Carbon dioxide emissions and governance: A nonparametric analysis for the G-20

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Abstract

This paper applies nonparametric estimators to examine countries' carbon dioxide (CO_2) emissions and governance relationship. By using data for the time period 1996-2010 of the twenty largest economies (Group of twenty, G-20) the dynamics of the considered relationship are analyzed. Six governance measures are included in our analysis (Voice and Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law and Control of Corruption) as have been defined in World Governance Indicators from the World Bank. The empirical findings reveal a nonmonotonic relationship between countries' CO_2 emissions and the examined governance measures. In addition and with respect to the environmental policy makers, a significant difference on the number of governance measures influencing countries' carbon dioxide emissions which is subject to countries' specific regional and development variations is recorded. Finally, the carbon dioxide emissions-governance relationship is highly nonlinear and appears that countries' higher governance quality does not always result to lower carbon dioxide emission levels.

JEL classification: C14; H11; Q5.

Keywords: Carbon dioxide emissions; Governance; G-20 countries; Nonparametric analysis.

1. Introduction

A vast amount of researchers have examined the role of government and institutions and their influence on economic growth. Acemoglu et al. (2003) have found that weak institutions are the cause for slow economic growth, corruption, political instability and low investments. Easterly and Levine (1997) reach a similar conclusion about the slow growth while Baumol (1990) argues that institutions influence entrepreneurship's activities and determine whether they are productive or corrupted. Chang (2011) challenges the argument that institutions have a significant positive, direct effect on growth.

However, Boettke et al. (2011) criticize Chang's (2011) results by stating that property rights have a direct effect on economic growth while policies have an indirect effect on growth. La Porta et al. (1999) argue that economic growth is not affected only by economic institutions but also by political and cultural factors. Przeworski and Limongi (1993) support that politics affect growth. Specifically, the size of government affects negatively growth, whereas government expenditures affect it positively. . Djankov et al. (2003) point out that government is a key factor for the protection of property rights and as a result **to** economic growth, because government can effectively protect them but also can violate them. La Porta et al. (2004) examine two institutional aspects which promote general freedom. They have found that independent justice promotes economic freedom while constitutional review promotes political freedom.

Several authors (Rose, 1990; Matsuo, 1998; Rentz, 1998; Komarek et al., 2011; LaBelle, 2012) highlighted the importance and the role of governance and institutions on reducing countries' emission levels and increase countries' environmental quality. According to Panayotou (1997) the relationship of

environmental quality and income growth depends among other factors on government policies and institutions. Dinda (2004) emphasizes the authority's capacity to implement environmental regulation across countries as a main determinant of the economic growth-environmental quality relationship. Grossman and Krueger (1995) also consider government policy as an important factor of environmental quality pointing that as poor countries develop and become richer there is an increasing demand for environmental quality and 'environmental stringency' through governance and political institutions.

Furthermore, Arrow et al. (1995) and Kaufmann et al. (1998) recognize the need of inclusion of policy variables in order to describe the income- environment relationship throughout the growth process and the role of institutions. Institutional quality or governance, according to Kaufmann et al. (1999), includes firstly the process by which the authority is selected, secondly the government's ability to manage the resources and implement sound policies and finally the respect of the public for the institutions.

During the last two decades several variables for measuring governance (or institutional quality) have been presented in the literature. For instance Hall and Johnes (1999) following Knack and Keefer (1995) have used an index from Political Risk Services, the government antidiversion policies index consisting of the average from five categories. This measure has also been used by Acemoglu et al. (2001) and Glaeser et al. (2004). Moreover, Hall and Johnes (1999) employed the index of Sachs and Warner (1995) in relation to the openness of international trade.

Rodrik et al. (2002) and Glaezer et al. (2004) apply a combined index of government effectiveness constructed by Kaufmann et al. (2003) while Dollar and Kraay (2003) use an index which measures the quality of institutions constructed by

Kaufmann et al. (2002). Knack and Keefer (1995) measure institutions using two political instability proxies. The first measure, political violence, is introduced by Barro (1991) and is measured by revolutions and coups, and assassinations, while the second measure is based on Gastil index of democracy[1]. Finally, another approach is Business International (BI) indices which include corruption index used by Mauro (1995).

Given the fact that carbon dioxide (CO_2) emissions are the main determinant of countries' environmental quality which play a major role over global warming and climate change (Harvey, 1996; Ezcurra, 2007), our study uses for the first time the World Governance Indicators as have been provided by the World Bank in order to evaluate in a nonparametric context G-20 (Group of twenty) countries' carbon dioxide emissions and governance relationship.

2. A brief review of the relative literature

Governance (or institutional quality) is a multidimensional concept to be expressed by one indicator. Hence governance can be characterized by several aggregated indicators that each of them focuses on one specific dimension. Institutions contribute to the determination of public choice and therefore are of major importance in the enforcement and implementation of environmental quality regulation. Thus, the sustainability of natural resources and the conservation of the environment interact directly and indirectly with the institutional quality.

