Does governance contribute to the public spending – CO_2 emissions nexus in developing economies? Policy lessons for sustainable development

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Article**
JEL: E60, Q53, Q54, Q56
https://doi.org/10.3326/pse.48.1.4

* This research work is supported by the University of Finance – Marketing (UFM). The author would like to thank to two anonymous reviewers for their valuable help in completing this article.

** Received: December 19, 2022
Accepted: May 5, 2023

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PUBLIC SECTOR ECONOMICS
48 (1) 79-101 (2024)

Abstract

Global climate change due to increasing CO_2 emissions threatens the development and survival of many countries, especially those on the coast. Intentional government spending by sectors can lower CO_2 emissions to help these countries in sustainable development. Meanwhile, governance has some importance in enabling governments to achieve their economic development goals. Does governance affect the public spending – CO_2 emissions nexus in developing economies? The paper seeks answers by employing the system GMM Arellano-Bond estimators to assess the impact of public spending, governance/institutional quality, and their interaction on CO_2 emissions for a sample of 109 developing economies between 2002 and 2021. The results seem counter-intuitive that public spending reduces and governance increases CO_2 emissions, while their interaction lowers them. Furthermore, private investment and economic growth promote CO_2 emissions, while trade openness decreases them. The findings in this paper provide some policy lessons for governments of developing economies to protect environment.

Keywords: public spending, CO_2 emissions, governance, developing economies

1 INTRODUCTION

Global climate change and global warming have emerged as hotly debated topics worldwide, driven by the excessive discharge of emissions harmful to the Earth such as CO_2 and SO_2. These gases come from unsustainable production and consumption, and the over-exploitation of natural resources. According to United Nations (2022), generating power, manufacturing goods, cutting down forests, using transportation, producing food, powering buildings, and consuming too much are the causes of global climate change. Notably, generating electricity and heat by burning fossil fuels (gas, oil, and coal) has the largest contribution to climate change, making up 90% of all CO_2 emissions and nearly 75% of greenhouse gas emissions. The most obvious consequence is that more than 70% of the population living in developing and coastal countries (Bangladesh, India, Indonesia, Philippines, Japan, Thailand, China, and Vietnam) will be severely affected due to sea level rise (Climate Central, 2019). Therefore, the United Nations suggests that countries need to work together to overcome the climate challenges facing mankind. Governments must act immediately with the instruments at hand (fiscal policy, with government spending playing a key role) to address climate change, and move toward sustainable development (Fernández, López and Blanco, 2018). Some fiscal instruments in environmental protection are public spending, direct taxes, and indirect taxes (Postula and Radecka-Moroz, 2020). "Taxes and charges are often labelled pricing instruments, as they impose a price on the environmentally harmful aspects of production or consumption and thus aim at influencing consumer behaviour by increasing prices." (Kosonen and Nicodème, 2009). Meanwhile, public spending on environmental protection includes protection of biodiversity landscapes, pollution abatement, and wastewater and waste management. In particular, governments in developing economies should reform and improve governance/institutional quality to make sure that public spending on environmental protection is effectively allocated and used.

Regarding the academic aspect, studies on the role of public spending in environmental protection are relatively numerous, and this topic is considered a research stream in economics. Nearly all studies confirm that government spending can reduce harmful emissions, thus improving environmental quality. However, no existing papers check the influence of governance/institutional quality on the public spending – CO_2 emissions nexus. Institutional reforms tend to lead to sustainable growth and development (Acemoglu, Johnson and Robinson, 2005; Acemoglu and Robinson, 2008). More importantly, institutional reforms provide, propose, and create feasible solutions to help countries solve their internal problems and achieve the goals of the United Nations. Institutional quality is a crucial factor in dealing with environmental issues. Institutional improvement is a suitable instrument for the control of CO_2 emissions (Salman et al., 2019). Institutional quality plays a direct and indirect role in environmental protection via regulations and policies. Institutional structure (bureaucratic quality, corruption control, law and order, government stability, and democracy) may be an appropriate catalyst in the promotion of environmental quality (Uzar, 2021). Therefore, this paper suggests the research question: "Does governance contribute to the public spending – CO_2 emissions nexus?" It will look for the answer to contribute to the literature under the following hypotheses:

H1: Public spending has tended to reduce CO_2 emissions in a group of 109 developing countries from 2002 to 2021.

H2: Institutional quality/governance has tended to reduce CO_2 emissions in a group of 109 developing countries from 2002 to 2021.

H3: The interaction term has tended to reduce CO_2 emissions in a group of 109 developing countries from 2002 to 2021.

Motivated by the recognition that (1) people in developing economies are heavily affected by climate change and global warming, (2) there is an important role of governance in the public spending – CO_2 emissions nexus, this paper uses the system of GMM (Generalized Method of Moments) Arellano-Bond estimators to study the impact of public spending, governance, their interaction on CO_2 emissions for a group of 109 developing economies between 2002 and 2021. The findings of this paper should provide some policy lessons for governments in developing economies.

