influence on the environment. López and Mitra (2000) model this relationship and argue that the inverted U-shaped relationship between pollution and per capita income is affected by corruption. According to their theoretical analysis, the turning point where the slope of this curve starts to decline takes place at later stages of income in economies where corruption is present. Damania (2002) develop a theoretical model where pollution abatement is affected negatively by corruption.

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1 When discussing corruption we understand this concept according to its most commonly used definition, the ”abuse of public power for private gain” (Treisman 2007).

More specifically, the literature theoretically assumes that corruption affect environmental performance and natural resource management negatively through two causal processes: One is focused on that corruption affects the substantial stringency of environmental policy, as bribery and lobbying directed towards decision-makers shape the formulation of environmental regulations in corrupt societies (Damania et al. 2003:492; Fredriksson & Svenson 2003:1385; Fredriksson et al. 2004:208; Welsch 2004:685). Another explanation instead focuses on that corruption hampers law enforcement and compliance – allowing emitters to evade responsibility or violators to avoid sanctions through bribery to public officials – and thus tend to encourage pollution or overexploitation (Robbins 2000:427; Messer 2000:55; Esty et al. 2005:304; Smith & Walpole 2007:251-252; Leader-Williams et al. 2009:297; Miller 2011:51). The former argument has also been theoretically developed to include other actors, indicating that corruption can be a facilitating mechanism for environmental lobbyists.

Fredriksson et al. (2007) argues that there is a positive effect on the probability of ratification of environmental agreements from the intensity of environmental lobbying and that this effect is increased from levels of corruption, where lobbyists have a greater influence on decisions. So if corruption opens up possibilities for influence by both industry and environmental lobbyists, then why would we expect corruption to result in adverse effects on the environment? A literature focused on how certain environmental regulations are formulated develops an argument that can be useful to understand this question: "This argument is based on the view that industry is able to exert its preference for a particular instrument because it is more likely to be wellorganized than consumers" (Hahn 1990:23). According to this reasoning corruption could very well increase the possibilities for lobbying to both industry and environmental actors, but it is the former who will have the relatively larger influence in the end over the formulation of policy.

The empirical findings lend support for these arguments but also make visible some existing controversies. A wide body of research has demonstrated a pattern where national levels of corruption is said to affect numerous measures of environmental outcomes. Fredriksson et al. (2004) report that corruption increases the energy intensity of production in a number of sectors on a sample of 12 OECD countries for the period 1982-1996. In another study Fredriksson et al. (2003) analyzes the effect from corruption on environmental regulations in the United States. The authors use panel data on four industrial sectors on the state-level over the years 1977-1987 and find that corruption substantially decreases the stringency of regulations.

Fredriksson and Svensson (2003) develop this argument by looking into the interacting effect from political instability. Their argument contends that corruption decreases the stringency of environmental regulations but that this effect is reduced as the degree of political instability increases. They test this argument on a cross-sectional sample of 63 countries and find – by analyzing a measure of environmental stringency facing producers in the agriculture sector – empirical support for their claim.

Damania et al. (2003) report an effect from trade liberalization on the stringency of environmental regulations, measured as the lead content in gasoline, that is contingent on the level of corruption. Analyzing a panel of 48 developed and developing countries in the time period 1982-1992 they find that high levels of corruption are associated with reduced stringency of environmental policy and that the effect from trade policies on an increase in the demand for environmental policy is conditional on the level of corruption.

Morse (2006) reports negative effects on the Environmental Sustainability Index from corruption. This trend is consistent with the results reported by Pellegrini and Gerlagh (2006). They find negative effects from corruption in a study of environmental commitment in a cross-sectional sample of 62 developed and developing countries. Besides pollution and environmental policies, a number of studies have focused on outcomes in natural resource management. Meyer et al. (2003) find that corruption has a small but significantly positive effect on the officially reported rate of deforestation in a sample of 117 countries from 1990-2000. Koyncu and Yilmaz (2009), using three different measurements of corruption and official figures on deforestation for three different time periods across a wide sample of countries, report that corruption increases the rate of deforestation.

Wright et al. (2007) come to a similar conclusion using a different measure of forest conservation. They analyze satellite-based data on the effectiveness of combating fire in 823 forest reserves in a number of countries. Their findings indicate that the management of forest reserves is more effective in countries with lower levels of corruption. Studies have also proposed that biodiversity is affected by corruption, drawing attention to the correlation between corruption and the presence of poaching and threat to extinct species (Smith et al. 2003; Smith et al. 2005; Leader-Williams et al. 2009).

Other studies report that governance capacity correlate negatively with the occurrence of illegal fishing (Agnew et al. 2009; Österblom et al. 2010). A relatively small number of studies using qualitative approaches consistently report a negative impact from corruption on the effectiveness on natural resource management (Robbins 2000; Smith et al. 2003; Miller 2011; Pellegrini 2011; Sundström 2013).

While this literature lend support for the proposed negative environmental effects from corruption and bad governance, there exist controversies regarding the issue of *measurements* and the role of *economic development*. Regarding measurements, Ewers and Smith (2007) argue that the relationship between corruption and the environment is in many aspects a product of which empirical measure is used by researchers to gauge the wide concept of "environmental outcomes". They argue that environmental degradation, measured with "the ecological footprint approach" is insignificantly correlated with national levels of corruption. Reacting to the attention on corruption as an obstacle in conservation Ferraro (2005) argue that some of the previous analysis are simplistic. Also Katzner (2005) highlight that since corruption has a negative effect on prosperity, this might hamper the possibly negative effects on the environment from economic activities[2].

With regards to the role played by economic development Welsch (2004) propose that there are two effects from corruption on pollution, one direct positive effect but also one indirect, functioning through the suppressing effect on income. As decreased prosperity may lead to lower emissions at some income levels and higher emissions at others, this effect is more difficult to estimate. The study differs from much of this literature as it analyzes the effect of corruption and income on 12 different indicators of environmental performance. Using a sample of 122 countries Welsch finds that although pollution is reduced by the indirect suppressing effect from corruption on income, the direct and positive effect from corruption on pollution is larger.

