RESEARCH ARTICLE

The environmental impact of governance: a system-generalized method of moments analysis

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Abstract

To investigate the role of governance on environmental quality, two hypotheses are developed; when good governance practices dominate governance structures, then improvement in governance levels leads to better environmental outcomes, and when bad governance practices dominate governance structures, then improvement in governance levels leads to deterioration in environmental outcomes. To test these hypotheses for 115 countries clustered as high, middle, and low income over the period of 2000 to 2015, system generalized method of moments is employed. The results show that an improvement in governance increases environmental quality in high income countries, while it decreases environmental quality in middle- and low-income countries. We concluded that high-income countries should improve governance structures to get better environmental outcomes without changing their environment-oriented policies and governance practices, and middle- and low-income countries should bring in structural changes to their governance systems by prioritizing environmental outcomes over economic outcomes for improving environmental quality.

Keywords DEA · Environmental quality · Governance · Granger causality · K-means clustering · N-shaped EKC · System GMM

Introduction

Global warming from fossil fuels has been linked time and again to the numerous catastrophic events that have been taking place around the globe in the last couple decades. Levels of CO2 PPM (parts per million) have been ever increasing and along with that, global temperatures as well. The year 2020 alone witnessed many dramatic climatic phenomenon including Australia's and California's wildfires, China's worst floods in decades, a first ever heat wave in Antarctica with temperatures rising above 20° along with micro plastic found in the Antarctic ice, destruction of crops by locusts swarming across parts of Africa, the Middle East, and Asia. Another major environmental concern is that of deforestation, which is increasingly being caused by land clearing for raising livestock and growing commercial crops such as sugarcane and palm oil, making agriculture the leading cause of deforestation (Earth.Org 2020). With the current rate of deforestation, only 10% of the planet's forests would remain by the year 2030 and we could lose all the forests in less than 100 years, which further adds to the loss of biodiversity, hence, a threat to human survival in turn. A third major environmental concern is air pollution. Estimates of the WHO show that approximately 4.2 to 7 million people die from air pollution around the world every year. A report of the EU's environmental agency showed that there were approximately 400,000 annual deaths in the EU in 2012. The estimates of UNICEF show that 258,000 people died due to air pollution in Africa during 2017. In the wake of the COVID-19 pandemic, the role that air pollution plays in transporting the virus molecules has been given more attention. Recent reports have also shown correlation between air pollution and COVID-19-related mortalities, and an association of airborne particles aggravating the spread of the disease. Scientists also predict that if immediate policy actions at the local and global level are not taken, then an average of five new pandemic diseases will emerge on an

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annual basis in the near future (Sir David Attenborough 2020). They shift the focus to global policy makers whose decisions on economic activities for future are critical and go a long way in affecting further damage done to the environment. From foreign trade policies that can change composition and direction of trade and hence, discourage over-utilization of resources that ultimately add to environmental costs by way of increased wastages, to regulatory policies that enhance governance structures for better environmental outcomes, the role played by governance actors at the global level is crucial.

Kraay, A., Kaufmann, D., and Mastruzzi, M. (2010) have defined governance in terms of authority exercised by traditions and institutions in a country. Governance not only includes selecting, monitoring, and replacing the governments, but also encompasses the ability to formulate and implement sound policies effectively by the governments, along with public respect for the state and its institutions governing economic and social interactions among them. Governance does not relate to governments alone, but it extends to the society and institutions involving complex human interactions within and outside of those institutions, which sometimes impose significant negative externalities on the environmental quality. Environmental governance, also known as green governance gained momentum post the 1972 United Countries Conference on Human Development in Stockholm that led to the creation of United Countries Environment Programme (UNEP 2009); after which, policies on environmental governance at the national and global level were increasingly taken up. The economic theory of placing growth above future needs was discarded and global consensus on environmental matters was reached in 1987 when the UN General Assembly chaired by Norwegian Prime Minister Gro Harlem Brundtland established World Commission on Environment and Development, which identified sustainable development as a solution (Brundtland et al. 1987).

The aim of the study is to investigate the relationship between governance and environmental quality for 115 countries clustered as high, middle, and low income by system generalized method of moments (system GMM) analysis over the period of 2000 and 2015 and to devise policy implications for countries in each cluster for better environmental outcomes. The significance of this paper is highlighted in the positive (or negative) outcomes that good (or bad) governance structures have on the environmental quality. Better governed policies and structures call for repercussions for non-compliance. Numerous environmental agreements which have been voluntary in nature (for members to enter into) have often led to inefficient environmental outcomes. Hence, the importance of role played by governance on environmental outcomes must be studied. The paper contributes to the literature on the effect of governance on environmental quality in several ways. First, it builds two hypotheses to explain the effect of good and bad governance on environmental quality. Second,

it divides countries into three clusters based on their income levels by K-means clustering algorithm as an alternative to the World Bank classifications such as high-, upper middle-, lower middle-, and low-income countries. Third, it employs system GMM analysis to test the two hypotheses for three clusters and to determine the effect of control variables on environmental quality. Fourth, it measures the comparative environmental performance of countries in each cluster by employing output-oriented panel data envelopment analysis. Finally, it gives policy implications for countries in three clusters to attain better environmental outcomes.

The paper is structured in six sections. Next section presents the theoretical perspective and the literature review. Third section presents the preliminary analysis. Fourth section describes two different types of methodology that have been used in the estimation results. Fifth section presents the estimation results and discussion. Last section concludes.

Background

Theoretical perspective

UNDP (1997) highlights principles of good governance, which have been linked in the present study to the sub-dimensions of Worldwide Governance Indicators (WGI) (Kaufmann et al. 2010) to describe environmental outcomes of the same. According to UNDP (1997), governance can be seen as the exercise of economic, political, and administrative authority to manage a country's affairs at all levels. It comprises the mechanisms, processes, and institutions, through which citizens and groups articulate their interests, exercise their legal rights, meet their obligations, and mediate their differences. In order to investigate the outcomes of governance, it becomes imperative to highlight characteristics of efficient governments and institutions, which have been linked to principles of good governance.