The paper has the following structure. Section 1 is the introduction, highlighting the practical and academic contexts for this research, while section 2 presents some facts on global CO_2 emissions. Section 3 describes the theoretical framework and literature review, while section 4 notes the methodology and research data. Section 5 reports the results and discussion, and section 6 provides the conclusion and the policy lessons.

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2 SOME FACTS ON GLOBAL CO_2 EMISSIONS

An official report by United Nations (2022) on climate change shows that in 2020, the eight largest emitters (international transport and 7 G20 members) contributed 55% of total greenhouse gas emissions: international transport, Russia, Brazil, Indonesia, India, the European Union, the United States, and China. The whole G20 contributed more than 75% of the total. However, the emissions by the top 8 fell by 3.8% to 35.5 GtCO2e in 2020 from 32.8 GtCo2e in 2019.

From the national inventories in 2020, the land use, land use change, and forest (LULUCF) sector saw a net decrease in emissions inventories of 17 G20 countries, the United States, Russia, India, the European Union, and China. The greenhouse gas emissions was 33% in Russia, 17% in the United States, 9% in India, and 8% in the European Union and 8% in China. In contrast, the LULUCF sector saw a net increase in Brazil and Indonesia, making up 22% and 44% of their total.

In most large emitters, including Indonesia, Brazil, Russia, India, and China, greenhouse gas emissions re-increased in 2021, exceeding pre-pandemic levels. The highest rises from 2019 to 2021 were found in China and Indonesia, at 5.9% and 6.8% respectively. The emissions by international transport in 2021 were still lower than 2019 levels. Greenhouse gas emissions per capita in the European Union and the United States are likely to have decreased during the past decade, but those in other regions to have increased. Least developed economies, on average, emit 2.3 tCO2e. India keeps up at 2.4 tCO2e, followed by 7.2 tCO2e in European Union, 7.5 tCO2e in Indonesia and Brazil, 9.7 tCo2e in China, and 14 tCO2e in the United States. Cumulative carbonic emissions vary significantly among global regions and countries. From 1850 to 2019, the least developed economies contributed 0.5% to total fossil carbonic emissions. Meanwhile, Brazil and Indonesia contributed 1%, India 3%, Russia 7%, China 13%, the European Union 17%, and the United States 25%.

According to Hausfather and Friedlingstein (2023), in 2022, global emissions of CO_2 (including fossil fuel and land use) rose by about 0.8%, stemming from rising fossil fuel CO_2 emissions and steady land use emissions. They remain high at 40.5GtCO2 as compared with the 2019 peak of 40.9GtCO2. Notably, the Democratic Republic of the Congo, Brazil, and Indonesia contribute about 60% to global land use emissions. In 2022, in the United States, emissions rose by approximately 1.5% due to the combination of a high decrease in coal emissions (-4.6%), a modest increase in oil emissions (+2%), and a high increase in gas emissions (+4.7%). By contrast, emissions in the EU fell by 0.8% due to global energy market disruption and low gas use linked with the war between Russia and Ukraine. As in the EU, emissions in China were reduced by 0.9% because of lockdowns connected with the pandemic. However, India is likely to see emissions rising by 6% due to a high increase in coal emissions (+5%) and oil emissions (+10%). Meanwhile, the remaining world takes a 1.7% rise in emissions, coming from increases in cement production (+3%), oil (+3.1%), and coal (+1.6%) use and a slight decline in gas emissions (-0.1%).

3 THEORETICAL BACKGROUND

3.1 THEORETICAL FRAMEWORK

López, Galinato and Islam (2011) describe a theoretical model to provide predictions for testing the nexus between the allocation of government expenditure and the environment in the general equilibrium condition. This model makes three assumptions. First, production pollution stems from the mostly industrial sector (agriculture, mining, manufacturing, and related industries), while the service sector and human capital-producing sector are relatively unpolluting (Mani and Wheeler, 1997). Second, the industrial sector (polluting sector) is more fossil fuel-intensive and capital-intensive than the human capital-producing sector (knowledge sector) and the service sector (clean sector) (Antweiler, Copeland and Taylor, 2001). Third, although public spending on private services and goods can address all three sectors, they are mostly focused on the polluting sector (López and Islam, 2008). The theoretical analysis notes some conditions under which the redistribution of public expenditure from private to public goods and services can lead to lower pollution by production. This means that when there is an increase in government spending on private goods and services and on public ones by the same ratio, the pollution-enhancing impacts of increasing the former seem to be offset by the pollution-decreasing impacts of the latter.

Regarding institutional quality, we suggest that regulations and policies issued by governments can have a significant effect on the public spending – CO_2 emissions relationship. Institutional improvement can promote the effective allocation of public spending on environmental protection. Accordingly, public spending on environmental protection should be monitored and supervised strictly and transparently, and effectively implement regulations and policies that reduce CO_2 emissions and enhance environmental quality.

3.2 LITERATURE REVIEW

The global warming phenomenon and its consequences have led to more and more research on the role of government in mitigating climate change. Therefore, in recent decades, sustainable economic development has become a crucial goal for most economies. To achieve this goal, Fernández, López and Blanco (2018) argue that there is a need to reduce and stabilize greenhouse gas emissions, implementing the transition to a zero- or low-carbon production system. Regarding this topic, several studies have focused on public expenditures on sectors that reduce polluted gases and gases that cause environmental change, while others note the role of total public spending in environmental protection.