As a contrast Cole (2007) builds on this argument, but present somewhat conflicting findings. Studying emissions of CO_2 and SO_2 over the period of 1987-2000 in 94 countries Cole reports that the indirect and negative effect from corruption is larger than the positive and direct effect. Also Halkos and Tzeremes (2013b) present a nuanced picture of this relationship. They perform a nonparametric analysis of the impact from the different composite parts of the World Governance Indicators on CO_2 emissions over the years 1996-2010 in the G20 countries. Their findings indicate a nonlinear relationship where increased governance quality does not necessarily lead to reduced CO_2 emissions.

To summarize, the theoretical predictions and empirical findings from the literature seem to suggest a negative impact from high national levels of corruption on different environmental measurements. Given the discussion above we have identified two points of

[2] For an overview of the current debate on the existence of Environmental Kuznets Curves (EKC) the reader is referred to Halkos and Tzeremes (2009).

critique towards the previous literature that are important for the design of this study. First, while some exceptions exists, such as Golden and Min (2012) and Halkos and Tzeremes (2013a), most studies within this scholarship focus on nations as the geographical unit and seldom studies sub-entities within countries as the unit of analysis. Second, as the review above has discussed this literature has often had problems incorporating the role of economic development.

The design of this study attempts to account for some of these aspects by focusing on environmental efficiency at the subnational level. We focus on regions in order to account for differences within countries, as this limit the risk of ecological fallacies when making inferences only based on national values. As previously mentioned, Barrett et al. (2006) noted that since the degrees of corruption often vary within countries, the use of single national corruption indicators has some inherent problems in explaining the variance in environmental outcomes. To account for the role of economic development we focus on environmental efficiency, broadly understood as the relationship between desirable economic output and undesirable ecological output given the circumstances specified in the sections below. The aim of our article is hence to examine the effect of French, German and U.K. NUTS level 1 regions' governance quality on their environmental efficiency levels.

3. Data

Our study constructs regional environmental efficiency indicators for 36 NUTS level 1 regions for France, Germany and the U.K [3] We construct regions' environmental performances following several other studies (Färe et al., 1989; Färe et al., 1996; Chung et al., 1997; Färe et al., 2004; Halkos and Tzeremes, 2009, 2013a, 2013c) by defining regional environmental production as a set of inputs and outputs. The inputs used in our study are the

[3] For more information regarding the European NUTS classifications see: http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction.

total regional labor force (for all NACE activities measured in thousands) and regional capital stock (in million €). However since regional capital stock is not available we have calculated it following the perpetual inventory method as in several other studies method (Feldstein and Foot, 1971; Verstraete, 1976; Epstein and Denny, 1980; Nadiri and Prucha, 1996; Terregrossa, 1997). In addition as has been defined by several authors (Färe et al., 1989; Färe et al., 1996; Chung et al., 1997) the environmental production is defined by two kinds of outputs (the 'good' and the 'bad' outputs). The 'good' output in our case is the regional gross domestic product (measured at constant prices in million €).

Furthermore, in our study we use three 'bad' (or the undesirable) outputs defining regional environmental production process. These are the regional quantities of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) measured in metric tones. López and Mitra (2000) points out that "reductions in certain pollutants may simply reflect changes in the composition of pollution. Lower emissions of a particular pollutant may involve increases in other pollutants" (p. 138). We therefore argue that it is highly beneficial study more than just one pollutant and therefore use data on three different types of emissions. In our analysis the inputs and outputs used are referred to the year 2009[4] and they have been collected from three different regional databases (EUROSTAT[5], OECD[6] and European Environmental Agency[7]).

Additionally, since we investigate the effect of regions' government quality on their environmental performance a governance indicator has been used in our analysis. Although there exist numerous indicators on governance and the levels of corruption on the country level, few measurements exist that capture regional differences in this aspect. To date, the

[4] Regional pollutant data are scarce and therefore our study is limited only for the year 2009 and for 36 NUTS level 1 regions for which the data are available.
[5] Available from: http://epp.eurostat.ec.europa.eu/portal/page/portal/region_cities/regional_statistics/data/main_tables.
[6] Available from: http://stats.oecd.org/Index.aspx?DataSetCode=REG_LAB_TL3
[7] Available from: http://prtr.ec.europa.eu/.

most comprehensive governance indicator on the sub-national level is the European Quality of Government Index (EQI), constructed by a research team at the Quality of Government Institute, at the University of Gothenburg, with funding from the European Commission (see Charron et al. 2011). In this project, the researchers issued a survey during the year 2009 of around 34 000 citizens in 18 countries on three types of public services (health care, education and law enforcement). The participants were surveyed on how they would evaluate these services numerically according to their *quality*, *impartiality* and *corruption*. The questionnaire consisted of 16 questions related to these themes of good governance, which were then compiled into a sub-national index.

To additionally introduce a country context to the index, the researchers merged the regional scores with external measures of governance. By introducing a factor accounting for these regions' deviation from the country average of the World Bank's World Government Indicator (WGI) the researchers received the EQI. In this sense the measure gauges both political and administrative forms of corruption (For a more detailed description on the survey and the creation of the index, see Charron et al. 2013[8]).

In all, the index measures the quality, impartiality and corruption of government in these subnational units, where higher values equal better governance and lower levels more partiality, ineffectiveness and corruption in government (see also Charron and Lapuente 2013). Specifically, the index scores of the EQI are standardized and set so that 0 is the value for region in the original sample with the lowest quality of government and 100 is the value for the region with the highest. In total, the EQI cover 172 regions. Due to the limitations of the availability of regional figures on pollutants, as described previously, we include 36 regions from the three countries in our analysis. The descriptive statistics of the variables used in our analysis are presented in Table 1.

[8] For extensive sensitivity tests between the regional measure of quality of government and national WGI scores, see Charron (2010).

