Cross country comparisons of environmental efficiency under institutional quality. Evidence from European economies

Cristian Barra
Department of Economics and Statistics, University of Salerno, Fisciano, Italy, and
Pasquale Marcello Falcone
Department of Business and Economics, University of Naples Parthenope, Naples, Italy

Received 20 May 2023
Revised 26 July 2023
11 September 2023
Accepted 11 September 2023

Abstract

Purpose – The paper aims at addressing the following research questions: does institutional quality improve countries' environmental efficiency? And which pillars of institutional quality improve countries' environmental efficiency?

Design/methodology/approach – By specifying a directional distance function in the context of stochastic frontier method where GHG emissions are considered as the bad output and the GDP is referred as the desirable one, the work computes the environmental efficiency into the appraisal of a production function for the European countries over three decades.

Findings – According to the countries' performance, the findings confirm that high and upper middle-income countries have higher environmental efficiency compared to low middle-income countries. In this environmental context, the role of institutional quality turns out to be really important in improving the environmental efficiency for high income countries.

Originality/value – This article attempts to analyze the role of different dimensions of institutional quality in different European countries' performance – in terms of mitigating GHGs (undesirable output) – while trying to raise their economic performance through their GDP (desirable output).

Highlights

(1) The paper aims at addressing the following research question: does institutional quality improve countries' environmental efficiency?

(2) We adopt a directional distance function in the context of stochastic frontier method, considering 40 European economies over a 30-year time interval.

(3) The findings confirm that high and upper middle-income countries have higher environmental efficiency compared to low middle-income countries.

(4) The role of institutional quality turns out to be really important in improving the environmental efficiency for high income countries, while the performance decreases for the low middle-income countries.

Keywords Stochastic frontier, Environmental efficiency, Institutional quality, European countries

Paper type Research paper

1. Introduction and literature

Economic performance of a particular country/region is affected by possible inefficiency in production processes. Production factors like energy sources, capital and labor are employed to generate services and goods but, they concurrently produce undesirable outputs (e.g. carbon

JEL Classification — D24, O52, Q51

Journal of Economic Studies
Vol. 51 No. 9, 2024
pp. 75-111
Emerald Publishing Limited
0144-3585
DOI 10.1108/JES-05-2023-0264

dioxide, nitrous oxide emissions, etc.). The burning of fossil fuel for transportation, heat and electricity represents the primary source of greenhouse gas (GHG) emissions. Inefficiencies in the use of energy will bring even higher amount of pollutants (Caferra and Falcone, 2023). Therefore, it is paramount to direct energy and environmental policies towards an increasing share of renewables (Lopolito *et al.*, 2022) and a greater economic and environmental efficiency of public institutions (Yan *et al.*, 2023). Several scientific contributions demonstrate how environmental efficiency significantly increased as a result of tailored policies implementation (Hu *et al.*, 2023). Environmental strategies and policies have shown to be, oftentimes, effective for the reduction of GHGs and air pollutants such as nitrogen oxides and carbon monoxide (Nabernegg *et al.*, 2019; Walter, 2021). From nineties to the first decade of the new millennia, the EU and the US have extended environmental standards and simultaneously have verified significant decreases in emissions from manufacturing notwithstanding an intensification in output (Brunel, 2017; Levinson, 2015). Shapiro and Walker (2018) corroborated these results showing that the reduction of emissions is predominantly determined by within-product changes in emissions intensity rather than changes in output. Economic efficiency and environmental efficiency should be simultaneously pursued to guarantee economic performance, energy security and environmental sustainability for country's economy (Robaina-Alves *et al.*, 2015). Although a traditional fossil fuels oriented linear model can ensure economic efficiency based on industrially efficient and low-cost production processes or technologies, it can give also rise to environmental inefficiency due to the presence of higher level of pollutants or others environmental damages (D'Alisa *et al.*, 2017). To enhance environmental and economic efficiency, decision makers and businesses are embracing and stepping forward the circular economy idea by adopting eco-innovative advances also thanks to the implementation of environmentally friendly innovations (Aldieri *et al.*, 2020). The reason of focusing on circularity is based on the assumption that this would give rise to a reduction in resource consumption whereas maintaining the value of products and services, and mitigating the environmental impacts, over long term (D'Adamo *et al.*, 2022; Pamučar *et al.*, 2023). Recently, literature is emphasizing the relevance of such new perspective to measure productivity growth (see Halkos and Aslanidis, 2023).

In several circumstances, the production of a (desirable) good output causes also some (undesirable) bad outputs as by-products which could negatively affect the production of good outputs (i.e. inputs and outputs are potentially endogenous). Several approaches have been proposed and formalized to model pollutants as bad outputs (see Cherchye *et al.*, 2015). Hailu and Veeman (2001), treating bad outputs as inputs, review the pros and cons concerning the different techniques to environmentally adjusted analysis applicable to the Canadian pulp and paper industry. Färe *et al.* (2007), focusing on the U.S. coal-fired electric power plants for 1985–1995, incorporate environmental performance measures treating, as undesirable outputs, the pollutant emissions. The same treatment to the pollutants is reserved by Wang *et al.* (2013) who utilize the multi-directional efficiency analysis approach to investigate Chinese regional energy and emissions efficiency. Several contributions consider the emission of pollutants using the materials balance principle. For instance, Rødseth (2016), using a numerical example, proposes a novel measure for the environmental efficiency appraisal able to account for the efforts towards pollution control. Atkinson and Tsionas (2021) suggest two different functional relationships, imposing the parametric analog of materials balance, when considering the production of bad outputs and the use of bad inputs. Other authors use a different technology for undesirable and desirable outputs (e.g. Murty *et al.*, 2012; Sueyoshi and Goto, 2012). A promising method to encompass inefficiency into the appraisal of a production function is the use of a Stochastic Frontier Analysis (SFA) suggested by Aigner *et al.* (1977). Based on the review of the literature, principally at the macro perspective, there are few works investigating the environmental and economic efficiency, specifically in the use of SFA models. Castiglione *et al.* (2018)

emphasize that SFA, compared to the Data Envelopment Analysis (DEA), permits to face the occurrence of a possible random shock, affecting the production output, that is not controlled by the producer. Besides, Méon and Weill (2005) highlight that two-stages approaches, such as (DEA), are unreliable since they accept that the inefficiency component, in the first stage regression, is independently and identically distributed, but it is then infringed in the second stage.

The novelty of this work lies in its triple contribution, which addresses key gaps in the existing literature on the relationship between economic performance, environmental efficiency and institutional quality. Firstly, the paper introduces a directional distance function within the context of the stochastic frontier method, where greenhouse gas (GHG) emissions are considered as undesirable outputs and GDP as the desirable output. This novel approach allows for the computation of environmental efficiency as part of the overall production function for European countries over a three-decade period (1990–2019). By incorporating the Stochastic Frontier Analysis (SFA), the study enables cross-country comparisons of economic and environmental efficiency, providing valuable insights into how European countries have performed over time. This contributes to a better understanding of the interplay between economic growth and environmental sustainability, serving as a crucial resource for policymakers seeking to align economic and environmental objectives. Secondly, the work delves into the effect of institutional quality on countries' environmental efficiency, which is a relatively unexplored area in the literature. While previous research has acknowledged the impact of institutions on innovation systems and environmental sustainability, few studies have specifically analyzed how institutional quality influences environmental efficiency by affecting innovation systems (Canh *et al.*, 2019; Sun *et al.*, 2022). There is unanimity in recognizing that low quality of institutions is related to a lower efficiency (Barra and Ruggiero, 2022) due to three main motivations: 1) it represents a cost for innovators preventing thus, resources from productive activities; 2) it decreases the motivations for investment in innovative segments of the economy and 3) it hinders the knowledge diffusion promoting the growth of generic rather than specific forms of capital and disincentive foreign direct investments (Méon and Weill, 2005). Environmental economics literature unfolds that institutional quality fosters the environmental sustainability by decreasing emissions (Riti *et al.*, 2021; Tateishi *et al.*, 2020) and by alleviating the relationship between ecological pressure and the complexity of the economic system (Ahmad *et al.*, 2021). However, only a small number of studies have analyzed how environmental efficiency is impacted by the quality of institutions. For instance, Sun *et al.* (2019) found a significant positive influence of institutional quality on total factor energy efficiency. Tateishi *et al.* (2020) provide evidence that higher standards of political institutional quality were beneficial for environmental efficiency. Moreover, the literature is scarce in providing detailed information on the effect of different dimensions of institutional quality (e.g. control of corruption, government effectiveness, political stability, regulatory quality, etc.) towards environmental efficiency. This paper seeks to bridge this gap, with its third contribution, by investigating the relationship between different dimensions of institutional quality (e.g. control of corruption, government effectiveness, political stability, regulatory quality, etc.) and environmental efficiency. Understanding these relationships can provide deeper insights into the drivers of environmental efficiency and offer valuable guidance for policymakers looking to design effective institutional reforms to promote environmental sustainability. Specifically, the study aims to be one of the first attempts to analyze the role of various dimensions of institutional quality in the context of different European countries' performance. Purposely, it focuses on the mitigation of GHGs (as undesirable outputs) while simultaneously striving to improve economic performance through GDP (as desirable output). The research questions highlighted in the paper are:

RQ1. Does institutional quality improve countries' environmental efficiency?

RQ2. Which pillars of institutional quality improve countries' environmental efficiency?

By investigating the research questions, this paper seeks to bridge a significant gap in the existing literature, providing fresh perspectives on how institutional quality influences environmental efficiency in diverse European countries. The study aims to contribute valuable insights to our understanding of the role institutions play in promoting environmental sustainability. Moreover, the findings have the potential to guide policymakers in identifying specific areas where institutional reforms can enhance environmental efficiency and foster greener economic development.

Based on our preliminary results, we find that high and upper middle-income countries exhibit higher environmental efficiency compared to low middle-income countries. Notably, institutional quality plays a crucial role in improving environmental efficiency, particularly for high-income countries. In our analysis, when institutional quality is included in the model (using the Translog specification as the benchmark), the performance of high-income countries improves. Conversely, for low middle-income countries, the inclusion of institutional quality leads to a decrease in performance. This suggests that low middle-income countries may be hindered by their lower levels of institutional quality. These empirical findings indicate a positive correlation between institutional quality and environmental efficiency. In essence, economies with stronger and more effective institutions tend to achieve higher levels of environmental efficiency. This highlights the significance of fostering institutional reforms and promoting good governance practices to enhance environmental performance in countries with different income levels.

The work is organized as following: Section 2 introduces the methodology used to calculate the environmental efficiency and then the impact of institutional quality on the countries' performance. Section 3 describes the data employed, making more attention to the variables selected in order to measure the countries' performance, in addition to the indicators of institutional quality and other exogenous variables that allow to control for the environmental context. Section 4 shows the results about the environmental efficiency and the main differences between countries portioned by income. This section also presents the effect of the institutional quality, considering different dimensions, upon environmental inefficiency. Section 5 concludes, pointing out to the relevant policy implications.

2. A stochastic environment distance frontier

We adopt a Translog functional form as benchmark specification in the context of output directional distance function (hereafter DDF), which has more flexible properties than Cobb–Douglas (used as sensitivity analysis) in accordance with usual practice and in contrast to the primary empirical research. In our scenario, we incorporate two bad outputs (CO_2 emissions and nitrous oxide emissions) to check how countries perform in terms of environmental efficiency when this information is considered in the production function. Furthermore, Hausman's test (available on request) confirms that our model exploits fixed effects in the context of panel data (null hypothesis is largely rejected - p-value approaches 0) [1]. Basically, unlike the classic parametric method, this method can manage several outputs at the same time, overcoming one of the parametric method's shortcomings. Furthermore, when compared to the non-parametric method (Data Envelopment Analysis, DEA), it allows for the imposition of a functional relationship between inputs and outputs, allowing for a better understanding of the intensity with which the inputs affect the outcome. Finally, the parametric approach is unaffected by the presence of outliers, which is a common issue in non-parametric techniques and can distort the results.

For simplicity, hereafter in our formulation does not include a subscript t, but the inefficiency component is time varying in order to examine how the environmental (in) efficiency changes over time. Formally,

$$\ln\left(D_i^o\right)=\sum_{m=1}^{M}\alpha_m lny_{mi}+\sum_{k=1}^{K}\beta_k lnx_{ki}+\sum_{m=1}^{M}\sum_{k=1}^{K}\rho_{mk}\left(lny_{mi}*lnx_{ki}\right)+v_i \tag{1}$$

where y denotes the outputs vector (i.e. real gross domestic product per capita and carbon dioxide emissions metric tons per capita - for Specification A; adding also nitrous oxide emissions - for Specification B) and x the inputs vector (i.e. number of employees engaged and capital stock) [2] Normalizing by y_i, that guarantees the linear homogeneity of degree 1 in outputs ($\sum_{m=i}^{M}\alpha_m=1$) as suggested by Lovell *et al.* (1994), the output-oriented distance function becomes:

$$\ln\left(\frac{D_i}{y_i}\right)=\sum_{m=1}^{M}\alpha_m lny_{mi}+\sum_{k=1}^{K}\beta_k lnx_{ki}+\sum_{m=1}^{M}\sum_{k=1}^{K}\rho_{mk}\left(lny_{mi}*lnx_{ki}\right)+v_i \tag{2}$$

where $y_{mi}=\frac{y_{mi}}{yi}, y_{ni}=\frac{y_{ni}}{yi}$ and this $y_i=1$. Time dummies are also considered in order to capture exogenous or business cycle effects that can influence the production process of the decision-making units (i.e. country). It's obvious that lnD_i^o is not observable. Then, in order to solve this problem, we can re-written $\left(\frac{D_i}{y_i}\right)=\ln\left(D_i^o\right)-\ln(y_i)$. Thus, we transfer $\ln\left(D_i^o\right)$ to the residuals, that is on the right and side of equation, and using $-\ln(y_i)$ as dependent variable (i.e. real gross domestic product per capita) [3] (see Coelli and Perelman, 2000). In our case, we follow Paul *et al.* (2000), that is imposing $\ln(y_i)$. Equation (2) thus becomes:

$$\ln(y_i)=\sum_{m=1}^{M}\alpha_m lny_{mi}+\sum_{k=1}^{K}\beta_k lnx_{ki}+\sum_{m=1}^{M}\sum_{k=1}^{K}\rho_{mk}\left(lny_{mi}*lnx_{ki}\right)+v_i-u_i \tag{3}$$

where u term stands for inefficiency component, obtained from the truncation to zero of the distribution $N(m_i,\sigma_u^2)$, where $m_i=\mu+z_i\delta$, μ denoting the location parameter, z_i a vector of determinants of (technical) efficiency and δ is a vector of unknown coefficients; indeed v denotes the vector of random variables assumed to be i.i.d. $N(0,\sigma_v^2)$, and independent of the u. In other words, the inefficiency of country i is assumed to systematically vary with respect to some determinants. Time dummies are also included in order to capture the influence of exogenous factors. All monetary aggregates are deflated 2010 Dollars. Our sample begins in 1990 and ends in 2019, because some country-level data are not available before and after that range. All the regression analysis is carried out with STATA 14.2.