According to Deacon (1999), governments determine the implementation of the regulation of treatment of natural resources and thus the exclusion of the institutional quality of the estimation of the environmental quality might lead to

[1] Democracy Country Ratings (Gastil index of Democracy) can be obtained from: http://www.freedomhouse.org/.

biased results. Bhattaray and Hammig (2001) argue that institutions affect the income-environment relationship[2] trough the effectiveness of the exercised policy.

One of the dimensions that a large body of literature includes is the indicator of democracy. On the one hand democracy according to some surveys affect positively environment. Congleton (1992), with a cross-country analysis supports that more liberal democracies pose environmental regulations. Furthermore, Torras and Boyce (1998) and Barret and Graddy (2000) find a positive effect of civil rights and political liberties on the environment. Li and Reuveny (2006) examine statistically the effect of democracy on human-induced environmental deterioration. The results show that democracy has a positive effect on environmental quality.

Besides, Bernauer and Koubi (2009) combine in a statistical model economic, geophysical indicators and environmental variables with political ones such as democracy, labour union strength, green party strength, civil liberties and presidential versus parliamentary systems. Concerning the empirical findings, democracy level, presidential systems and green parties' strength contribute positively to air quality. Neumayer (2002) verifies the positive relationship democracy- environmental commitment via a cross-country analysis, including civil rights, political freedom, voice and accountability indicators.

On the other hand, Midlarsky (1998) using measures of environmental protection and democracy level determinants in a multiple regression, concludes that the hypothesis of positive contribution of democracy in environment necessitates does

[2] The income-environmental quality relationship relies on the idea examined first by Kuznets (1955) who found an inverted 'U'-shaped relationship between growth and income inequality. This was then tested in an Environmental Economics framework known as the Environmental Kuznets Curve (EKC) hypothesis. Several studies have verified the EKC hypothesis by proving empirical country level evidence (Ekins, 1997; Stern, 1998, 2002, 2004; Ansuategi and Perrings, 2000; Cavlovic et al., 2000; Andreoni and Levinson, 2001; Antweiler et al., 2001; Bulte and van Soest, 2001; Dasgupta et al., 2002; Halkos, 2003).

not hold. Chang and Cho (2005) also claim the negative relationship of democracy and the environmental conditions.

Another dimension of institutional quality is the corruption determinant. According to Pellegrini and Gerlagh (2006) a broader definition of democracy includes also the measurement of corruption which affects the environmental stringency negatively.

Welsch (2004) using cross-country regressions tests the effect of corruption at given level of income in the cases of air and water pollution. The effect of corruption is noticeable in developing countries due to amendment of their environmental quality. Cole (2007) concludes rectifying the absence of the endogeneity of the corruption in the results of Welsch's study that the total impact of corruption in air pollution is negative for high income countries.

Fredriksson and Svensson (2003) investigate the separate impact of corruption and political instability variable on the implementation of environmental policy in the agricultural sector through a cross-country analysis. The variables of corruption and political instability interact and play a crucial role in the domain of environmental policy regulation.

Additionally, Damania et al. (2003) explore and verify the negative relationship between corruption and environment by extending the analysis considering the effect of trade. Dutt (2009) tries to analyze the environment-income relationship in the context of governance and institutions such as accountability of government, quality of policy services, index of corruption and political liberties and civil rights. Bhattarai and Hamming (2004) examine the existence of EKC including the rule of law along with institutional indicators like corruption, bureaucracy and

civil rights. The study confirms the hypothesis of the importance of governance factors.

Rule of law indicators include the contract enforceability and property rights determinants. Kerekes (2011) in the context of a cross-country analysis indicate that property rights are positively correlated with air pollution but negatively with water and land degradation. Culas (2007) studies the EKC relationship between income and deforestation including institutional factors such as enforceability of contracts and the efficiency of bureaucracy which represents the government effectiveness dimension.

Still, the above determinants play a crucial role for the protection of property rights which are important for economic growth. Bhattacharya and Lueck (2009) estimate the importance of two types of property rights (monotonic and non-motonic) in the framework of the income-environmental quality relationship which is confirmed in terms of an EKC hypothesis.

3 Data and Methodology

3.1 Description of variables

In order to examine the carbon dioxide emissions-governance relationship we use data for the time period 1996-2010, concerning the Group of twenty (G-20) countries[3]. These are countries from different development stages (i.e. they are advanced, developing and emerging countries) which together represent around 90% of global GDP, 80% of global trade and two-thirds of the world's population. In addition it is well-known that they are responsible for producing the majority of worldwide carbon dioxide emissions and for designing, implementing and imposing global environmental policies.

[3] The G-20 group includes 19 member countries (as in our study) and the European Union (for details see: http://www.g20.org).

In our analysis we are using as a metric of pollution for G-20 countries' carbon dioxide emissions (CarDio) measured in metric tones (International Energy Agency- IEA, 2011). In addition we are using the six governance measures (World Governance Indicators-WGI) provided by the World Bank as proxies of countries' governance quality (Kaufmann et al., 2006). The institutional quality indicator constitutes of six governance indices which are measured in units ranging from about -2.5 to 2.5. Higher values are related to higher governance quality. The indicators are constructed using an unobserved components methodology (Kaufmann et al., 2010).

