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CO_2 Emissions and Institutions: Moderating Role of Governance in Environmental Sustainability

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Abstract: The paper deals with the impact of institutional quality, as well as its interdependence with economic performance, on environmental degradation during the period from 2002 to 2021 for a panel of 27 transition countries. The main aim of the study is to investigate the interaction role of institutional quality on the association between economic growth, urbanization and CO_2 emissions in selected countries. Based on the system Generalized Method of Moments estimation results, we find that overall institutional quality, as well as bolstering regulatory structures, strengthening of the rule of law, improving the control of corruption and enhancing government efficiency is positively associated with carbon emissions. The institutional advancement is conducive to economic expansion, which contributes to the deterioration of environmental quality. Our empirical findings reveal that the advancement in institutional framework together with economic expansion and urbanization augment environmental degradation. Given results have important policy implications, indicating that the institutional setting may cause trade-offs between promoting economic growth and the environmental protection.

Keywords: institutional quality, governance, CO_2 emissions, transition countries, urbanization, economic growth.

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Introduction

In recent decades, global climate change has emerged as one of the most urgent and significant issues facing the international community. The degradation of the environment is intensifying conflicts over natural resources, heightening social tensions, and, in some cases, leading to outbreaks of violence. One potential solution to this issue is the development of appropriate policies aimed at decarbonization and reducing pollution in the energy sector and manufacturing. In the early stages of development (the factor-driven phase), the main focus of policymakers tends to be on poverty reduction and improving living standards through economic activity and industrialization. As a result, environmental concerns are often overlooked in favor of policies that prioritize rapid industrial growth.

The cumulative effects of accelerated economic growth, population increase, transportation, agricultural practices, deforestation, land use changes, urbanization, and other factors lead to lasting changes in natural ecosystems. These changes result in the depletion of natural resources due to unsustainable consumption practices, endanger human health, and cause various economic, social, and political repercussions. Therefore, it is crucial for governments, businesses, and civil society to work together in building inclusive, transparent, and efficient governance systems that ensure environmental justice, human rights, and sustainability for current and future generations. Strengthening institutional structures and regulatory policies can catalyze systemic transformation, fostering more equitable and sustainable development while addressing and reversing detrimental environmental trends through a fair and green recovery.

In order to investigate the impact of the quality of institutions on CO_2 emissions, we applied the system GMM (Generalized Method of Moments) estimator on a sample of 27 transition countries[3] over the period 2002-2021. We argue that the impact of GDP per capita on pollution rely on the quality of institutional setting in transition countries. Our primary hypothesis (H1) is that improvements in institutional settings decrease CO_2 emissions in transition countries. Also, we test two additional hypotheses: the impact of combined effect of GDP per capita and

[3] Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyz Republic, Latvia, Lithuania, Moldova, Montenegro, North Macedonia, Poland, Romania, the Russian Federation, Serbia, Slovakia, Slovenia, Tajikistan, Ukraine and Uzbekistan. Considering the study's timeframe (beginning in 2002), we intentionally included countries in the sample that joined the European Union in 2004, 2007, and 2013–countries that, as a result, officially ceased to be classified as economies in transition.

overall institutional quality on CO_2 emissions is negative (H2), as well as advancement in institutional framework coupled with urbanization accelerates environmental degradation (H3). This empirical study represents the first effort to analyse the moderating role of institutional setting on carbon emissions through economic performance and urbanization in transition countries.

This paper is organized into five sections. In Section 2 we give a literature review of the empirical studies dealing with the impact on environmental quality. Section 3 provides model and data used in the empirical analysis; in Section 4 we present the results and provide interpretations. In the final section, we provide conclusion and policy implications for transition countries.

Literature review

Institutional quality as a factor in improving the environmental situation

The overwhelming majority of studies on the topic under consideration show that the *development of the institutional environment* or its individual components *contributes to the reduction of CO_2 emissions* (see Table 1, Appendix I). This result can be explained by the following assumptions, which can reasonably be considered both in aggregate and separately.

First, with the improvement of the institutional environment, there is a *public demand* for more effective regulation in the environmental sphere. As a result, countries pursue more active climate policies, including introducing restrictions on the emission of harmful gases. The environmental commitment in such institutionally developed countries can lead to better environmental protection (Neumayer 2016). In particular, it is believed that developed political institutions contribute to the improvement of the environmental situation, since people are allowed to voice their views on environmental problems (Carlsson and Lundström 2003).

Second, there is a hypothesis that developed institutions facilitate the implementation of "green transition" technologies by companies, which, in turn, increase the level of competitiveness and efficiency of production (i.e., pursuing *economic goals*, countries reduce the burden on the environment). In this regard, there are several channels of influence of economic regulations on environmental quality, such as bans on the use of non-renewables, the establishment of barriers to the development of pollution-intensive industries, the creation of incentives to increase demand for environment-friendly products, the application of a higher tax burden in industries with a significant carbon footprint (Zhang *et al.* 2018; Gani 2012; Carlsson and Lundström 2003). There is a point of view that it is economic institutions that determine incentives for individuals and firms to care for natural resources, and a stable economic situation motivates business to invest in green projects (Panayotou 1997).

Third, individual elements of the institutional environment (e.g., efficient anticorruption policies or law enforcement) reduce the risks of *legal gaps* and non-compliance with environmental standards, and help to achieve the intended goals of reducing the burden on the environment (Ozturk and Al-Mulali 2015). Thus, a significant number of scholars are confident in the connection between the effectiveness of institutions and the effectiveness of policies in the field of "green transition."

It is assumed that a developed institutional environment contributes to the respect of international ecological conventions and the implementation of *international obligations* in this field, including efforts to achieve climate neutrality. However, in practice, many major greenhouse gas emitters, which are believed to have the highest standards of institutional development, avoid international commitments to reduce atmospheric pollution. Here are just a few examples. The Doha Amendment of the Kyoto Protocol (2012), in which GHG reduction commitments for the period 2013-2020 were formalized, was not signed or ratified by the USA (the second largest emitter of greenhouse gases in the world), Canada and Japan. In contrast, China, India and Brazil ratified the Doha Amendment. The "Global Coal to Clean Power Transition Statement" (2021) developed at the UN Climate Change Conference assumes that developed and developing countries will abandon coal consumption in the 2030s and 2040s, respectively. However, only 45 countries have committed to energy reform, but some top coal consumers like the United States, Japan and Australia did not support this initiative. Thus, overall institutional development does not always mean international leadership in implementing green initiatives.

The activities of the European Union represent one of the best-known examples of the implementation of *climate policy measures at the supranational level*. The key goals of the "green transition" of the EU member states are sustainable development and reduction of the anthropogenic load on the environment. To a large extent, the achievement of these goals is closely linked to the implementation of the "Fit for 55" package of measures (2021) within the framework of the European Green Deal (2019). The main targets of "Fit for 55" are reduction of net greenhouse gas emissions by at least 55% by 2030 (compared to 1990 levels) and achievement of climate neutrality by 2050.