3. Research design

3.1 Selected inputs and outputs

The dataset refers to European countries over the period 1990–2019 and it has been constructed using data which are publicly available on the Penn Table website. We chose European countries for our research due to reliable data availability, facilitating consistent estimations. European countries were selected for several reasons: their diverse economies enable a comprehensive analysis of environmental efficiency and institutional quality across various economic contexts. Europe's robust datasets support rigorous empirical analysis, and its environmental policy history offers insights for regions seeking improved efficiency. EU integration encourages cooperation, exploring spillover effects in environmental policy.

European countries' global environmental influence necessitates understanding their efficiency and institutions for international sustainability efforts.

The sample is composed by 40 countries, each of which yields data over the thirty-year period, so we have a total of 1200 observations.

Referring to the literature on this subject, production technology is specified with two inputs: 1 - labor (number of employees engaged); 2 - capital stock (based on cumulating and depreciation past investments using the perpetual inventory method, PIM).

Moving to the output side, three measures are included in the model reflecting the output growth research functions of European countries: 1 - real gross domestic product per capita (in constant US dollars, at base year 2010); 2 - carbon dioxide per capita (stemming from the burning of fossil fuels and the manufacture of cement, including carbon dioxide produced during consumption of solid, liquid and gas fuels and gas faring) - for Specification A; adding also nitrous oxide emissions emitted during "agricultural, land use, and industrial activities; combustion of fossil fuels and solid waste; as well as during treatment of wastewater" - for Specification B.

3.2 Factors affecting country environmental (in)efficiency

At this stage, stochastic frontier scores are linked with several factors, in particular related to the institutional indicators and some characteristics of the marketplace and the environment where the institutions are located, that may influence countries' performances. These factors are modelled as variables, which directly influence the mean of the inefficiency term. In other words, they affect the efficiency with which inputs are converted into outputs. The model to be estimated takes on the following form:

$$\delta_{it} = \alpha + \sum_{k=i}^{K} Z_{it} + i_{it} \tag{4}$$

where Z denotes the vector of exogenous variables included in the component of inefficiency term, such as: Electric Power Consumption (kWh per capita; Source: World Bank; see Ang, 2007; Halicioglu, 2009; Jalil and Mahmud, 2009; Saboori and Sulaiman, 2013); Trade Freedom (Source: Heritage Foundation; see Jalil and Mahmud, 2009; Sharma, 2011); Urban Population (% of total; Source: World Bank; see Sharma, 2011) [4]. Since our contribution is to understand the role of the institutional quality on environmental inefficiency, the main variables are represented by Institutional Quality indicators (using both WB and ICRG database), accurately defined in the Supplementary Material (see Barra and Zotti, 2018; Barra and Ruggiero, 2022). Time trend have been included with the aim of capturing the inefficiency changes over time, while i refers to single country and t denotes time period.

3.3 Data

We merged five distinct datasets using the alpha three-digit code (ISO3) to evaluate environmental efficiency and subsequently the impact of institutional quality, assuring the sample's right construction. First, we used the data provided by the Penn Table to obtain information on the main inputs (capital stock and labor) and output (real gross domestic product). The information on environmental variables employed as alternative output (i.e. CO_2 pc) was obtained from the API (application programming interface) database, while the information about the institutional quality indicators included in the inefficiency component from the World Bank and Heritage Foundation sites.

Finally, information on institutional quality was obtained from two sources: World Bank Governance Indicators (WBGI) Dataset (developed by Kaufmann *et al.*, 2009) and International Country Risk Guide (ICRG) database. The use of two different sources for the institutional quality allows to corroborate our empirical findings, guaranteeing for a better comparison. To capture the overall effect of institutional quality on environmental inefficiency, we use two alternative indicators, denoted as WB and ICRG, respectively, computed as the average of all the six indicators (lie in the range [−2.5,2.5]. Higher scores imply higher institutional quality) available in the WBGI dataset and all the twelve indicators available in the ICRG dataset (Government Stability, Socioeconomic conditions, Investment Profile, Internal Conflict, External Conflict should lie in the range [0, 12]. Corruption, Military in Politics, Religious Tensions, Law and Order, Ethnic Tensions, Democratic Accountability should lie in the range [0, 6]. Bureaucracy Quality lies in the range [0, 4]).

The list of countries (portioned by income), statistics and pairwise correlation are presented in the Supplementary Material, with Table A1, Table A2 and Table A3, respectively.

Statistics, disaggregated by high, middle- and low-income countries in order to better appreciate the main environmental differences, are reported in Table A2. As it possible to notice, a dual structure characterizing the sample of countries (i.e. high-income vs low and middle income) is appreciable when considering both the determinants of institutional quality as well as the variables referring to production function. As expected, descriptive statistics show that high-income economies are characterized by a more consolidated economic structure, as marked by the level of real GDP, energy consumption, urban population, etc. A different picture arises when looking at the descriptive statistics concerning the environmental efficiency components, with the high-income countries registering the worst performance in terms of CO_2 emissions. The overall level of institutional quality depicts a situation in which, on average, low- and middle-income countries present frailer governance relatively to higher income countries. This is symptomatic of scarce levels of socio-economic development and a slow catching-up process with the most developed economies.

The correlations between the variables are shown in the Supplementary Material – Table A3. We will concentrate on the primary correlations, which are those between outputs and inputs as well as composite indicators of institutional quality (WB and ICRG). In general, the data show: (1) a negative association between real GDP, labor, capital, nitrous oxide emissions and the two composite indicators of institutional quality (WB and ICRG); and (2) a positive correlation between CO2 emissions and the two composite indicators of institutional quality (WB and ICRG).

4. Empirical evidence

4.1 Environmental efficiency

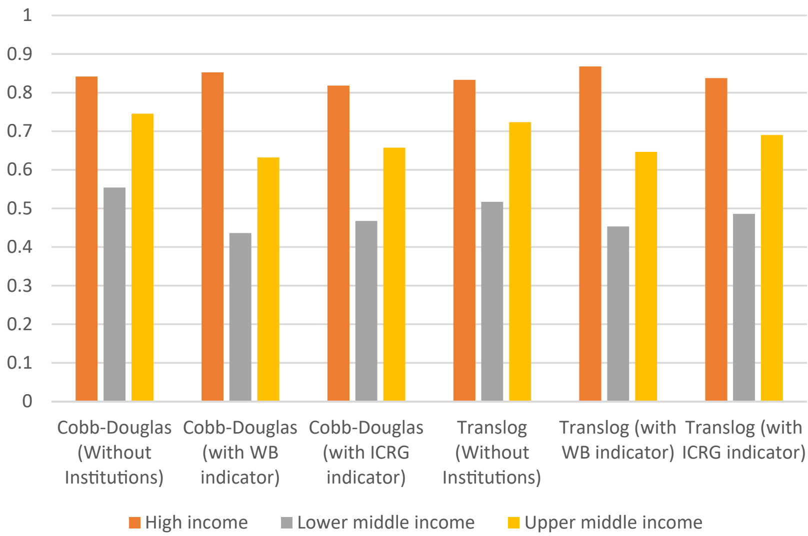
In this section, we present the environmental efficiency resulting from the model described in equation (3) focusing on two parametric specifications: Cobb–Douglas and Translog. The main difference between these two specifications is the functional form. Indeed, Cobb–Douglas is generally used, thanks to its simplicity of being linearized with the application of logarithms. Translog function allows obtaining a more realistic efficiency scores but has the issue of multicollinearity to account with. The second form is statistically equivalent to the first one, thus the rising gains of the estimation explain the application of the Translog function (our benchmark) to scrutinize the environmental efficiency.

We will start discussing the empirical findings considering these two functional forms, that is Cobb–Douglas and Translog, and considering CO_2 as a further output (Specification A). This allows to underline the advantage of using the directional distance function method, as it allows to manage multiple outputs simultaneously compared to the traditional parametric method. Furthermore, compared to the non-parametric method (i.e. Data Envelopment Analysis, DEA), it allows to impose a functional relationship between inputs and outputs, understanding the intensity of which the inputs affect the output. Moreover, the parametric approach is not influenced by the presence of outliers, a very frequent problem in non-parametric technique and with can bias the results.

For easier interpretation and better understanding of how countries perform based on similar characteristics (Symmetric case), we portioned countries into three main groups: High Income (HI), Low-Middle Income (LMI) and Upper-Middle Income (UMI) based on the information provided by the Eurostat site (for more information about these countries, see the Supplementary Material – Table A4 and Table A5).

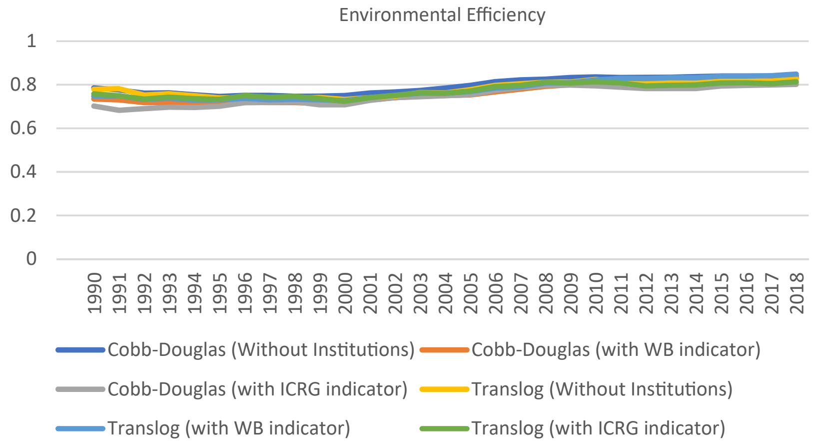
The results confirm that HI and UMI countries have higher environmental efficiency compared to LMI countries (Figure 1). Moreover, an improvement in the efficiency of the HI countries can be noted when the indicator of institutional quality has been inserted in the model (especially in the case of Translog specification, our benchmark), while the performance decreases for the LMI countries. Probably, this empirical finding could be explained because LMI countries present lower levels of institutional quality compared to other countries. In such countries, the lower quality of environmental efficiency can be attributed to two main factors. Firstly, weaker institutional quality, including corruption and ineffective governance, hampers the enforcement of environmental regulations and incentives for adopting eco-friendly technologies (Aldieri *et al.*, 2023). Secondly, limited financial resources and dependence on traditional industries with less efficient technologies pose challenges in transitioning to cleaner practices (Foster and Rosenzweig, 2010). Addressing both institutional quality and technology adoption is crucial to enhancing environmental efficiency in these countries.

The time series of environmental efficiency are very interesting. In fact, it emerges that, especially at the turn of 2004, environmental efficiency improved, increasing after that period (Figure 2). This could be due to different motivations. First, since the ratification of the Kyoto Protocol for the European Union (May 2002), several Member States have taken different initiatives to moderate emissions of greenhouse gases and this was notable in the average level of environmental efficiency, particularly on the period after the entry into force of the



Source(s): Authors own creation

Figure 1.
Environmental efficiency by income (specification A)



Source(s): Authors own creation

Figure 2. Environmental efficiency by year (specification A)

protocol on February 2005. Second, on July 2002 the European Parliament and the Council adopted the 6th Environment Action Program to set out the framework for environmental policy-making in the European Union for the period 2002–2012. Noteworthy, it offered discontinuity from the previous program finally moving from the remediation to prevention of environmental degradation by setting out key environmental objectives to be achieved in four thematic areas - climate change, nature and biodiversity, environment and health and natural resources and waste. Finally, the largest expansion of the EU, occurred on 1 May 2004, brought in ten new countries and a combined population of almost 75 million. A pre-condition the EU membership is the adoption and implementation of the EU community policies such as anti-dumping policy, state aid, competition policy and environmental policy with likely effects to economic and environmental efficiency for the accession countries.

As suggested by the literature (Kumbhakar and Malikov, 2018), often CO_2 and nitrous are used together in the production set as bad outcomes. Thereafter, to understand if our analysis, and therefore the environmental efficiency, has been influenced by the specification employed, we add in our production function the variable nitrous oxide emissions emitted during "agricultural, land use, and industrial activities; combustion of fossil fuels and solid waste; as well as during treatment of wastewater" from API database as output (Specification B). In this way, we insert another piece of information useful to improve and complete the production set, allowing a better juxtaposition to the frontier.

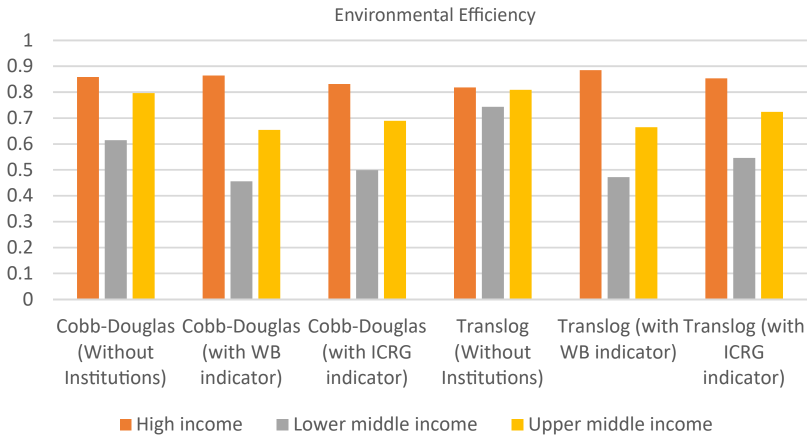
Apart from minor discrepancies, there are no discernible differences in environmental efficiency when countries are divided by portioned income (Figure 3).

When we examine the dynamics of efficiency through time (Figure 4), we may see subtle variations. Indeed, there is only a minor difference in the early period when Translog was implemented without institutions (countries begin with a lower degree of environmental efficiency than the scores achieved in Specification A).