Adewuyi (2016), Fernández, López and Blanco (2018), Petrović and Lobanov (2020), and Shao, Zhang and Irfan (2022) are studies that employ public expenditure composition in an empirical model. Adewuyi (2016) applies some estimators (PMG, MG, and fixed effects model) to examine the impact of expenditures by households, companies, and governments on CO_2 emissions in 40 large economies (10 countries with the highest level of emissions in each region: Asia, Africa,

Europe, and America) from 1990 to 2015. The results indicate public spending decreases CO_2 emissions worldwide. Meanwhile, Fernández, López and Blanco (2018) use the OLS regression to assess the impact of government expenditure on R&D on CO_2 emissions for a group of 15 European countries, the United States, and China over the period 1990-2013. The findings show that government expenditure on R&D reduces CO_2 emissions. In conclusion, this work indicates that public expenditure on R&D should be encouraged, not only as an engine of economic growth but also as a driver of sustainable development, in which economic growth can be achieved with low CO_2 emissions. Petrović and Lobanov (2020) employ some estimation methods (fixed effects model, MG, and common correlated effects pooled) to test the influence of public expenditure on R&D on CO_2 emissions for a sample of 16 OECD countries from 1981 through 2014. The results show that public expenditure on R&D decreases CO_2 emissions in these countries. Recently, Shao, Zhang and Irfan (2022) have applied the ARDL estimator to a panel dataset of the 10 largest countries in the OECD between 1990 and 2019 to check the effect of public expenditure on entertainment, culture, and society on CO_2 emissions. The results report that these expenditures reduce CO_2 emissions. According to these researchers, governments can use these expenditures to raise awareness in the population of the relationship of social responsibility, responsible consumption, and sustainability with society, health, the environment, and ecology. This finding implies that the appropriate allocation of budgets to entertainment and culture promotes the effectiveness of environmental protection through the welfare, awareness, and satisfaction of the people.

Similarly, Halkos and Paizanos (2013; 2016; 2017), Zhang et al. (2017), Huang (2018; 2021), Levytska and Romanova (2020), and Feng et al. (2022) are studies that use general government expenditure in the empirical models. Halkos and Paizanos (2013) examine the impact of government spending on the environment using a group of 77 countries from 1980 to 2000 and some estimation methods (OLS regression, fixed effects model, difference fixed effects model, and GMM Arellano-Bond). The results show that government spending reduces SO_2 emissions but does not affect CO_2 emissions. Meanwhile, public spending indirectly reduces SO_2 emissions for low-income countries and increases SO_2 emissions for high-income countries. However, public expenditure does indirectly decrease CO_2 emissions for all countries with different incomes. This implies that the effect of public spending on emissions is conditional on the level of income. Following this paper, Halkos and Paizanos (2016) apply the VAR model for the quarterly time series dataset of the United States from 1973 to 2013 to explore the impact of fiscal policy on CO_2 emissions. The findings report that the expansionary fiscal policy reduces emissions by production and consumption, while fiscal deficit due to tax cuts increases CO_2 emissions by consumption. Halkos and Paizanos (2017) apply the fixed effects model and random effects model to a panel dataset of 94 countries from 1970 to 2008. The results indicate the effect that public spending has on the reduction of SO_2 and NO_x emissions. Meanwhile, Zhang et al. (2017) consider the influence of government spending on three types

of emissions employing GMM Arellano-Bond estimation for a panel sample of 106 cities in China between 2002 and 2014. The results note this influence is different for different types of emissions, negative for SO_2 emissions, an inverted U shape for soot emissions, and a U shape for COD emissions. Furthermore, Huang (2018) uses a spatial Durbin model for a panel group of 30 cities in China from 2008 through 2013 to study the impact of government environmental protection expenditure on SO_2 emissions. The final result reveals that this expenditure decreases SO_2 emissions. Levytska and Romanova (2020) apply a modified generalized regression network model for a time series dataset of Ukraine from 1979 to 2017. They find that public spending can improve environmental protection. Recently, Huang (2021) uses the fixed effects model and difference GMM estimation for a group of 20 municipalities, county-level cities, and counties in Taiwan between 2013 and 2018 to explore the impact of public spending on environmental protection. He notes the positive impact of public spending. Lately, Feng et al. (2022) apply the system GMM estimation to measure the relationship between government spending and green economic performance for a panel sample of 46 selected countries in BRI over the period 2008 and 2018. The findings show that government spending has a positive impact on green economic performance. In addition, the analysis indicates that public expenditures in human capital and renewable energy lead to green economic performance through labour and technology progress.

Unlike the above studies, Galinato and Galinato (2016) examine the influence of change and composition in public expenditures on deforestation due to agriculture land expansion and CO_2 emissions. The empirical results indicate that government expenditure increases forest clearing for agriculture production in the short run, increasing CO_2 emissions. However, it is not significant in the long run. Meanwhile, Moshiri and Daneshmand (2020) employ an ARDL model for a time series dataset of Iran between 1976 and 2014. They do not find any evidence for the impact of public spending on environmental protection.