Among the many mechanisms for the formation of a low-carbon economy, it is worth highlighting the technological modernization of industrial facilities that make products with a large "carbon footprint," as well as to minimize non-renewable energy consumption. In particular, in the "Directive ... on the promotion of the use of energy from renewable sources" (amendments of 2023), it is proposed to increase their share in the energy balance to 42.5% by 2030 (previously it was planned to reach 32% target). In addition, European bureaucrats intend to accelerate the transition to carbon and climate neutrality by implementing the "REPowerEU" strategy (2022), which is aimed at reducing dependence on Russian energy resources and increasing energy efficiency. A number of countries considered in this paper follow the EU's unified climate and energy policy, so state intervention in the field of environmental protection is regulated by the relevant legal framework. The scope of our article does not allow us to consider in detail the features of the institutional environment in the 27 countries selected for analysis, but we provide a list of the latest national initiatives dealing with "green transition" in Table 2 of Appendix I.

The first scientific publications on the impact of institutions on the environmental situation, which appeared at the turn of the 1990s and 2000s, mostly confirmed the thesis that institutions serve as important determinants of environmental degradation. Researchers analyzed relevant data on the enforcement of contracts and rule of law (Panayotou 1997), political rights and civil liberties (Torras and Boyce 1998), level of democracy (Deacon 1999), corruption (Lopez and Mitra 2000). With improved access to statistics not only for developed but also for developing countries, there has been an increase in the number of works on this topic. A review of studies published in the 21st century allows us to conclude that the prevailing point of view is a *decrease in greenhouse gas emissions as institutional quality develops* (see, e. g., Apergis and Ozturk 2015; Ali *et al.* 2019; Güney 2022).

As follows from Table 1 (see Appendix I), the authors use individual indicators as well as indices developed by international organizations as proxies of institutional quality. Bhattacharya *et al.* (2017) on the example of 85 countries find that Index of Economic Freedom, which includes five sub-indices, has a negative impact on CO_2 emissions. Chhabra *et al.* (2023) come to the same result for the BRICS member countries, using a combination of three indices – Institutional Quality Index, Political Stability Index and Political Efficiency Index – as a proxy of institutional setting. According to the authors, the most important role in reducing CO_2 emissions is played by control of corruption, better law and order, and government stability. Using OECD data on Environmental Policy Stringency Index, Yirong (2022) shows that its increase reduces emissions in the long run in both linear and non-linear models.

The Worldwide Governance Indicators (WGI) are widely used to assess the impact of institutional quality on environmental pollution, as World Bank statistics for more than 200 territories over the period 1996–2022 can be used to build the model. For example, Lau *et al.* (2018) argue that control of corruption and rule of law play a crucial role in reducing CO_2 emissions in high-income countries, although the results for low-income countries are less clear. Simionescu (2021) and Simionescu *et al.* (2022) show, using the example of CEE and SEE countries, that only three of the governance indicators (regulatory quality, control of corruption and rule of law), as well as economic freedom, have a significant negative impact on GHG emissions in the long-run. Stef *et al.* (2023) came to similar results in their study: rule of law, voice and accountability, and control of corruption are among the critical factors in combating CO_2 emissions in 136 selected countries.

In recent years, the number of papers studying the *moderating role of institutional setting in environmental sustainability* has been increasing. It is assumed that institutions can play a moderating role in the process of environmental degradation in an open economy. According to the well-known 'pollution haven hypothesis', developed countries seek to transfer harmful industries from their territory to developing countries (characterized by the availability of natural resources, cheap labor and low environmental standards), which ultimately leads to serious environmental consequences for the recipient of FDI. However, a number of studies show that the scale of environmental burden during a period of increasing trade turnover and flows of attracted capital may depend on the quality of national institutions. The mitigation of this effect in societies with a developed institutional environment is noted, for example, by Chhabra *et al.* (2023): pollution caused by high trade openness in BRICS countries might be reduced by effective institutional setting. Using the example of Asian countries, Bakhsh *et al.* (2021) show that the interaction between institutional quality indicators and FDI inflows significantly reduces CO_2 emissions. Khan and Rana (2021), also studying Asian countries, find that advanced institutions reduce atmospheric pollution, and that better economic and political institutions mediate the adverse impact of income, trade openness, and FDI on CO_2 emissions.

Advanced institutional setting is believed to have a mitigating effect not only in case of the "pollution haven hypothesis," but also in general – when the environmental burden increases due to accelerated economic growth. However, the research results remain quite contradictory. Wawrzyniak and Doryń (2020) show, using almost a hundred countries as an example, that government effectiveness modifies the relationship between economic growth and CO_2

emissions, but they do not confirm the moderating role of the control of corruption. Based on a sample of 115 developing countries, Xaisongkham and Liu (2022) argue that government effectiveness and the rule of law reduce CO_2 emissions, but the interaction effect of government effectiveness and GDP with emissions is positive and statistically significant.

Institutional quality as a factor in the deterioration of the environmental situation

Despite the coherent theory of the indirect influence of institutional quality on the reduction of anthropogenic greenhouse gas emissions, it is not confirmed empirically in a significant number of studies. Some authors confirm the positive relationship between institutional indices and emissions or negative relationship that does not always remain linear, but has U-shape or N-shape. Arguing that *the development of institutions increases anthropogenic pollution,* many researchers leave this statement without interpretation.

The main hypothesis explaining such results is the following. The presence of *advanced institutions* (especially economic ones, such as economic freedom) *stimulates business activity* – the rise of output in industries with high carbon footprint accompanied by trade and financial openness can lead to environmental degradation. The mitigating role of the other institutes in this case is recognized as insignificant. For example, Carlsson and Lundström (2003) show that economic freedom has a positive effect on CO_2 emissions in high-income countries, but in low-income countries the relationship is negative. For the countries of South Asia, Amin *et al.* (2023) find a positive relationship between the economic freedom index and carbon dioxide emissions. Shahnazi and Shabani (2021) on the example of the EU member states confirm the U-shaped relationship between economic freedom and CO_2 emissions. According to their results, the economic freedom passed its turning point in the EU as a whole, so its further increase will boost emissions.

As we noted above, most scientists believe that the relationship between control of corruption and atmospheric pollution is inverse. In contrast, Goel *et al.* (2013) argue that both higher corruption and a larger shadow economy result in lower pollution levels, and Halkos and Tzeremes (2013) also find that control of corruption do not lead to a reduction of pollution. Not only economic but also political institutions can have a positive impact on air pollution. Allard *et al.* (2018) show that the Political rights and civil liberties index positively affects emissions (except for lower-middle-income countries). Nevertheless, the authors conclude that improved institutions in high-income countries might not have any direct impact on the ecological situation, unless the given institution is directly connected to environmental quality.

Some researchers prove that the moderating role of institutional setting in the case of emissions could also be positive, not negative. Sarkodie *et al.* (2020) find that political institutions can influence environmental pollution only in combination with economic growth and expansion of energy consumption: a 1% increase in the coupling effect of governance, income, and renewable energy consumption leads to the rise of emissions by 0.79%. Hu and Khan (2023), using WGI data, conclude that institutional quality positively affects carbon dioxide emission, but the interaction between the institutes and urbanization significantly mitigates it. On the example of 42 developing countries Yang *et al.* (2022) also show, that the growth of institutional quality index triggers the increase of CO_2 emissions, while the interaction between this index and income inequality leads to the opposite results.

Empirical model, variable description and data source

The aim of our study was to search for a relationship between institutional quality and anthropogenic emissions into the atmosphere in 27 transition countries during the first two decades of the 21st century. In addition, we aimed to explore whether the dynamics of renewable energy consumption, trade openness, urbanization and cropland area affect emissions. Particular attention is paid to finding an answer to the question if there is a mitigation effect of institutional setting on pollution that potentially caused by economic growth and urbanization.