Table 1: Descriptive statistics of the variables

	Capital Stock (000')	Labour force (000')	Current GDP (millions €)	CH_4 (in tonnes)	CO_2 (in tonnes)	N_2O (in tonnes)	EQI
			All regions-NUTS 1 (36)				
Mean	24000456.15	2625.814	176290.056	27877.611	27566272.14	2143.539	80.594
Std	14377375	1722.034	136937.673	37669.065	41510036.02	3342.193	5.872
Min	7391667.206	284.7	26829	124	2419000	38.1	67.947
Max	62098956.42	7974.6	541880	200085	196817797	15300	91.673
			French regions-NUTS 1 (8)				
Mean	23942759.8	3195.488	232649.25	20906.875	16286500	2738.938	73.121
Std	14329030.77	1171.722	136077.618	19319.067	8738085.962	2691.056	3.337
Min	8884885.483	1506.3	96606	7124	6212000	150.7	67.947
Max	54444488.9	5223.1	541880	67026	26275000	7824.7	77.329
			German regions-NUTS 1 (16)				
Mean	20191758.59	2388.075	152025.063	19382.813	28032799.81	2480.7	83.331
Std	15922445.97	2255.087	156891.424	48607.537	46513297.8	4356.985	4.07
Min	7391667.206	284.7	26829	124	2419000	38.1	76.314
Max	62098956.42	7974.6	531242	200085	196817797	15300	91.673
			UK regions-NUTS 1 (12)				
Mean	29117183.8	2563.017	171070.583	43851.167	34464083.33	1297.058	81.925
Std	11474887.53	1142.142	105449.422	25235.982	48363040	1960.138	5.156
Min	8607011.688	783.5	47312	1601	4293000	59.7	72.339
Max	50742262.77	4411.2	430882	85467	178180000	6999	89.604

4. Methods

4.1 Measurement of regions' environmental performance levels

Recently Halkos and Tzeremes (2013a) introduced an innovative application of the model proposed by Färe and Grosskopf (2004) based on the probabilistic characterization of directional distance function (Simar and Vanhems, 2012). In our case we apply the same approach in order to measure the effect of French, German and U.K. NUTS level 1 regions' governance quality on their environmental efficiency levels. In order to characterize regions' environmental production technology let $\mathbf{x}=\left(x_1,...,x_N\right)\in\Re_+^N$ denote an input vector which can produce a set of undesirable (bad) outputs $\mathbf{u}=(u_1,...,u_J)\in\Re_+^J$ and desirable (good) outputs $\mathbf{v}=\left(v_1,...,v_M\right)\in\Re_+^M$. Then the environmental production technology can be defined as:

$$\mathbf{P}=\left\{(\mathbf{u},\mathbf{v},\mathbf{x})\middle|\,\mathbf{x}\text{ can produce }(\mathbf{u},\mathbf{x})\right\} \quad (1)$$

Moreover, in order to determine the environmental production technology several assumptions needs to be taken, following Shephard (1970), and Färe and Primont (1995). Therefore, we assume that the output sets are closed and bounded and that inputs are freely disposal. In addition $\mathbf{P}$ can be an environmental output set if:

1. $(\mathbf{v},\mathbf{u}) \in \mathbf{P}$ and $0 \leq \theta \leq 1$ then $(\theta\mathbf{v},\theta\mathbf{u},\mathbf{x}) \in \mathbf{P}$ (i.e. the outputs are weakly disposable) and

2. $(\mathbf{v},\mathbf{u},\mathbf{x}) \in \mathbf{P}$, $\mathbf{u}=0$ implies that $\mathbf{v}=0$ (i.e. the null jointness assumption of good and bad outputs).

Moreover data envelopment analysis (DEA) framework is used in order to formalize regions' environmental technology. For that case let us assume k regions under examination whereas the observed activities can be defined as $(\mathbf{v}_k,\mathbf{u}_k,\mathbf{x}_k)$ where $k=1,...,K$. Then the environmental output can be formalized as:

$$
\begin{aligned}
\hat{\mathbf{P}} = \Big\{ (\mathbf{v},\mathbf{u},\mathbf{x}) : & \sum_{k=1}^{K} \omega_k v_{km} \geq v_m, m=1,...,M, \\
& \sum_{k=1}^{K} \omega_k u_{kj} = u_j, j=1,...,J, \\
& \sum_{k=1}^{K} \omega_k x_{kn} \leq x_n, n=1,...,N, \\
& \omega_k \geq 0, k=1,...,K \Big\}
\end{aligned}
\tag{2}
$$

ω_k, $k=1,...,K$ indicate the intensity variables which are not negative and imply constant return to scale.[9] The inequality in the good outputs and the equality in the bad outputs help us to impose the weak disposability assumption and only strong disposability of good outputs. However the null-jointness is imposed by the following restrictions on bad outputs:

[9] In our case the regional environmental performance follows the assumption of constant returns to scale (CRS). According to Picazo-Tadeo et al. (2012: 802) from an ecological perspective, economic activity is commonly characterised by constant returns to scale. According to Sahoo and Tone (2013) the convexity postulate can assume away some important technological features.Several authors therefore suggest that a convexity axiom can be dropped (Scarf 1981a, 1981b, 1986; Kuosmanen 2003; Tone and Sahoo, 2003; Zelenyuk and Zheka 2006). Still, if a researcher wants to impose the convexity postulate in this model, it is suggested to follow the DEA modelling remarks raised by Kuosmanen (2005), Färe and Grosskopf (2009) and Kuosmanen and Podinovski (2009). A similar model to the one applied here when assuming the convexity axiom can be found in Halkos and Tzeremes (2013c).

$$\sum_{k=1}^{K} u_{kj} > 0, j = 1,...,J,$$
$$\sum_{j=1}^{J} u_{kj} > 0, k = 1,...,K. \quad (3).$$

Following Chung et al. (1997) we apply the directional distance function approach in order to be able to reduce bad outputs and expand good outputs. For that purpose we use a direction vector $\mathbf{g} = (\mathbf{g}_v, -\mathbf{g}_u)$, where $\mathbf{g}_v = 1$ and $-\mathbf{g}_u = -1$ [10]. The efficiency score for a region k' can then be obtained from:

$$D\left(\mathbf{v}^{k'}, \mathbf{u}^{k'}, \mathbf{x}^{k'}; \mathbf{g}_v, \mathbf{g}_u\right) = \sup\left\{\beta \middle| \left(\mathbf{v}^{k'} + \beta\mathbf{g}_v, \mathbf{u}^{k'} - \beta\mathbf{g}_u, \mathbf{x}^{k'}\right) \in \mathbf{P}\right\} \quad (4).$$