More analytically[4]:

Voice and Accountability (VoicAccoun) captures perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media.

Political Stability and Absence of Violence (PolStab) measures the perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including domestic violence and terrorism.

Government Effectiveness (GovEff) captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.

Regulatory Quality (RegQual) captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.

[4] The definitions are taken from World Bank's site at: http://info.worldbank.org/governance/wgi/resources.htm.

Rule of Law (RuLaw) captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.

Control of Corruption (ConCorr) captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.

Table 1 presents the descriptive statistics of the variables used in our analysis. As can be observed from the standard deviations there are a lot of disparities among the nineteen countries under consideration. In addition, we follow the natural grouping between the nineteen nations (see table 1) adopted in South Korea meeting in 2010. This grouping has been in place for country members to be able to decide which nation gets to chair for the G-20 leaders' meeting for a given year (Carin, 2010)[5].

As has been mentioned by Huynh and Jachno-Chavéz (2009) nonparametric techniques are suitable for analyzing WGI since will take into consideration differences among countries in different regions, making comparisons valid in a unifying estimation framework. In addition they highlight that when analyzing WGI measures in a nonparametric setting there is no need of correction of standard errors and/or testing techniques since the governance measures are generated from parametric models and their precision is dominated by the overall slow rate of convergence of the nonparametric estimators applied (Sperlich, 2009).

[5] We follow this sub-grouping in our analysis since it represents the "natural-internal" dynamics existing within the G-20 nations and thus it will provide us with further information regarding the global governance-carbon dioxide emissions relationship.

Table 1: Descriptive statistics of variables for the period 1996-2010

Variables	***CarDio***	***VoicAccoun***	***PolStab***	***GovEff***	***RegQual***	***RuLaw***	***ConCorr***
Mean	301272.76690	0.48106	0.07682	0.71775	0.61177	0.52688	0.54662
Std	427922.78260	0.85368	0.84836	0.81751	0.76001	0.92624	1.01307
Min	8208.00000	-1.70412	-2.12546	-0.76010	-0.92848	-1.07124	-1.13966
Max	2092239.16667	1.67285	1.39664	2.03012	2.03504	1.82570	2.23786
Group 1	***Group 2***	***Group 3***	***Group 4***	***Group 5***			
Australia	*India*	*Argentina*	*France*	*China*			
Canada	*Russia*	*Brazil*	*Germany*	*Indonesia*			
Saudi Arabia	*South Africa*	*Mexico*	*Italy*	*Japan*			
United States	*Turkey*	-	*UK*	*South Korea*			

Therefore, in our case the investigation of the carbon dioxide emissions-governance relationship for a country i at time t can be represented as:

$$E\left[\mathrm{CarDio}_{it}\middle|\mathrm{VoicAccoun}_{it},\mathrm{PolStab}_{it},\mathrm{GovEff}_{it},\mathrm{RegQual}_{it},\mathrm{RuLaw}_{it},\mathrm{ConCorr}_{it}\right] = g\left(\mathrm{VoicAccoun}_{it},\mathrm{PolStab}_{it},\mathrm{GovEff}_{it},\mathrm{RegQual}_{it},\mathrm{RuLaw}_{it},\mathrm{ConCorr}_{it}\right) \quad (1).$$

Equation (1) presents the conditional mean of the underlined relationship and as can be observed $g(.)$ is assumed to be a smooth continuous but otherwise unknown function and therefore is not restricted to robust linear specifications.

3.2 Nonparametric analysis

Let the variable CarDio be the dependent variable denoted by y_i and the independent variables (VoicAccoun, PolStab, GovEff, RegQual, RuLaw and ConCorr) be represented as X_i which is a q-vector. We also assume that all are continuously distributed with a joint density $f(y,x)$, with a marginal density of X_i defined as $f(x)=\int f(y,x)dy$ and with the conditional density of y_i given X_i defined as $f(y|x)=f(y,x)/f(x)$. Then in a nonparametric setting the following regression function will take the form:

$$g(x) = E(y_i | X_i = x) \tag{2}.$$

Following Li and Racine (2007, Theorem 2.1, p.59) the regression function can be written as:

$$g(x) = \frac{\int y f(y,x) dy}{f(x)} \tag{3},$$

thus we can estimate g by replacing the density functions by their nonparametric estimates. Therefore the estimate of the joint density can be computed non-parametrically as:

$$\hat{f}(y,x) = \frac{1}{n|H|h_y} \sum_{i=1}^{n} K\left(H^{-1}(X_i - x)\right) k\left(\frac{y_i - y}{h_y}\right) \tag{4}.$$

Where h_y is a bandwidth for smoothing in the y direction, whereas $H = diag(h_1,...,h_q)$.