The use of institutional environment indicators is usually associated with serious assumptions regarding their direct impact on air pollution. A number of these indicators related to regulatory quality or rule of law have an indirect impact on emission reduction, indicating the [potential] ability of a country to set limits and implement initiatives in the environmental sphere. Even less obvious is the connection between carbon dioxide emissions from industry, energy and transport and such indicators as political rights or voice and accountability. It is assumed that the presence of civil liberties should determine responsible behavior of residents in relation to nature, but it is not entirely clear why a developed political environment in a particular country cannot be combined with a high level of motorization, the use of fossil fuels in thermal power plants or the development of metallurgy, which are mainly responsible for CO_2 emissions. There are a significant number of countries with a developed institutional environment that have competitive advantages in traditional energy and heavy industry.

Unfortunately, there are practically no indicators that directly, rather than indirectly, reflect the attitude towards compliance with environmental standards at the national level. A limited number of studies use the Environmental Policy Stringency Index, which is calculated by the OECD for 28 developed countries (the organization defines stringency as "the degree to which environmental policies put an explicit or implicit price on polluting"). Thus, for regions with developing markets, the use of this indicator is not possible.

As a result, many authors claim to study the relationship between the quality of the institutional environment and carbon dioxide emissions, but in fact use only a few or even one indicator as a proxy of institutional quality (IQ) instead of wide range of them. It is obvious that economic freedom, control of corruption or civil liberties do not separately form the institutional environment and are in themselves highly controversial factors directly determining CO_2 emissions into the atmosphere. The way out is to use indices (e.g. Institutional quality index by Worldwide Governance Indicators), however, as Allard *et al.* (2018) rightly note, there are two problems in this regard: the methodology can change over time, and the index values in developed countries, having reached their maximum values, do not change over the measured years. As a rule, authors use such proxies of institutional setting when studying the causes of atmospheric pollution as Institutional quality index, Index of Economic Freedom, Political rights and civil liberties index, Environmental Policy Stringency Index, Economic complexity index and Globalization index.

We use the balanced panel data of 27 transition countries from 2002 to 2021. The extent of our analysis spans until 2021, which is the most recent year with available CO_2 emissions data. Our dependent variable is carbon dioxide emissions measured in metric tons as proxy of environmental degradation. The indices of institutional quality (government effectiveness (GE), control of corruption (CC), rule of law (RL) and regulatory quality (RQ)) range from -2.5 to 2.5 and each of them is included separately in the model due to the potential issue of multicollinearity. The overall or composite governance indicator (WGI) is calculated with the help of the Principal Component Analysis (PCA) which is used to mitigate the potential risks associated with omitted-variable bias.

The most of statistics was obtained from the WDI World Bank, while data on emissions and cropland was taken from "CO_2 emissions of all world countries – 2022 Report" by the European Union and Food and Agriculture Organization of the United Nations (FAOSTAT), respectively. All variables, with the exception of the indices of the institutional quality, are expressed in natural logarithms aimed to overcome the problems related to heteroscedasticity and data sharpness. For example, such approach was used by Khan and Rana (2021). The description of variables and their data sources are shown in Table 1.

Table 1: Description of variables

Variables	Definition and measurement	Source
CO_2	CO_2 emissions, Mt	CO_2 emissions of all world countries – 2022 Report, Publications Office of the European Union
GDP	GDP per capita (constant 2015 US$)	WDI database, World Bank
TO	Trade openness (% of GDP)	WDI database, World Bank
REC	Renewable energy consumption (% of total final energy consumption)	WDI database, World Bank
UR	Urban population (% of total population)	WDI database, World Bank
CR	Cropland, thous. ha	FAOSTAT
WGI	Overall governance indicator	This indicator is calculated with the help of PCA[4]. Author's calculation based on WDI database, World Bank.
CC	Control of corruption	WDI database, World Bank
RL	Rule of law	WDI database, World Bank
RQ	Regulatory quality	WDI database, World Bank
GE	Governance effectiveness	WDI database, World Bank

Source: Authors

The following econometric specification was used to identify the effect of overall institutional quality and different governance dimensions, with specified control variables on the CO_2 emissions:

[4] The PCA combines various governance-related indicators into a single composite governance indicator. It summarizes the most important dimensions of governance while also reducing the risk of bias that might arise from ignoring relevant variables.

$$CO_{2i,t}=\beta_0+\beta_1 CO2_{i,t-1}+\beta_2 GDP_{i,t}+\beta_3 TO_{i,t}+\beta_4 REC_{i,t}+\beta_5 UR_{i,t}+\beta_6 CR_{i,t}+ \\ +\beta_7 IQ_{i,t}+\varepsilon_{it} \quad i=1,\dots,N,\ t=1,\dots,T \tag{1}$$

where i stands for the country (i = 1, 2, ..., 27), t refers to the time period (2002–2021), ε_{it} is the error term, and the coefficients β_1, β_2, β_3, β_4, β_5, β_6 and β_7 show the impacts of the independent variables on the dependent one. CO_{2it} represents CO_2 emissions; CO_{2it-1} is lagged dependent variable, GDP_{it} is the GDP per capita; TO_{it} denotes trade as a share of GDP; REC_{it} is renewable energy consumption as percentage of total final energy consumption; UR_{it} is urbanization; CR_{it} stands for cropland; IQ_{it} denotes the dimensions of institutional setting. Worldwide Governance Indicators (WGI) – overall institutional quality obtained with the help of PCA, as well as GE, CC, RL and RQ.

The coefficient of the GDP per capita could have either positive or negative sign. In line with the Pejović *et al.* (2021), Stef *et al.* (2023) and Raihan (2023), we utilize renewable energy consumption as percentage of total final energy consumption as indicator for energy security and sustainability. For the REC variable, the sign is expected to be negative, since renewables displace fossil fuel-based energy sources. Such direct displacement contribute to lower overall CO_2 emissions from the energy sector. Therefore, we postulate that the coefficient of REC_{it} is negatively associated with the dependent variable.

We also included trade openness, cropland and urbanization as these variables proved to have a significant impact on CO_2 emissions (Radmehr *et al.* 2021; Salahodjaev *et al*. 2022; Voumik *et al.* 2023). We assume, that urbanization will have positive impact on CO_2 emissions, because of its connection with traffic intensification and industrialization. The cropland area change is expected to positively affect the carbon dioxide emissions: organic soils emit carbon dioxide when they are drained to be converted to cropland or grassland (this process can lead to 20-40% loss of the original soil carbon stocks because of CO_2 sinking). Trade openness is usually used as a proxy of general economic openness creating conditions for the boost of industrial production and, hence, to possible rise of pollution level.

The main independent variables in our models are indices of institutional setting. Our hypothesis is that institutional quality change in transition countries has positive impact on CO_2 emissions since its possible role in economic boost, while its interaction with GDP per capita could exert either positive or negative impact on pollution. We opted for four indices of institutional quality – government effectiveness, control of corruption, rule of law, and regulatory quality due to their potential effect on environmental degradation (see Literature review). The functioning of the public governance is presented with the help of RL and GE – they are governance dimensions closely interconnected and bolster each other in maintaining efficient institutional framework. The RQ and CC are used as essential benchmarks for investigating the confidence in institutional setting. The signs of these indices, as well as the overall governance indicator, could be either positive or negative. In respect to given four indices, the data on political stability and voice and accountability are rarely used to explain the environmental degradation. Nevertheless, some authors find inverse correlation between them and carbon emissions (see Gani 2012; Hu and Khan 2023; Stef *et al.* 2023), while the others do not reveal any impact (Simionescu *et al*. 2022).