From the literature perspective, there is no study to explore the role of governance/institutional quality in the public spending – CO_2 emissions nexus. This paper uses the system GMM Arellano-Bond estimators (one-step and two-step) to fill this gap and make a novel contribution to the literature.

4 METHODOLOGY

4.1 EMPIRICAL MODEL

Following Feng et al. (2022), the empirical model is corrected and modified as follows:

$$CO2_{it} = \tau_0 + \tau_1 CO2_{it-1} + \tau_2 EXP_{it} + \tau_3 GO_{it} + \tau_4 (\mathrm{EXP} \times GO)_{it} + Y_{it}\tau' + \rho_i + \sigma_{it} \quad (1)$$

where i denotes the country index, while t denotes the time index. $CO2_{it}$ is the CO_2 emissions per capita (tons), a proxy for environmental quality, $CO2_{it\text{-}1}$ is the initial

level of CO_2 emissions. EXP_{it} is total government expenditure (% GDP), GO_{it} is the governance dimension (rule of law, regulatory quality, control of corruption, voice and accountability, political stability, government effectiveness), and $(EXP \times GO)_{it}$ is the interaction between government expenditure and the governance dimension. Y_{it} includes some control regressors (private investment, economic growth, and trade openness). ρ_i is an unobserved country-specific, time-invariant effect and σ_{it} is an observation-specific error term. τ_1, τ_2, τ_3, τ_4, τ' are estimated parameters. The control regressors in the empirical models are selected by reviewing the literature. Private investment promotes more production, leading to more CO_2 emissions (Halkos and Paizanos, 2013; Adewuyi, 2016; Zhang et al., 2017; Huang, 2018; Petrović and Lobanov, 2020). Meanwhile, economic growth improves the living standard of the people and produces more goods and services, increasing more consumption and pollution (Adewuyi, 2016; Zhang et al., 2017; Fernández, López and Blanco, 2018; Huang, 2018; Petrović and Lobanov, 2020; Feng et al., 2022; Shao, Zhang and Irfan, 2022). Similarly, an openness policy promotes more exports and imports, enabling people to consume more goods and services and boosting pollution (Halkos and Paizanos, 2013; Adewuyi, 2016; Huang, 2018; Petrović and Lobanov, 2020).

To estimate (1), the paper applies the GMM Arellano and Bond (1991) suggested first by Holtz-Eakin, Newey and Rosen (1988). The first difference in all regressors is taken to eliminate country-specific fixed effects (ρ_i). Following this step, the regressors in the first difference are used as instrumented variables in lags under the assumption that time-varying errors in the original models do not have serial correlations (Judson and Owen, 1999). It is the difference GMM (DGMM) that can handle simultaneity biases in estimations.

In a case in which regressors are highly persistent, their past values do not provide information about their future changes, making their lags weaker instrumental variables. Therefore, it will be necessary to combine the original equation and the equation in the difference to have a system of two equations, one in the difference that is instrumented by lags and one in the level that is instrumented by lags in the differences (Arellano and Bover, 1995). It is the system GMM (SGMM) that can promote effectiveness by handling weak instruments in DGMM and reducing the biases in estimates. The consistency of SGMM is based on the assumption that there is no serial correlation, the instruments are valid, and changes in additional instruments do not correlate with fixed effects.

In practice, the two-step SGMM (2SGMM) is more asymptotically efficient than the one-step SGMM. Unfortunately, as Roodman (2009) shows, there is a problem in employing 2SGMM for some small samples. The problem is that instruments will proliferate quadratically as the time dimension rises, so the number of instrumental variables is larger than the number of countries (panel units). Roodman (2009) suggests applying a rule of thumb to keep the number of instrumental variables lower than the number of countries.

The Arellano-Bond test, Sargan test, and Hansen test are employed to check the validity of instrumental variables in 2SGMM. The Sargan and Hansen tests discover endogenous phenomena, while the Arellano-Bond tests detect the serial correlation of the errors in the second difference. Therefore, the paper ignores AR(1) and uses AR(2).

4.2 RESEARCH DATA

The dataset consists of CO_2 emissions (metric tons per capita), total government expenditure, gross fixed capital formation, real GDP per capita, trade openness, and governance indicators extracted from World Bank and IMF databases. The research sample contains 109 developing economies[1] over the period 2002-2021.

Table 1 presents the data description, while tables 2A and 2B report the descriptive statistics. Table 2B indicates that developing economies have poor governance, so they should reform the institutional environment to promote economic activities effectively. Meanwhile, tables 3A and 3B describe the matrixes of correlation coefficients. Table 3A shows that public spending, private investment, economic growth, and trade openness are positively associated with CO_2 emissions. Table 3B notes that the correlation coefficients among governance dimensions are more than 0.8; hence, they should be employed separately in the empirical equations to eliminate collinearity.

To ensure the stability and reliability of regressors in the empirical equations, their stationarity is tested and shown in table 4. The results show that all regressors are stationary at a significance level of 1%, confirming that they have a similar integration order I(0).