Governance practices should be participatory; i.e., all men and women should have a voice in decision-making along with freedom of speech. The WGI dimension of voice and accountability also relates to the extent to which citizens of a country participate in selecting their governments, along with the existence of free media (Kaufmann et al. 2010). Participatory governance structures can be built upon processes that allow for public interest litigations in the courts of law. Public voice and participation in environmental issues can be encouraged if governance structures so allow. But flawed democracies and countries not giving equal (voting) rights to women, minorities or socially backward classes can dampen the construct of good governance. And for voices to be constructive, necessary environment laws need to be in place and rule of law must prevail to ensure compliance. Both the 1997 policy paper of UNDP and WGI dimension of rule of law

cover this aspect, particularly quality of contract enforcement, property rights, the police, and the courts (Kaufmann et al. 2010). But mere existence of rule of law can still lead to bad governance practices if incidences of police brutality, hasty court orders, and populist policies questioning peace and environmental damage continue.

With growing concerns on environment as climate change and loss of biodiversity speed up, the governance structures need to be responsive in the sense that adequate fast track courts for the same exist, and if not, necessary amendments to existing laws and rules are taken up when needed. But procedural delays due to red-tape highlight bad governance structures that can cost the environment long-term damage in issues requiring immediate action, like forest fires and protecting species on the brink of extinction. The dimension of political stability in the WGI can also be linked to this with regard to having stable political environment that fosters such amendments and protects from lobbyists that could adversely affect the environment. Considering the current rate of loss of biodiversity, economic activities that further threaten the environment need to be strictly penalized and discouraged as a step towards sustainable living. The principle of accountability given by UNDP and that of control of corruption by WGI go a long way on that front since they go hand in hand. Accountability is linked to decision-makers, and participatory governance can increase accountability and hence, better compliance to environmental laws. But if political and legal practices exist that provide immunity to offenders, participatory governance structures alone cannot ensure accountability. The law must treat everyone equally if bad governance is to be dealt with effectively.

Compliance can further be enhanced via transparent governance practices, which provide easy access to information to stakeholders such that any discrepancies do not go unnoticed. Regular dialogs, press conferences, and environment conventions held from time to time, including free media, enhance transparency of decision-makers and governance actors. Absence of free media and lack of access to information are important determinants of bad governance that can take away public confidence even when policies are egalitarian. But having laws that provide a right to information in countries make data more accessible to general public, and such transparency boosts public confidence in their governments and public support to increased expenditures on environment policies (Kulin and Johansson Sevä 2019). Greater public support helps framing of consensus-oriented policies, which cater better to the larger set of stakeholders, comprising all life forms in environmental matters. Such policies also ensure the principle of equity by treating all life forms as equal. Article 51A(g) of the Constitution of India prescribes a Fundamental Duty "to have compassion for living creatures" and calls upon all the citizens and the law to protect the rights of non-humans.

Consensus-oriented policies are used to mean those between environmentalists or conservationists and those lobbyists whose interest lies in getting licenses and clearances for economic activities that could harm the environment. Finding common grounds on policy basis in such circumstances can be challenging, but are not non-existent. Policies that subsidize renewable energy resources, government procurements of alternative inputs and sustainable technologies, tax benefits to producers with ethical and sustainable production processes, etc. are some examples of consensus oriented policies. Policies that have a strategic vision promote sustainable development and need to be backed up by rules and regulations that make compliance certain and add to their effectiveness. The dimension of WGI pertaining to regulatory quality also throws light on capacities of governments to frame and implement sound policies and regulations that promote overall development. But short-sighted governance actors who practice populism for vote banks and bad governance in the form of poor regulatory quality leading to unsound policies do more harm than good. Hence, good governance practices can effectively and efficiently bring out better environmental outcomes that ensure reduced levels of carbon dioxide emissions, adequate forest covers, and higher consumption of renewable energy vis-à-vis non-renewable energy.

An important aspect of governance outcomes relates to the existing level of economic growth in countries. Lower-income countries prioritize governance structures that provide better economic outcomes even at the cost of environmental outcomes. In a bid to boost economic activity for current growth, the needs of the future are compromised and political reasons outweigh environmental outcomes. Using governance performance based on WGI indicators, countries performing poorly are seen to prioritize economic outcomes over environmental outcomes such that improvements in their governance levels can be detrimental to their environment up to a certain level. Governance improvements that lead to better environmental outcomes are witnessed only after a certain level of governance performance is achieved, and it is then that better environmental outcomes outweigh negative externalities of economic activities. From the discussion, the following hypotheses can be drawn to investigate the relationship between governance and environmental outcomes:

Hypothesis 1 When good governance practices dominate governance structures, then improvement in governance level leads to better environmental outcomes for countries that have governance performance above a certain level.

Based on the dimensions of governance by Kaufmann et al. (2010), improvement in voice and accountability increases the freedom of expression and association with better informed

citizens about environmental concerns. Their participation in seeking solutions to environmental issues by using free media and their voting power to change ineffective governments can lead to better environmental outcomes. Stable political systems with absence of violence/terrorism enhance public support for environmental policy of governments and decrease in terrorism and political violence, which reduce incidence of forest fires and demolition of natural resources, leading to better environmental outcomes. Improved government effectiveness enhances functioning of civil services which have a tendency to prioritize protection and clean environment. Government decisions that have freedom from political pressures, interest groups and lobbyists pursuing encroaching open green fields and forests for human settlements and exploiting natural resources, lead to better environmental outcomes. The same holds true for control of corruption and decreased likelihood of the state being captured by elites and private interests. Higher regulatory quality enhances government ability to formulate and implement policies and regulations that promote and protect environmental quality. Higher rule of law with responsive police forces and courts increase rule-abiding attitudes, thereby decreasing incidence of crime and violations that otherwise negatively affect environmental quality.