Finally, we assume that the positive impact of GDP per capita and urbanization on pollution in transition countries is moderated by the quality of institutional setting. This study added the interaction terms with institutional quality in the equations as follows:

$$CO2_{i,t}=\beta_0 +\beta_1 CO2_{i,t-1} + \beta_2 GDP_{i,t} +\beta_3 TO_{i,t} +\beta_4 REC_{i,t} + \beta_5 UR_{i,t} + \beta_6 CR_{i,t} + + \beta_7 GDP_{i,t}{*}IQ_{i,t} +\varepsilon_{it} \quad i=1,\dots, N,\ t=1,\dots, T \tag{2}$$

$$CO2_{i,t}=\beta_0 +\beta_1 CO2_{i,t-1} + \beta_2 GDP_{i,t} +\beta_3 TO_{i,t} +\beta_4 REC_{i,t} + \beta_5 UR_{i,t} + \beta_6 CR_{i,t} + + \beta_7\, URB_{i,t}{*}IQ_{i,t} +\varepsilon_{it} \quad i=1,\dots, N,\ t=1,\dots, T \tag{3}$$

To investigate the influence of institutional development efficiency on CO_2 emissions, we prefer the usage of a dynamic model instead of a static one and employed the system Generalized Method of Moments estimator (GMM) (Blundell and Bond 1998). Potential endogeneity problems, unobserved heterogeneity and dynamic panel bias could be eliminated by using instruments, i.e. lags of dependent variable (for instance, the current value of CO_2 emissions is largely conditioned by the value from the past period). The system GMM, as well as the difference GMM, is suitable for dynamic models characterized by an increasing number of observations and fixed time dimensions. The application of this method provides unbiased and consistent estimations of parameters. This estimation technique is more efficient than the difference GMM due to the use of additional moment conditions. Moreover, the lagged values are poor instruments for the differences in the difference GMM if the variables are highly persistent as is the case with the variables of institutional quality. The chosen estimator is asymptotically efficient and robust to heteroscedasticity and autocorrelation (Roodman 2009).

The specification of the dynamic model of the two-step system GMM will undergo two diagnostic tests: Arellano-Bond test for first- and second-order autocorrelation and Hansen test of overidentifying restrictions. We expect the presence of the first-order autocorrelation in the differenced error term, but there should not be second-order autocorrelation in the series. The validity of the instruments was assessed based on the Hansen test. We applied the Windmeijer (2005) finite sample corrected standard errors with the help of Stata's 'small' command. The one-year lagged CO_2 emissions and GDP per capita are identified as potentially endogenous, with GMM-style instruments, while other explanatory variables are taken as exogenous regressors. We have indicated that the GMM instruments only be constructed for fourth lags of the endogenous variables with the intention to maintain the number of instruments. The collapse option is used to reduce the size of the instruments matrix in order to obtain one instrument per variable instead of one instrument for each variable in each period. By using command robust, we specify that the resulting standard errors are consistent with panel-specific autocorrelation and heteroscedasticity.

Empirical results and discussion

The main results of our calculations are presented in the given section. In Table 2, we reported descriptive statistics for selected variables (mean, standard deviation, minimum and maximum values, skewness, kurtosis and the number of observations). According to the descriptive analysis, the mean value of CO_2 emissions is 3.414, the maximum value is 7.571, the minimum value is 1.035 while the standard deviation amounts to 1.523. The standard deviation of GDP per capita is 0.873, while 8.618 is calculated as mean value. From 6.064 at the lowest point to 10.118 at the highest, the value of this variable varied. In addition, outcome of our control variables TO, UR and CR show that the mean is 4.562, 4.040 and 7.689, and the standard deviation is 0.337, 0.232 and 1.596. Regarding the quality of institutional setting, the mean value of composite institutional indicator, CC, RL, RQ, GE is 1.50, -0.264, -0.149, 0.155 and -0.023, with the maximum value of 4.298, 1.580, 1.389, 1.687 and 1.345, and the minimum value of -3.626, -1.428, -1.478, -2.242 and -1.241, respectively.

Table 2: Descriptive statistics

Variables	Mean	Median	Std. dev.	Min	Max	Skewness	Kurtosis	N
CO_2	3.414	3.144	1.523	1.035	7.571	0.669	2.958	592
GDP	8.618	8.689	0.873	6.064	10.118	-0.532	2.641	594
TO	4.562	4.561	0.337	3.113	5.245	-0.402	3.175	591
REC	2.522	2.855	1.041	-0.328	4.167	-0.779	2.762	562
UR	4.040	4.049	0.232	3.277	4.380	-1.393	5.244	594
CR	7.689	7.571	1.596	2.526	11.745	0.278	4.108	582
WGI	1.50e	-0.168	1.929	-3.626	4.298	0.142	1.916	563
CC	-0.264	-0.309	0.668	-1.428	1.580	0.315	2.231	567
RL	-0.149	-0.209	0.734	-1.478	1.389	0.206	1.914	567
RQ	0.155	0.205	0.764	-2.242	1.687	-0.339	2.466	563
GE	-0.023	-0.118	0.668	-1.241	1.345	0.113	1.850	563

Source: Authors' calculations

CO_2 emissions are negatively correlated with the majority of variables, with the exception of GDP per capita, urbanization and cropland. The relationship between GDP per capita and the governance indices (WGI, CC, RL, RQ and GE), as well as between CO_2 and CR, showed strong correlation coefficients exceeding 0.7, suggesting potential multicollinearity issues (see Table 3). Consequently, we conducted supplementary tests to ensure that multicollinearity was not adversely affecting our analysis. Our examination revealed that none of the variables exhibited a variance inflation factor (VIF) surpassing 10[5]. Thus, we determined that the findings were conducive to continued analysis.

[5] The results will be provided upon the request.

Table 3: Correlation matrix

Variable	CO_2	GDP	TO	REC	UR	CR	WGI	CC	RL	RQ	GE
CO_2	1.00										
GDP	0.31	1.00									
TO	-0.26	0.30	1.00								
REC	-0.68	0.04	0.29	1.00							
URB	0.43	0.64	0.14	-0.25	1.00						
CR	0.86	0.03	-0.31	-0.63	0.25	1.00					
WGI	-0.05	0.81	0.49	0.36	0.45	-0.28	1.00				
CC	-0.06	0.77	0.51	0.36	0.44	-0.31	0.95	1.00			
RL	-0.06	0.80	0.50	0.35	0.42	-0.27	0.98	0.93	1.00		
RQ	-0.08	0.73	0.45	0.37	0.43	-0.23	0.95	0.84	0.92	1.00	
GE	-0.02	0.81	0.43	0.29	0.47	-0.25	0.96	0.89	0.93	0.90	1.00

Source: Authors' calculations

The results of Equation 1 are presented in table 4. In terms of diagnostics, the p-value of the Hansen test of overidentifying restrictions and AR(2) (test for Arellano and Bond autocorrelation in the residuals of second orders) were greater than 0.5, implying that our findings are consistent and credible for further analysis. Analysis of the calculation results led us to the following conclusions. The coefficients on lagged CO_2 emissions are positive and highly statistically significant in all our models, suggesting the persistence in the CO_2 emissions. The coefficients of *GDP per capita* are negative and statistically significant in almost all our models, meaning that an increase in GDP per capita decreases CO_2 emissions. We conclude that there is a strong link between economic development and air pollution: a 1% increase in GDP per capita leads to a decrease of CO_2 emissions by 0.15% – 0.19%.