The additional DEA estimator of (4) can then be obtained as:

$$\begin{aligned} &\hat{D}\left(\mathbf{v}^{k'}, \mathbf{u}^{k'}, \mathbf{x}^{k'}; \mathbf{g}_v, \mathbf{g}_u\right) = \max \beta \\ &s.t. \quad \sum_{k=1}^{K} \omega_k v_{km} \geq v_{k'm} + \beta g_{vm}, m = 1,...,M, \\ &\qquad \sum_{k=1}^{K} \omega_k u_{kj} = u_{k'j} - \beta g_{uj}, j = 1,...,J, \\ &\qquad \sum_{k=1}^{K} \omega_k x_{kn} \leq x_{k'n} \\ &\qquad \omega_k \geq 0, k = 1,...,K. \end{aligned} \quad (5).$$

Efficiency is next indicated when $\hat{D}\left(\mathbf{v}^{k'}, \mathbf{u}^{k'}, \mathbf{x}^{k'}; \mathbf{g}_v, \mathbf{g}_u\right) = 0$ and inefficiency by $\hat{D}\left(\mathbf{v}^{k'}, \mathbf{u}^{k'}, \mathbf{x}^{k'}; \mathbf{g}_v, \mathbf{g}_u\right) > 0$.

4.2 Conditional directional distance functions under environmental technology

Following Daraio and Simar (2005), who extend the probabilistic formulation of the production process firstly introduced by Cazals et al. (2002)[11], let the joint probability

[10] This is the most common assumption made for directional distance functions when measuring environmental efficiency levels. However, different directions can be chosen in order for the researcher to test the environmental efficiency under different environmental policy scenarios (see among others Picazo-Tadeo et al., 2012).

[11] For the theoretical background and the asymptotic properties of nonparametric conditional efficiency measures see Jeong et al. (2010).

measure of the environmental production to be defined as $(\mathbf{v},\mathbf{u},\mathbf{x})$ and the joint probability function of $H_{\mathbf{v},\mathbf{u},\mathbf{x}}(.,.)$ can be defined as:

$$H_{\mathbf{v},\mathbf{u},\mathbf{x}}(x,v,u)=\text{Prob}(\mathbf{x}\le x,\mathbf{v}\ge v,\mathbf{u}\ge u) \quad (6).$$

In addition the following decomposition can be obtained as:

$$H_{\mathbf{v},\mathbf{u},\mathbf{x}}(x,v,u)=\text{Prob}(\mathbf{v}\ge v,\mathbf{u}\ge u|\mathbf{x}\le x)\text{Prob}(\mathbf{x}\le x)=S_{\mathbf{v},\mathbf{u}|\mathbf{x}}(v,u|x)F_{\mathbf{x}}(x) \quad (7),$$

where

$F_{\mathbf{x}}(x)=\text{Prob}(\mathbf{x}\le x)$ and $S_{\mathbf{v},\mathbf{u}|\mathbf{x}}(v,u|x)=\text{Prob}(\mathbf{v}\ge v,\mathbf{u}\ge u|\mathbf{x}\le x)$.

In addition let $\mathbf{z}=(z_1,...,z_r)\in R^r$ denote the exogenous factor to the production process (in our case is the regional governance quality-EQI). Then equation (6) becomes:

$$H_{\mathbf{v},\mathbf{u},\mathbf{x}|\mathbf{z}}(x,v,u|z)=\text{Prob}(\mathbf{x}\le x,\mathbf{v}\ge v,\mathbf{u}\ge u|\mathbf{z}=z) \quad (8),$$

which complete characterizes the regional environmental production process. Then, in the same lines to Daraio and Simar (2005, 2006, 2007), the following decomposition can be derived:

$$\begin{aligned}&H_{\mathbf{v},\mathbf{u},\mathbf{x}|\mathbf{z}}(x,v,u|z)=\text{Prob}(\mathbf{v}\ge v,\mathbf{u}\ge u|\mathbf{x}\le x,\mathbf{z}=z)\text{Prob}(\mathbf{x}\le x|z)\\&=S_{\mathbf{v},\mathbf{u}|\mathbf{x},\mathbf{z}}(v,u|x,z)F_{\mathbf{x}|\mathbf{z}}(x|z)\end{aligned} \quad (9).$$

The estimator of the conditional survival function introduced above can then be obtained from:

$$\hat{S}_{\mathbf{v},\mathbf{u}|\mathbf{x},\mathbf{z}}(v,u|x,z)=\frac{\sum_{i=1}^{n}I(\mathbf{v}\ge v,\mathbf{u}\ge u,\mathbf{x}\le x)K_h(\mathbf{z}_i,z)}{\sum_{i=1}^{n}I(\mathbf{x}\le x)K_h(\mathbf{z}_i,z)} \quad (10),$$

where $K_h(\mathbf{z}_i,z)=h^{-1}K((\mathbf{z}_i,z)/h)$ with $K(.)$ being a univariate kernel defined on a compact support (Epanechnikov in our case) and h is the appropriate bandwidth calculated following Bădin et al. (2010)[12].

By following Simar and Vanhems (2012) the probabilistic characterization of the directional distance function, measuring environmental efficiency, will then take the form of:

$$D\left(\mathbf{v}^{k'},\mathbf{u}^{k'},\mathbf{x}^{k'};\mathbf{g}_v,\mathbf{g}_u\right)=\sup\left\{\beta>0\middle|H_{\mathbf{x},\mathbf{v},\mathbf{u}}\left(\mathbf{v}^{k'}+\beta\mathbf{g}_v,\mathbf{u}^{k'}-\beta\mathbf{g}_u,\mathbf{x}^{k'}\right)>0\right\} \quad (11),$$

In addition the conditional form of the model will take the form of:

$$D\left(\mathbf{v}^{k'},\mathbf{u}^{k'},\mathbf{x}^{k'};\mathbf{g}_v,\mathbf{g}_u\middle|\mathbf{z}\right)=\sup\left\{\beta>0\middle|H_{\mathbf{v},\mathbf{u}|\mathbf{x},\mathbf{z}}\left(\mathbf{v}^{k'}+\beta\mathbf{g}_v,\mathbf{u}^{k'}-\beta\mathbf{g}_u,\mathbf{x}^{k'}\middle|\mathbf{z}=z\right)>0\right\} \quad (12).$$