Hypothesis 2 When bad governance practices dominate governance structures, then improvement in governance level leads to worse environmental outcomes for countries that have governance performance below a certain level. That is, improvements in governance of countries with poor governance levels will initially worsen the environmental outcomes, until they reach a certain level of governance where their governance structures are dominated with good governance practices.

Based on dimensions of governance by Kaufmann et al. (2010), enhancing voice and participation increases the likelihood of citizens selecting governments based on electoral promises prioritizing economic well-being rather than better environmental priorities. This is probable in low-income countries, and in that case, increase in the extent of free media adds to the increasing control of governments who give meager attention to environmental outcomes. Improving political stability and reducing violence/terrorism further increases the chance of re-election to the incumbent government leading to worse environmental outcomes. Effectiveness of the incumbent government further increases its freedom from pressures groups such as conservationists and environmentalists. Improvement in regulatory quality improves the perceptions of public in favor of the government, increasing support for the future policies and regulations that prioritize economic well-being, which permit and promote private sector development over environmental concerns. With regard to corruption, controlling it at the lower levels of administration does not

yield better outcomes, if corruption at the higher levels persists. Improvement in rule of law increases the qualitative and quantitative extent of contract enforcement and property rights against public goods and resources, leading to worse environmental outcomes.

The two hypotheses taken in the study do not consider good and bad governance as opposite concepts, but rather two separate concepts with distinguishing characteristics of their own. Since governance structures are not all good or all bad, it is important to identify which one dominates and how it impacts the environmental quality.

Literature review

While there is abundant literature on the positive role of governance in improving environmental outcomes, studies that conclude a negative relation between the two are lacking. According to Harman (2005), good environmental regulation and policy frameworks that ensure compliance and enforcement foster good governance. In turn, compliance is more likely when rule of law and good governance prevail. In a study by Samimi, Ahmadpour, and Ghaderi (2012) for 21 countries in Middle East and North Africa (MENA) region for 2002–2007, it is found that governance quality positively impacts environmental quality and suggests having policies that improve governance indicators as they negatively impact environmental degradation. But the role of governments in protecting the environment goes beyond framing effective environmental policies, since ineffective and corrupt governments lack public support for increased government spending on such policies (Kulin and Johansson Sevä 2019). Tan (2006) investigated the impact of governance indicators on environment quality for 123 countries. The results show that rule-of-law and government-effectiveness improve air quality, while regulatory-quality, rule-of-law, and voice-and-accountability favorably improve water quality. But the six governance indicators were found to be negatively correlated with wilderness, while there was no evidence of the impact of governance on biodiversity. Shrotria (2012) highlights effectiveness of good governance in bringing better environmental outcomes via the role played by judiciary in India. She analyzed environmental cases responded to by the courts in India via public interest litigations (PILs) filed by ordinary citizens, which otherwise are a matter of the legislature and the executive. Hence, public participation, government responsiveness, rule of law, and consensus are crucial in bringing about effective and efficient environmental outcomes.

Literature shows that each sub-dimension of governance significantly impacts environmental outcomes. An important observation given by Leitão (2016) is that environmental degradation is an important cost of corruption and he suggests enhanced transparency as a cure to corruption and weak governance. "Good governance including a broad commitment to

the rule of law is crucial for environmental sustainability." Iwińska et al. (2019) find a positive and statistically significant association between democracy and environment using Spearman rank order correlation analysis for the years 2006–2014. Purcel (2019) analyzes the impact of political stability in 47 low- and lower-middle-income countries and shows that stability of both the political and social structures plays a crucial role in mitigating CO2 pollution in developing countries. Studies on environmental impact of corruption have shown a negative relationship between the two, as corruption dampens rule of law and policy compliances (Fredriksson and Mani 2002; Habib et al. 2020; Ridzuan et al. 2019). On the policy front, they recommend institutional improvements by adopting more transparent laws and heavily penalizing corrupt officials and entrepreneurs whose unlawful practices cause higher environmental pollution. An interesting U-shaped forest-income curve was derived by Galinato and Galinato (2012) showing an initial decline in forest cover as per capita income increases, and a rise after an income turning point. Their study finds that the forest-income curve shifts up or down changes with changes in political stability and corruption. Political stability flattens the CO2 emissions–income curve; i.e., it leads to smaller changes of CO2 emissions per unit change in income.

Regulatory and institutional quality matters for environmental outcomes as well. Issever Grochová (2015) shows that more efficient institutional setting helps improve environmental quality with economic development using panel vector autoregressive techniques for 166 countries for the years 1996 to 2013. Adopting more environmentally friendly policies and low-carbon growth strategies could avoid a possible "pollution-trap" and reduce environmental degradation.

This study takes into account certain control variables (GDP per capita, physical capital, human capital, and infrastructure) that have significant impact on environmental quality. Literature on GDP-environment relationship shows that GDP deteriorates environmental quality in initial development stages but as income levels increase, the effect reverses. Tan (2006) finds that GDP has a greater impact on improving air quality as opposed to water quality, but a negative impact on wilderness and no impact on biodiversity. Zilio and Recalde (2011) tested the Energy Environmental Kuznets Curve (EEKC) hypothesis, and based on co-integration, their results did not support the hypothesis for a stable long-run relationship between GDP per capita and human environmental pressure (energy consumption). But Grossman and Krueger (1995) find no evidence on negative environmental effects of economic growth. Instead, they find that economic growth initially causes deterioration, and after a turning point (that differs for countries), it brings in improvements. Similarly, Douglas and Selden (1995) suggest a diminishing marginal propensity to emit (MPE) carbon dioxide as GDP per capita rises. This shows that emissions are not sensitive to average output growth. Instead, lower-income countries have high MPE which cause higher emissions as output and population increase. Selden and Song (1994) show that per capita emissions and per capita GDP have an inverted U-shaped relationship, which suggests that emissions will decrease in the long run.