4.2 Production function parameters: investigating the role of institutional quality

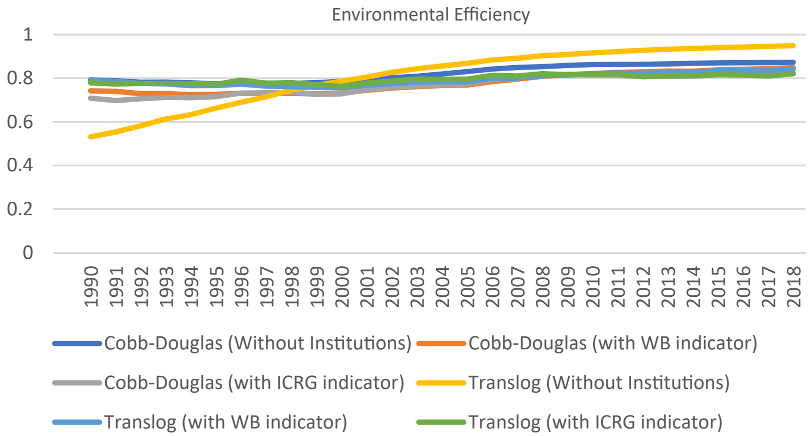
The results about the intensity of the institutional quality indicator upon environmental inefficiency has been presented in Table 1 (Specification A) and Table 2 (Specification B).

The determinants in the inefficiency component, such as WB (Mean), ICRG (Mean), ln(Electric Power Consumption), Trade Freedom, ln(Urban Population) and Trend, provide



Source(s): Authors own creation

Figure 3.
Environmental efficiency by income (specification B)



Source(s): Authors own creation

Figure 4.
Environmental efficiency by year (specification B)

insights into the factors affecting the environmental inefficiency of the countries. As benchmark, we consider the average of two institutional quality indicators based on two different sources, that is WB and ICRG [5]. Notably, WB and ICRG represent measures of institutional quality, and their negative coefficients suggest that higher institutional quality is associated with lower inefficiency, indicating that stronger institutions contribute to improved environmental efficiency. Let's delve into the quantitative explanations of these determinants:

(1) WB (Mean): The coefficient for WB is negative, and the value is around −0.667 to −0.675, depending on the model specification. This negative coefficient indicates that higher quality of governance is associated with lower inefficiency in the production process. In other words, countries with better institutional quality, characterized by effective and transparent governance structures, tend to have more efficient environmental practices.

y = ln(Real gross domestic product per capita)	(1) Cobb–douglas	(2) Cobb–douglas	(3) Cobb–douglas	(4) Translog	(5) Translog	(6) Translog
Production function parameters						
ln(Number of person engaged)	0.414***	0.535***	0.474***	0.349***	0.482***	0.400***
	[0.0208]	[0.0155]	[0.0182]	[0.0168]	[0.0140]	[0.0153]
ln(Capital stock)	0.611***	0.484***	0.543***	0.604***	0.506***	0.569***
	[0.0212]	[0.0155]	[0.0187]	[0.0163]	[0.0145]	[0.0159]
ln(CO_2 pc)	0.00270	−0.0124***	−0.0100	−0.0818***	−0.0655***	−0.0724***
	[0.00899]	[0.00456]	[0.00633]	[0.0115]	[0.00773]	[0.00977]
ln(Number of person engaged)^2				0.333***	0.318***	0.289***
				[0.0463]	[0.0350]	[0.0396]
ln(Capital stock)^2				0.232***	0.198***	0.202***
				[0.0359]	[0.0316]	[0.0331]
ln(Number of person engaged)*ln(Capital stock)				−0.541***	−0.501***	−0.474***
				[0.0659]	[0.0614]	[0.0625]
ln(CO_2 pc)^2				−0.00893***	−0.00543***	−0.00730***
				[0.00208]	[0.00135]	[0.00168]
ln(Number of person engaged)*ln(CO_2 pc)				−0.00377	0.000727	−0.00216
				[0.0234]	[0.0135]	[0.0181]
ln(Capital stock)*ln(CO_2 pc)				0.0152	0.00476	0.00944
				[0.0198]	[0.0118]	[0.0156]
Constant	0.247***	0.282***	0.346***	0.239***	0.235***	0.252***
	[0.0519]	[0.0415]	[0.0735]	[0.0430]	[0.0368]	[0.0408]
Determinants in the inefficiency component						
WB (Mean)		−0.677***			−0.753***	
		[0.0643]			[0.0702]	
ICRG (Mean)			−0.506***			−0.713***
			[0.0724]			[0.112]
ln(Electric power consumption)	−0.509	0.0168***	0.108***	−1.210	0.0134***	0.127***
	[1.469]	[0.00399]	[0.0118]	[1.225]	[0.00433]	[0.0165]

(*continued*)

Table 1.
Cobb–Douglas and translog parameters' estimation (Specification A)

Table 1.

y = ln(Real gross domestic product per capita)	(1) Cobb–douglas	(2) Cobb–douglas	(3) Cobb–douglas	(4) Translog	(5) Translog	(6) Translog
Trade freedom	−0.0366	−0.000482	−0.00673***	−0.0211	−0.000438	−0.00927***
	[0.0886]	[0.000414]	[0.00135]	[0.0208]	[0.000420]	[0.00208]
ln(Urban population)	0.370	−0.000242	0.0100	0.188	0.00347	0.0278
	[1.052]	[0.0100]	[0.0139]	[0.259]	[0.0104]	[0.0240]
Trend	−0.500	−0.0157***	−0.0182***	−0.187	−0.0171***	−0.0184***
	[1.263]	[0.00413]	[0.00596]	[0.199]	[0.00404]	[0.00695]
Country	40	40	40	40	40	40
Period	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019
Observations	1133	1133	1133	1133	1133	1133

Note(s): Standard errors in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$
Time dummies included in the production function, but not reported in the estimation
Source(s): Authors own creation

Table 2. Cobb–Douglas and translog parameters' estimation (Specification B)

y = ln(Real gross domestic product per capita)	(1) Cobb–douglas	(2) Cobb–douglas	(3) Cobb–douglas	(4) Translog	(5) Translog	(6) Translog
Production function parameters						
ln(Number of person engaged)	0.475***	0.566***	0.516***	0.427***	0.531***	0.462***
	[0.0236]	[0.0178]	[0.0204]	[0.0184]	[0.0143]	[0.0156]
ln(Capital stock)	0.528***	0.445***	0.490***	0.503***	0.472***	0.510***
	[0.0237]	[0.0187]	[0.0215]	[0.0191]	[0.0165]	[0.0200]
ln(CO_2 pc)	0.00153	−0.0120**	−0.00871	−0.0682***	−0.0486***	−0.0564***
	[0.00598]	[0.00466]	[0.00631]	[0.00805]	[0.00702]	[0.00890]
ln(Nitrous)	−0.196***	−0.0907***	−0.129***	−0.306***	−0.122***	−0.175***
	[0.0272]	[0.0196]	[0.0224]	[0.0208]	[0.0174]	[0.0286]
ln(Number of person engaged)^2				0.473***	0.584***	0.544***
				[0.0432]	[0.0425]	[0.0538]
ln(Capital stock)^2				0.210***	0.414***	0.347***
				[0.0389]	[0.0407]	[0.0551]
ln(Number of person engaged)*ln(Capital stock)				−0.685***	−0.989***	−0.880***
				[0.0757]	[0.0794]	[0.104]
ln(CO_2 pc)^2				−0.00561***	−0.00278**	−0.00395***
				[0.00124]	[0.00112]	[0.00132]
ln(Nitrous)^2				0.225***	0.356***	0.269***
				[0.0356]	[0.0283]	[0.0395]
ln(Number of person engaged)*ln(CO_2 pc)				0.0397***	0.0285***	0.0420***
				[0.00807]	[0.00881]	[0.00750]
ln(Capital stock)*ln(CO_2 pc)				−0.0242***	−0.0233***	−0.0309***
				[0.00778]	[0.00752]	[0.00626]
ln(Number of person engaged)*ln(Nitrous)				−0.503***	−0.431***	−0.451***
				[0.0314]	[0.0313]	[0.0387]
ln(Capital stock)*ln(Nitrous)				0.366***	0.405***	0.382***
				[0.0325]	[0.0311]	[0.0405]
ln(CO_2 pc)*ln(Nitrous)				−0.0436***	−0.0384**	−0.0446**
				[0.0152]	[0.0170]	[0.0178]

(*continued*)

Table 2.

y = ln(Real gross domestic product per capita)	(1) Cobb–douglas	(2) Cobb–douglas	(3) Cobb–douglas	(4) Translog	(5) Translog	(6) Translog
Constant	0.305***	0.301***	0.379***	0.852***	0.204***	0.310***
	[0.0572]	[0.0441]	[0.0808]	[0.113]	[0.0373]	[0.0661]
Determinants in the inefficiency component						
WB (MEAN)		−0.667***			−0.675***	
		[0.0685]			[0.0702]	
ICRG (Mean)			−0.458***			−0.442***
			[0.0827]			[0.126]
ln(Electric power consumption)	−0.141	0.0168***	0.0994***	0.0217***	0.0114***	0.0866***
	[0.255]	[0.00405]	[0.0129]	[0.00375]	[0.00317]	[0.0194]
Trade freedom	−0.0127	−0.000489	−0.00613***	0.000260	−0.000335	−0.00531***
	[0.0154]	[0.000405]	[0.00141]	[0.000346]	[0.000335]	[0.00188]
ln(Urban population)	0.104	−0.00303	0.00600	−0.00435	−0.00477	0.00146
	[0.209]	[0.0100]	[0.0135]	[0.00561]	[0.00779]	[0.0129]
Trend	−0.227	−0.0176***	−0.0209***	−0.0455***	−0.00676*	−0.00677
	[0.297]	[0.00416]	[0.00589]	[0.00949]	[0.00350]	[0.00495]
Country	40	40	40	40	40	40
Period	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019
Observations	1133	1133	1133	1133	1133	1133

Note(s): Standard errors in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$
Time dummies included in the production function, but not reported in the estimation
Source(s): Authors own creation

(2) ICRG (Mean): Similar to WB, the coefficient for ICRG is negative, and the value is around −0.458 to −0.442, depending on the model specification. This negative coefficient suggests that higher ICRG scores (representing better institutional quality) are associated with lower inefficiency, indicating that stronger institutions and reduced country risks contribute to improved environmental efficiency.

The Specifications adopted (A and B) show empirical findings very similar. Overall, institutional quality plays a key role in reducing environmental inefficiency. This means that if a country imposes efficient rules and fighting corruption would reach a higher degree of virtuosity, these could allow a better fit to the frontier, thus reducing environmental inefficiency and ensuring green growth as emphasized in Wang *et al.* (2023).

4.3 Assessing the role of different dimensions of institutional quality

It's often useful to understand the channel through which institutional quality can influence environmental efficiency. This can serve to explain the role of intuitions behind the empirical findings. In order to explore whether institutional factors, related to WB and ICRG, affect the variability of environmental efficiency, we proceed to include in the component of inefficiency (as explained in eq. 4) different dimensions of institutional quality.

We then proceeded to decompose the WB and ICRG indicators. In the first case (i.e. WB indicators), we have six dimensions, while in the second case (i.e. ICRG indicators), we can count on a broader disaggregation, relying on twelve dimensions (see the legend – below the Tables - for a summary about the in-depth definition of these indicators).

Table A6 reports the Translog parameters' estimation, focusing on the role of different dimensions of WB (Specification A). Each determinant has a negative and significant (1% level) corresponding coefficient, which indicates higher values of each governance determinant are associated with lower inefficiency in the production function analysis. Among the WB determinants, "PS" (political stability) has the largest negative coefficient, suggesting that it has the most significant impact on reducing inefficiency. Table A7 displays the Translog parameters' estimation considering the role of different dimensions of ICRG (Specification A). Consider both the magnitude (absolute values) and statistical significance (p-values) of the coefficients, and we can observe that, among the ICRG determinants, "ET" (ethnic tensions) has the largest negative coefficient and moderating them can be critical for promoting efficiency and economic performance in the analyzed context. When moving to Specification B, Table A8 and Table A9 detail the Translog parameters' estimation, focusing on the role of different dimensions of WB and ICRG, respectively. The measures of governance that have a preeminent impact on inefficiency is "RL" (rule of law) when considering different dimensions of WB and "SEC" (socioeconomic conditions) when considering different dimensions of ICRG.

5. Conclusions and discussions

Appraising economic development together with the environmental efficiency is paramount for judging the pace of transition towards sustainability. Climate change challenges necessitate tailored policies to curtail the pollution caused by the massive utilization of fossil fuels (D'Adamo *et al.*, 2020) and a growing amount of environmental economics literature has been dedicated to highlight that economic development of countries can bring to some environmentally detrimental consequences such as higher greenhouse gas emissions and more waste (İnal *et al.*, 2022; Jayachandran, 2022). This strand of literature, form different perspectives, has therefore attempted to mutually consider environmental efficiency when formulating undesirable outputs to calculate countries' performance. Although these contributions often contend that the economic development of countries, consumption of energy and environmental efficiency are strictly correlated, little is said on how institutional quality affects environmental efficiency.

In this work, considering 40 European economies over a 30-year time interval, we examine the impact of institutional quality towards environmental efficiency within the framework of a Stochastic Frontier Analysis. Our analysis adheres to the Kuznets curve as it provides evidence that HI countries have higher environmental efficiency when compared to LMI ones. Besides, the efficiency of HI countries becomes more marked when considering the institutional quality determinants with LMI countries presenting inferior levels of institutional quality compared to others. Robustness of results is demonstrated by adding in the production function another (bad) output, such as nitrous. Furthermore, the sensitivity analysis, based on the decomposition of the WB and ICRG indicators, corroborate the empirical evidence emphasizing, once again, that institutional quality acts as a decisive factor in safeguarding sustainability, through an improved environmental efficiency.

This study found a positive and significant impact of institutional quality on environmental efficiency. The intuition is that effective institutions can provide the necessary incentives and regulatory mechanisms to promote sustainable practices, leading to reduced emissions, better resource management and improved environmental performance (Barra and Ruggiero, 2022). The outcomes are consistent with findings of Sun *et al.* (2019) who carried out the study to find the effect of institutional quality and green innovation on technical energy efficiency. Moreover, institutional quality fosters the environmental efficiency of countries by decreasing emissions (Riti *et al.*, 2021; Tateishi *et al.*, 2020) and by alleviating the relationship between ecological pressure and the complexity of the economic system (Ahmad *et al.*, 2021).