In addition $K(.)$ is a product kernel function and $k(.)$ is a univariate kernel function that satisfies the following conditions:

$$\int k(u) du = 1, \quad k(u) = k(-u), \quad \int u^2 k(u) du = \kappa_2 > 0 \tag{5}.$$

In equation (5) $k(u) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}u^2}$, $-\infty < u < \infty$ denotes the Gausian kernel (see for details Li and Racine, 2007, p. 8-11). Moreover, the nonparametric estimate of marginal density of X_i can be defined as:

$$\begin{aligned} \hat{f}(x) = \int \hat{f}(y,x) &= \frac{1}{n|H|h_y} \sum_{i=1}^{n} K\left(H^{-1}(X_i - x)\right) \int k\left(\frac{y_i - y}{h_y}\right) dy = \\ &= \frac{1}{n|H|} \sum_{i=1}^{n} K\left(H^{-1}(X_i - x)\right) \end{aligned} \tag{6},$$

and

$$\int y \hat{f}(y,x)dy = \frac{1}{n|H|h_y}\sum_{i=1}^{n} K\left(H^{-1}(X_i - x)\right)\int y k\left(\frac{y_i - y}{h_y}\right)dy$$
$$= \frac{1}{n|H|}\sum_{i=1}^{n} K\left(H^{-1}(X_i - x)\right)y_i \qquad (7).$$

Finally, the local constant estimator or the Nadaraya (1964), Watson (1964) nonparametric estimator can be obtained as:

$$\hat{g}(x) = \frac{\sum_{i=1}^{n} K\left(H^{-1}(X_i - x)\right)y_i}{\sum_{i=1}^{n} K\left(H^{-1}(X_i - x)\right)} \qquad (8).$$

A crucial point to our analysis is the choice of bandwidth (i.e. the smoothing parameter chosen). For that reason we follow the local constant (lc) least squares cross-validation approach introduced by Li and Racine (2007, p. 69) choosing $h_1,...,h_q$ to minimize the objective:

$$CV_{lc}(h_1,...,h_q) = n^{-1}\sum_{i=1}^{n}\left(y_i - \hat{g}_{-i}(X_i)\right)^2 M(X_i) \qquad (9),$$

where $\hat{g}_{-i}(X_i) = \sum_{l\neq i}^{n} y_l\left(K(X_i - X_l)/h\right)/\sum_{l\neq i}^{n}\left(K(X_i - X_l)/h\right)$, which is the leave–one-out kernel estimator of $g(X_i)$ and $0 \leq M(.) \leq 1$ is a weight function (for details see Li and Racine (2007), pp. 4-14).

4. Empirical results

Following Huynh and Jachno-Chavéz (2009) we construct conditional density plots between the six governance measures and countries' carbon dioxide emissions. Figure 1 presents the conditional density plots[6] between countries' carbon dioxide emissions and the six WGI variables. More analytically, subfigure 1a presents the conditional density plot of CarDio with VoicAccoun, subfigure 1b with PolStab,

[6] For bandwidth selection we have used the least-squares cross validation approach (Hall et al., 2004).

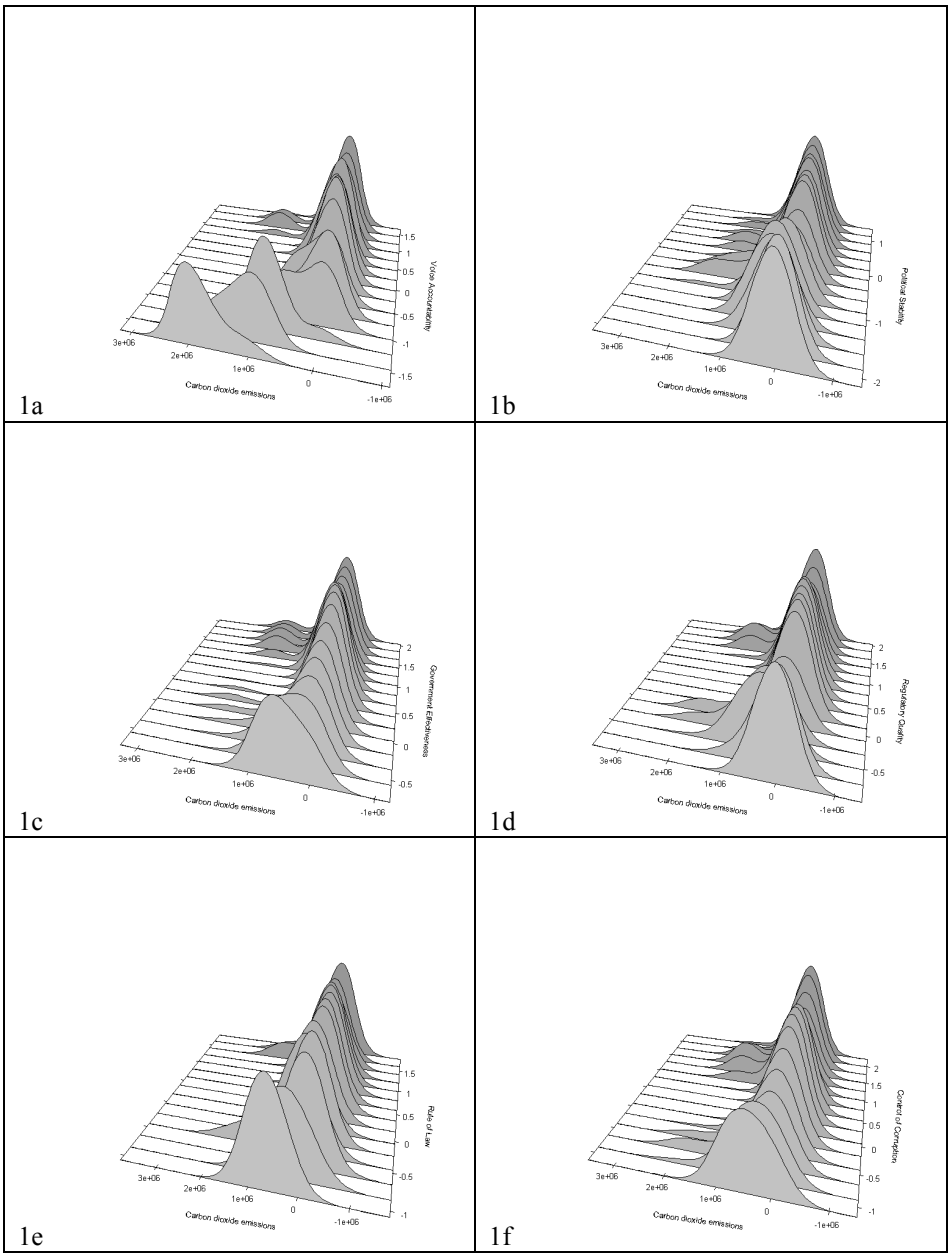
subfigure 1c with GovEff, subfigure 1d with RegQual, subfigure 1e with RuLaw and subfigure 1f with ConCorr. As can be observed there are large dispersions for lower levels of governance especially in the cases of Voice and Accountability, Government Effectiveness and Control of Corruption.