Finally, the DEA program for the environmental efficiency score for a region k' when using the conditional output oriented directional distance function can be calculated as:

$$\begin{aligned}
&\hat{D}\left(\mathbf{v}^{k'},\mathbf{u}^{k'},\mathbf{x}^{k'};\mathbf{g}_v,\mathbf{g}_u\middle|\mathbf{z}\right)=\max\beta\\
&s.t.\quad \sum_{\substack{k=1,\dots,K|\\|\mathbf{z}_k-z|\le h}}\omega_k v_{km}\ge v_{k'm}+\beta g_{vm}, m=1,\dots,M,\\
&\qquad\sum_{\substack{k=1,\dots,K|\\|\mathbf{z}_k-z|\le h}}\omega_k u_{kj}=u_{k'j}-\beta g_{uj}, j=1,\dots,J,\\
&\qquad\sum_{\substack{k=1,\dots,K|\\|\mathbf{z}_k-z|\le h}}\omega_k x_{kn}\le x_{k'n}\\
&\qquad\omega_k\ge 0, k=1,\dots,K \text{ such that } |\mathbf{z}_k-z|\le h.
\end{aligned} \quad (13)$$

As previously shown, environmental efficient regions under the effect of region's governance quality level will be indicated when $\hat{D}\left(\mathbf{v}^{k'},\mathbf{u}^{k'},\mathbf{x}^{k'};\mathbf{g}_v,\mathbf{g}_u\middle|\mathbf{z}\right)=0$ and inefficient regions will respectively be specified by values of $\hat{D}\left(\mathbf{v}^{k'},\mathbf{u}^{k'},\mathbf{x}^{k'};\mathbf{g}_v,\mathbf{g}_u\middle|\mathbf{z}\right)>0$[13].

12 The calculation of bandwidth by Bădin et al. (2010) is based on the Least Squares Cross Validation (LSCV) criterion introduced by Hall et al. (2004) and Li and Racine (2007).

13 As in the study of Halkos and Tzeremes (2013c) we are using efficiency estimates rather that inefficiencies by adopting the transformation by Chung et al. (1997) and Chambers et al. (1998). According to Podinovski and Kuosmanen (2011) the conventional radial Farrell input and output efficiency measures can be obtained as special cases of the directional distance functions.

As can be realised the regional environmental performance levels obtained from equation (13) are different compared to the regional environmental performance levels derived from equation (5) since the exogenous variable $\mathbf{z}$ is assumed that influences directly the shape of regions' environmental production frontier (i.e., the conditional directional distance function in (13) does not assume a separability condition). Therefore regions' environmental performance levels obtained are determined by the regions' capital stock, regions' labor force, regions' GDP levels, from regions' pollutant levels (CO_2, CH_4 and N_2O) and from regions' governance quality.

4.3 Determining the effect of regions' governance quality

In order to identify the effect of regions' governance quality levels ($\mathbf{z}$) on their environmental efficiency (EE) levels without specifying in prior any functional relationship, our paper applies a nonparametric regression in the principles of Daraio and Simar (2005, 2006, 2007). When $\mathbf{z}$ is univariate (as in our case), a scatter plot of the ratio $\frac{\hat{D}\left(\mathbf{v}^{k'},\mathbf{u}^{k'},\mathbf{x}^{k'};\mathbf{g}_v,\mathbf{g}_u\middle|\mathbf{z}\right)}{\hat{D}\left(\mathbf{v}^{k'},\mathbf{u}^{k'},\mathbf{x}^{k'};\mathbf{g}_v,\mathbf{g}_u\right)}=Q$ against $\mathbf{z}$ and its smooth nonparametric regression line would be able to describe the effect of $\mathbf{z}$ on regions' environmental efficiency levels. Let the nonparametric regression smoothing be presented as:

$$Q_k = g\left(\mathbf{z}_k\right)+\varepsilon_k, k=1,...,K \quad (14),$$

where ε_k is the error term with $E\left(\varepsilon_k\middle|\mathbf{z}_k\right)=0$, and g is the mean regression function, since $E\left(Q_k\middle|\mathbf{z}_k\right)=g\left(\mathbf{z}_k\right)$. Then the nonparametric regression estimator introduced from Nadaraya (1964) and Watson (1964) can be obtained as:

$$\hat{g}\left(\mathbf{z}\right)=\frac{\sum_{k=1}^{K}\mathrm{K}\left(\frac{z-\mathbf{z}_k}{h_k}\right)Q_k}{\sum_{k=1}^{K}\mathrm{K}\left(\frac{z-\mathbf{z}_k}{h_k}\right)} \quad (15)$$

In addition $\mathrm{K}(.)$ is the Gaussian kernel and h represents the bandwidth calculated by the least squares cross-validation data driven method as suggested by Hall et al. (2004). Based on a recent study by Halkos and Tzeremes (2013d) we follow a bootstrap based significance test for nonparametric regression as has been introduced from several authors (Racine 1997; Racine et al. 2006; Li and Racine 2007) in order to compute a significance level of the observed effect of the EQI on regions' environmental performance levels.

Finally, since we use output oriented conditional and unconditional distance functions according to Daraio and Simar (2005, 2006, 2007) an increasing nonparametric regression line between Q and EQI will indicate a favorable exogenous factor, where as a decreasing line will indicate an unfavorable factor.

5. Empirical results

Table 2 presents the analytical results derived from the unconditional $\left[D\left(\mathbf{v},\mathbf{u},\mathbf{x};\mathbf{g}_v,\mathbf{g}_u\right)\right]$ and conditional $\left[D\left(\mathbf{v},\mathbf{u},\mathbf{x};\mathbf{g}_v,\mathbf{g}_u|\mathbf{z}\right)\right]$ measure for the 36 regions in focus. Under the unconditional measures it is reported that 14 regions are environmental efficient (i.e. efficiency score equals to 1). More analytically one efficient region is reported from France (*Île de France*), ten regions are reported as efficient from Germany (*Baden Wuttemberg*, *Bavaria*, *Berlin*, *Bremen*, *Hamburg*, *Mecklenburg-Vorpommen*, *North Rhine Westphalia*, *Rhineland-Palatinate*, *Saarland* and *Schleswig-Holstein*) and three regions from the U.K. (*Northeast England*, *London* and *South West England*). The descriptive statistics suggest that German regions report, in average terms, the highest environmental efficiency scores (0.882) whereas the U.K. regions the lowest (0.708). The French regions appear to have regional environmental efficiency values (in average terms) between these two 'extremes'.