The evidence testified in this work is not exempt from limitations mainly due to data availability. As more information is accessible and gathered, this analysis could expand and benefit, for example, by a more comprehensive list of pollutants (bad outputs), a larger sample of countries and the possibility to appreciate the effect of institutional quality determinants upon environmental efficiency across different sectors in the economy. Notwithstanding these drawbacks, we deem the study able to provide implications for policy making. Specifically, results highlight the key role of government effectiveness in ameliorating the environmental efficiency suggesting that policy actions, aimed at boosting the socio-economic development of LMI countries, should be pursued. For instance, policies able to direct the development path of less developed countries (e.g. improve the quality of infrastructures, reduce the digital divide, etc.) can favor cooperation, knowledge flow and learning mechanisms so as to activate and speed the catching-up process with the most developed economies. The evidence suggests that policies able to improve the quality of government represent a precondition to improve environmental efficiency of countries and we believe that such implication should be rooted in the European context. Indeed, Member States should be directed to undertake actions for ensuring transparency and quality of government regulations by monitoring, examining, developing and reporting on national regulatory decision-making processes. Paying particular attention to government quality and transparency is paramount because countries are learning from each other on how to progress regulations and this, in turn, could affect international trade, investment or other aspects of international relations with further positive effects on the economic and environmental dimensions of efficiency across the EU area. These reflections should be placed within the combination of recent shocks that unsettled worldwide economies. Precisely, the recent conflict in Ukraine, at time when many countries have yet to overcome the negative effects of the Covid-19 pandemic, risks to intensifies the composite policy trade-offs requiring judicious macroeconomic management (Falcone and Sica, 2023). This is particularly evident for LMI countries that have minimum space to engross negative impacts and foster resilience towards energy and food price increases. Multilateral cooperation and policy stability are paramount and might ease not only the socio-economic development of these areas but would also allow them to be embedded in the European context and to reduce the observed gap with the most developed areas. A future complementary line of research could be assessing the effect of the political uncertainty upon environmental efficiency of countries, also giving particular attention to the theory of Kuznets, being very relevant in this environmental context.

Notes

1. To determine whether analytic specification or estimator is appropriate, it is necessary to pick amongst the pooled regression, fixed effects and random effects models. The first step toward achieving this goal is to determine whether individual impacts are significant. If not, the pooled regression model is the best option. The Breusch–Pagan test (Breusch and Pagan, 1980) is used to assess this. The test results show that the constant coefficient model is incorrect for the data. In the second stage, choose between fixed effects and random effects models. The Hausman test is used to decide which choice is superior (Hausman, 1978; Hausman and McFadden, 1984). The null hypothesis states that the random effects model is the greatest option, whereas the alternative hypothesis states that the fixed effects model is the best option. The test results reject the null hypothesis, leading to the conclusion that the fixed coefficient model gives the most accurate estimating strategy for the data. For the sake of space conservation, these tests are available upon request.
2. We employ the Im *et al.*, (2003) technique to implement unit root tests to determine whether the variables employed display stationary behavior. The test results reject the null hypothesis for the inputs and outputs used in our specifications, confirming that panels are stationary. Other procedures, however, have been implemented, indicating that there is no unit root. For the sake of space conservation, these tests are available upon request.
3. However, using the other outputs as alternative dependent variables has no effect on the results and is therefore harmless.
4. See Barra and Zotti (2018) for a definition.
5. To address the absence of details for some variables and to ensure the construction of a very long-time frame (i.e. panel data) for our analysis, the imputation technique has been adopted.

References

Ahmad, M., Ahmed, Z., Majeed, A. and Huang, B. (2021), “An environmental impact assessment of economic complexity and energy consumption: does institutional quality make a difference?”, *Environmental Impact Assessment Review*, Vol. 89, 106603, doi: 10.1016/j.eiar.2021.106603.

Aigner, D., Lovell, C.A.K. and Schmidt, P. (1977), “Formulation and estimation of stochastic Frontier production function models”, *Journal of Econometrics*, Vol. 6 No. 1, pp. 21-37.

Aldieri, L., Barra, C., Ruggiero, N. and Vinci, C.P. (2020), “Innovative performance effects of institutional quality: an empirical investigation from the Triad”, *Applied Economics*, Vol. 52 No. 50, pp. 5464-5476.

Aldieri, L., Barra, C., Ruggiero, N. and Paolo Vinci, C. (2023), “Corruption and firms’ efficiency: international evidence using an instrumental variable approach”, *Economia Politica*, Vol. 40 No. 2, pp. 731-759.

Ang, J.B. (2007), “CO2 emissions, energy consumption, and output in France”, *Energy Policy*, Vol. 35 No. 10, pp. 4772-4778.

Atkinson, S.E. and Tsionas, M.G. (2021), “Generalized estimation of productivity with multiple bad outputs: the importance of materials balance constraints”, *European Journal of Operational Research*, Vol. 292 No. 3, pp. 1165-1186, doi: 10.1016/j.ejor.2020.11.025.

Barra, C. and Ruggiero, N. (2022), "How do dimensions of institutional quality improve Italian regional innovation system efficiency? The Knowledge production function using SFA", *Journal of Evolutionary Economics*, Vol. 32 No. 2, pp. 591-642.

Barra, C. and Zotti, R. (2018), "Investigating the non-linearity between national income and environmental pollution: international evidence of Kuznets curve", *Environmental Economics and Policy Studies*, Vol. 20, pp. 179-210.

Breusch, T.S. and Pagan, A.R. (1980), "The Lagrange multiplier test and its applications to model specification in econometrics", *The Review of Economic Studies*, Vol. 47 No. 1, pp. 239-253.

Brunel, C. (2017), "Pollution offshoring and emission reductions in EU and US manufacturing", *Environmental and Resource Economics*, Vol. 68 No. 3, pp. 621-641.

Caferra, R. and Falcone, P.M. (2023), "From the 'age of instability' to the 'age of responsibility': economic uncertainty and sustainable investments", *Journal of Economic Studies*, Vol. 50 No. 6, pp. 1297-1316.

Canh, N.P., Schinckus, C. and Thanh, S.D. (2019), "Do economic openness and institutional quality influence patents? Evidence from GMM systems estimates", *International Economics*, Vol. 157, pp. 134-169.

Castiglione, C., Infante, D. and Zieba, M. (2018), "Technical efficiency in the Italian performing arts companies", *Small Business Economics*, Vol. 51 No. 3, pp. 609-638.

Cherchye, L., Rock, B.De and Walheer, B. (2015), "Multi-output efficiency with good and bad outputs", *European Journal of Operational Research*, Vol. 240 No. 3, pp. 872-881, doi: 10.1016/j.ejor.2014.07.028.

Coelli, T. and Perelman, S. (2000), "Technical efficiency of European railways: a distance function approach", *Applied Economics*, Vol. 32 No. 15, pp. 1967-1976.

D'Adamo, I., Falcone, P.M., Imbert, E. and Morone, P. (2022), "Exploring regional transitions to the bioeconomy using a socio-economic indicator: the case of Italy", *Economia Politica*, Vol. 39 No. 3, pp. 989-1021.

D'Adamo, I., Falcone, P.M., Martin, M. and Rosa, P. (2020), "A sustainable revolution: let's go sustainable to get our globe cleaner", *Sustainability*, Vol. 12, p. 4387, doi: 10.3390/su12114387.

D'Alisa, G., Germani, A.R., Falcone, P.M. and Morone, P. (2017), "Political ecology of health in the Land of Fires: a hotspot of environmental crimes in the south of Italy", *Journal of Political Ecology*, Vol. 24 No. 1, pp. 59-86.

Färe, R., Grosskopf, S. and Pasurka, C.A. Jr (2007), "Environmental production functions and environmental directional distance functions", *Energy*, Vol. 32 No. 7, pp. 1055-1066.

Falcone, P.M. and Sica, E. (2023), *Sustainable Finance and the Global Health Crisis*, Taylor & Francis, Abingdon.

Foster, A.D. and Rosenzweig, M.R. (2010), "Microeconomics of technology adoption", *Annual review Economic*, Vol. 2 No. 1, pp. 395-424.

Hailu, A. and Veeman, T.S. (2001), "Alternative methods for environmentally adjusted productivity analysis", *Agricultural Economics*, Vol. 25 Nos 2-3, pp. 211-218.

Halicioglu, F. (2009), "An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey", *Energy Policy*, Vol. 37 No. 3, pp. 1156-1164.

Halkos, G.E. and Aslanidis, P.S.C. (2023), "New circular economy perspectives on measuring sustainable waste management productivity", *Economic Analysis and Policy*.

Hausman, J.A. (1978), "Specification tests in econometrics", *Econometrica: Journal of the Econometric Society*, pp. 1251-1271, doi: 10.2307/1913827.

Hausman, J. and McFadden, D. (1984), "Specification tests for the multinomial logit model", *Econometrica: Journal of the Econometric Society*, pp. 1219-1240, doi: 10.2307/1910997.

Hu, S., Wang, A., Du, K. and Si, L. (2023), "Can China railway express improve environmental efficiency? Evidence from China's cities", *Environmental Impact Assessment Review*, Vol. 99, 107005, doi: 10.1016/j.eiar.2022.107005.

Im, K.S., Pesaran, M.H. and Shin, Y. (2003), "Testing for unit roots in heterogeneous panels", *Journal of Econometrics*, Vol. 115 No. 1, pp. 53-74.

İnal, V., Addi, H.M., Çakmak, E.E., Torusdağ, M. and Çalışkan, M. (2022), "The nexus between renewable energy, CO2 emissions, and economic growth: empirical evidence from African oil-producing countries", *Energy Reports*, Vol. 8, pp. 1634-1643, doi: 10.1016/j.egyr.2021.12.051.

Jalil, A. and Mahmud, S.F. (2009), "Environment Kuznets curve for CO2 emissions: a cointegration analysis for China", *Energy Policy*, Vol. 37 No. 12, pp. 5167-5172.

Jayachandran, S. (2022), "How economic development influences the environment", *Annual Review of Economics*, Vol. 14, pp. 229-252.

Kaufmann, D., Kraay, A. and Mastruzzi, M. (2009), *Governance Matters VIII: Aggregate and Individual Governance Indicators, 1996-2008*, World Bank Policy Research Working Paper No. 4978, The World Bank, Washington, available at: https://ssrn.com/abstract=1424591.

Kumbhakar, S.C. and Malikov, E. (2018), "Good modeling of bad outputs: editors' introduction", *Empirical Economics*, Vol. 54, pp. 1-6.

Levinson, A. (2015), "A direct estimate of the technique effect: changes in the pollution intensity of US manufacturing, 1990-2008", *Journal of the Association of Environmental and Resource Economists*, Vol. 2 No. 1, pp. 43-56.

Lopolito, A., Falcone, P.M. and Sica, E. (2022), "The role of proximity in sustainability transitions: a technological niche evolution analysis", *Research Policy*, Vol. 51 No. 3, 104464.

Lovell, C.A.K., Travers, P., Richardson, S. and Wood, L. (1994), "Resources and functionings: a new view of inequality in Australia", in *Models and Measurement of Welfare and Inequality*, Springer, pp. 787-807.

Méon, P.-G. and Weill, L. (2005), "Does better governance foster efficiency? An aggregate Frontier analysis", *Economics of Governance*, Vol. 6 No. 1, pp. 75-90.

Murty, S., Russell, R.R. and Levkoff, S.B. (2012), "On modeling pollution-generating technologies", *Journal of Environmental Economics and Management*, Vol. 64 No. 1, pp. 117-135.

Nabernegg, S., Bednar-Friedl, B., Muñoz, P., Titz, M. and Vogel, J. (2019), "National policies for global emission reductions: effectiveness of carbon emission reductions in international supply chains", *Ecological Economics*, Vol. 158, pp. 146-157, doi: 10.1016/j.ecolecon.2018.12.006.

Pamučar, D., Durán-Romero, G., Yazdani, M. and López, A.M. (2023), "A decision analysis model for smart mobility system development under circular economy approach", *Socio-Economic Planning Sciences*, Vol. 86, 101474, doi: 10.1016/j.seps.2022.101474.

Paul, C.J.M., Johnston, W.E. and Frengley, G.A.G. (2000), "Efficiency in New Zealand sheep and beef farming: the impacts of regulatory reform", *Review of Economics and Statistics*, Vol. 82 No. 2, pp. 325-337.

Riti, J.S., Shu, Y. and Kamah, M. (2021), "Institutional quality and environmental sustainability: the role of freedom of press in most freedom of press countries", *Environmental Impact Assessment Review*, Vol. 91, 106656, doi: 10.1016/j.eiar.2021.106656.

Rødseth, K.L. (2016), "Environmental efficiency measurement and the materials balance condition reconsidered", *European Journal of Operational Research*, Vol. 250 No. 1, pp. 342-346.

Robaina-Alves, M., Moutinho, V. and Macedo, P. (2015), "A new Frontier approach to model the eco-efficiency in European countries", *Journal of Cleaner Production*, Vol. 103, pp. 562-573.

Saboori, B. and Sulaiman, J. (2013), "Environmental degradation, economic growth and energy consumption: evidence of the environmental Kuznets curve in Malaysia", *Energy Policy*, Vol. 60, pp. 892-905.

Shapiro, J.S. and Walker, R. (2018), "Why is pollution from US manufacturing declining? The roles of environmental regulation, productivity, and trade", *American Economic Review*, Vol. 108 No. 12, pp. 3814-3854.

Sharma, S.S. (2011), "Determinants of carbon dioxide emissions: empirical evidence from 69 countries", *Applied Energy*, Vol. 88 No. 1, pp. 376-382.

Sueyoshi, T. and Goto, M. (2012), "Data envelopment analysis for environmental assessment: comparison between public and private ownership in petroleum industry", *European Journal of Operational Research*, Vol. 216 No. 3, pp. 668-678.

Sun, H., Edziah, B.K., Sun, C. and Kporsu, A.K. (2019), "Institutional quality, green innovation and energy efficiency", *Energy Policy*, Vol. 135, 111002.

Sun, H., Edziah, B.K., Sun, C. and Kporsu, A.K. (2022), "Institutional quality and its spatial spillover effects on energy efficiency", *Socio-Economic Planning Sciences*, Vol. 83, 101023, doi: 10.1016/j.seps.2021.101023.

Tateishi, H.R., Bragagnolo, C. and de Faria, R.N. (2020), "Economic and environmental efficiencies of greenhouse gases' emissions under institutional influence", *Technological Forecasting and Social Change*, Vol. 161, 120321, doi: 10.1016/j.techfore.2020.120321.