In addition it seems there is evidence of bi-modality for high values of governance and especially in the cases of Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality and for Control of Corruption. As stated by Huynh and Jachno-Chavéz (2007) conditional density plots provide us with more complete picture of the underlying processes generating countries' carbon dioxide emissions and governance.

Moreover, figure 2 displays the results from the estimations of nonparametric functions for 1996 (subfigure 2a), 2000 (subfigure 2b), 2005 (subfigure 2c) and 2010 (subfigure 2d). In order to understand the visualization of the effect of governance on countries' carbon dioxide emissions let us check the results obtained for the year 1996[7]. The top left panel in subfigure 2a indicates the effect of Voice Accountability on carbon dioxide emissions. Similarly, the top right panel indicates the effect of PolStab, the middle left panel indicates the effect of GovEff and the middle right the effect of RegQual. Finally, the third row of panels in subfigure 2a indicates the effect of RuLaw (bottom left panel) and the effect of ConCorr (bottom right panel).

[7] The results presented using partial regression plots (carbon dioxide emissions curves) since nonparametric methods do not yield scalar estimates of marginal effects (Huynh and Jachno-Chavéz, 2009, p. 128). In addition the significance nonparametric tests (analogue to the standard parametric t-test) introduced by Racine (1997), Racine et al. (2006), Li and Racine (2007) and Racine (2008) have been applied in order to check the significance of the governance variables on explaining the variations of countries' carbon dioxide emissions for each examined year (i.e. 1996, 2000, 2005 and 2010). The results obtained for each repressor using cross-validated bandwidths and 399 bootstrap replications reveal statistical significance for all the variables at different significance levels (1%, 5% and 10%). The analytical results from the significance tests are available upon request.

Figure 1: Conditional density plots of carbon dioxide emissions and governance



Generally, these curves are presenting the carbon dioxide emissions path of a country member of G-20 for a specific year in respect to a particular governance measure. In addition to the carbon dioxide emissions curves, the plots are also presenting the 90% bootstrap confidence intervals. Therefore, as can be observed the curves represent slices of the fitted hyperplane conditional on the examined variables. In the case of VoicAccoun the results reveal that regardless the examined year a

negative relationship (almost monotonic) of countries' voice accountability and carbon dioxide emissions is revealed. As a result the higher the VoicAccoun levels within the country the lower its carbon dioxide emissions will be.

In addition when looking at the case of Political Stability and Absence of Violence (PolStab) we realize that the effect on countries' CarDio levels is neutral except in the case of 2005 (subfigure 2c) where a negative effect emerges. Mixed results are also reported among the years for the case of Government Effectiveness (GovEff) on G-20 countries' CarDio levels. A negative relationship for 1996 and a positive relationship for 2000 are also recorded.

However, for the years 2005 (subfigure 2c) and 2010 (subfigure 2d) positive trends are recorded after certain GovEff levels, which after those particular levels the effect becomes neutral. Mixed results are also reported in the effect of Regulatory Quality (RegQual). Positive relationships for the years 1996, 2000 and 2005 are recorded but a negative relationship is realized for the year 2010 (subfigure 2d). When examining the effect of Rule of Law (RuLaw) on countries' CarDio levels a positive relationship is revealed for 1996, 2005 and 2010 and a negative relationship is recorded for the year 2000.