Table 4: The results of two-step SYS-GMM

Variables	1	2	3	4	5
CO_2(-1)	0.831*** (0.102)	0.834*** (0.091)	0.841***(0.106)	0.869***(0.099)	0.813***(0.121)
GDP	-0.174* (0.088)	-0.158* (0.083)	-0.193**(0.095)	-0.167**(0.080)	-0.137 (0.107)
TO	-0.010 (0.084)	-0.018 (0.077)	-0.008 (0.085)	-0.004 (0.082)	-0.002 (0.096)
REC	-0.115** (0.054)	-0.105** (0.045)	-0.111* (0.057)	-0.104**(0.047)	-0.122* (0.067)
UR	0.360** (0.146)	0.336** (0.142)	0.407** (0.164)	0.365***(0.118)	0.282 (0.170)
CR	0.126** (0.061)	0.129**(0.060)	0.120*(0.062)	0.088*(0.051)	0.132* (0.077)
WGI	0.081*** (0.024)				
CC		0.226***(0.064)			
RL			0.221***(0.070)		
RQ				0.148***(0.034)	
GE					0.207**(0.086)
No. of Observation	525	525	525	525	525
No. of groups	27	27	27	27	27
No. of instruments	9	9	9	9	9
Hansen test					
(*p* value)	0.482	0.551	0.524	0.312	0.535
AR(1)					
(*p* value)	0.000	0.000	0.000	0.000	0.000
AR(2)					
(*p* value)	0.725	0.781	0.746	0.847	0.404

*Note: Standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10%, respectively.*

Source: Authors' calculations

The coefficient of *trade openness* is negative but not statistically significant in any of our models, so it is not a crucial factor of environmental degradation in given countries. Thus, in the case of selected transition countries we cannot prove the destruction effect of cross-border economic relations on environment (in line with 'pollution haven' hypothesis).

Renewable and non-renewable energy consumption (or generation) are often used in papers dealing with the factors of carbon emissions. Like many other authors, we find significant negative impact of *renewable energy consumption* on CO_2 emissions, which confirms the assumption about the need of substitution of fossil fuels by alternative sources in energy balance of transition countries. Specifically, a 1% increase in renewable energy consumption leads to a decrease in CO_2 emissions by 0.10 – 0.12%. We could single out Bhattacharya *et al.* (2017), Allard *et al*. (2018), Sarkodie *et al.* (2020) Shahnazi and Shabani (2021), Simionescu *et al.* (2022) among the numerous authors with the relevant results.

We also argue that *urbanization* has positive impact on CO_2 emissions in transition countries (it is statistically significant in all models except the last one). Urbanization growth by 1% appears to increase CO_2 emissions by 0.33 – 0.40%. The growth of urban settlements is accompanied by an obvious increase in the burden on environment, in particular, atmosphere (increasing energy demand, emissions from rising number of vehicles, establishment of new industrial zones, etc.). Our results are also confirmed by Ali *et al.* (2019), Hu and Khan (2023) and Magazzino *et al.* (2023).

Instead of aggregated data on agricultural development (agriculture value-added or its share in GDP) we use statistics on *cropland area*, since almost all carbon dioxide emissions in agriculture are associated with land-use change in favor of croplands (livestock and crop production is responsible for direct emissions of CH4 and N2O, but not CO_2). According to our calculations, 1% increase in cropland area results in CO_2 emissions increase by 0,09-0,13%; their relationship is statistically significant. Zaman and Abd-el Moemen (2017), Spawn *et al*. (2019) and Magazzino *et al.* (2023) came to similar conclusions.

As for the key hypothesis for this work about the influence of *institutional quality* on air pollution, our calculations confirm it. The overall governance indicator is positively associated with carbon emissions, suggesting that institutional advancement is conducive to economic expansion, which contributes to the deterioration of environmental quality. Moreover, a higher institutional quality index is correlated with higher carbon emissions, indicating the low effectiveness of institutions in promoting environmental sustainability. Improving institutional quality typically involves strengthening governance mechanisms, enhancing transparency, and ensuring the rule of law, which are generally associated with positive outcomes such as economic development, social stability, and environmental protection. However, there are instances where they could inadvertently lead to increased CO_2 emissions due to the boost in economic sectors with high "carbon footprint" like transport (emissions from vehicles) or construction (cement and steel production for large-scale infrastructure projects, deforestation). While economic expansion can bring about technological advancements and investments in cleaner energy sources, it also leads to higher energy consumption overall. At the same time, many transition countries still rely on thermal energy, which is based on burning coal. To sum up, the growth in manufacturing, transportation, and energy sector, caused by better institutional setting, could contribute to higher emissions of carbon dioxide and other greenhouse gases. Our findings are in line with the results of Usman and Jahanger (2021) for 93 countries, Azam *et al.* (2021) and Yang *et al.* (2022) for 66 and 42 developing countries, respectively, Hu and Khan (2023) for The Belt and Road Initiative countries, Amin *et al.* (2023) for five South Asian countries.

The coefficients of different governance dimensions prove to be positive and statistically significant at 1 percent significance level. According to the magnitude of their coefficients, CC has the strongest effect on pollution, followed by RL, GE, and RQ (the potential impact varies from 0,15 to 0,23%, depending on the type of governance indicator). Bolstering regulatory structures, improving control of corruption, strengthening of the rule of law and enhancing government efficiency may inadvertently lead to regulatory capture or create conditions for favoring specific industries. In some cases, leading companies with significant political influence may lobby for less stringent environmental regulations or exemptions, triggering the increase of GHG emissions. Given outcomes are in line with the findings of Goel *et al.* (2013) and Halkos and Tzeremes (2013) for control of corruption, Abid *et al.* (2016) for rule of law and regulatory quality, Wawrzyniak and Doryń (2020) for government effectiveness, Hu and Khan (2023) for all WGI indicators excluding political stability.

Table 5: The results of two-step SYS-GMM: the interdependence between institutional quality and economic performance

Variables	1	2	3	4	5
CO_2(-1)	0.836***(0.101)	0.848*** (0.105)	0.846***(0.090)	0.869***(0.098)	0.819*** (0.119)
GDP	-0.171*(0.087)	-0.189**(0.093)	-0.155*(0.083)	-0.165**(0.080)	-0.136 (0.103)
TO	-0.034 (0.084)	-0.033 (0.085)	-0.038 (0.079)	-0.019 (0.083)	-0.024 (0.095)
REC	-0.114** (0.053)	-0.109* (0.056)	-0.104**(0.045)	-0.105**(0.047)	-0.118*(0.065)
UR	0.381**(0.152)	0.430**(0.169)	0.356** (0.146)	0.377***(0.122)	0.303* (0.171)
CR	0.121* (0.060)	0.113* (0.060)	0.118** (0.059)	0.087* (0.051)	0.127* (0.076)
GDP*WGI	0.009***(0.002)				
GDP*RL		0.024*** (0.007)			
GDP*CC			0.024***(0.007)		
GDP*RQ				0.017***(0.004)	
GDP*GE					0.023** (0.009)
No. of Observation	525	525	525	525	525
No. of groups	27	27	27	27	27
No. of instruments	9	9	9	9	9
Hansen test					
(*p* value)	0.548	0.594	0.613	0.327	0.489
AR(1)					
(*p* value)	0.000	0.000	0.000	0.000	0.000
AR(2)					
(*p* value)	0.702	0.748	0.748	0.814	0.521

Note: Standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10%, respectively.