Walter, J.M. (2021), "The political economy of market-based and information-based environmental policies", *International Review of Environmental and Resource Economics*, Vol. 15 No. 4, pp. 359-385, doi: 10.1561/101.00000137.

Wang, K., Wei, Y.-M. and Zhang, X. (2013), "Energy and emissions efficiency patterns of Chinese regions: a multi-directional efficiency analysis", *Applied Energy*, Vol. 104, pp. 105-116.

Wang, X., Wang, Y. and Wei, C. (2023), "The impact of natural resource abundance on green economic growth in the belt and road countries: the role of institutional quality", *Environmental Impact Assessment Review*, Vol. 98, 106977, doi: 10.1016/j.eiar.2022.106977.

Yan, J., Zeng, C., Zhou, X. and Wang, X. (2023), "Evaluation and comparative analysis of urban public institutions energy-environmental efficiency from the perspective of dual carbon", *Journal of Cleaner Production*, Vol. 414, 137732, doi: 10.1016/j.jclepro.2023.137732.

Further reading

Alvarado, R., Deng, Q., Tillaguango, B., Méndez, P., Bravo, D., Chamba, J., Alvarado-Lopez, M. and Ahmad, M. (2021), "Do economic development and human capital decrease non-renewable energy consumption? Evidence for OECD countries", *Energy*, Vol. 215, 119147.

Fang, Z. and Chen, Y. (2017), "Human capital and energy in economic growth–Evidence from Chinese provincial data", *Energy Economics*, Vol. 68, pp. 340-358.

Ouedraogo, I., Ngoa Tabi, H., Atangana Ondoa, H. and Jiya, A.N. (2022), "Institutional quality and human capital development in Africa", *Economic Systems*, Vol. 46 No. 1, 100937, doi: 10.1016/j.ecosys.2021.100937.

Twum, F.A., Long, X., Salman, M., Mensah, C.N., Kankam, W.A. and Tachie, A.K. (2021), "The influence of technological innovation and human capital on environmental efficiency among different regions in Asia-Pacific", *Environmental Science and Pollution Research*, Vol. 28, pp. 17119-17131.

Supplementary Material

High income (HI)	Low-middle income (LMI)	Upper-middle income (UMI)
Austria	Armenia	Albania
Belgium	Georgia	Azerbaijan
Cyprus	Kyrgyzstan	Belarus
Czech Republic	Rep of Moldova	Bosnia and Herzegovina
Denmark	Tajikistan	Bulgaria
Estonia	Ukraine	Croatia
Finland	Uzbekistan	Kazakhstan
France		Montenegro
Germany		North Macedonia
Greece		Romania
Hungary		Russian Federation
Iceland		Serbia
Ireland		Turkey
Italy		Turkmenistan
Latvia		
Lithuania		
Luxembourg		
Netherlands		
Norway		
Poland		
Portugal		
Slovakia		
Slovenia		
Spain		
Sweden		
Switzerland		
United Kingdom		

Source(s): Authors own creation

Table A1.
List of countries

Table A2.
Summary of statistics

	High income Mean	SD	Low-middle income Mean	SD	Upper-middle income Mean	SD	Full sample Mean	SD
Real GDP	7561.0707	10179.6140	2.6817e+08	1.8165e+09	6.7228e+08	8.4918e+09	2.0158e+08	4.4466e+09
Number of person engaged	7.7863	10.4277	7.7985	9.1978	11.5099	19.3105	8.8112	13.4912
Capital stock	35716.9336	48925.4665	1.4371e+09	9.5952e+09	3.3848e+09	4.2056e+10	1.0213e+09	2.2042e+10
CO_2 pc	5.1468e+14	3.0036e+14	3.1366e+14	2.2542e+14	3.5493e+14	2.5310e+14	4.5567e+14	2.9417e+14
Nitrous	10566.6795	13997.3834	8474.1111	11296.4216	12544.3636	17482.0711	10953.6000	14895.7793
Electric power consumption	4.4885e+14	2.8440e+14	2.4853e+14	1.4904e+14	2.9522e+14	3.1547e+14	3.9158e+14	2.9620e+14
Trade freedom	80.1551	10.6217	57.6133	59.3773	84.6291	44.0632	79.6948	30.1861
Urban population	63900.5038	26118.1184	51087.8159	22480.2386	54606.5125	19818.6762	60383.7046	24742.8741
Government stability	7.8251	1.9680	10.3690	5.5954	8.2157	3.2538	8.1233	2.8608
Socioeconomic conditions	7.5964	1.8851	3.8861	1.1956	4.7529	2.3789	6.5362	2.4701
Investment profile	9.3512	2.2596	7.1292	2.0884	6.9812	2.6484	8.5328	2.6100
Internal conflict	10.6025	1.2990	9.8620	2.1051	9.3072	1.7260	10.1907	1.6050
External conflict	10.8679	1.0438	9.3014	2.3664	9.3624	2.3261	10.3364	1.7702
Corruption	4.2524	1.1580	1.9342	0.4631	2.3127	1.1102	3.5451	1.4709
Military in politics	5.6557	0.5225	4.2324	0.5771	4.1074	1.0448	5.1232	1.0147
Religious tensions	5.3429	0.6585	5.4611	0.4985	4.9398	0.7923	5.2409	0.7126
Law and order	5.1220	0.9482	4.0062	0.6910	3.7140	0.7813	4.6511	1.0974
Ethnic tensions	4.4855	1.1197	5.0375	2.2537	3.8836	1.0897	4.3614	1.2746
Democratic accountability	5.6358	0.5637	4.8449	2.3518	2.7723	3.8527	4.7891	2.5052
Bureaucracy quality	3.4505	0.6100	1.1611	0.3659	1.5883	0.9918	2.7667	1.1839

(*continued*)

Table A2.

	High income Mean	SD	Low-middle income Mean	SD	Upper-middle income Mean	SD	Full sample Mean	SD
ICRG (Mean)	6.6823	0.6060	5.6021	1.0590	5.1615	0.7614	6.1831	0.9776
Control of corruption	1.2024	0.9192	−0.6425	0.3406	−0.5230	0.5956	0.5895	1.1635
Government effectiveness	1.3196	0.5870	−0.4162	0.3470	−0.1314	0.5940	0.7903	0.9245
Political stability	0.9045	0.4327	−0.6220	1.2932	−0.2328	0.7291	0.4772	0.8601
Rule of law	1.3036	0.6220	−0.5153	0.2851	−0.5311	0.5686	0.6626	1.0534
Regulatory quality	1.2809	0.4638	−0.1393	0.4222	−0.2720	0.7464	0.7473	0.9143
Voice and accountability	1.2384	0.3209	−0.3809	0.4712	−0.3216	0.7509	0.6879	0.8952
QG (Mean)	1.2083	0.4782	−0.4527	0.2261	−0.3353	0.4773	0.6591	0.8809
Observations	780		90		330		1200	

Note(s): Own elaboration; SD: standard deviation
Source(s): Authors own creation

Table A3.
Pairwise correlations

	Real GDP	Number of person engaged	Capital stock	CO_2 pc	Nitrous	Electric power consumption	Trade freedom	Urban population	Government stability	Socioeconomic conditions	Investment profile	Internal conflict	External conflict	Corruption
Real GDP	1.00													
Number of person engaged	0.08**	1.00												
Capital stock	1.00***	0.08***	1.00											
CO_2 pc	−0.06*	−0.07**	−0.06*	1.00										
Nitrous	0.12***	0.91***	0.13***	−0.04	1.00									
Electric power consumption	0.01	0.14***	0.02	0.11***	0.14***	1.00								
Trade freedom	−0.24***	−0.18***	−0.25***	0.09***	−0.18***	0.08**	1.00							
Urban population	0.01	0.03	0.01	0.05	0.04	0.06**	0.01	1.00						
Government stability	0.02	−0.04	0.02	−0.15***	−0.07**	−0.09***	−0.50***	−0.06*	1.00					
Socioeconomic conditions	−0.09***	−0.10***	−0.09***	0.16***	−0.10***	0.24***	0.24***	0.23***	−0.01	1.00				
Investment profile	−0.08***	−0.09***	−0.09***	0.11***	−0.15***	0.12***	0.20***	0.12***	0.11***	0.62***	1.00			
Internal conflict	0.15***	−0.34***	0.15***	0.02	−0.27***	0.01	−0.16***	0.07**	0.22***	0.23***	0.13***	1.00		
External conflict	0.01	−0.19***	0.01	0.11***	−0.10***	0.05	0.10***	0.01	−0.14***	0.12***	−0.05	0.45***	1.00	
Corruption	−0.01	−0.14***	−0.01	0.16***	−0.04	0.10***	0.04	0.24***	−0.05	0.47***	0.06**	0.40***	0.43***	1.00
Military in politics	−0.04	−0.17***	−0.04	0.21***	−0.12***	0.23***	0.12***	0.17***	−0.08***	0.56***	0.33***	0.52***	0.53***	0.56***
Religious tensions	0.04	−0.06**	0.04	0.02	−0.06*	−0.09***	−0.03	0.12***	0.08***	0.19***	0.07**	0.34***	0.21***	0.36***
Law and order	−0.04	−0.20***	−0.04	0.16***	−0.11***	0.12***	0.03	0.22***	−0.00	0.57***	0.21***	0.46***	0.42***	0.73***
Ethnic tensions	0.18***	−0.22***	0.18***	0.09***	−0.15***	−0.11***	−0.18***	0.08**	0.15***	0.09***	−0.05	0.45***	0.31***	0.32***
Democratic accountability	0.18***	−0.14***	0.18***	0.13***	−0.06**	0.08**	−0.28***	0.12***	0.13***	0.35***	0.26***	0.29***	0.15***	0.44***
Bureaucracy quality	−0.09***	−0.21***	−0.09***	0.25***	−0.10***	0.24***	0.18***	0.24***	−0.10***	0.67***	0.38***	0.36***	0.42***	0.77***
ICRG (Mean)	0.03	−0.25***	0.02	0.16***	−0.19***	0.13***	−0.06*	0.21***	0.28***	0.73***	0.55***	0.64***	0.44***	0.69***
Control of corruption	−0.07**	−0.21***	−0.07**	0.18***	−0.13***	0.13***	0.22***	0.24***	−0.03	0.69***	0.40***	0.39***	0.33***	0.78***

(*continued*)

	Real GDP	Number of person engaged	Capital stock	CO_2 pc	Nitrous	Electric power consumption	Trade freedom	Urban population	Government stability	Socioeconomic conditions	Investment profile	Internal conflict	External conflict	Corruption
Government effectiveness	−0.06*	−0.14***	−0.06*	0.18***	−0.06*	0.19***	0.20***	0.23***	−0.10***	0.73***	0.44***	0.33***	0.31***	0.72***
Political stability	−0.06**	−0.37***	−0.06**	0.13***	−0.31***	0.10***	0.16***	0.07**	−0.04	0.52***	0.33***	0.54***	0.51***	0.54***
Rule of law	−0.07**	−0.20***	−0.07**	0.20***	−0.12***	0.20***	0.23***	0.24***	−0.14***	0.74***	0.43***	0.31***	0.33***	0.76***
Regulatory quality	−0.01	−0.20***	−0.01	0.13***	−0.12***	0.18***	0.13***	0.18***	−0.05	0.69***	0.46***	0.34***	0.31***	0.69***
Voice and accountability	−0.11***	−0.24***	−0.11***	0.25***	−0.13***	0.18***	0.22***	0.21***	−0.23***	0.63***	0.41***	0.35***	0.42***	0.71***
QG (Mean)	−0.07**	−0.25***	−0.07**	0.19***	−0.16***	0.18***	0.21***	0.22***	−0.10***	0.73***	0.45***	0.41***	0.40***	0.77***

	Military in politics	Religious tensions	Law and order	Ethnic tensions	Democratic accountability	Bureaucracy quality	ICRG (mean)	Control of corruption	Government effectiveness	Political stability	Rule of law	Regulatory quality	Voice and accountability	QG (mean)
Real GDP														
Number of person engaged														
Capital stock														
CO_2 pc														
Nitrous														
Electric power consumption														
Trade freedom														
Urban population														
Government stability														
Socioeconomic conditions														
Investment profile														
Internal conflict														

(*continued*)

Table A3.

Table A3.

	Military in politics	Religious tensions	Law and order	Ethnic tensions	Democratic accountability	Bureaucracy quality	ICRG (mean)	Control of corruption	Government effectiveness	Political stability	Rule of law	Regulatory quality	Voice and accountability	QG (mean)
External conflict														
Corruption														
Military in politics	1.00													
Religious tensions	0.39***	1.00												
Law and order	0.62***	0.47***	1.00											
Ethnic tensions	0.43***	0.44***	0.39***	1.00										
Democratic accountability	0.48***	0.20***	0.39***	0.25***	1.00									
Bureaucracy quality	0.67***	0.24***	0.75***	0.22***	0.47***	1.00								
ICRG (Mean)	0.77***	0.46***	0.76***	0.48***	0.62***	0.78***	1.00							
Control of corruption	0.59***	0.32***	0.73***	0.23***	0.41***	0.84***	0.77***	1.00						
Government effectiveness	0.61***	0.25***	0.70***	0.17***	0.41***	0.86***	0.74***	0.90***	1.00					
Political stability	0.62***	0.28***	0.58***	0.34***	0.34***	0.68***	0.69***	0.68***	0.66***	1.00				
Rule of law	0.65***	0.32***	0.74***	0.21***	0.52***	0.86***	0.77***	0.89***	0.91***	0.69***	1.00			
Regulatory quality	0.60***	0.26***	0.63***	0.18***	0.58***	0.80***	0.76***	0.83***	0.85***	0.68***	0.90***	1.00		
Voice and accountability	0.69***	0.27***	0.67***	0.19***	0.56***	0.82***	0.72***	0.82***	0.83***	0.64***	0.88***	0.84***	1.00	
QG (Mean)	0.68***	0.31***	0.74***	0.24***	0.51***	0.89***	0.81***	0.94***	0.94***	0.79***	0.96***	0.93***	0.91***	1.00

Note(s): $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$
Source(s): Authors own creation