Furthermore, Table 2 presents the conditional measures of regions' environmental performance levels. Under the conditional measures regions' environmental efficiencies are subject to the effect of their governance quality levels. In this case 16 regions are reported as environmental efficient. More analytically, from France one region is environmental efficient (*Île de France*) from Germany 11 regions (*Baden Wuttemberg*, *Bavaria*, *Berlin*, *Bremen*, *Hamburg*, *Mecklenburg-Vorpommen*, *North Rhine Westphalia*, *Rhineland-Palatinate*, *Saarland*, *Schleswig-Holstein* and *Lower Saxony*) and from the U.K. four regions (*London*, *South West England*, *South East England* and *Northwest England*).

Table 2: Conditional and unconditional regional environmental performance levels

Region	$D(\mathbf{v},\mathbf{u},\mathbf{x};\mathbf{g}_v,\mathbf{g}_u)$	$D(\mathbf{v},\mathbf{u},\mathbf{x};\mathbf{g}_v,\mathbf{g}_u \mid \mathbf{z})$		$D(\mathbf{v},\mathbf{u},\mathbf{x};\mathbf{g}_v,\mathbf{g}_u)$	$D(\mathbf{v},\mathbf{u},\mathbf{x};\mathbf{g}_v,\mathbf{g}_u \mid \mathbf{z})$
Île de France	1.000	1.000	*All regions-NUTS 1 (36)*		
Bassin Parisien	0.593	0.594	*Mean*	0.797	0.807
Nord - Pas-de-Calais	0.701	0.594	*Std*	0.182	0.195
Est	0.622	0.596	*Min*	0.545	0.515
Ouest	0.804	0.804	*Max*	1.000	1.000
Sud-Ouest	0.846	0.846	*French regions-NUTS 1 (8)*		
Centre-Est	0.863	0.882	*Mean*	0.763	0.745
Méditerranée	0.673	0.640	*Std*	0.139	0.159
Baden Wuttemberg	1.000	1.000	*Min*	0.593	0.594
Bavaria	1.000	1.000	*Max*	1.000	1.000
Berlin	1.000	1.000	*German regions-NUTS 1 (16)*		
Brandenburg	0.584	0.571	*Mean*	0.882	0.897
Bremen	1.000	1.000	*Std*	0.174	0.174
Hamburg	1.000	1.000	*Min*	0.545	0.545
Hessen	0.909	0.897	*Max*	1.000	1.000
Mecklenburg-Vorpommen	1.000	1.000	*UK regions-NUTS 1 (12)*		
Lower Saxony	0.711	1.000	*Mean*	0.708	0.728
North Rhine Westphalia	1.000	1.000	*Std*	0.179	0.205
Rhineland-Palatinate	1.000	1.000	*Min*	0.569	0.515
Saarland	1.000	1.000	*Max*	1.000	1.000
Saxony	0.642	0.621			
Saxony-Anhalt	0.545	0.545			
Schleswig-Holstein	1.000	1.000			
Thuringia	0.721	0.721			
Northeast England	1.000	0.515			
Northwest England	0.591	1.000			
Yorkshire-Humber	0.601	0.562			
East Midland England	0.569	0.556			
West Midland England	0.593	0.593			
East of England	0.611	0.611			
London	1.000	1.000			
South East England	0.621	1.000			
South West England	1.000	1.000			
Wales	0.632	0.623			
Scotland	0.586	0.584			
N. Ireland	0.687	0.687			

Again as in the case for unconditional measures German regions are report to have in average terms highest environmental performance (0.897) whereas the U.K. regions are report to have the lowest environmental efficiency performance (0.728). The paradox under the unconditional and conditional measures between the French and the U.K. regions is the fact that even though more U.K. regions are reported to bee environmental efficient in average terms French regions have overall higher environmental performances. This is mainly due to the higher standard deviation value of the reported efficiencies among the U.K. regions. This result is also confirmed for NUTS 2 level in the study of Halkos and Tzeremes (2013a) indicating a high variance in the environmental efficiency of the U.K. regions.