Table 1

Dataset description

Variable	Definition	Type	Source
CO_2 emissions (CO_2, tons)	CO_2 emissions (metric tons per capita).	log	World Bank
Public spending (EXP, %)	Total expenditure consists of total expense and the net acquisition of nonfinancial assets.	%	IMF
Private investment (PIN, %)	Gross fixed capital formation (% GDP).	%	IMF

[1] Azerbaijan, Zimbabwe, Armenia, Zambia, Argentina, Vietnam, Albania, Ukraine, Angola, Uruguay, Algeria, Uganda, Burkina Faso, Uzbekistan, Burundi, Turkmenistan, Brazil, Turkey, Bosnia & Herzegovina, Tajikistan, Botswana, Tanzania, Bhutan, Thailand, Bolivia, Timor-Leste, Benin, Togo, Belarus, Tonga, Belize, Tunisia, Bangladesh, Sudan, Cambodia, Saudi Arabia, Senegal, China, Serbia, Chile, Sierra Leone, Chad, South Africa, Cameroon, Sri Lanka, Colombia, Congo, Dem. Rep., Romania, Comoros, Russian Federation, Congo, Rep., Rwanda, Cote d'Ivoire, Philippines, Costa Rica, Poland, Croatia, Peru, Dominican Rep., Paraguay, Egypt, Arab Rep., Panama, Ecuador, Pakistan, El Salvador, Oman, Eswatini, North Macedonia, Equatorial Guinea, Nigeria, Gabon, Niger, Georgia, Nicaragua, Gambia, Nepal, Ghana, Namibia, Guinea, Myanmar, Guatemala, Mozambique, Guinea-Bissau, Morocco, Hungary, Montenegro, Honduras, Mongolia, Indonesia, Moldova, India, Mexico, Iraq, Mauritius, Iran, Mauritania, Jordan, Mali, Jamaica, Malaysia, Kazakhstan, Madagascar, Kiribati, Libya, Kenya, Lao PDR, Kyrgyz Rep., Lebanon, and Lesotho.

Variable	Definition	Type	Source
Economic growth (GDP, USD)	GDP per capita (constant 2010 US$).	log	World Bank
Trade openness (OPE, %)	The sum of exports and imports of goods and services measured as a share of gross domestic product.	%	World Bank
Regulatory Quality (GO1)	Regulatory Quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.	level	World Bank
Rule of Law (GO2)	Rule of Law captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.	level	World Bank
Voice and Accountability (GO3)	Voice and Accountability captures perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media.	level	World Bank
Control of Corruption (GO4)	Control of Corruption captures perceptions of the extent to which public power is exercised for private gain, including both as well as "capture" of the state by elites and private interests.	level	World Bank
Government Effectiveness (GO5)	Government Effectiveness captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.	level	World Bank
Political Stability (GO6)	Political Stability and Absence of Violence/ Terrorism measures perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism.	level	World Bank

Source: Author's preparation.

Table 2A

Descriptive statistics

Variable	Obs.	Mean	Std. dev.	Min.	Max.
CO_2	2,180	2.645	3.192	0.020	17.819
EXP	2,180	28.617	15.491	3.787	181.949
PIN	2,180	23.474	8.333	2.000	81.021
GDP	2,180	4,941.198	7,769.721	267.31	77,544.032
OPE	2,180	76.024	33.308	0.784	210.400

Source: Author's calculation.

Table 2B

Descriptive statistics (governance dimensions)

Variable	Obs.	Mean	Std. dev.	Min.	Max.
GO1	2,180	-0.525	0.604	-1.672	1.662
GO2	2,180	-0.450	0.610	-1.962	1.254
GO3	2,180	-0.425	0.813	-3.180	1.422
GO4	2,180	-0.409	0.665	-2.348	1.536
GO5	2,180	-0.517	0.610	-1.870	1.348
GO6	2,180	-0.430	0.778	-2.259	1.311

Source: Author's calculation.

Table 3A

The matrix of correlation

	CO_2	EXP	PIN	GDP	OPE
CO_2	1				
EXP	0.297***	1			
PIN	0.145***	0.104***	1		
GDP	0.865***	0.250***	0.079***	1	
OPE	0.290***	0.312***	0.172***	0.221***	1

*Note: *** denotes a 1% significance level, ** 5% significance level, and * 10% significance level.*

Source: Author's calculation.

Table 3B

The matrix of correlation (governance dimensions)

	GO1	GO2	GO3	GO4	GO5	GO6
GO1	1					
GO2	0.806***	1				
GO3	0.599***	0.514***	1			
GO4	0.732***	0.841***	0.451***	1		
GO5	0.874***	0.858***	0.629***	0.810***	1	
GO6	0.622***	0.568***	0.449***	0.665***	0.653***	1

*Note: *** denotes a 1% significance level, ** 5% significance level, and * 10% significance level.*

Source: Author's calculation.