Country	Cobb–Douglas Without institutions	Cobb–Douglas With QG indicator (mean)	Cobb–Douglas With ICRG indicator (mean)	Translog Without institutions	Translog With QG indicator (mean)	Translog With ICRG indicator (mean)
Albania	0.6474	0.4613	0.4855	0.6525	0.5336	0.6093
Armenia	0.6823	0.5275	0.5700	0.6125	0.5375	0.5782
Austria	0.8710	0.9136	0.8715	0.8766	0.9247	0.8877
Azerbaijan	0.7035	0.5817	0.6320	0.6418	0.5324	0.6064
Belarus	0.6800	0.5448	0.5977	0.6833	0.5899	0.6509
Belgium	0.8723	0.9061	0.8624	0.8375	0.9000	0.8487
Bulgaria	0.9107	0.8438	0.8725	0.9107	0.8431	0.8920
Croatia	0.7938	0.7060	0.7039	0.8027	0.7667	0.7710
Cyprus	0.8157	0.8551	0.7916	0.7946	0.8581	0.8068
Czech Republic	0.7495	0.7359	0.6891	0.6835	0.7316	0.6812
Denmark	0.8832	0.9208	0.8794	0.8811	0.9282	0.8918
Estonia	0.8024	0.7621	0.7295	0.7653	0.7928	0.7521
Finland	0.8638	0.9098	0.8720	0.8233	0.9045	0.8582
France	0.8706	0.8937	0.8492	0.8859	0.9102	0.8767
Germany	0.8733	0.9000	0.8603	0.8917	0.9121	0.8863
Greece	0.7472	0.7357	0.6948	0.7158	0.7517	0.7116
Hungary	0.8517	0.8161	0.8070	0.8550	0.8467	0.8439
Iceland	0.8723	0.9175	0.8830	0.8846	0.9295	0.9040
Ireland	0.9229	0.9469	0.9274	0.9303	0.9539	0.9393
Italy	0.8329	0.8378	0.8086	0.8277	0.8554	0.8241
Kazakhstan	0.7000	0.5782	0.6327	0.6542	0.5810	0.6349
Latvia	0.7084	0.6562	0.6213	0.6839	0.6971	0.6650
Lithuania	0.8389	0.7891	0.7692	0.8676	0.8478	0.8440
Luxembourg	0.8795	0.9303	0.9027	0.7797	0.9018	0.8485
Montenegro	0.8904	0.8412	0.8284	0.9206	0.9106	0.9030
Norway	0.9229	0.9524	0.9338	0.9374	0.9599	0.9480
Poland	0.8755	0.8396	0.8398	0.8747	0.8401	0.8628
Portugal	0.7228	0.7405	0.6848	0.6917	0.7545	0.6978
Republic of Mold	0.5397	0.4213	0.4494	0.5354	0.4604	0.4921
Romania	0.8141	0.6761	0.7141	0.7082	0.6345	0.6817
Russian Federation	0.6265	0.5012	0.5178	0.5893	0.4999	0.5350
Serbia	0.5923	0.4885	0.4914	0.6008	0.5374	0.5537
Slovakia	0.8396	0.8111	0.7962	0.8698	0.8653	0.8596
Slovenia	0.7939	0.8039	0.7587	0.8058	0.8445	0.8062
Spain	0.8355	0.8468	0.7988	0.8401	0.8687	0.8291
Sweden	0.8698	0.9153	0.8776	0.8765	0.9270	0.8962
Switzerland	0.8873	0.9289	0.8978	0.8876	0.9345	0.9047
Turkey	0.8874	0.8087	0.8140	0.8746	0.7988	0.8382
Ukraine	0.4398	0.3602	0.3838	0.4033	0.3619	0.3873
United Kingdom	0.8856	0.9116	0.8773	0.9098	0.9280	0.9080
Mean (HI)	0.8417	0.8526	0.8182	0.8335	0.8677	0.8374
Mean (LMI)	0.5539	0.4363	0.4677	0.5170	0.4532	0.4858
Mean (UMI)	0.7455	0.6323	0.6575	0.7235	0.6467	0.6900
Mean (Full)	0.7945	0.7631	0.7494	0.7805	0.7782	0.7719

Source(s): Authors own creation

Table A4. Environmental efficiency by countries (N = 40) and years (1990–2019). Specification A

Country	Cobb–Douglas Without institutions	Cobb–Douglas With QG indicator (mean)	Cobb–Douglas With ICRG indicator (mean)	Translog Without institutions	Translog With QG indicator (mean)	Translog With ICRG indicator (mean)
Albania	0.7296	0.4929	0.5380	0.7900	0.5898	0.6658
Armenia	0.6849	0.5318	0.5750	0.7525	0.5255	0.6020
Austria	0.8643	0.9130	0.8647	0.8146	0.9344	0.8932
Azerbaijan	0.7301	0.5821	0.6363	0.7792	0.4416	0.5495
Belarus	0.8005	0.5997	0.6807	0.7972	0.6437	0.7553
Belgium	0.8818	0.9121	0.8698	0.8141	0.9212	0.8741
Bulgaria	0.9160	0.8524	0.8805	0.9017	0.8439	0.8928
Croatia	0.8316	0.7304	0.7350	0.8158	0.8070	0.8036
Cyprus	0.8231	0.8612	0.7955	0.8129	0.8842	0.8416
Czech Republic	0.7829	0.7549	0.7122	0.7478	0.7578	0.7059
Denmark	0.8993	0.9292	0.8939	0.8257	0.9413	0.9033
Estonia	0.8527	0.7966	0.7795	0.8071	0.8555	0.8122
Finland	0.8900	0.9225	0.8934	0.8081	0.9075	0.8610
France	0.8940	0.9072	0.8709	0.8680	0.9274	0.9061
Germany	0.8800	0.9051	0.8651	0.8327	0.9212	0.8888
Greece	0.7992	0.7617	0.7278	0.7874	0.7732	0.7437
Hungary	0.8747	0.8362	0.8307	0.8432	0.8767	0.8680
Iceland	0.8905	0.9261	0.8971	0.8154	0.9334	0.8956
Ireland	0.9408	0.9559	0.9434	0.8542	0.9357	0.9150
Italy	0.8403	0.8417	0.8100	0.8218	0.8792	0.8503
Kazakhstan	0.7722	0.6042	0.6768	0.7925	0.6283	0.7234
Latvia	0.7968	0.7012	0.6820	0.7833	0.7222	0.6969
Lithuania	0.8940	0.8369	0.8307	0.8847	0.9074	0.9102
Luxembourg	0.8548	0.9257	0.8884	0.8201	0.9268	0.8991
Montenegro	0.8809	0.8354	0.8133	0.9417	0.8857	0.8822
Norway	0.9191	0.9526	0.9316	0.8632	0.9670	0.9499
Poland	0.8946	0.8567	0.8573	0.8613	0.8804	0.8988
Portugal	0.7362	0.7484	0.6897	0.7464	0.7576	0.6972
Republic of Mold	0.5920	0.4389	0.4784	0.7466	0.4924	0.5533
Romania	0.8452	0.6967	0.7420	0.8186	0.6712	0.7429
Russian Federation	0.6886	0.5206	0.5477	0.7439	0.5005	0.5571
Serbia	0.6969	0.5270	0.5480	0.7315	0.5782	0.6171
Slovakia	0.8504	0.8202	0.8047	0.8132	0.8748	0.8525
Slovenia	0.7938	0.8065	0.7567	0.7911	0.8516	0.8116
Spain	0.8550	0.8588	0.8131	0.8220	0.8892	0.8515
Sweden	0.8663	0.9163	0.8746	0.7995	0.9381	0.8996
Switzerland	0.8440	0.9175	0.8660	0.7777	0.9138	0.8634
Turkey	0.8982	0.8216	0.8266	0.8454	0.8172	0.8466
Ukraine	0.5678	0.3953	0.4440	0.7311	0.3968	0.4818
United Kingdom	0.8916	0.9162	0.8816	0.8494	0.9327	0.9033
Mean (HI)	0.8580	0.8643	0.8317	0.8179	0.8847	0.8533
Mean (LMI)	0.6148	0.4553	0.4991	0.7434	0.4715	0.5457
Mean (UMI)	0.7962	0.6540	0.6892	0.8092	0.6643	0.7240
Mean (Full)	0.8232	0.7780	0.7689	0.8100	0.7954	0.7959

Source(s): Authors own creation

Table A5. Environmental efficiency by countries (N = 40) and years (1990–2019). Specification B

Table A6. Translog parameters' estimation. The role of different dimensions of WB (Specification A)

y = ln(Real gross domestic product pc)	(1)	(2)	(3)	(4)	(5)	(6)
Production function parameters						
ln(Number of person engaged)	0.482***	0.440***	0.498***	0.397***	0.447***	0.432***
	[0.0140]	[0.0149]	[0.0157]	[0.0165]	[0.0137]	[0.0150]
ln(Capital Stock)	0.506***	0.528***	0.484***	0.575***	0.548***	0.538***
	[0.0145]	[0.0161]	[0.0164]	[0.0154]	[0.0133]	[0.0151]
ln(CO_2 pc)	−0.0655***	−0.0725***	−0.0643***	−0.0787***	−0.0563***	−0.0760***
	[0.00773]	[0.00889]	[0.00792]	[0.00891]	[0.00782]	[0.00838]
ln(Number of person engaged)^2	0.318***	0.249***	0.317***	0.317***	0.331***	0.307***
	[0.0350]	[0.0407]	[0.0356]	[0.0401]	[0.0348]	[0.0349]
ln(Capital Stock)^2	0.198***	0.184***	0.201***	0.216***	0.199***	0.209***
	[0.0316]	[0.0363]	[0.0313]	[0.0340]	[0.0306]	[0.0303]
ln(Number of person engaged)*ln(Capital Stock)	−0.501***	−0.420***	−0.500***	−0.510***	−0.524***	−0.509***
	[0.0614]	[0.0693]	[0.0609]	[0.0669]	[0.0607]	[0.0590]
ln(CO_2 pc)^2	−0.00543***	−0.00770***	−0.00535***	−0.00837***	−0.00422***	−0.00709***
	[0.00135]	[0.00160]	[0.00140]	[0.00145]	[0.00132]	[0.00141]
ln(Number of person engaged)*ln(CO_2 pc)	0.000727	−0.00956	0.00638	−0.0100	0.00734	−0.00980
	[0.0135]	[0.0166]	[0.0144]	[0.0152]	[0.0116]	[0.0134]
ln(Capital Stock)*ln(CO_2 pc)	0.00476	0.0162	0.00313	0.0172	−0.00286	0.0134
	[0.0118]	[0.0145]	[0.0123]	[0.0131]	[0.0103]	[0.0118]
Constant	0.235***	0.246***	0.253***	0.287***	0.226***	0.274***
	[0.0368]	[0.0414]	[0.0373]	[0.0471]	[0.0350]	[0.0411]
Determinants in the inefficiency component	CORR	GE	PS	RQ	VOICE	RL
WB	−0.753***	−0.571***	−0.670***	−0.508***	−0.655***	−0.559***
	[0.0702]	[0.0644]	[0.0611]	[0.0772]	[0.0558]	[0.0559]
ln(Electric Power Consumption)	0.0134***	−0.00760	0.0172***	0.00551	0.0212***	0.00862
	[0.00433]	[0.00892]	[0.00359]	[0.00692]	[0.00459]	[0.00649]

(*continued*)

Table A6.

Determinants in the inefficiency component	CORR	GE	PS	RQ	VOICE	RL
Trade Freedom	−0.000438	0.00165	0.000401	0.0000370	−0.00359***	−0.000704
	[0.000420]	[0.00212]	[0.000473]	[0.000807]	[0.000544]	[0.000481]
ln(Urban Population)	0.00347	0.0220	0.00499	0.00778	−0.00189	0.0150
	[0.0104]	[0.0155]	[0.00779]	[0.0165]	[0.0114]	[0.0146]
Trend	−0.0171***	−0.00941**	−0.0197***	−0.0296***	−0.0117***	−0.0231***
	[0.00404]	[0.00450]	[0.00462]	[0.00660]	[0.00424]	[0.00561]
Country	40	40	40	40	40	40
Period	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019
Observations	1133	1133	1133	1133	1133	1133

Note(s): Standard errors in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$
Time dummies included in the production function; CORR (Control of Corruption): reflects 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 (higher values indicate strong governance performance in controlling corruption). It indicates the perceived overall level of corruption specifically referring to the abuse of public power for private gain. GE (Government Effectiveness) reflects perceptions of the quality of public ser-ices, 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. It is related to the quality of public service provision and the quality of the bureaucracy. PS (Political stability): measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism and represents the sustainability of governments. In countries with high political instability there is room for higher corruption and very poor accountability of public spending; RL (Rule of law): reflects 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. It is related to what extent an independent judiciary exists as well as civil rights are guaranteed and protected, reflecting whether there are fair judgements for people and organizations. Societies characterized by a high level of weakness in law may have more corruption and abuses in public administration; RQ (Regulatory quality): reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. It measures the incidence of market unfriendly policies such as price controls or inadequate bank supervision, as well as perceptions of the burdens imposed by excessive regulation in areas such as foreign trade and business development. VOICE (Voice and accountability): reflects 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 whether media are free. It measures various aspects of the political process such as civil liberties and political rights. It captures the equality of rights of all citizens and the extent to which citizens of a country are able to participate in the selection of governments as well as the independence of the media
Source(s): Authors own creation