Finally the effect of Control of Corruption (ConCorr) appears to be negative for 2000, 2005 and 2010. But, for the year 1996 the relationship between countries' ConCorr and CarDio levels exhibit an inverted 'U' shape. As can be observed the results are mixed and subject to G-20 countries' governance changes over the years. Therefore, in order to 'grasp' the dynamic effects over the examine period (1996-2010) we apply the same analysis for all the years having in total 285 observations.

Figure 2: The yearly effect of governance on carbon dioxide emissions for 1996 (2a), 2000 (2b), 2005 (2c) and 2010 (2d).

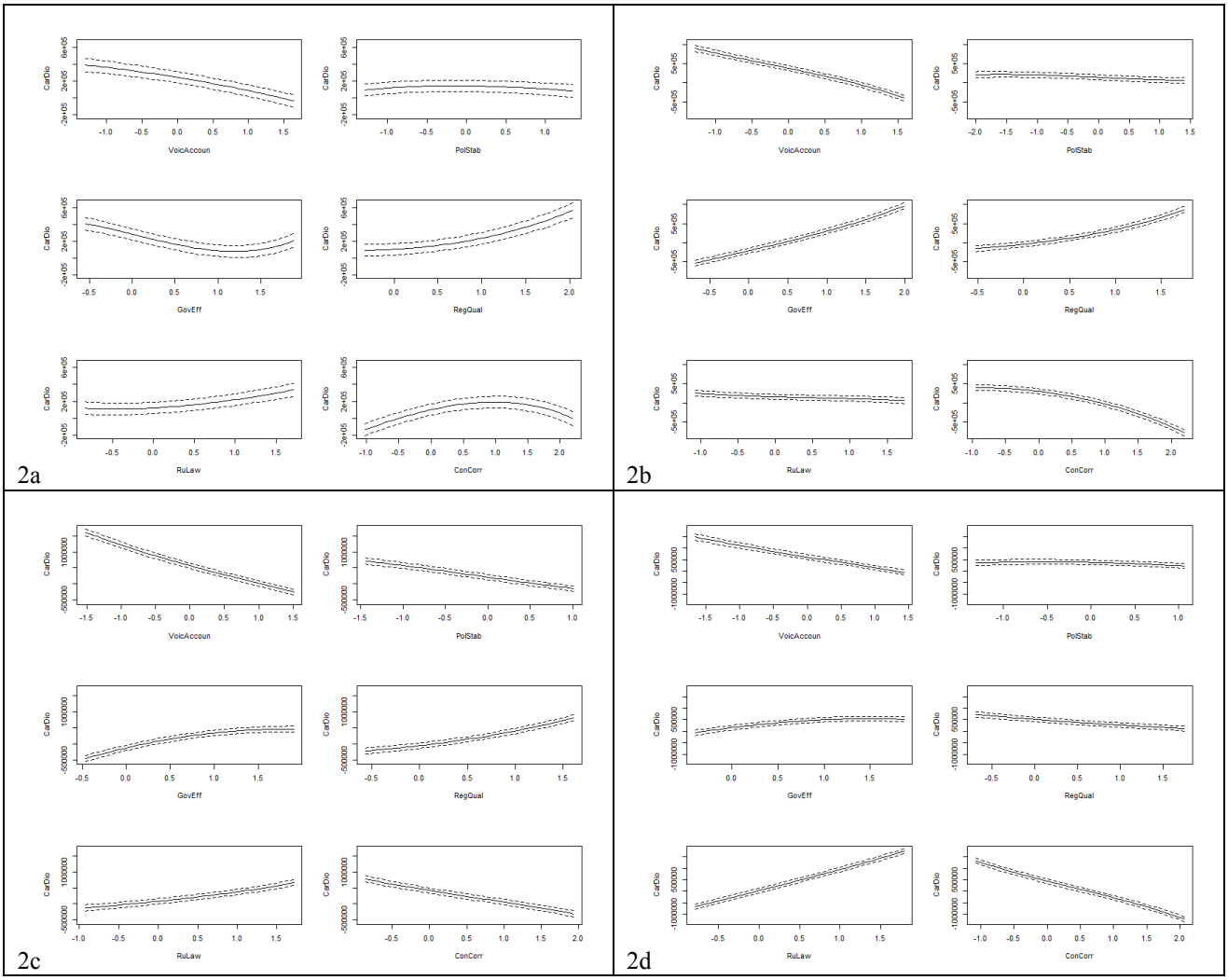


Figure 3 presents similar visualization for the G-20 countries as in figure 2. However since it takes into account the entire period rather than certain years, the dynamic effects of the underline relationships can also be observed more clearly. Furthermore 90% bootstrap confidence intervals based on 399 replications are presented[8]. In addition to figure 3, table 2 presents the obtained *p-values* of the nonparametric significance test following the bootstrap algorithms highlighted by Racine (1997), Racine et al. (2006), Li and Racine (2007) and Racine (2008). Table 2