Source: Authors' calculations

In Table 5, we present the GMM estimates of Equation (2) using interaction term between GDP per capita and different proxies for quality of institutions. According to the outcomes of a dynamic relationship between variables, the one period lagged dependent variable is highly statistically significant in all our models. REC have a negative effect on carbon emissions, which range from 0.10 to 0.12. The statistically significance and positive sign of the multiplicative term of the GDP per capita with composite institutional index, suggests that enhanced institutional setting encourages the expansion of economic activities, which negatively affects the quality of the environment. The *interactions between GDP per capita and indices of institutional quality on CO_2 emissions* are statically significant and positive throughout the estimated models, which implies that the advancement in institutional framework together with economic expansion augment environmental degradation. It's noteworthy, that the order of magnitude of coefficients of the governance indicators is larger than the coefficients of their interaction terms with GDP per capita. Similar results are shown, for example, in the publication by Xaisongkham and Liu (2022), while Khan and Rana (2021) come to the opposite conclusions. The presented calculations confirm our initial hypothesis that emissions into the atmosphere in transition countries increase under the mutual influence of economic expansion and institutional evolution. In order to mitigate this effect, it is necessary to implement targeted solutions in the field of green technologies that would not limit the economic growth potential in the selected countries.

Table 6: The results of two-step SYS-GMM: the interdependence between institutional quality and urbanization

Variables	**1**	**2**	**3**	**4**	**5**
CO_2(-1)	0.838*** (0.100)	0.850*** (0.104)	0.843***(0.089)	0.873***(0.099)	0.820*** (0.118)
GDP	-0.174** (0.086)	-0.194** (0.093)	-0.162* (0.083)	-0.165**(0.079)	-.0139 (0.106)
TO	-0.020 (0.084)	-0.019 (0.084)	-0.030 (0.077)	-0.008 (0.082)	-0.009 (0.096)
REC	-0.116** (0.053)	-0.111* (0.056)	-0.107**(0.044)	-0.105**(0.048)	-0.121* (0.066)
UR	0.377** (0.146)	0.429*** (0.164)	0.364** (0.144)	0.369***(0.119)	0.298* (0.170)
CR	0.119** (0.058)	0.112* (0.058)	0.121** (0.057)	0.084 (0.051)	0.126* (0.073)
URB*WGI	0.019*** (0.005)				
URB*RL		0.054*** (0.016)			
URB*CC			0.056***(0.016)		
URB*RQ				0.035***(0.008)	
URB*GE					0.050** (0.020)

Variables	1	2	3	4	5
No. of Observation	525	525	525	525	525
No. of groups	27	27	27	27	27
No. of instruments	9	9	9	9	9
Hansen test (*p* value)	0.502	0.552	0.577	0.307	0.433
AR(1) (*p* value)	0.000	0.000	0.000	0.000	0.000
AR(2) (*p* value)	0.708	0.738	0.755	0.826	0.526

Note: Standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10%, respectively.

Source: Authors' calculations

An additional objective was to identify the possible effect of institutional quality on the extent to which urban growth impacts environmental quality. In Table 6, all the interaction terms between indices of institutional quality and urbanization are positive and significant. The sign and significance of these interaction terms indicates that better quality of institutional setting does not play crucial role in mitigating environmental damage from urbanization. The positive moderating role of institutions could be partly explained by the fact that policy-makers even in the conditions of institutional development might prioritize economic expansion and urban areas growth at the expense of environmental protection. In contrast to our conclusions, Hu and Khan (2023) show that although WGI indices have positive impact on carbon emissions, the interaction between them and urbanization mitigates environmental degradation.

Conclusion

The study was conducted to evaluate the impact of the quality of institutions on carbon emissions in 27 transition countries over the period 2002 to 2021. The moderating effects of institutions in shaping GDP and urbanization outcome were tested with the help of the system GMM estimation technique. Our empirical findings revealed that GDP per capita has negative impact on CO_2 emissions. We also found the pollution-augmenting impact of land use change and urbanization whereas the renewable energy consumption lessens environmental degradation. These results are consistent with the findings of other studies that have also examined the impact of these variables on air pollution. In particular, carbon dioxide emissions in agriculture are associated with land-use change in favor of croplands: organic soils emit this gas when they are drained to be converted to cropland. As for urbanization process, the growth of densely populated settlements results in more environmental risks (higher energy demand, use of newly established industrial facilities, expanding fleet of public and private transport, etc.). It is widely recognized that the use of renewable energy sources is an effective way for many countries to reduce greenhouse gas emissions.

The coefficients of different governance indicators are positive and statistically significant: control of corruption has the strongest impact on pollution, followed by rule of law, governance effectiveness and regulatory quality. An overall governance indicator is also positively associated with carbon emissions, so one can make conclusion, that institutional advancement ensures economic expansion, which contributes to the environmental degradation. Thus, we do not confirm the hypothesis H1 (strengthening institutional framework leads to environmental sustainability). Explaining the obtained results, we could assume that better institutional setting provides opportunities for development of capital-intensive economic sectors including those with high “carbon footprint” (like manufacturing, transportation, and energy generation). The interactions between GDP per capita, urbanization and indices of institutional quality on CO_2 emissions are statistically significant and positive, which shows that the advancement in institutional framework together with economic growth augment environmental degradation. Our empirical findings diverge from initial assumption H2 (strengthening institutional setting, combined with economic outcome, reduce environmental degradation). We confirm the hypothesis H3 that advancement in institutional framework coupled with urbanization accelerates environmental degradation.

The negative effect of institutional quality on environmental outcomes can be also attributed to the fact that the data we used highlighted institutional advancements that are not directly linked to the adoption and enforcement of environmental protection policies. Moreover, a positive correlation between institutional quality index and carbon emissions could indicate the low effectiveness of institutions in promoting environmental sustainability. We hypothesize that these institutional reforms were primarily focused on stimulating economic growth and creating a conducive environment for investment, rather than on enacting regulations to enhance environmental quality. Policymakers dealing with economic challenges such as rising unemployment, inflation, and inequality often prioritize these issues over environmental concerns, treating them as secondary and something to address once more immediate problems are resolved. We contend that these four dimensions of institutional quality are not influencing climate change policy regulation. Besides, our findings suggested that the relationship between economic performance, urbanization, and environmental degradation is dependent on the quality of institutions in transition countries.

One can single out the main limitation of this empirical study: our research does not fully address specific legislative measures that directly influence the reduction of CO_2 emissions, mostly due to data missing. These national or supranational policies could play a key role in the relationship between institutional quality and environmental situation. Thus, the analysis of such measures may be included among promising areas for future research.

Based on study results we could provide important policy considerations for transition countries. While these countries have established institutional frameworks for environmental protection and sustainable development, they are often hindered by poor implementation of regulations. This is due to factors such as inadequate financial resources, inconsistencies between enacted laws, low rates of action plan execution, limited environmental awareness, and unclear or overlapping responsibilities among various institutions. Effective environmental protection policies require coordination within public administration, access to relevant data, and the active participation of all stakeholders in the decision-making process. While improvements in institutional setting are generally associated with positive development outcomes, careful attention must be paid to ensure that these improvements are coupled with policies and regulations that mitigate environmental impacts and promote sustainable development. Regulators must develop and implement a balanced approach that takes into account both the interest of economic actors and national goals to reduce environmental impact. In addition, policymakers should focus on ensuring that environmental regulations are effectively enforced, preventing potential pollutants from bypassing rules due to insufficient oversight. This includes strengthening enforcement mechanisms and fostering greater transparency and accountability in governance.