y = ln(Real gross domestic product pc)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Production function parameters												
ln(Number of person engaged)	0.347***	0.413***	0.355***	0.356***	0.351***	0.405***	0.375***	0.352***	0.374***	0.350***	0.358***	0.425***
	[0.0167]	[0.0145]	[0.0159]	[0.0164]	[0.0166]	[0.0185]	[0.0163]	[0.0169]	[0.0173]	[0.0164]	[0.0161]	[0.0247]
ln(Capital Stock)	0.605***	0.554***	0.604***	0.609***	0.602***	0.556***	0.581***	0.602***	0.572***	0.607***	0.603***	0.530***
	[0.0161]	[0.0144]	[0.0157]	[0.0163]	[0.0165]	[0.0180]	[0.0164]	[0.0163]	[0.0191]	[0.0165]	[0.0160]	[0.0228]
ln(CO_2 pc)	−0.0823***	−0.0641***	−0.0803***	−0.0739***	−0.0826***	−0.0720***	−0.0792***	−0.0826***	−0.0868***	−0.0801***	−0.0744***	−0.0808***
	[0.0112]	[0.00850]	[0.0108]	[0.0111]	[0.0117]	[0.00928]	[0.0102]	[0.0114]	[0.0105]	[0.0116]	[0.0104]	[0.00910]
ln(Number of person engaged)^2	0.329***	0.246***	0.335***	0.330***	0.324***	0.250***	0.306***	0.330***	0.260***	0.334***	0.330***	0.248***
	[0.0455]	[0.0385]	[0.0441]	[0.0458]	[0.0454]	[0.0394]	[0.0412]	[0.0460]	[0.0473]	[0.0475]	[0.0433]	[0.0374]
ln(Capital Stock)^2	0.237***	0.173***	0.231***	0.221***	0.243***	0.192***	0.225***	0.232***	0.208***	0.228***	0.220***	0.182***
	[0.0356]	[0.0299]	[0.0354]	[0.0374]	[0.0368]	[0.0312]	[0.0330]	[0.0355]	[0.0349]	[0.0374]	[0.0345]	[0.0329]
ln(Number of person engaged)*ln(Capital Stock)	−0.544***	−0.404***	−0.545***	−0.529***	−0.545***	−0.433***	−0.512***	−0.539***	−0.446***	−0.537***	−0.531***	−0.413***
	[0.0660]	[0.0627]	[0.0656]	[0.0657]	[0.0655]	[0.0635]	[0.0626]	[0.0657]	[0.0717]	[0.0668]	[0.0647]	[0.0640]
ln(CO_2 pc)^2	−0.00910***	−0.00645***	−0.00880***	−0.00747***	−0.00924***	−0.00752***	−0.00858***	−0.00916***	−0.0102***	−0.00856***	−0.00736***	−0.00830***
	[0.00201]	[0.00136]	[0.00193]	[0.00210]	[0.00213]	[0.00145]	[0.00173]	[0.00206]	[0.00180]	[0.00220]	[0.00184]	[0.00158]
ln(Number of person engaged)*ln(CO_2 pc)	−0.00726	0.00499	−0.00565	0.00479	−0.0114	−0.00618	−0.00979	−0.00665	−0.0158	−0.00154	0.00523	−0.00713
	[0.0221]	[0.0121]	[0.0214]	[0.0249]	[0.0239]	[0.0132]	[0.0189]	[0.0231]	[0.0188]	[0.0253]	[0.0199]	[0.0138]
ln(Capital Stock)*ln(CO_2 pc)	0.0176	0.00391	0.0166	0.00554	0.0207	0.0118	0.0175	0.0177	0.0265	0.0126	0.00449	0.0159
	[0.0187]	[0.0108]	[0.0182]	[0.0209]	[0.0203]	[0.0117]	[0.0161]	[0.0196]	[0.0162]	[0.0214]	[0.0170]	[0.0123]
Constant	0.234***	0.235***	0.249***	0.228***	0.232***	0.253***	0.264***	0.244***	0.303***	0.230***	0.238***	0.357***
	[0.0414]	[0.0338]	[0.0436]	[0.0413]	[0.0416]	[0.0433]	[0.0426]	[0.0436]	[0.0530]	[0.0403]	[0.0415]	[0.0623]
Determinants in the inefficiency component	GS	SEC	IP	IC	EC	CORR	MP	RT	LO	ET	DA	BQ
ICRG	0.640	−0.353***	−0.225***	−0.654**	−1.635	−0.352***	−0.768***	−0.659	−0.393***	−5.627	−0.215***	−0.308***
	[0.721]	[0.0471]	[0.0455]	[0.295]	[3.365]	[0.0515]	[0.183]	[0.693]	[0.0658]	[6.046]	[0.0509]	[0.0476]
ln(Electric Power Consumption)	−0.702	0.0397***	0.0118	0.0510	−0.106	0.0388***	0.0746***	−1.085	0.0329*	−2.092	−0.00550	0.0320***
	[0.867]	[0.00638]	[0.0185]	[0.0439]	[0.440]	[0.00844]	[0.0186]	[0.979]	[0.0185]	[2.463]	[0.0243]	[0.00602]
Trade Freedom	0.0173	−0.0000835	−0.00829*	−0.00514	−0.0656	−0.00139	−0.00299*	−0.0198	−0.00107	−0.281	−0.0139***	−0.00105
	[0.0238]	[0.000407]	[0.00458]	[0.00553]	[0.133]	[0.000891]	[0.00180]	[0.0175]	[0.00156]	[0.281]	[0.00372]	[0.000959]
ln(Urban Population)	0.376	0.0191	0.0501	0.165	0.563	0.0133	0.0438	0.176	0.0509	2.741	0.0418	0.00735
	[0.509]	[0.0166]	[0.0365]	[0.136]	[1.269]	[0.0149]	[0.0431]	[0.222]	[0.0348]	[3.299]	[0.0478]	[0.00906]

(*continued*)

Table A7.
Translog parameters' estimation. The role of different dimensions of ICRG (Specification A)

Table A7.

Determinants in the inefficiency component	GS	SEC	IP	IC	EC	CORR	MP	RT	LO	ET	DA	BQ
Trend	−0.255	0.00298	0.0137	−0.108*	−0.521	−0.0313***	−0.0565***	−0.180	−0.0332***	−1.955	−0.0162	−0.0152***
	[0.308]	[0.00516]	[0.0124]	[0.0611]	[1.113]	[0.00761]	[0.0174]	[0.169]	[0.00833]	[2.087]	[0.0146]	[0.00548]
Country	40	40	40	40	40	40	40	40	40	40	40	40
Period	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019
Observations	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133

Note(s): Standard errors in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Time dummies included in the production function; GS (**Government Stability):** This is an assessment both of the government's ability to carry out its declared program(s), and its ability to stay in office. The risk rating assigned is the sum of three subcomponents, each with a maximum score of four points and a minimum score of 0 points. A score of 4 points equates to Very Low Risk and a score of 0 points to Very High Risk); **SC (Socioeconomic conditions):** This is an assessment of the socioeconomic pressures at work in society that could constrain government action or fuel social dissatisfaction. The risk rating assigned is the sum of three subcomponents, each with a maximum score of four points and a minimum score of 0 points. A score of 4 points equates to Very Low Risk and a score of 0 points to Very High Risk; **IP (Investment Profile):** This is an assessment of factors affecting the risk to investment that are not covered by other political, economic and financial risk components. The risk rating assigned is the sum of three subcomponents, each with a maximum score of four points and a minimum score of 0 points. A score of 4 points equates to Very Low Risk and a score of 0 points to Very High Risk; **IC (Internal Conflict):** This is an assessment of political violence in the country and its actual or potential impact on governance. The highest rating is given to those countries where there is no armed or civil opposition to the government and the government does not indulge in arbitrary violence, direct or indirect, against its own people. The lowest rating is given to a country embroiled in an on-going civil war. The risk rating assigned is the sum of three subcomponents, each with a maximum score of four points and a minimum score of 0 points. A score of 4 points equates to Very Low Risk and a score of 0 points to Very High Risk; **EC (External Conflict):** The external conflict measure is an assessment both of the risk to the incumbent government from foreign action, ranging from non-violent external pressure (diplomatic pressures, withholding of aid, trade restrictions, territorial disputes, sanctions, etc.) to violent external pressure (cross-border conflicts to all-out war); CORR (**Corruption):** This is an assessment of corruption within the political system. Such corruption is a threat to foreign investment for several reasons: it distorts the economic and financial environment; it reduces the efficiency of government and business by enabling people to assume positions of power through patronage rather than ability; and, last but not least, introduces an inherent instability into the political process; MP (**Military in Politics):** The military is not elected by anyone. Therefore, its involvement in politics, even at a peripheral level, is a diminution of democratic accountability. However, it also has other significant implications; RT (**Religious Tensions):** Religious tensions may stem from the domination of society and/or governance by a single religious group that seeks to replace civil law by religious law and to exclude other religions from the political and/or social process; the desire of a single religious group to dominate governance; the suppression of religious freedom; the desire of a religious group to express its own identity, separate from the country as a whole; LO (**Law and Order):** "Law and Order" form a single component, but its two elements are assessed separately, with each element being scored from zero to three points. To assess the "Law" element, the strength and impartiality of the legal system are considered, while the "Order" element is an assessment of popular observance of the law. Thus, a country can enjoy a high rating – 3 – in terms of its judicial system, but a low rating – 1 – if it suffers from a very high crime rate if the law is routinely ignored without effective sanction (for example, widespread illegal strikes); **ET (Ethnic Tensions):** This component is an assessment of the degree of tension within a country attributable to racial, nationality or language divisions. Lower ratings are given to countries where racial and nationality tensions are high because opposing groups are intolerant and unwilling to compromise. Higher ratings are given to countries where tensions are minimal, even though such differences may still exist; **DA (Democratic Accountability)**: This is a measure of how responsive government is to its people, on the basis that the less responsive it is, the more likely it is that the government will fall, peacefully in a democratic society, but possibly violently in a non-democratic one; BQ (**Bureaucracy Quality):** The institutional strength and quality of the bureaucracy is another shock absorber that tends to minimize revisions of policy when governments change. Therefore, high points are given to countries where the bureaucracy has the strength and expertise to govern without drastic changes in policy or interruptions in government services. In these low-risk countries, the bureaucracy tends to be somewhat autonomous from political pressure and to have an established mechanism for recruitment and training. Countries that lack the cushioning effect of a strong bureaucracy receive low points because a change in government tends to be traumatic in terms of policy formulation and day-to-day administrative functions

Source(s): Authors own creation

Table A8. Translog parameters' estimation. The role of different dimensions of WB (Specification B)

y = ln(Real gross domestic product pc)	(1)	(2)	(3)	(4)	(5)	(6)
Production function parameters						
ln(Number of person engaged)	0.495***	0.534***	0.461***	0.499***	0.507***	0.528***
	[0.0153]	[0.0162]	[0.0163]	[0.0141]	[0.0167]	[0.0151]
ln(Capital Stock)	0.486***	0.458***	0.519***	0.506***	0.475***	0.469***
	[0.0194]	[0.0195]	[0.0177]	[0.0161]	[0.0205]	[0.0182]
ln(CO_2 pc)	−0.0549***	−0.0521***	−0.0589***	−0.0393***	−0.0583***	−0.0476***
	[0.00829]	[0.00751]	[0.00793]	[0.00710]	[0.00783]	[0.00737]
ln(Nitrous)	−0.143***	−0.118***	−0.176***	−0.137***	−0.163***	−0.129***
	[0.0211]	[0.0180]	[0.0261]	[0.0190]	[0.0232]	[0.0182]
ln(Number of person engaged)^2	0.528***	0.547***	0.563***	0.579***	0.589***	0.538***
	[0.0520]	[0.0446]	[0.0508]	[0.0431]	[0.0431]	[0.0451]
ln(Capital Stock)^2	0.363***	0.364***	0.363***	0.396***	0.402***	0.366***
	[0.0501]	[0.0430]	[0.0503]	[0.0416]	[0.0432]	[0.0436]
ln(Number of person engaged)*ln(Capital Stock)	−0.882***	−0.901***	−0.913***	−0.974***	−0.993***	−0.893***
	[0.0973]	[0.0832]	[0.0967]	[0.0805]	[0.0810]	[0.0845]
ln(CO_2 pc)^2	−0.00438***	−0.00369***	−0.00464***	−0.00127	−0.00385***	−0.00259**
	[0.00135]	[0.00122]	[0.00117]	[0.00110]	[0.00115]	[0.00121]
ln(Nitrous)^2	0.297***	0.291***	0.298***	0.334***	0.371***	0.332***
	[0.0326]	[0.0298]	[0.0356]	[0.0293]	[0.0340]	[0.0282]
ln(Number of person engaged)*ln(CO_2 pc)	0.0312***	0.0322***	0.0337***	0.0379***	0.0271***	0.0319***
	[0.0107]	[0.00914]	[0.00783]	[0.00794]	[0.00802]	[0.00927]
ln(Capital Stock)*ln(CO_2 pc)	−0.0216**	−0.0237***	−0.0239***	−0.0320***	−0.0224***	−0.0248***
	[0.00963]	[0.00777]	[0.00691]	[0.00670]	[0.00668]	[0.00811]
ln(Number of person engaged)*ln(Nitrous)	−0.435***	−0.373***	−0.461***	−0.430***	−0.477***	−0.413***
	[0.0339]	[0.0316]	[0.0351]	[0.0313]	[0.0327]	[0.0313]
ln(Capital Stock)*ln(Nitrous)	0.384***	0.329***	0.397***	0.400***	0.425***	0.387***
	[0.0344]	[0.0335]	[0.0358]	[0.0320]	[0.0342]	[0.0320]
ln(CO_2 pc)*ln(Nitrous)	−0.0409**	−0.0510***	−0.0446***	−0.0310*	−0.0438***	−0.0289
	[0.0176]	[0.0167]	[0.0164]	[0.0158]	[0.0159]	[0.0178]
Constant	0.247***	0.228***	0.341***	0.234***	0.297***	0.203***
	[0.0511]	[0.0384]	[0.0728]	[0.0396]	[0.0561]	[0.0384]

(*continued*)

Table A8.