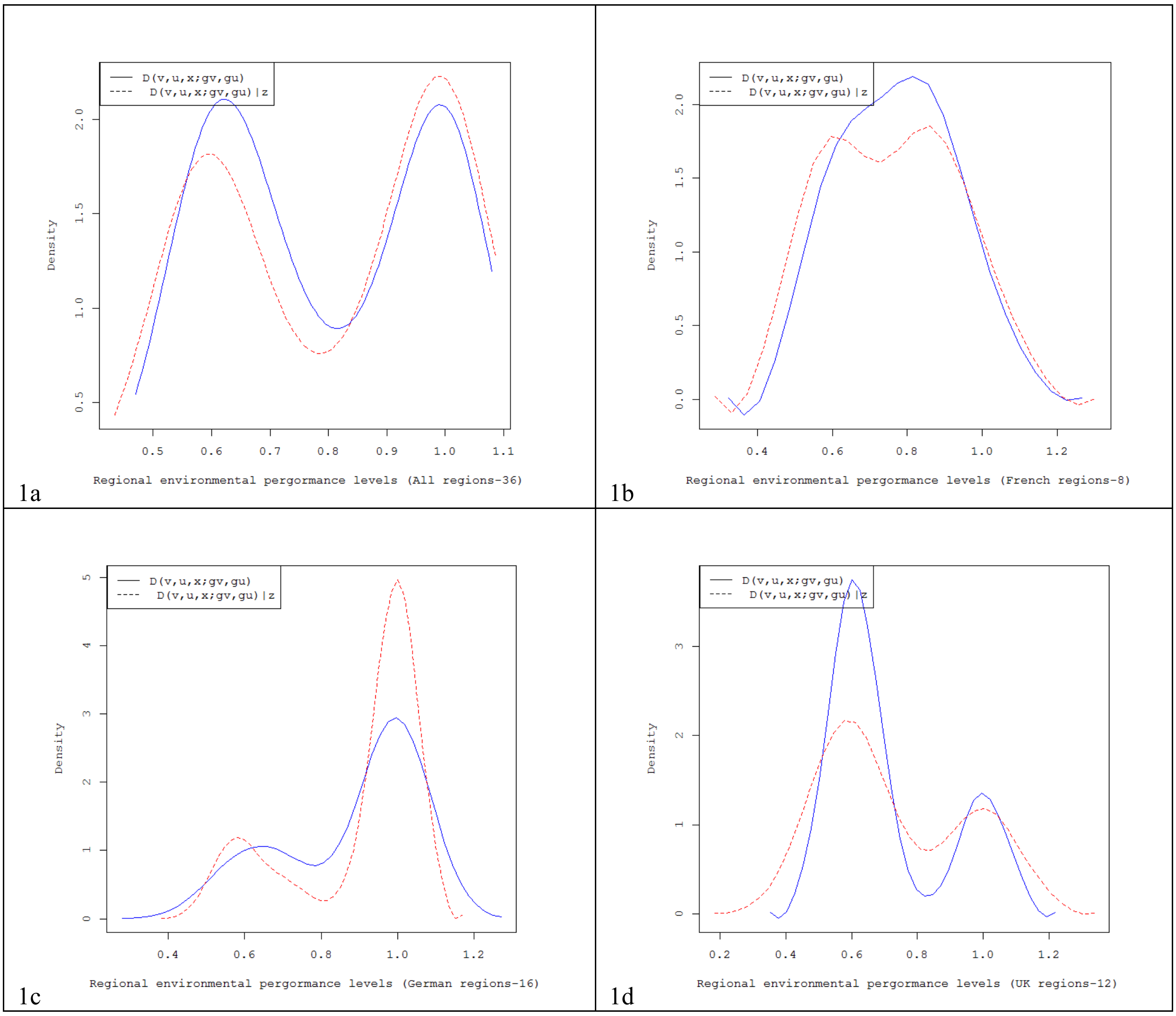
Furthermore, Figure 1 illustrates the kernel density functions of regions' environmental efficiency scores for the unconditional (solid line) and unconditional measures (dashed line)[14]. More analytically sub-Figure 1a provides the distribution of all regions' environmental efficiency levels. As can be observed we have a picture of twin-peak both for conditional and unconditional environmental efficiency scores. The first peak is at 0.6 and the second at 1. Therefore we can assume that there are two groups among the 36 regions, which indicate a potential environmental efficiency polarization. Similar result can be observed for the German regions (sub-Figure 1c) and for the U.K. regions (sub-figure 1d).

However for the case of German regions the probability of regions to have environmental efficiency scores equal to 1 is extremely higher compared to environmental efficiency values equal to 0.6. However this comes in contrast for the U.K. regions, in which the opposite phenomenon can be observed (analogously with the German regions). Finally, for the case of French regions (sub-Figure 1b) the unconditional environmental efficiency scores present a platykurtic distribution of the estimated environmental efficiency scores. However, for the conditional case again the twin-peak phenomenon is observed for two

[14] For the construction of the density plots we have used the 'normal reference rule-ofthumb' approach for bandwidth selection (Silverman 1986) and a second order Gaussian kernel.

regional environmental efficiency scores (0.5 and 0.9). This indicates that there is a polarization in those environmental efficiency values of the French regions when the quality of governance is taken into account.

Figure 1: Kernel density functions of regions' environmental efficiencies derived from conditional and unconditional directional distance functions using Gaussian kernel and the appropriate bandwidth.



The results presented in Figure 2 illustrate the effect of regions' governance quality levels on their obtained environmental efficiency scores following the visualization approach by Daraio and Simar (2005, 2006, 2007). Moreover we follow the nonparametric regression significance test proposed by several authors (Racine 1997; Racine et al. 2006; Li and Racine

2007) in order to compute a significance level of the observed effect of regions' governance quality levels on their environmental efficiency scores.[15] In all four cases presented in Figure 2 we obtained p-values less than 0.05 indicating a statistical significance of EQI explaining regions' environmental efficiency.[16] More analytically, sub-Figure 2a presents the effect of EQI for all the regions. As can be observed there is an increasing nonparametric line up to a certain EQI level (the value 85 on the scale of EQI; where 0 is the European region with the worst value and 100 is the value of the region with the best), indicating a positive effect on regions' environmental efficiency levels.

However after that point the effect becomes negative. For the case of French regions we observe an increasing line indicating that when the EQI increases French regions' environmental efficiency levels are also increasing. For the case of German regions the picture is completely different. It appears that the effect of EQI is positive up to a certain EQI level (83), which after that point the effect becomes slightly negative. Finally, for the case of the U.K. it is observed a slight negative effect of EQI up to 81. However the effect becomes positive up to 85 and then it turns again to negative. As can be clearly realised there is a nonlinear relationship between regions' governance quality levels and their environmental performances.