Table 4

Fisher type unit root tests

Variables	Augmented Dickey-Fuller test		Phillips-Perron test	
	Prob > chi2		Prob > chi2	
	Without trend	With trend	Without trend	With trend
CO_2	317.964***	283.801***	372.570***	295.218***
EXP	259.473**	278.028***	306.929***	370.393***
PIN	326.516***	254.230**	273.501***	176.643
GDP	308.696***	219.896	379.940***	201.929
OPE	322.259***	337.557***	281.902***	308.407***

Variables	Augmented Dickey-Fuller test		Phillips-Perron test	
	Prob > chi2		Prob > chi2	
	Without trend	With trend	Without trend	With trend
GO1	268.640***	266.250***	385.181***	451.596***
GO2	376.661***	316.394***	429.727***	377.175***
GO3	341.992***	327.326***	450.591***	454.349
GO4	243.557	245.751*	353.052***	399.309***
GO5	321.891***	318.653***	332.987***	372.622***
GO6	285.816***	344.309***	347.170***	339.510***

*Note: *** denotes a 1% significance level, ** 5% significance level, and * 10% significance level.*

Source: Author's calculation.

5 RESULTS

5.1 2SGMM ESTIMATES

Table 5 illustrates 2SGMM estimates for the baseline regression (without the interaction term between public spending and governance), while table 6 reports 2SGMM estimates for the full model (with the interaction term). Every column in the tables is a model corresponding with a governance dimension. In all estimation procedures, the paper discovers that private investment is endogenous; hence, it uses private investment as an instrumented regressor in the GMM style and CO_2 emissions, public spending, governance, economic growth, and trade openness as instrumental regressors in the IV style.

Without the interaction term, the estimates across models note that public spending reduces CO_2 emissions, while governance increases them. With the presence of the interaction term, the estimates are still consistent, meaning that public spending decreases and governance boosts CO_2 emissions, but their interaction term lowers them. Hence, the main result is that public spending reduces CO_2 emissions, and this negative impact is amplified by governance.

Most developing economies are experiencing the extreme effects of climate change. In particular, coastal developing economies are likely to be hardest hit. Therefore, governments in these economies try to improve environmental quality through activities such as limiting plastic waste, propagating green awareness, and changing the lifestyles and consumption of the population. Public spending on these goals is always encouraged and directed to stabilize people's health and lives. In particular, government expenditures on high-tech agricultural development and environmental protection are conducted to reduce negative impacts on the environment and move towards sustainable development. Because of this, government spending reduces CO_2 emissions, validating the H1 hypothesis and this result is completely consistent with previous studies such as Halkos and Paizanos (2013; 2016), Zhang et al. (2017), Huang (2018), and Feng et al. (2022).

In contrast to public spending, governance increases CO_2 emissions, which does not support the H2 hypothesis. Does this seem counter-intuitive? Most developing

economies have poor living standards and low income, so regulations and policies (governance) are designed, issued, and implemented to promote economic development and growth that creates more jobs and improves people's living standards. Improving institutional quality/governance aims at boosting the production and consumption of goods and services. Unfortunately, production technologies and management in these economies are outdated and environmentally friendly, and products do not meet the necessary green standards, which increases CO_2 emissions. Azam, Liu and Ahmad (2021) note that institutional quality degrades environmental quality by increasing CO_2 and CH_4 emissions in a group of 66 developing countries from 1991 to 2017. This finding suggests that institutional reforms in developing countries should be performed to regulate economic activities more eco-friendly.

However, regarding environmental protection, governance has a positive role. According to an official report by the United Nations (2022), most developing economies, especially those along coasts, will be hit the hardest by climate change and global warming. Because of this, regulations and policies issued by governments in these economies will focus on public spending to enhance environmental quality. Improving governance/institutional quality will effectively promote the allocation and use of public expenditures on environmental protection. These expenditures will be supervised and monitored transparently and strictly by the people to achieve the environmental goals suggested by the United Nations. Therefore, the interaction term between public spending and governance decreases CO_2 emissions, supporting the H3 hypothesis.

Private investment has always preponderantly aimed at expanding the production of goods and services and encouraging consumption. These economic activities generate more emissions during production and consumption, so private investment will generally increase CO_2 emissions. This finding can be found in previous related studies such as Halkos and Paizanos (2013), Adewuyi (2016), Zhang et al. (2017), and Petrović and Lobanov (2020). In the same vein, economic growth focuses on raising people's living standards and incomes and creating more jobs. Economic growth implies more production and more consumption. In particular, developing economies are always trying to promote economic growth with the desire to catch up with developed countries, so economic growth increases CO_2 emissions in these countries. This result has also been shown in previous studies such as Adewuyi (2016), Zhang et al. (2017), Fernández, López and Blanco (2018), Huang (2018), Petrović and Lobanov (2020), Feng et al. (2022), and Shao, Zhang and Irfan (2022).

Unlike previous studies, this paper discovers that trade openness reduces CO_2 emissions in developing economies. However, this finding is similar to that of Huang (2018). On the one hand, an economic openness policy can promote import and export in developing economies, increasing CO_2 emissions. On the other hand, this policy enables these countries to find in and receive from other countries the advanced and eco-friendly technologies and management models that can be used to produce green, environmentally friendly products to meet stringent consumer standards in other developed countries. Therefore, the final effect is the reduction of CO_2 emissions.