Determinants in the inefficiency component	CORR	GE	PS	RQ	VOICE	RL
WB indicators	−0.461***	−0.586***	−0.329***	−0.541***	−0.406***	−0.622***
	[0.0785]	[0.0630]	[0.0729]	[0.0570]	[0.0555]	[0.0756]
ln(Electric Power Consumption)	−0.00538	0.0140***	0.00995**	0.0198***	0.0119***	0.00824**
	[0.00729]	[0.00296]	[0.00432]	[0.00304]	[0.00375]	[0.00352]
Trade Freedom	0.00177	0.000424	0.000262	−0.00289***	−0.000383	−0.00119***
	[0.00168]	[0.000423]	[0.000522]	[0.000488]	[0.000323]	[0.000401]
ln(Urban Population)	0.00756	−0.00194	−0.00583	−0.0105	0.000254	−0.00664
	[0.0108]	[0.00655]	[0.00904]	[0.00788]	[0.00803]	[0.00834]
Trend	−0.0000324	−0.0104**	−0.0146***	−0.00410	−0.0114***	−0.00153
	[0.00388]	[0.00419]	[0.00492]	[0.00354]	[0.00430]	[0.00353]
Country	40	40	40	40	40	40
Period	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019
Observations	1133	1133	1133	1133	1133	1133

Note(s): Standard errors in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Time dummies included in the production function; CORR (Control of Corruption): reflects 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 (higher values indicate strong governance performance in controlling corruption). It indicates the perceived overall level of corruption specifically referring to the abuse of public power for private gain. GE (Government Effectiveness) reflects 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. It is related to the quality of public service provision and the quality of the bureaucracy. PS (Political stability): measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism and represents the sustainability of governments. In countries with high political instability there is room for higher corruption and very poor accountability of public spending; RL (Rule of law): reflects 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. It is related to what extent an independent judiciary exists as well as civil rights are guaranteed and protected, reflecting whether there are fair judgements for people and organizations. Societies characterized by a high level of weakness in law may have more corruption and abuses in public administration; RQ (Regulatory quality): reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. It measures the incidence of market unfriendly policies such as price controls or inadequate bank supervision, as well as perceptions of the burdens imposed by excessive regulation in areas such as foreign trade and business development. VOICE (Voice and accountability): reflects 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 whether media are free. It measures various aspects of the political process such as civil liberties and political rights. It captures the equality of rights of all citizens and the extent to which citizens of a country are able to participate in the selection of governments as well as the independence of the media

Source(s): Authors own creation

y = ln(Real gross domestic product pc)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Production function parameters												
ln(Number of person engaged)	0.430***	0.450***	0.430***	0.429***	0.430***	0.489***	0.455***	0.424***	0.459***	0.427***	0.448***	0.519***
	[0.0183]	[0.0152]	[0.0176]	[0.0199]	[0.0180]	[0.0202]	[0.0188]	[0.0184]	[0.0205]	[0.0194]	[0.0191]	[0.0218]
ln(Capital Stock)	0.496***	0.524***	0.514***	0.515***	0.502***	0.471***	0.481***	0.506***	0.476***	0.502***	0.490***	0.439***
	[0.0189]	[0.0187]	[0.0201]	[0.0328]	[0.0199]	[0.0249]	[0.0195]	[0.0190]	[0.0220]	[0.0197]	[0.0201]	[0.0247]
ln(CO_2 pc)	−0.0684***	−0.0477***	−0.0679***	−0.0655***	−0.0697***	−0.0562***	−0.0644***	−0.0671***	−0.0691***	−0.0672***	−0.0633***	−0.0640***
	[0.00786]	[0.00806]	[0.00793]	[0.00963]	[0.00805]	[0.00852]	[0.00778]	[0.00798]	[0.00776]	[0.00797]	[0.00790]	[0.00770]
ln(Nitrous)	−0.315***	−0.141***	−0.250***	−0.260***	−0.293***	−0.213***	−0.286***	−0.313***	−0.261***	−0.310***	−0.294***	−0.210***
	[0.0201]	[0.0239]	[0.0351]	[0.0750]	[0.0315]	[0.0316]	[0.0254]	[0.0213]	[0.0328]	[0.0197]	[0.0263]	[0.0322]
ln(Number of person engaged)^2	0.477***	0.454***	0.512***	0.511***	0.525***	0.493***	0.463***	0.485***	0.432***	0.482***	0.475***	0.497***
	[0.0421]	[0.0534]	[0.0586]	[0.0566]	[0.0497]	[0.0553]	[0.0465]	[0.0439]	[0.0489]	[0.0440]	[0.0495]	[0.0546]
ln(Capital Stock)^2	0.220***	0.298***	0.265***	0.262***	0.279***	0.311***	0.212***	0.218***	0.205***	0.212***	0.216***	0.301***
	[0.0374]	[0.0496]	[0.0618]	[0.0852]	[0.0532]	[0.0588]	[0.0476]	[0.0395]	[0.0513]	[0.0376]	[0.0511]	[0.0608]
ln(Number of person engaged)*ln(Capital Stock)	−0.704***	−0.738***	−0.778***	−0.768***	−0.802***	−0.802***	−0.675***	−0.706***	−0.632***	−0.696***	−0.697***	−0.790***
	[0.0734]	[0.0991]	[0.116]	[0.126]	[0.0947]	[0.107]	[0.0875]	[0.0774]	[0.0929]	[0.0753]	[0.0953]	[0.109]
ln(CO_2 pc)^2	−0.00571***	−0.00305**	−0.00567***	−0.00537***	−0.00602***	−0.00395***	−0.00495***	−0.00525***	−0.00610***	−0.00572***	−0.00443***	−0.00489***
	[0.00120]	[0.00120]	[0.00129]	[0.00141]	[0.00127]	[0.00125]	[0.00118]	[0.00124]	[0.00123]	[0.00121]	[0.00124]	[0.00121]
ln(Nitrous)^2	0.232***	0.242***	0.245***	0.212***	0.224***	0.224***	0.204***	0.219***	0.226***	0.219***	0.222***	0.267***
	[0.0343]	[0.0334]	[0.0380]	[0.0402]	[0.0368]	[0.0404]	[0.0346]	[0.0352]	[0.0339]	[0.0355]	[0.0354]	[0.0375]
ln(Number of person engaged)*ln(CO_2 pc)	0.0329***	0.0431***	0.0387***	0.0383***	0.0346***	0.0366***	0.0374***	0.0427***	0.0347***	0.0378***	0.0419***	0.0348***
	[0.00805]	[0.00770]	[0.00813]	[0.00747]	[0.00711]	[0.00789]	[0.00782]	[0.00807]	[0.00777]	[0.00863]	[0.00779]	[0.00724]
ln(Capital Stock)*ln(CO_2 pc)	−0.0191**	−0.0289***	−0.0256***	−0.0234***	−0.0201***	−0.0245***	−0.0249***	−0.0269***	−0.0188**	−0.0213***	−0.0290***	−0.0210***
	[0.00768]	[0.00641]	[0.00790]	[0.00753]	[0.00700]	[0.00703]	[0.00735]	[0.00780]	[0.00745]	[0.00775]	[0.00774]	[0.00684]
ln(Number of person engaged)*ln(Nitrous)	−0.507***	−0.375***	−0.491***	−0.471***	−0.505***	−0.448***	−0.463***	−0.509***	−0.461***	−0.501***	−0.485***	−0.464***
	[0.0306]	[0.0355]	[0.0353]	[0.0594]	[0.0365]	[0.0334]	[0.0315]	[0.0316]	[0.0343]	[0.0352]	[0.0313]	[0.0300]
ln(Capital Stock)*ln(Nitrous)	0.369***	0.334***	0.375***	0.349***	0.372***	0.372***	0.335***	0.371***	0.339***	0.361***	0.355***	0.383***
	[0.0312]	[0.0368]	[0.0363]	[0.0364]	[0.0348]	[0.0366]	[0.0337]	[0.0325]	[0.0330]	[0.0348]	[0.0335]	[0.0339]
ln(CO_2 pc)*ln(Nitrous)	−0.0352**	−0.0197	−0.0566***	−0.0379**	−0.0426***	−0.0215	−0.0463***	−0.0431***	−0.0431***	−0.0388***	−0.0388***	−0.0338**
	[0.0154]	[0.0145]	[0.0157]	[0.0167]	[0.0155]	[0.0148]	[0.0157]	[0.0147]	[0.0142]	[0.0143]	[0.0143]	[0.0137]
Constant	0.865***	0.270***	0.664**	0.388**	0.334***	0.330***	0.804***	0.822***	0.694***	1.660	0.749***	0.448***
	[0.116]	[0.0476]	[0.270]	[0.179]	[0.0599]	[0.0678]	[0.171]	[0.114]	[0.152]	[2.369]	[0.177]	[0.107]
Determinants in the inefficiency component	GS	SEC	IP	IC	EC	CORR	MP	RT	LO	ET	DA	BQ
ICRG	0.0234***	−0.268***	−0.0425***	−0.0921	−0.240	−0.217***	−0.113***	0.0457***	−0.0962***	0.0218	−0.0308***	−0.199***
	[0.00514]	[0.0569]	[0.0148]	[0.161]	[0.219]	[0.0617]	[0.0234]	[0.0142]	[0.0307]	[0.0193]	[0.00787]	[0.0569]
ln(Electric Power Consumption)	0.0131***	0.0326***	0.0243***	0.0238	0.0539**	0.0300***	0.0387***	0.0132***	0.0294***	−0.0301*	0.0266***	0.0266***
	[0.00393]	[0.00543]	[0.00681]	[0.0151]	[0.0269]	[0.00567]	[0.00528]	[0.00474]	[0.00472]	[0.0168]	[0.00471]	[0.00360]
Trade Freedom	0.00179***	0.000102	−0.000272	0.000326	−0.00845	−0.000506	0.000117	0.000325	0.000115	0.000518	−0.00154***	−0.000241
	[0.000451]	[0.000363]	[0.000774]	[0.00150]	[0.00762]	[0.000500]	[0.000279]	[0.000349]	[0.000389]	[0.000499]	[0.000558]	[0.000516]

(*continued*)

Table A9.
Translog parameters' estimation. The role of different dimensions of ICRG (Specification B)

Table A9.

Determinants in the inefficiency component	GS	SEC	IP	IC	EC	CORR	MP	RT	LO	ET	DA	BQ
ln(Urban Population)	−0.00443	0.00479	−0.000778	0.00734	−0.00922	−0.00362	−0.00561	−0.00462	0.0000159	−0.00619	−0.00634	−0.00396
	[0.00548]	[0.0127]	[0.00496]	[0.0328]	[0.0586]	[0.00694]	[0.00531]	[0.00541]	[0.00515]	[0.00590]	[0.00493]	[0.00455]
Trend	-0.0506^{***}	0.00526	−0.0134	−0.0221	−0.0722	-0.0116^{*}	-0.0392^{***}	-0.0394^{***}	-0.0219^{**}	−0.110	-0.0268^{**}	−0.00630
	[0.00932]	[0.00475]	[0.0147]	[0.0183]	[0.0613]	[0.00593]	[0.0121]	[0.00998]	[0.00853]	[0.159]	[0.0129]	[0.00411]
Country	40	40	40	40	40	40	40	40	40	40	40	40
Period	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019	1990–2019
Observations	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133

Note(s): Standard errors in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Time dummies included in the production function; GS (**Government Stability):** This is an assessment both of the government's ability to carry out its declared program(s), and its ability to stay in office. The risk rating assigned is the sum of three subcomponents, each with a maximum score of four points and a minimum score of 0 points. A score of 4 points equates to Very Low Risk and a score of 0 points to Very High Risk); **SC (Socioeconomic conditions):** This is an assessment of the socioeconomic pressures at work in society that could constrain government action or fuel social dissatisfaction. The risk rating assigned is the sum of three subcomponents, each with a maximum score of four points and a minimum score of 0 points. A score of 4 points equates to Very Low Risk and a score of 0 points to Very High Risk; **IP (Investment Profile):** This is an assessment of factors affecting the risk to investment that are not covered by other political, economic and financial risk components. The risk rating assigned is the sum of three subcomponents, each with a maximum score of four points and a minimum score of 0 points. A score of 4 points equates to Very Low Risk and a score of 0 points to Very High Risk; **IC (Internal Conflict):** This is an assessment of political violence in the country and its actual or potential impact on governance. The highest rating is given to those countries where there is no armed or civil opposition to the government and the government does not indulge in arbitrary violence, direct or indirect, against its own people. The lowest rating is given to a country embroiled in an on-going civil war. The risk rating assigned is the sum of three subcomponents, each with a maximum score of four points and a minimum score of 0 points. A score of 4 points equates to Very Low Risk and a score of 0 points to Very High Risk; **EC (External Conflict):** The external conflict measure is an assessment both of the risk to the incumbent government from foreign action, ranging from non-violent external pressure (diplomatic pressures, withholding of aid, trade restrictions, territorial disputes, sanctions, etc.) to violent external pressure (cross-border conflicts to all-out war); CORR (**Corruption):** This is an assessment of corruption within the political system. Such corruption is a threat to foreign investment for several reasons: it distorts the economic and financial environment; it reduces the efficiency of government and business by enabling people to assume positions of power through patronage rather than ability and, last but not least, introduces an inherent instability into the political process; MP (**Military in Politics):** The military is not elected by anyone. Therefore, its involvement in politics, even at a peripheral level, is a diminution of democratic accountability. However, it also has other significant implications; RT (**Religious Tensions):** Religious tensions may stem from the domination of society and/or governance by a single religious group that seeks to replace civil law by religious law and to exclude other religions from the political and/or social process; the desire of a single religious group to dominate governance; the suppression of religious freedom; the desire of a religious group to express its own identity, separate from the country as a whole; LO (**Law and Order):** "Law and Order" form a single component, but its two elements are assessed separately, with each element being scored from zero to three points. To assess the "Law" element, the strength and impartiality of the legal system are considered, while the "Order" element is an assessment of popular observance of the law. Thus, a country can enjoy a high rating – 3 – in terms of its judicial system, but a low rating – 1 – if it suffers from a very high crime rate if the law is routinely ignored without effective sanction (for example, widespread illegal strikes); **ET (Ethnic Tensions):** This component is an assessment of the degree of tension within a country attributable to racial, nationality or language divisions. Lower ratings are given to countries where racial and nationality tensions are high because opposing groups are intolerant and unwilling to compromise. Higher ratings are given to countries where tensions are minimal, even though such differences may still exist; **DA (Democratic Accountability)**: This is a measure of how responsive government is to its people, on the basis that the less responsive it is, the more likely it is that the government will fall, peacefully in a democratic society, but possibly violently in a non-democratic one; BQ (**Bureaucracy Quality):** The institutional strength and quality of the bureaucracy is another shock absorber that tends to minimize revisions of policy when governments change. Therefore, high points are given to countries where the bureaucracy has the strength and expertise to govern without drastic changes in policy or interruptions in government services. In these low-risk countries, the bureaucracy tends to be somewhat autonomous from political pressure and to have an established mechanism for recruitment and training. Countries that lack the cushioning effect of a strong bureaucracy receive low points because a change in government tends to be traumatic in terms of policy formulation and day-to-day administrative function

Source(s): Authors own creation

About the authors

Cristian Barra is an Associate Professor of Economic Policy at the Department of Economics and Statistics – University of Salerno (Italy) where he holds courses on Microeconomics and Corporate Governance. He obtained a PhD in Economics of Public Sector at the University of Salerno (Italy) and a MSc in Economics and Finance at the University of Naples "Federico II" (Italy). His works focus on productivity and efficiency analysis, economics of innovation, financial economics and institutional economics and are regularly published in esteemed and highly impacted journals.

Pasquale Marcello Falcone is an Associate Professor of Economic Policy at the Department of Business and Economics - University of Naples "Parthenope" (Italy) where he holds courses on Environmental Economics and Policy. He obtained a PhD in Economics at the University of Foggia (Italy) and a MSc in Economics at the University of Leicester (UK). His works focus on the mechanisms through which sustainability transitions can be intertwined with socio-economic, policy and financial aspects and are regularly published in esteemed and highly impacted journals. He has been included in the Top 100,000 Scientists worldwide across all knowledge areas (PLOS Biology). Pasquale Marcello Falcone is the corresponding author and can be contacted at: pasquale.falcone@uniparthenope.it