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EMISIJE UGLJEN-DIOKSIDA I INSTITUCIJE: ULOGA UPRAVLJANJA U ODRŽIVOSTI ŽIVOTNE SREDINE

Apstrakt: Rad se bavi uticajem kvaliteta institucija, kao i njegovom međuzavisnošću sa ekonomskim performansama, na degradaciju životne sredine u periodu od 2002. do 2021. godine za panel od 27 tranzicionih zemalja. Glavni cilj istraživanja je ispitivanje uloge interakcije kvaliteta institucija na povezanost između ekonomskog rasta, urbanizacije i emisije ugljen-dioksida u odabranim zemljama. Na osnovu rezultata GMM metoda ocenjivanja, utvrdili smo da je ukupni kvalitet institucija, kao i jačanje regulatornih struktura, poboljšanje vladavine prava, unapređenje kontrole korupcije i poboljšanje efikasnosti vlade pozitivno povezano sa emisijama ugljen-dioksida. Institucionalni napredak pogoduje ekonomskoj ekspanziji, što doprinosi pogoršanju kvaliteta životne sredine. Naši empirijski nalazi potvrdjuju da napredak u institucionalnom okviru zajedno sa ekonomskim rastom i urbanizacijom povećavaju degradaciju životne sredine. Dobijeni rezultati imaju značajne implikacije za kreatore politika, ukazujući da institucionalni okvir može izazvati razmenu između promocije ekonomskog rasta i zaštite životne sredine.

Ključne reči: kvalitet institucija, upravljanje, emisije ugljen-dioksida, zemlje u tranziciji, urbanizacija, ekonomski rast.

Appendix I

Table 1: Studies exploring the impact of institutional quality on CO2 emissions

Author	Period	Countries	Variables				Methods	Results
			Emissions (dependent variable)	Economic situation, income	Energy	Other		
Apergis and Ozturk (2015)	1990-2011	14 Asian	CO_2	GDP		PD, LA, IN%, IQ	GMM, DOLS, FMOLS	∩-EKC (+), IQ → CO_2 ↓
Bhatta-charya *et al.* (2017)	1991-2012	85	CO_2 pc	GDP	RE, NRE	EF	FMOLS, GMM	RE, EF → CO_2 ↓
Allard *et al.* (2018)	1994-2012	74	CO_2 pc	GDP pc	RE%	PA, TO, PR	QPR	PR, PA, TO → CO_2; RE → CO_2 ↓; N-EKC (+)
Lau *et al.* (2018)	2002-2014	100	CO_2 pc	GDP pc		FDI, TO, CC, RL	GMM	CC, RL, TO → CO_2 ↓; ∩-EKC (+ in developed)
Ali *et al.* (2019)	1996-2010	47 developing	CO2	GDP	EC	IQ, FD, TO, UR	GMM	IQ→ CO_2 ↓; GDP, EC, TO, UR → CO_2
Sarkodie *et al.* (2020)	1990-2017	47 SSA	GHG	GDP pc	RE%	FDI, PI, TO, UR	DHM	RE→ CO_2 ↓; GDP, FDI, PI, GDP*PI*RE→ CO_2
Wawrzyniak and Doryń (2020)	1995-2014	93	CO_2 pc	GDP pc	RE pc, FF pc	CC, GE, RM, FDI pc	GMM	GDP*GE → CO_2 ↓; ∩-EKC (+)
Bakhsh *et al.* (2021)	1996-2016	40 Asian	CO_2 pc	GDP pc	EC	FDI, IQ, PA, DC, TO	GMM	FDI*IQ, FDI*PA → CO_2 ↓
Khan and Rana (2021)	1996-2015	41 Asian	CO_2	GDP pc	EC	IQ, TO, FD, FDI, GE	VECM	GDP, EC, TO, FDI → CO_2; IQ, FD → CO_2 ↓; GDP*IQ, TO*IQ, FDI*IQ → CO_2 ↓;
Shahnazi and Shabani (2021)	2000-2017	28 EU	CO_2 pc	GDP pc	RE pc, NRE pc	EF, UR	SDPD	GDP, NRE, UR → CO_2; RE → CO_2 ↓; EF → CO_2 (U-shape); ∩-EKC (+)

Author	Period	Countries	Variables				Methods	Results
			Emissions (dependent variable)	Economic situation, income	Energy	Other		
Simionescu (2021)	1990-2019	7 CEE and SEE	GHG	GDP pc	EC pc, RE%	EF, HDI, CC, LP, FDI, AG, AG e	DPTM, VECM	RE, HDI, CC → CO_2 ↓; AG → CO_2 (N-shape); inv.N-EKC (+)
Güney (2022)	2005-2018	35	CO_2	GDP pc	FEg, SOg	IQ	AMG, CCEMG, FMOLS	IQ, SOg, IQ*SOg → CO_2 ↓ FEg, GDP→ CO_2
Simionescu *et al*. (2022)	1990-2019	10 CEE and SEE	GHG	GDP pc	RE%	DC, LP, CC, RL, RQ	ARDL	LP → CO_2; RE, DC, RQ, RL, CC → CO_2 ↓; U-EKC (+)
Xaisong-kham and Liu (2022)	2002-2016	115 developing	CO_2	GDP pc	RE	GE, RL, FDI, EM	GMM	GE, RL → CO_2 ↓; GDP*GE → CO_2; ∩-EKC (+)
Yang *et al*. (2022)	1984-2016	42 developing	CO_2 pc	GDP pc	EC	INI, IQ, IN%, TO	FMOLS, PMG	INI, IQ, EC, IN, TO → CO_2; INI*IQ → CO_2 ↓; ∩-EKC (+)
Yirong (2022)	1990-2019	5	CO_2	GDP pc		PA, PO, EPS	ARDL, NARDL	EPS → CO_2 ↓
Amin *et al*. (2023)	1995-2020	5 South Asian	CO_2 pc	GDP pc	RE%	PA, EF, TO, PO	AMG, CCEMG	GDP, EF, TO, PO → CO_2; RE, PA → CO_2 ↓
Chhabra *et al*. (2023)	1991-2019	BRICS	CO_2	GDP	RE pc, FF pc	TO, IQ	DCCE	GDP, TO, FFpc→ CO_2; IQ → CO_2 ↓
Hu and Khan (2023)	2002-2019	BRI	CO_2 pc	GDP pc	EC	IQ, UR, IN%, TR	GMM, OLS	GDP, EC, UR, IN, IQ → CO_2; TR, UR*IQ → CO_2 ↓
Stef *et al*. (2023)	1996-2016	136	CO_2 pGDP	GDP pc	EC pc, RE%, REg%, FF%, EI%	CC, RL, RQ, VA, FA, UR, GFCF, EX, FDI, CPI	XAI	CC, RL, RQ, VA → CO_2 ↓

Notes: BRI – Belt and Road Initiative countries, CEE – Central-Eastern Europe, EU – European Union, SEE – South-Eastern Europe, SSA – Sub-Saharan African countries.