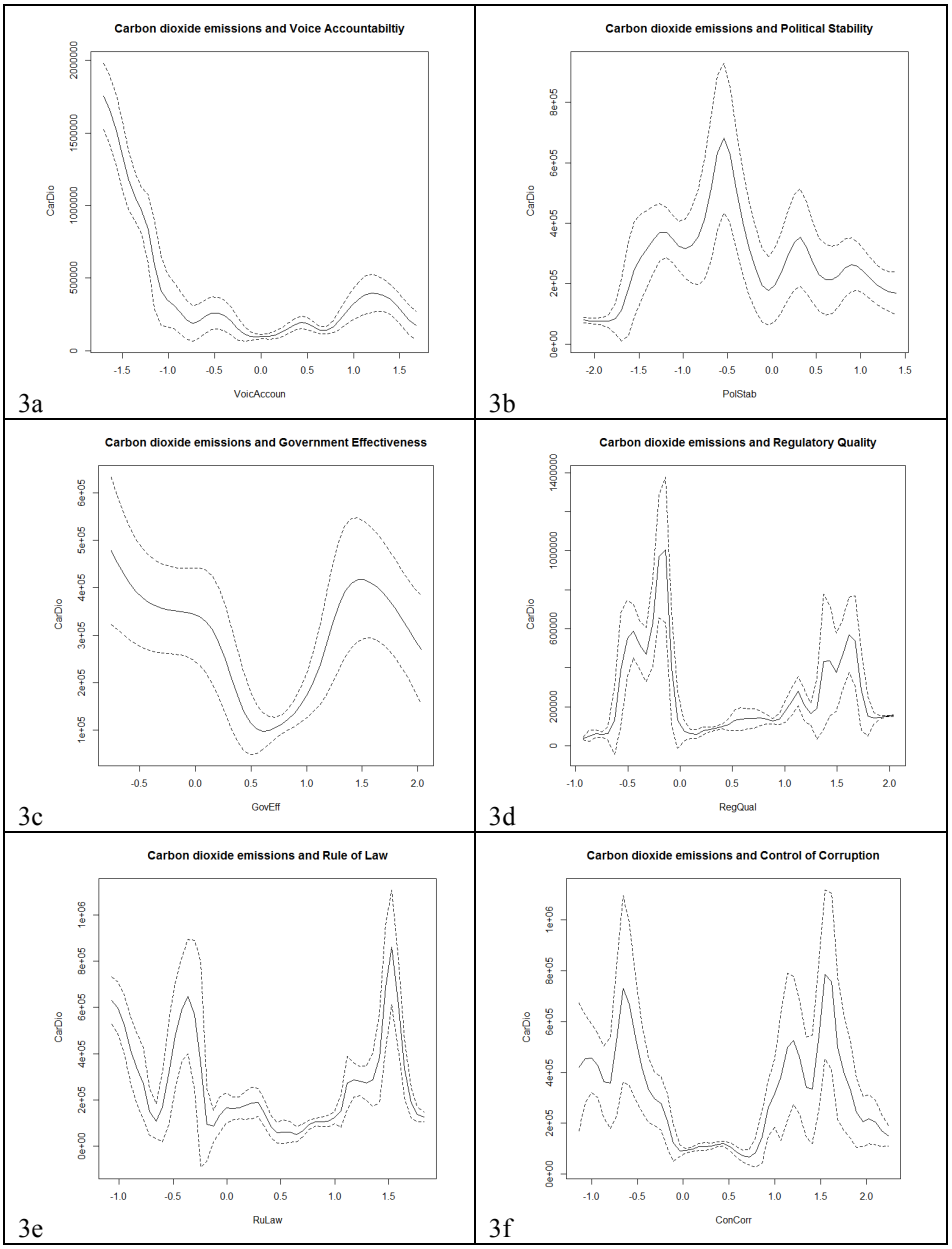
[8] Since they estimate stochastic variation of hyperplanes, and not of univariate functions the bootstrapped confidence intervals are not symmetric Huynh and Jachno-Chavéz (2009).

presents also the selected bandwidths following the local constant (lc) least squares cross-validation approach introduced by Li and Racine (2007, p. 69).

The results reveal that the governance variables are statistical significant (column labelled 'All Groups') at different levels on explaining G-20 carbon dioxide emissions variations for the time period 1996-2010. It appears that the effect of countries' VoicAccoun levels has a negative effect on carbon dioxide emissions up to a certain level and then the effect becomes rather neutral. The relationship between political stability and carbon dioxide emissions it appears to be highly nonlinear being positive up to a certain PolStab level (-0.5) and then becomes decreasing in a nonmonotonic way.

Furthermore, for the largest part of government effectiveness (subfigure 2c) a 'U' shape relationship (up to 1.5) is recorded and then the relationship becomes negative again. In the case of regulatory quality (subfigure 2d) it appears that for lower RegQual levels (-1.0 to 0.0) the relationship has the form of an inverted 'U' shape, having a starting positive effect and then after a certain RegQual level a sharp negative effect. In addition for positive values of RegQual the relationship appears to be positive again in a nonmonotonic form. Subfigure 2c presents the CarDio-RuLaw relationship. For a large part of RuLaw (up to 0.5) the relationship is decreasing indicating a negative effect of countries' rule of law levels on their carbon dioxide emissions.