The role played by human and physical capital is important in improving environment quality. This argument is supported by Kirschbaum and Soretz (2017) who show that as abatement expenditures increase, more physical capital is used in the production sector since human capital accumulation cannot be accelerated and the share human assigned to abatement decreases. Hence, the pollution level increases. On the environmental effects of infrastructure and communication, Takahashi et al. (2003) found that "the CO2 emissions emanating from fixed-line telephone networks during the use stage accounted for about 77% of the total." They also estimated prospective recovery by recycling equipment and facilities and the effect was a reduction of about 6% in CO2 emissions. Seiler (2003) studied the ecological impacts of infrastructure divided into primary impacts of transport infrastructure on nature and wildlife and secondary effects of industrial development and human settlements disrupting natural habitats and forest covers. The study points to contamination effects of chemical pollutants and noise from maintenance and operational activities on the surrounding environment. In addition, "infrastructure and traffic impose movement barriers to most terrestrial animals and cause the death of millions of individual animals per year." Infrastructural growth not only causes the loss and isolation of wildlife habitat, but also leads to a fragmentation of the landscape.

Preliminary analysis

Data and variables

The study takes a dataset of 115 countries for the period of 2000–2015 due to the data availability. To generate indices, principal component analysis (PCA) was used since there exists multicollinearity between indicators and sub-indicators.

Certain variables yield negative outcomes with a higher numeric value (e.g., CO2 emissions per capita and infant mortality rate). Such variables were converted so that a higher value indicates positive outcomes by using the following formula:

$$\text{Converted Value} = \text{Max Value} + \text{Min Value} - \text{Actual Value} \quad (1)$$

We measured environmental quality based on three indicators, namely forest area, renewable energy consumption, and CO2 emissions. The study measures governance using the six sub-dimensions of Worldwide Governance Indicators (WGI).

See Appendix Table 5 for the list of variables and Appendix Table 6 for descriptive statistics. Data that has been interpolated or extrapolated was less than 1% and simple averages were used for interpolation and 5-year moving average of growth rates was used for extrapolation.

Since time period (T) is 16, which is less than 20, we did not apply panel unit root tests.

Clustering countries: K-means clustering

The selected countries have been clustered as high-, middle-, and low-income countries based on values of natural logarithm of GDP per capita, using K-means cluster analysis to analyze overall groupwise impact of governance on environment. It is one of the oldest and most reliable clustering methods (Baxter 1994; Milligan 1980) and is applicable even when there exists no hierarchical relationships among the units in the dataset, i.e., countries in this study. Once the number of clusters (K) to be formed is specified, the process of K-means clustering assigns every data point to the closest centroids, and each cluster is formed by each collection of those points. Based on the points assigned to that cluster, the centroid of each cluster is updated repeatedly until no point changes clusters (Wu, 2012).

In this study, $K=3$ (high-, middle-, and low-income countries) and $D = \{x_1 \ldots \ldots x_n\}$ is the data set to be clustered, x_i being the natural logarithm of GDP per capita of ith country ($n=115$) for the years 2000–2015. K-means can be expressed as an objective function that depends on the proximities of the data points to the cluster centroids as follows:

$$\min_{\{m_k\},\ 1 \leq k \leq K} \sum_{k=1}^{K} \sum_{x \in C_k} \pi_x \mathrm{dist}(x, m_k) \qquad (2)$$

where $K=3$ is the number of clusters chosen, n_k is the number of countries assigned to cluster C_k, π_x is the weight of; $m_k = \sum_{x \in C_k} \frac{\pi_x x}{n_k}$ is the centroid of cluster C_k, and "dist" computes the distance between x and centroid m_k, $1 \leq k \leq K$ (Wu, 2012).

Table 1 shows number of counties in each cluster, based on values of natural logarithms of GDP per capita. See Appendix Table 7 for list of countries in each cluster.

Table 2 presents the results of ANOVA that show significant overall differences between clusters.

Table 1 Number of countries in each cluster

Cluster	Panel A: high	Panel B: middle	Panel C: low	Total
No. of countries	39	49	27	115

Methodology

System GMM

System GMM is designed for situations with "small T, large N" panels, which means that few time periods and many individuals are required, and the independent variables do not have to be strictly exogenous, which means that they are correlated with past and possibly current realizations of the error term, and also system GMM overcomes the problems of fixed effects, heteroskedasticity, and autocorrelation within individuals.

According to Roodman (2009), system GMM estimates the following model:

$$y_{it} = \alpha y_{i,t-1} + X'_{it}\beta + \varepsilon_{it} \qquad (3)$$

$$\varepsilon_{it} = \mu_i + \nu_{it} \qquad (4)$$

$$E(\mu_i) = E(\nu_{it}) = E(\mu_i \nu_{it}) = 0 \qquad (5)$$

The disturbance term ε_{it} comprises μ_i (fixed effects) and ν_{it} (idiosyncratic shocks) which are orthogonal to each other.

$$\Delta y_{it} = (\alpha-1)\Delta y_{i,t-1} + \Delta X'_{it}\beta + \Delta \nu_{it} \qquad (6)$$

$$E[\Delta w_{it}\mu_i] = 0 \qquad (7)$$

where w_{it} is the instrumenting variable, which is uncorrelated with the fixed effects, μ_i, which means that $E[\Delta w_{it}\mu_i]$ is time-invariant.

The system GMM estimator given by Arellano and Bover (1995) and Blundell and Bond (1998) is an improvement over that given by Arellano and Bond (1991). It adds an additional equation (Eq. (6)) other than the original Eq. (3) and improves the efficiency of the estimator. Arellano and Bond (1991) instrument differences with levels in difference GMM, Blundell and Bond (1998) instrument levels with differences in system GMM (Roodman 2009). They also made an additional assumption about the absence of correlation between fixed effects and the first differences of instrumental variables (Eq. (7)). This allows the model to introduce more instruments. An important assumption is that ν_{it} is not serially correlated. But if it is, for instance, serially correlated of order 1, then $y_{i,t-2}$ is endogenous to the $\nu_{i,t-1}$ in the error term in differences, $\Delta\varepsilon_{it} = \nu_{it} - \nu_{i,t-1}$, which might invalidate it as an instrument and would require to be lagged by three or more. And if there exists second-order correlation, then even longer lags would be required (Roodman 2009).