Variables typically used in research of carbon emission factors: CO_2, CO_2 pc, CO_2 pGDP – CO_2 emissions (t / kt), the same per capita, the same per GDP (carbon intensity); GHG – greenhouse gas emissions; GDP, GDP pc – gross domestic product, the same per capita; RE, RE pc, RE% – renewable energy consumption, the same per capita, the same of total energy consumption (%); NRE, NRE pc – non-renewable energy consumption, the same per capita; EC, EC pc – energy consumption, the same per capita; FEg – fossil fuel energy generation; SOg – electricity generation from solar PV; REg% – renewable energy generation of total energy (%); FF pc, FF% – fossil fuel consumption per capita, the same of total energy consumption (%); EI% – net energy imports (% of total energy consumption).

Variables dealing with institutional quality: IQ – Institutional quality index (Worldwide Governance Indicators); EF – Index of Economic Freedom; EPS – Environmental Policy Stringency Index (by OECD); PI – Political institutional quality (by QoG Institute); PR – Political rights and civil liberties index; CC – control of corruption; GE – government effectiveness; RQ – regulatory quality; RL – rule of law; VA – voice and accountability

Other variables: AG – agricultural sector value-added; AG e – employment in agriculture; CPI – consumer price index; DC – domestic credit to private sector (% of GDP); EM – employment structure; EX – exports; FA – forest area; FD – financial development; FDI – FDI inflows (% of GDP); FDI pc – FDI inflows per capita; GE – government expenditure; GFCF – gross fixed capital formation; HDI – Human Development Index; IN% – industrial sector value-added as % of GDP; INI – income inequality (Gini coefficient); LA – land area (km2); LP – labour productivity; PA – patent applications; PD – population density, PO – population; RM – personal remittances per capita; TO – trade openness; TR – international trade; UR – urbanization.

Methods: AMG – augmented mean group; ARDL – auto regressive distributed lag; CCEMG – common correlated effects mean group; DCCE – dynamic common correlated effects method; DHM – dynamic heterogeneous model; DOLS – dynamic ordinary least squares; DPTM – dynamic panel threshold model; FMOLS – fully modified ordinary least square; GMM – generalized method of moments; NARDL – nonlinear autoregressive distributed lag; PMG – pooled mean group method; QPR – quantile panel regression; SDPD – spatial dynamic panel data; STIRPAT – Stochastic Impacts by Regression on Population, Affluence, and Technology; VECM – vector error correction model; XAI – explainable artificial intelligence.

Results: U-EKC – U-shaped EKC; ⍰-EKC – inverted U-shaped EKC; N-EKC – N-shaped EKC; inv.N-EKC – inverted N-shaped EKC.

Table 2: Strategic documents in the field of climate policy (national and macroregional level)

Albania	• National Energy and Climate Plan (2021) • National Strategy on Climate Change and Action Plans (2019) • National Strategy of Energy 2018-2030 (2018)
Armenia	• National Program of Adaptation to Climate Change (2021) • Energy Sector Development Strategic Program to 2040 (2021)
Azerbaijan	• Law on the Efficient Use of Energy Sources and Energy Efficiency (2021)
Belarus	• National Action Plan for the Development of "Green" Economy in Belarus for 2021-2025 (2021) • State Program for Environmental Protection and Sustainable Use of Natural Resources 2021-2025 (2021)
Bosnia and Herzegovina	• Climate Change Adaptation and Low Emissions Growth Strategy by 2035 (2020)
Georgia	• Georgia's 2030 Climate Strategy and Action Plan (2021)
Kazakhstan	• Strategy to Achieve Carbon Neutrality Until 2060 (2022) • Environmental Code of the Republic of Kazakhstan (2021)
Kyrgyz Republic	• Program for the Development of a Green Economy in the Kyrgyz Republic for 2019-2023 (2019)
Moldova	• Law … on Climate Action (2024)
Montenegro	• Climate Resilience Strategy and Action Plan (2019)
North Macedonia	• Long-Term Strategy on Climate Action and Action Plan (2021) • Energy Development Strategy until 2040 (2020)
the Russian Federation	• Strategy of Socio-Economic Development of the Russian Federation with Low Greenhouse Gas Emissions until 2050 (2021) • Federal Law … On Limiting Greenhouse Gas Emissions (2021) • Energy Strategy to 2035 (2020)
Serbia	• Serbian Law on Climate Change (2021) • Low Carbon Development Strategy 2023-2030 (2023) • Decree on the Types of Activities and Gases with a Greenhouse Effect (2021)
Tajikistan	• National Strategy for Adaptation to Climate Change of the Republic of Tajikistan for the period up to 2030 (2019)
Ukraine	• Law … on the State Climate Policy (2024) • Concept of State Climate Change Policy Implementation until 2030 (2016)
Uzbekistan	• Strategy on the Transition of the Republic of Uzbekistan to a "Green" Economy 2019-2030 (2019)

<table>
<tr><td>Bulgaria</td><td rowspan="11">• Communication on The European Green Deal (2019)
• Fit for 55 (2021)
• REPowerEU. Affordable, secure and sustainable energy for Europe (2022)
• Directive … on the promotion of the use of energy from renewable sources (2018)</td><td>• National Energy and Climate Plan (NECP) (2019)
• Long-Term Climate Change Mitigation Strategy by 2050 (2022)
• Climate Neutrality Roadmap (2024)</td></tr>
<tr><td>Croatia</td><td>• National Energy and Climate Plan (NECP) (2019)
• Law on Climate Change and the Protection of the Ozone Layer (2019)</td></tr>
<tr><td>Czech Republic</td><td>• National Energy and Climate Plan (NECP) (2019)
• Climate Protection Policy (2017)</td></tr>
<tr><td>Estonia</td><td>• National Energy and Climate Plan (NECP) (2019)
• Climate Change Adaptation Plan 2030 (2017)</td></tr>
<tr><td>Hungary</td><td>• National Energy and Climate Plan (NECP) (2019)
• National Clean Development Strategy 2020-2050 (2021)
• Climate and Nature Protection Plan (2020)</td></tr>
<tr><td>Latvia</td><td>• National Energy and Climate Plan (NECP) (2020)
• Latvia’s Strategy to Achieve Climate Neutrality by 2050 (2019)</td></tr>
<tr><td>Lithuania</td><td>• National Energy and Climate Plan (NECP) (2019)
• National Climate Change Management Agenda (2021)</td></tr>
<tr><td>Poland</td><td>• National Energy and Climate Plan (NECP) (2019)
• The 2030 National Environmental Policy (2019)
• Energy Policy until 2040 (2021)</td></tr>
<tr><td>Romania</td><td>• National Energy and Climate Plan (NECP) (2020)
• Romania's Long-Term Strategy for Reducing Greenhouse Gas Emissions (2023)
• The National Strategy on Adaptation to Climate Change 2022-2030 (2022)</td></tr>
<tr><td>Slovakia</td><td>• National Energy and Climate Plan (NECP) (2019)
• Greener Slovakia – Strategy of the Environmental Policy of the Slovak Republic until 2030 (2019)
• Low-Carbon Development Strategy until 2030 with a View to 2050 (2020)</td></tr>
<tr><td>Slovenia</td><td>• National Energy and Climate Plan (NECP) (2020)
• Long-Term Climate Strategy until 2050 (2021)</td></tr>
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Note: information collected by authors from Climate Change Laws of the World (https://climate-laws.org), Energy Policy Reviews by International Energy Agency (https://www.iea.org), the websites of national governments and ministries.