Figure 3: Global effect of governance on G-20 carbon dioxide emissions for 1996-2010



However after that point the relationship appears to be increasing up to certain RuLaw level (1.5) and then decreasing again. Similar results are also reported for the case of control of corruption (subfigure 2f). There is a negative relationship up to a certain ConCorr level (0.8) which after that point the effect becomes positive, indicating that higher control of corruption increases countries' CarDio levels. But when ConCorr levels reach 1.7 then the effect after that point becomes negative again,

indicating that a further increase on countries' control of corruption will decrease their carbon dioxide emissions levels. The results reveal with the most emphatic way that the carbon dioxide emissions-governance relationship is highly nonlinear and appears that countries' higher governance quality does not always result to lower carbon dioxide emission levels.

Besides table 2 presents the bootstrapped *p-values* of the nonparametric significance tests[9] when performed for the different country groups (see also table 1). Therefore, we will be able to detect if governance variables are statistically significant for all the countries regardless the group they belong to. The results reveal that different governance variables are important for different country groups. For instance when looking at the statistical significance levels of the governance measures for the countries in Group 1 (Australia, Canada, Saudi Arabia and the United States), it is revealed that the rule of law and voice accountability do not affect those particular countries' CarDio levels.

Moreover, in the case of Group 2 (India, Russia, South Africa and Turkey) political stability appears to be the only influential factor. In contrast to Group 2 all governance factors appear to be important when explaining variations of CarDio levels for countries included in Group 3 (Argentina, Brazil and Mexico). Similarly, for Group 4 (France, Germany, Italy and the United Kingdom) government effectiveness, regulatory quality and the control of corruption seem to be the most influential factors on their carbon dioxide emissions levels. Finally, for Group 5 (China, Indonesia, Japan and South Korea) only regulatory quality and rule of law affect their carbon dioxide emission levels. Following those results it can be concluded that there is difference on the number of governance measures influencing

[9] Also table 2 presents the obtained bandwidths using the local constant (lc) least squares cross-validation approach presented previously.

countries' carbon dioxide emissions which is subject to regional/economic development variations.

Table 2: Results from the global effect of governance on G-20 countries' carbon dioxide emissions

	All Groups		**Group 1**		**Group 2**	
	p-value	*Bandwidth*	*p-value*	*Bandwidth*	*p-value*	*Bandwidth*
VoicAccoun	0.00251***	0.11865	0.61153	0.03206	0.54135	0.08624
PolStab	0.04261**	0.11456	0.03258**	0.18649	0.00000***	0.28518
GovEff	0.00501***	0.17338	0.05514*	0.08186	0.46867	0.10477
RegQual	0.02757**	0.02757	0.01003**	0.29978	0.78697	0.09231
RuLaw	0.00000***	0.05507	0.87469	0.03083	0.82957	0.10603
ConCorr	0.02506**	0.07275	0.04261**	0.16982	0.14035	0.13346
	Group 3		**Group 4**		**Group 5**	
	p-value	*Bandwidth*	*p-value*	*Bandwidth*	*p-value*	*Bandwidth*
VoicAccoun	0.02506**	0.05590	0.42857	0.02291	0.98652	0.02444
PolStab	0.04261**	0.26381	0.56892	0.06851	0.27820	0.17569
GovEff	0.05764*	0.07141	0.02757**	0.21454	0.27323	0.06877
RegQual	0.07769*	0.09860	0.05764*	0.07297	0.05013*	0.14190
RuLaw	0.03258**	0.10280	0.25063	0.04649	0.05263*	0.10344
ConCorr	0.00752***	0.09689	0.02757**	0.12851	0.12281	0.13434

10%, ** 5%, * 1% significance level*

5. Concluding remarks

This paper by using nonparametric methods analyzes for the first time the carbon dioxide emissions-governance relationship. With the help of several visualization methods the carbon dioxide emissions curves are produced investigating the relationship for the G-20 countries for the time period 1996-2010. The local constant estimator has been applied in our analysis alongside with least-squares cross validation approach for bandwidth selection. Moreover, nonparametric tests based on bootstrap procedures have been applied in order to reveal the statistical significance levels of countries governance measures on explaining CO_2 emissions variations.

In contrast to the parametric approaches, the flexible functional form of the nonparametric estimators applied, as they relax the assumptions of linearity, additivity and no interaction among the variables, helped us to reveal important features of the data. In addition the nonparametric methodology applied may help policy makers to understand "hidden" tradeoffs between countries' carbon dioxide emission levels and governance measures.

More analytically, our empirical results reveal that the carbon dioxide emissions – governance relationship is nonlinear. In addition it appears that different factors of governance influence differently countries' emissions levels. In respect to policy implications the results reveal that increased government quality does not ensure a reduction of countries' CO_2 emissions.

Finally, it appears that countries' regional and economic development variations are shaping the way and the number of governance measures influencing G-20 countries' carbon dioxide emissions levels. Therefore, CO_2 emissions reduction policies should be directed towards those governance measures which are specific to countries' unique regional and development factors.

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