Reduced form equation for the effect of governance on environmental quality with control variables is as follows:

$$env_{it} = \alpha env_{i,t-1} + \beta gov_{it} + \gamma cont_{it} + \varepsilon_{it} \qquad (8)$$

$$\varepsilon_{it} = \mu_i + \nu_{it} \qquad (9)$$

Table 2 ANOVA significance test

Variable: lnGDPPC	Cluster		Error		F	Sig.
	Mean square	df	Mean square	df		
2000	120.395	2	0.297	112	405.512	0.000
2001	119.920	2	0.286	112	419.920	0.000
2002	120.300	2	0.277	112	434.932	0.000
2003	119.558	2	0.269	112	444.808	0.000
2004	119.055	2	0.267	112	446.346	0.000
2005	106.495	2	0.460	112	231.416	0.000
2006	118.604	2	0.259	112	458.171	0.000
2007	118.588	2	0.258	112	460.478	0.000
2008	116.570	2	0.250	112	465.602	0.000
2009	112.682	2	0.244	112	461.585	0.000
2010	111.844	2	0.244	112	459.110	0.000
2011	111.176	2	0.247	112	450.165	0.000
2012	109.398	2	0.249	112	438.536	0.000
2013	107.551	2	0.253	112	425.482	0.000
2014	106.600	2	0.254	112	419.510	0.000
2015	106.598	2	0.259	112	410.826	0.000

$$E(\mu_i) = E(\nu_{it}) = E(\mu_i\nu_{it}) = 0 \tag{10}$$

$$\Delta env_{it} = \delta\Delta env_{i,t-1} + \phi\Delta gov_{it} + \varphi\,\Delta cont_{it} + \Delta\nu_{it} \tag{11}$$

$$E[\Delta w_{it}\mu_i] = 0 \tag{12}$$

env_{it} and $env_{i,\,t-1}$ represent environmental quality and its first lag for country i in year t. gov_{it} represents governance performance of country i in year t. $cont_{it}$ represents the control variables including natural logarithm of GDP per capita, physical capital, human capital, and infrastructure for country i in year t.

We used natural logarithm of GDP per capita, physical capital, human capital, and infrastructure as control variables since other than following policies to increase income per capita, governments can only invest in physical capital, human capital, or infrastructure, which directly or indirectly impacts environmental quality.

Data envelopment analysis

Current period CRS-DEA frontier has been used to rank countries in each cluster for their technical efficiencies. An output-oriented Malmquist DEA using one output variable (environmental quality) and those input variables for each cluster that had a significant impact on output variable, as computed in the following section, has been employed to calculate distance summaries, i.e., technical efficiencies of the countries. Based on the results, best and least performing countries in each cluster have been identified for the years 2000 and 2015; and based on the technical efficiency scores, countries in each

cluster have been ranked and rank differences have been computed for the 2 years to identify improvement or deterioration in ranks. The LP used to calculate output-oriented CRS distance function is as follows (Coelli 1996):

$$\left[d_o^t(x_t, y_t)\right]^{-1} = max_{\phi,\lambda}\phi \tag{13}$$

$$\text{Subject to} - \phi y_{it} + Y_t\lambda \geq 0 \tag{14}$$

$$x_{it} - X_t\lambda \geq 0 \tag{15}$$

$$\lambda \geq 0 \tag{16}$$

The computer software DEAP Version 2.1 by Tim Coelli has been used in this study to compute distances (technical efficiencies) using Malmquist index for panel DEA. Appendix Table 7 shows results for output-oriented CRS technical efficiencies of the three clusters for the years 2000 and 2016 and the ranks and changes therein.

Results and discussion

Before conducting system GMM analysis, exogenous and endogenous variables have to be determined. Endogeneity means that there exists a reverse causality stemming from dependent variable to independent variable.

Results of Table 3 show that dependent variable Granger causes all independent variables separately, which means that all independent variables are endogenous. Hence, system GMM analysis has been selected in the study and all independent variables have been taken as endogenous.

Table 3 Endogeneity test

Dependent variable: env

Independent variables	Z-bar	Z-bar tilde
gov	14.2625*	9.0581*
lngdppc	17.6183*	11.4430*
phycap	9.5479*	5.7076*
humcap	5.5592*	2.8730*
infra	16.0518*	10.3297*

*denote significance level at 1%. The null hypothesis for Dumitrescu and Hurlin (2012) Granger non-causality test is that dependent variable does not Granger cause independent variable

According to the estimation results in Table 4, lag of environmental quality has positive significant effect in all three clusters. The results support the theory of self-reinforcing environmental quality in the sense that past levels of environmental quality become an important determinant of current level of environmental quality due to strategic complementarity. Inspecting the coefficients of lag of environmental quality, it is seen that high-income countries have relatively slow conditional convergence and low-income countries have

Table 4 System GMM estimation results

Dependent variable: env

Variables	Panel A: high	Panel B: middle	Panel C: low
l.env	0.768***	1.056***	0.978***
	(0.093)	(0.044)	(0.028)
gov	0.074*	−0.028**	−0.018**
	(0.041)	(0.011)	(0.007)
lngdppc	−0.078***	0.005**	−0.009**
	(0.020)	(0.002)	(0.003)
phycap	0.007**	−0.003***	−0.001
	(0.003)	(0.001)	(0.001)
humcap	0.285*	0.062***	−0.023*
	(0.142)	(0.019)	(0.013)
infra	−0.025	−0.009*	0.004
	(0.032)	(0.005)	(0.008)
Prob>F	0.000	0.000	0.000
Observations	585	735	405
Countries	39	49	27
Instruments	20	14	20
Hansen	0.482	0.465	0.916
AR(2)	0.162	0.471	0.110

relatively fast conditional convergence, while middle-income countries have slow conditional convergence with respect to the environmental quality.