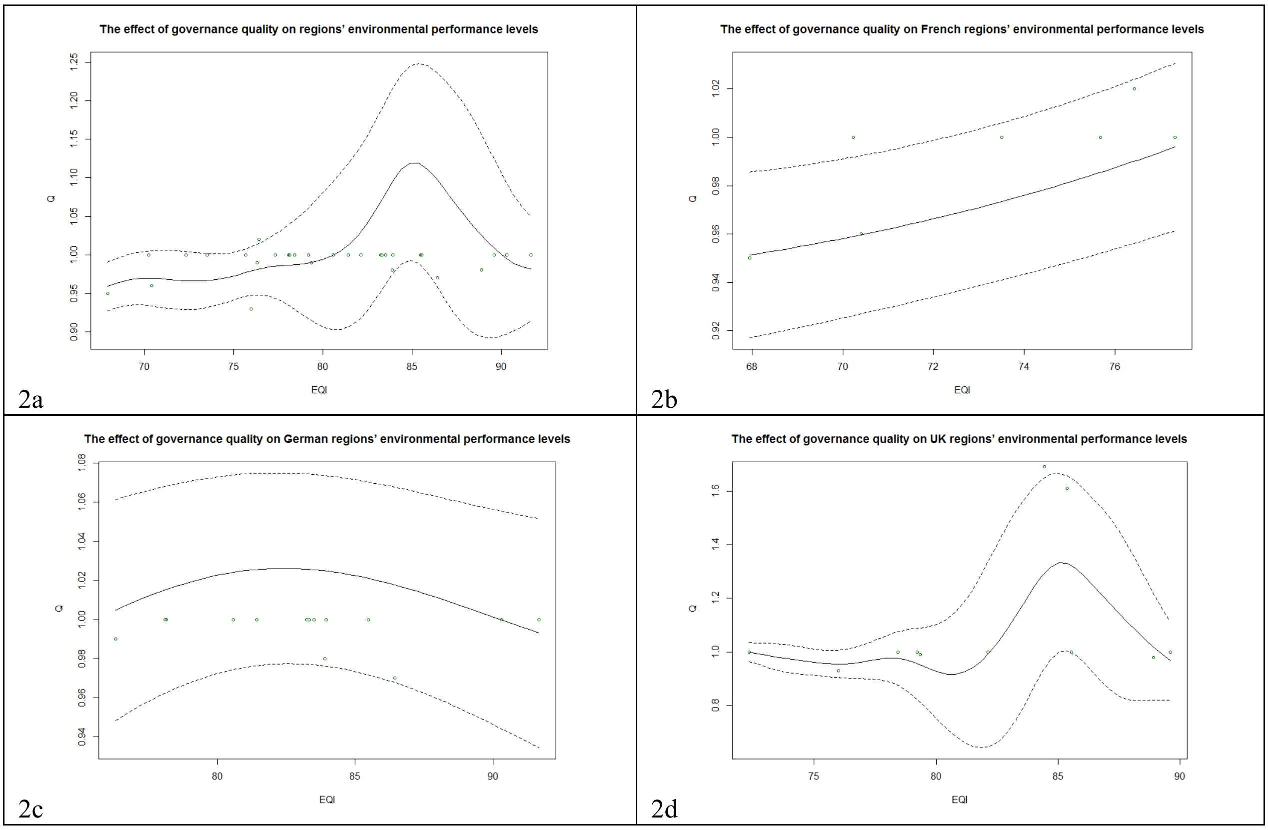
The results from our analysis suggest that the relationship between governance quality and regional environmental efficiency is non-linear and not uniform across the three different countries. Intuitively it is difficult to interpret these findings. The fact that we observe a nonlinear relationship between EQI and regions' environmental performance suggests that there are possibly other maybe "more influential" factors in regions and societies which after a certain point play a greater role than the overall regional institutional arrangements. Hence there are potentially interacting effects from omitted variables that future research might

[15] For an extensive application of this test on environmental efficiency scores see Halkos and Tzeremes (2013d).

[16] In addition, the dotted lines in Figure 2 indicate the bootstrapped pointwise error bounds (Racine 2008).

address. With regards to the observed differences between the three countries one possible explanation is that the institutional context of these countries explain this pattern. While it is not within the scope of this paper to disentangle this in detail, we observe that other authors have suggested some differences between these countries that might be important. For example, there are differences in the national administrative arrangements on the implementation of EU environmental policies between the U.K. and Germany (Knill and Lenschow 1998). Another potential explanation could be the corporatist structure of the three countries, as this has been said to influence environmental quality (e.g. Crepaz 1995; Neumayer 2003; Scruggs 1999).[17]

Figure 2: The effect of regions' governance quality on their environmental performance levels



17 "*...Corporatism refers to a system of interest representation in which a small number of strategic actors organized associations, represent large parts of the population in an encompassing fashion...*" (Crepaz 1995: 391-392). "*...The pluralist form of interest representation is characterised by a large number of atomistic interest groups which are in a competitive struggle over access to the legislative process, using 'pressure politics...*" (Crepaz 1995: 392).

For instance, according to Crepaz (1995) Germany is a country with corporatist tendencies, whereas the U.K. tends to be more pluralist. Therefore it could possible be the case that this factor would have some explanatory power for the observed variance. However, we would again stress that there could be other possible explanations of importance. Using these results as a stepping-stone for identifying potential venues for future research we believe it would be highly relevant for researchers to focus on why the relationship between corruption and environmental outcomes possibly differ across countries when analysing on sub-national units.

6. Concluding remarks

In this paper we measure for the first time the effect of regional governance quality on the environmental performance levels of 36 regions at the NUTS 1 level in France, Germany and the U.K. In order to measure regions' environmental performance we follow the same estimators as in the study by Halkos and Tzeremes (2013a) under the assumption of constant returns to scale. The methodological approach chosen is an application of the conditional directional distance functions introduced by Simar and Vanhems (2012). To our knowledge this study is the first to examine empirically the link between environmental performance and governance quality at a regional level. The results provided compliment to several other pre-mentioned studies examining empirically and theoretically the link between governance quality and environmental outcomes at the national level.

Our findings suggest a nonlinear relationship between regions government quality (the EQI index) and their environmental efficiency levels. With an exception for the French regions it appears that higher EQI values is not linearly associated with higher regional environmental efficiency levels. This particular result could have broader implications as it suggest that higher governance quality will not always result in increased environmental efficiency. Moreover, this finding, alongside with the high environmental efficiency variations (with and without the effect of EQI) among the 36 regions, suggests that other factors rather than regional institutional arrangements may influence more regions' environmental efficiency levels. Our results thus contribute empirically to the scholarly discussion and to our theoretical understanding of the link between governance quality and environmental outcomes.

Following several authors (e.g. Crepaz 1995; Struggs 1999; Neumayer 2003) one potential explanation for why we do not observe uniform effects from EQI in the three countries in focus may be based on the argument that the level of corporatism/pluralism in a society could influence regional environmental politics and the implementation of environmental policies. However, to examine the explanatory power of this or other potential arguments that can explain the variance we observe is beyond the scope of this study. Instead we believe that this topic may very well be the subject for future research. In this point it must be mentioned that regional data availability is a problem for empirical research and can significantly narrow down the researchers' options in hand. An increased availability of regional data on environmental indicators would benefit the research community as a whole and further enable us to inform our understanding of the relationship between governance and the environment.

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