Table 5

Public spending, governance, and CO_2 emissions: 2SGMM estimates, 2002-2021 (baseline regression)

Dependent variable: CO_2 emissions (tons)

Variables	**GO1**	**GO2**	**GO3**	**GO4**	**GO5**	**GO6**
CO_2 emissions (-1)	0.981*** (0.002)	0.977*** (0.002)	0.980*** (0.002)	0.979*** (0.002)	0.980*** (0.002)	0.982*** (0.002)
Public spending	-0.070*** (0.011)	-0.054*** (0.012)	-0.083*** (0.014)	-0.054*** (0.012)	-0.065*** (0.012)	-0.095*** (0.016)
Governance	2.228*** (0.420)	2.509*** (0.469)	1.709*** (0.393)	2.181*** (0.405)	1.835*** (0.416)	1.388*** (0.362)
Private investment	0.384*** (0.044)	0.369*** (0.046)	0.360*** (0.050)	0.393*** (0.048)	0.330*** (0.045)	0.396*** (0.053)
Economic growth	0.0003 (0.001)	0.0000 (0.001)	0.0023 (0.001)	-0.0004 (0.001)	0.001 (0.001)	0.001 (0.001)
Trade openness	-0.042*** (0.012)	-0.039*** (0.012)	-0.054*** (0.015)	-0.046*** (0.012)	-0.045*** (0.013)	-0.049*** (0.015)
Instrument	41	41	37	38	40	36
Country/Observation	109/1635	109/1635	109/1635	109/1635	109/1635	109/1635
AR(2) test	0.964	0.980	0.960	0.966	0.969	0.963
Sargan test	0.190	0.355	0.159	0.183	0.229	0.205
Hansen test	0.156	0.126	0.106	0.108	0.111	0.125

*Note: *** denotes a 1% significance level, ** 5% significance level, and * 10% significance level.*

Source: Author's calculation.

TABLE 6

Public spending, governance, and CO_2 emissions: 2SGMM estimates, 2002-2021 (full model)

Dependent variable: CO_2 emissions (tons)

Variables	GO1	GO2	GO3	GO4	GO5	GO6
CO_2 emissions (-1)	0.977***	0.973***	0.977***	0.979***	0.977***	0.981***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Public spending	-0.138***	-0.175***	-0.107***	-0.186***	-0.132***	-0.112***
	(0.027)	(0.035)	(0.022)	(0.031)	(0.028)	(0.021)
Governance	5.251***	6.499***	3.545***	5.234***	4.759***	3.041***
	(0.902)	(1.033)	(0.598)	(0.861)	(0.793)	(0.658)
Pub. spend * Governance	-0.097***	-0.130***	-0.052***	-0.103***	-0.082***	-0.053***
	(0.023)	(0.026)	(0.012)	(0.020)	(0.020)	(0.017)
Private investment	0.339***	0.357***	0.349***	0.393***	0.347***	0.396***
	(0.048)	(0.049)	(0.048)	(0.044)	(0.048)	(0.052)
Economic growth	0.003**	0.004***	0.003**	0.003**	0.003**	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Trade openness	-0.025***	-0.027***	-0.050***	-0.031***	-0.033***	-0.043***
	(0.010)	(0.011)	(0.014)	(0.011)	(0.011)	(0.013)
Instrument	36	37	38	39	37	37
Country/Observation	109/1635	109/1635	109/1635	109/1635	109/1635	109/1635
AR(2) test	0.949	0.968	0.977	0.957	0.966	0.946
Sargan test	0.167	0.353	0.204	0.211	0.205	0.231
Hansen test	0.160	0.205	0.229	0.340	0.114	0.229

*Note: *** denotes a 1% significance level, ** 5% significance level, and * 10% significance level.*

Source: Author's calculation.

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5.2 ROBUSTNESS CHECK

The paper uses 1SGMM to test the robustness of 2SGMM estimates. Table 7 reports the results for the baseline regression, while table 8 notes the results for the full model. Like 2SGMM estimation, we discover that private investment is endogenous.

In line with 2SGMM estimates, 1SGMM estimates indicate that public spending reduces and governance increases CO_2 emissions, but their interaction term decreases them. Furthermore, private investment boosts CO_2 emissions, while trade openness lowers them. These results confirm that 2SGMM estimates are reliable and robust.

TABLE 7

Public spending, governance, and CO_2 emissions: 1SGMM estimates, 2002-2021 (baseline regression)

Dependent variable: CO_2 emissions (tons)

Variables	GO1	GO2	GO3	GO4	GO5	GO6
CO_2 emissions (-1)	0.981***	0.977***	0.980***	0.979***	0.979***	0.983***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Public spending	-0.045*	-0.032	-0.054**	-0.038*	-0.050**	-0.071***
	(0.024)	(0.022)	(0.024)	(0.022)	(0.021)	(0.025)
Governance	1.803***	2.533***	1.817***	2.327***	1.986***	1.277***
	(0.550)	(0.556)	(0.438)	(0.526)	(0.517)	(0.457)
Private investment	0.309***	0.310***	0.284***	0.332***	0.280***	0.311***
	(0.076)	(0.075)	(0.097)	(0.097)	(0.076)	(0.100)
Economic growth	0.0006	0.0009	0.004**	0.001	0.003	0.003
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
Trade openness	-0.038**	-0.043***	-0.067***	-0.051***	-0.051***	-0.057***
	(0.018)	(0.017)	(0.020)	(0.018)	(0.016)	(0.018)
Instrument	41	41	37	38	40	36
Country/Observation	109/1635	109/1635	109/1635	109/1635	109/1635	109/1635
AR(2) test	0.952	0.983	0.961	0.957	0.964	0.961
Sargan test	0.190	0.355	0.159	0.183	0.229	0.205

*Note: *** denotes a 1% significance level, ** 5% significance level, and * 10% significance level.*

Source: Author's calculation.