Governance has a positive significant effect on the environmental quality for high performers, while it has negative significant effect on the environmental quality for middle and low performer countries. Since the good governance practices dominate governance structures of high-income countries, an improvement in governance performance leads to positive environmental outcomes because their policies are environment-oriented. Not only the public and NGOs but even domestic, foreign, and multinational firms are sensitive to environmental outcomes resulting from governments prioritizing those issues. So any improvement in governance directly contributes to environmental quality as it includes the voice and participation of the public, government, NGOs, and the business sector. The result supports Harman (2005), Samimi et al. (2012), Kulin and Johansson Sevä (2019), Shrotria (2012), Leitão (2016), and Fredriksson and Mani (2002). For middle- and low-income countries, bad governance practices dominate governance structures, and hence, an improvement in governance performance leads to negative environmental outcomes because their policies are economic growth-oriented, giving lesser priority to environmental outcomes. So, any improvement in governance leads to environmental deterioration since it only includes the voice of business sector and the increase in governance due to the increase in voice and accountability only bears fruit to capital owners and investors seeking opportunities to invest. This leads to environmental degradation by contributing to better economic outcomes. Same line of argument may be applied for the other dimensions of governance. Take an improvement in rule of law; its first aim is to increase the safety of public by increasing the number of police force and their equipment, at the cost of reducing personnel from forest protection since protecting the economic interests of people by way of property laws always takes precedence over regulation for the protection of environment in these countries. For the case of government effectiveness, the main interest of the government is always to satisfy pressure/interest groups and lobbyists whose voice is used for advertising the effectiveness of the government. Governments generally allow construction in green fields and encroaching forests to appease these groups, while manifesting itself as enhancing government effectiveness via intensified relationship with these groups, who run the majority of the business sector; and this comes at the cost of environmental

degradation. The result contradicts Purcel (2019), Habib et al. (2020), and Ridzuan et al. (2019).

Natural logarithm of GDP per capita has negative significant effect on environmental quality for high- and low-income countries, while it has positive significant effect on environmental quality for middle-income countries. The result supports the argument of the N-shaped environmental Kuznet curve (EKC) hypothesis which posits that the original EKC hypothesis will not hold in the long run (Allard et al. 2018). The development strategy of low income countries is industrialization, with citizens migrating from rural to urban areas and the economy in transition from agricultural-led to industrial-led. This causes environmental degradation to increase up to the first threshold level of income per capita due to the increase in the consumption of fossil fuels and the increase in industrial pollution. The middle-income countries lie within the first and second threshold of income per capita. These countries shift resources from energy-intensive industries to services and knowledge-based technology intensive-industries, with higher investments in R&D. Economic growth is accompanied by technological progress replacing obsolete technologies with imported ones from high-income countries although their governance structures and policies are not environment-oriented. Hence, an increase in income per capita up to the second threshold leads to environmental improvement in middle-income countries. High-income countries are above the second threshold of income per capita. The main reason behind it is the overutilization of land and resources leading to deforestation and destruction of natural resources due to the scale effect, although their governance structures and policies are environment-oriented.

Physical capital has positive significant effect on environmental quality in high-income countries. Physical capital utilized in high-income countries is most efficient and technology-driven compared with other two clusters. Hence, efficient utilization of physical capital leads to increasing returns to scale, contributing to environmental quality by lesser emission levels. Physical capital has negative significant effect on environmental quality in middle-income countries. Physical capital utilization in middle performer countries is not efficient and technology driven. It is generally overemployed leading to decreasing returns to scale, deteriorating environmental quality due to higher emission levels and increased working hours with repairs and maintenance. This result supports Kirschbaum and Soretz (2017). Physical capital has insignificant effect on environmental quality in low-income countries. Physical capital utilization in low-income countries is insufficient qualitatively and quantitatively compared to the size of their population or country. Hence, any improvement in physical capital is not reflected as a positive impact on environmental quality.

Human capital has positive significant effect on environmental quality in high- and middle-income countries. In these countries, an improvement in human capital positively contributes to environmental quality by way of sensitizing public towards environmental issues. Human capital has negative significant effect on environmental quality in low-income countries. In these countries, the lowest income earners are tied to the primary sectors with mostly agricultural jobs; and it lies in their best interests to nurture the nature. Increase in human capital means better paid jobs that are exploitative in nature for the environment, but are opted over primary sector jobs as they help alleviate poverty. Hence, priorities are given to economic issues rather than environmental issues.

Infrastructure has an insignificant effect on environmental quality in high- and low-income countries due to different factors. For the high-income countries, improvement in infrastructure means expansion of well-designed and sustainable infrastructural networks, which does not change emission levels, forest cover, or endanger biodiversity. For the low-income countries, the improvement in infrastructure means expansion of roads, railroads, or sanitation facilities, which does not impact the environmental outcomes since that coverage is low. But in middle-income countries, infrastructure has negative significant effect on environmental quality. For these countries, improvement in infrastructure means exceeding over capacity since it is inefficient and improvements are quantitative rather than qualitative. Improving infrastructure negatively contributes to environmental quality via higher emission levels in transportation. This result supports Seiler (2003).

The values in brackets are two-step robust standard errors. ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively. AR(2) is test for second-order serial correlation in the second-differenced residuals, under the null of no serial correlation. Hansen test of over-identification is under the null that all instruments are valid. All variables are treated endogenously. Second and deeper lags are instrumented according to AR(2) test of serial correlation. The p values are reported for the Hansen and AR(2) tests

The results of technical efficiency scores of countries in each cluster are given in Appendix Table 7. Among the high-income countries, countries that operated on the frontier (most efficient) for both years, i.e., 2000 and 2015, include Croatia, Saudi Arabia, and Sweden

while Brunei Darussalam was on the frontier only during 2000 and Slovenia, Finland, Bahamas, Portugal, and Greece for the year 2015. Bahrain was the most technically inefficient country among the high-income countries for both the years 2000 and 2015.

The results for middle-income cluster countries show that Congo, Eswatini, Gabon, and Paraguay were the most efficient countries lying on the frontier for the years 2000 and 2015, while Albania and Algeria were on the frontier only during the year 2000 and Guyana for the year 2015. Iran was the least technically efficient country among the middle-income countries for both the years 2000 and 2015 and its rank remained at the bottom during these years.

Lastly, among the low-income cluster countries, Burundi, Chad, and Tanzania lied on the frontier and were the most technically efficient during both years, i.e., 2000 and 2015, while Burkina Faso, Cambodia, and Mali lied on the frontier only during the year 2000. Kyrgyz Republic was the least efficient country in the low-income cluster for both the years 2000 and 2015, holding the lowest rank during both these years.

Conclusion

We analyzed the role of governance on environmental quality for 115 countries in 3 clusters with system GMM by taking physical capital, human capital, infrastructure, and natural logarithm of GDP per capita as control variables. We found that improvement in governance increases environmental quality in high-income countries, supporting first hypothesis and decreases environmental quality in middle- and low-income countries, supporting second hypothesis. We recommend high-income countries, whose level of governance is above a certain level and good governance practices dominate their governance structures, to improve governance structures for better environmental outcomes without changing their environment-oriented policies and governance practices. We recommend middle- and low-income countries, whose level of governance is below a certain level, to structurally change their governance by giving priority to environmental outcomes rather than economic outcomes since improvement in their current governance levels deteriorates environment due to the dominance of bad governance practices in their governance structures.

High-income countries should reverse overutilization of land and natural resources by shifting their priorities from economic gains to issues of sustainable environment. This should be viable for these countries as they already have environment-oriented policies and governance structures. Middle-income countries should increase their income per capita for better environmental outcomes by investing in R&D and renewable energy sources to replace their obsolete technologies relying on fossil fuels. This year, i.e., 2020, is set to see the highest uptake of renewable energy projects around the world ("The Biggest Environmental Problems Of 2020", 2020). Low-income countries should promote policies that increase their income per capita but not at the expense of the environment. This can be done by keeping a check on rural-urban migration, planning sustainable industrialization that produces less toxic wastes and emission levels, restricting the exploitation of natural resources and forest cover by way of fines and penalties, and investing in plant and machinery that uses less fossil fuels. High- and middle-income countries should improve their human capital by giving equal access to education and health for better consequent environmental outcomes. Low-income countries should redesign their curriculars at all levels of education to reeducate their citizens on the merits of better environmental quality over economic gains. Finally, middle-income countries should tackle overcapacity problems by investing in infrastructure quality instead of the quantity, i.e., diverting to renewable energy resources instead of additional transducers and encouraging electric vehicles instead of vehicles consuming fossil fuels.

The high-income countries, especially Bahrain and Estonia, should improve their governance and reverse overutilization of land to have better environmental outcomes. The middle-income countries, especially Algeria and Iran, should structurally change their governance by giving priority to environmental outcomes and follow policies to increase their income per capita for better environmental outcomes. The low-income countries, especially Mali and Kyrgyz Republic, should structurally change their governance by giving priority to environmental outcomes, promote policies to increase their income per capita, and redesign their curriculars at all levels of education to improve environmental outcomes. But mere existence of appropriate policies is insufficient if their effectiveness is not ensured. For that, non-compliance to such policies should have repercussions. This is where it becomes imperative to have good governance dominating the governance structures so that desired environmental outcomes are achieved effectively.

There are two main limitations of the study. First, we preferred to use Worldwide Governance Indicators (WGI) since they are more objective, or less subjective in other words. But WGI are based on 30 underlying data sources, in which each indicator includes principal component analysis (PCA) of similar variables from different data sources. Hence, there is a serious multicollinearity issue that cannot be solved with PCA. Second, due to the data availability, we analyzed only 115 countries in 3 clusters.

Appendix

Table 5. List of variables and data source

Code	Name	Description	Source
env	Environmental quality	PCA of following indicators	
		Forest area (% of land area)	WDI (2020)
		Renewable energy consumption (% of total final energy consumption)	WDI (2020)
		CO2 emissions (metric tons per capita)	WDI (2020)
gov	Governance quality	PCA of following indicators	
		Control of corruption: estimate	WGI (2020)
		Government effectiveness: estimate	WGI (2020)
		Political stability and absence of violence/terrorism: estimate	WGI (2020)
		Regulatory quality: estimate	WGI (2020)
		Rule of law: estimate	WGI (2020)
		Voice and accountability: estimate	WGI (2020)
lngdppc	Natural logarithm of GDP per capita	GDP per capita (constant 2010 US$)	WDI (2020)
phycap	Physical capital	Gross capital formation (% of GDP)	WDI (2020)
humcap	Human capital	PCA of following indices	
	Education index	Education index	UNDP (2020)
	Health quality index	PCA of following indicators	
		Physicians (per 1000 people)	WDI (2020)
		Life expectancy at birth, total (years)	WDI (2020)
		Mortality rate, infant (per 1000 live births)	WDI (2020)
infra	Infrastructure	PCA of following indicators	
		Individuals using the Internet (% of population)	WDI (2020)
		Mobile cellular subscriptions (per 100 people)	WDI (2020)

Table 6. Descriptive statistics

Variables	Obs	Mean	Std. dev.	Min	Max
Panel A: high					
env	624	−0.619	0.766	−3.006	1.245
gov	624	2.518	1.388	−1.647	4.585
lngdppc	624	10.440	0.491	9.217	11.626
phycap	624	23.102	4.769	10.217	40.014
humcap	624	1.255	0.500	−0.426	2.108
infra	624	1.095	0.949	−1.764	3.185
Panel B: middle					
env	784	0.081	0.735	−1.210	2.210
gov	784	−0.830	1.431	−3.621	2.845
lngdppc	784	8.519	0.568	7.246	9.639
phycap	784	25.211	7.072	7.542	57.990
humcap	784	0.048	0.784	−2.770	1.719
infra	784	−0.202	1.136	−1.904	2.241
Panel C: low					
env	432	0.747	0.504	−0.482	1.905
gov	432	−2.131	0.936	−4.513	−0.169
lngdppc	432	6.697	0.518	5.406	11.626
phycap	432	22.345	8.273	2.781	60.156
humcap	432	−1.890	0.852	−3.693	0.458
infra	432	−1.215	0.724	−1.919	1.357