Table 8

Public spending, governance, and CO_2 emissions: 1SGMM estimates, 2002-2021 (full model)

Dependent variable: CO_2 emissions (tons)

Variables	GO1	GO2	GO3	GO4	GO5	GO6
CO_2 emissions (-1)	0.979*** (0.002)	0.975*** (0.002)	0.978*** (0.002)	0.978*** (0.002)	0.978*** (0.002)	0.981*** (0.002)
Public spending	-0.084* (0.047)	-0.142*** (0.049)	-0.085*** (0.028)	-0.153*** (0.049)	-0.093** (0.040)	-0.084*** (0.027)
Governance	3.803*** (1.609)	6.104*** (1.514)	3.533*** (0.811)	5.330*** (1.277)	4.049*** (1.368)	2.770*** (0.842)
Pub. spend * Governance	-0.073* (0.039)	-0.124*** (0.040)	-0.051*** (0.016)	-0.100*** (0.032)	-0.073*** (0.030)	-0.049*** (0.019)
Private investment	0.244*** (0.101)	0.282*** (0.091)	0.287*** (0.097)	0.342*** (0.097)	0.269*** (0.081)	0.315*** (0.100)
Economic growth	0.002 (0.002)	0.004* (0.002)	0.005*** (0.002)	0.004** (0.002)	0.002 (0.002)	0.003 (0.002)
Trade openness	-0.021 (0.019)	-0.032** (0.016)	-0.064*** (0.0120)	-0.046*** (0.016)	-0.029 (0.018)	-0.054*** (0.017)
Instrument	36	37	38	39	37	37
Country/Observation	109/1635	109/1635	109/1635	109/1635	109/1635	109/1635
AR(2) test	0.938	0.968	0.987	0.958	0.960	0.937
Sargan test	0.167	0.353	0.204	0.211	0.205	0.231

*Note: *** denotes a 1% significance level, ** 5% significance level, and * 10% significance level.*

Source: Author's calculation.

6 CONCLUSION AND LESSONS

Developing economies, particularly those located along a coast, can be hit hard by the rising sea levels stemming from global warming and climate change. Governments in these economies promote public spending to serve the development and economic growth and improve environmental quality. In particular, they also try to improve and reform institutional quality to achieve economic goals. Given these facts, the paper uses 1SGMM and 2SGMM to examine the role of governance in public spending – CO_2 emissions nexus for a group of 109 developing economies during the period 2002-2021. Like Halkos and Paizanos (2013; 2016), Zhang et al. (2017), Huang (2018), and Feng et al. (2022), this paper finds that public spending reduces CO_2 emissions. It also reports a positive impact of institutional quality on CO_2 emissions as shown by Azam, Liu and Ahmad (2021). However, the interaction between institutional quality and public spending decreases CO_2 emissions. These results imply that public spending lowers CO_2 emissions and this negative impact is amplified by governance. Therefore, these findings emphasize that research on the public spending – CO_2 emissions/environmental quality nexus should take into account the role of institutional quality/governance. Furthermore, private investment and economic growth increase CO_2 emissions, while trade openness decreases them.

The findings in this paper provide some policy lessons for governments in developing economies over the course of economic development and growth. Some policy implications can be identified, as follows:

- Governments in developing countries should reform and improve institutional quality to make economic activities more environment-friendly.
- They should design, issue and enforce regulations and policies (institutional quality/governance) to increase public spending, especially on developing high-tech agricultural industries, supporting start-up projects targeting green and clean products, and encouraging people to be aware of environmental protection and consume eco-friendly products. Public spending should be partly used to plant trees and improve polluted waterways.
- They should implement some policies to encourage the private sector to apply advanced and eco-friendly technologies in production and management. More importantly, products need to meet environmental standards.
- Driving economic growth to create jobs and improve people's living standards is what most governments will do. However, developing economies should focus on a circular, sustainable economy that is not harmful to the environment.
- Trade openness in developing economies has a positive impact on the environment, so governments in these countries should use some appropriate policies to encourage domestic enterprises to import advanced and eco-friendly machines and equipment and apply environment-friendly processing technology and encourage people to choose environment-friendly imported products.

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Several developing economies do not have enough data, so the research sample consists only of 109 developing countries. This is a limitation of the research. Future studies should consider the different roles of institutional quality in public spending – CO_2 emissions between developed and developing economies.

Disclosure statement

The author has no conflict of interest to declare.

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