Table 7. Cross-country comparison of environmental performance

Country	2000 Rank	2000 TE Score	2015 Rank	2015 TE Score	Country	2000 Rank	2000 TE Score	2015 Rank	2015 TE Score
Panel A: high-income countries									
Brunei Darussalam	1	1	9	0.974	Italy	21	0.678	11	0.906
Croatia	1	1	1	1	Greece	22	0.677	1	1
Saudi Arabia	1	1	1	1	Czech Republic	23	0.673	24	0.707
Sweden	1	1	1	1	Cyprus	24	0.651	10	0.926
Slovenia	5	0.958	1	1	Germany	25	0.601	26	0.666
Finland	6	0.955	1	1	Canada	26	0.596	29	0.602
Bahamas, The	7	0.907	1	1	Singapore	27	0.579	34	0.528
Korea, Rep.	8	0.903	17	0.8	Malta	28	0.57	30	0.594
Estonia	9	0.901	19	0.79	United Kingdom	29	0.544	27	0.653
Portugal	10	0.857	1	1	Denmark	30	0.531	25	0.69
Slovak Republic	11	0.85	13	0.858	Israel	31	0.514	33	0.541
Japan	12	0.837	15	0.851	Belgium	32	0.512	31	0.579
Norway	13	0.829	21	0.77	Luxembourg	33	0.472	28	0.619
Austria	14	0.827	16	0.804	Netherlands	34	0.457	37	0.468
Barbados	15	0.809	14	0.853	Ireland	35	0.453	36	0.507
New Zealand	16	0.781	22	0.756	United States	36	0.42	32	0.553
Spain	17	0.724	12	0.864	Australia	37	0.386	38	0.396
Switzerland	18	0.701	23	0.729	Kuwait	38	0.178	35	0.522
France	19	0.694	20	0.777	Bahrain	39	0.092	39	0.343
Iceland	20	0.692	18	0.798					
Panel B: middle-income countries									
Albania	1	1	18	0.494	China	26	0.409	44	0.185
Algeria	1	1	48	0.063	Dominican Republic	27	0.406	20	0.475
Congo, Rep.	1	1	1	1	North Macedonia	28	0.393	22	0.446
Eswatini	1	1	1	1	Romania	29	0.357	27	0.373
Gabon	1	1	1	1	Chile	30	0.356	32	0.315
Paraguay	1	1	8	0.742	Belarus	31	0.353	31	0.317
Guyana	7	0.961	1	1	Mexico	32	0.348	29	0.335
Colombia	8	0.926	13	0.587	Jamaica	33	0.341	21	0.458
Guatemala	9	0.876	5	0.907	Mauritius	34	0.331	34	0.285
Brazil	10	0.842	6	0.796	Russian Federation	35	0.327	36	0.277
Indonesia	11	0.802	10	0.653	Bulgaria	36	0.31	28	0.353
Sri Lanka	12	0.783	9	0.69	Morocco	37	0.303	39	0.253
Peru	13	0.776	11	0.65	Armenia	38	0.276	33	0.296
Georgia	14	0.723	16	0.507	Moldova	39	0.25	35	0.28
Panama	15	0.718	14	0.551	Turkey	40	0.237	43	0.204
Ecuador	16	0.648	15	0.542	Tunisia	41	0.217	41	0.214
Philippines	17	0.629	17	0.498	Poland	42	0.197	40	0.251
Costa Rica	18	0.627	7	0.745	Hungary	43	0.177	38	0.269
Latvia	19	0.609	12	0.62	Egypt, Arab Rep.	44	0.17	42	0.211
El Salvador	20	0.587	25	0.411	Azerbaijan	45	0.167	45	0.164
Uruguay	21	0.519	19	0.478	Ukraine	46	0.142	37	0.277
Malaysia	22	0.492	23	0.443	South Africa	47	0.122	47	0.093
Thailand	23	0.45	26	0.406	Jordan	48	0.1	46	0.128
Lithuania	24	0.424	24	0.43	Iran, Islamic Rep.	49	0.056	49	0.004
Botswana	25	0.423	30	0.333					

Table 7. (continued)

Country	2000		2015		Country	2000		2015	
	Rank	TE Score	Rank	TE Score		Rank	TE Score	Rank	TE Score
Panel C: low-income countries									
Burkina Faso	1	1	7	0.853	Ghana	15	0.612	18	0.513
Burundi	1	1	1	1	Madagascar	16	0.575	12	0.675
Cambodia	1	1	5	0.908	Senegal	17	0.562	15	0.601
Chad	1	1	1	1	Vietnam	18	0.529	19	0.495
Mali	1	1	17	0.555	Haiti	19	0.477	16	0.6
Tanzania	1	1	1	1	Togo	20	0.447	21	0.448
Cameroon	7	0.861	4	0.917	Bolivia	21	0.433	22	0.42
Malawi	8	0.818	6	0.871	Kenya	22	0.416	20	0.455
Rwanda	9	0.812	11	0.693	Bangladesh	23	0.347	25	0.226
Benin	10	0.715	13	0.628	India	24	0.347	23	0.277
Nepal	11	0.689	9	0.804	Pakistan	25	0.221	24	0.227
Uganda	12	0.642	14	0.622	Mauritania	26	0.129	26	0.087
Gambia, The	13	0.637	8	0.839	Kyrgyz Republic	27	0.11	27	0.007
Cote d'Ivoire	14	0.622	10	0.764					

Declarations

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