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Green growth, governance, and green technology innovation. How effective towards SDGs in G7 countries?

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ABSTRACT
In light of the technological advancement and green growth in G7 economies, this research investigates the trends in sustainable development goals (SDGs) as reflected through social and environmental dimensions. Data were collected from 2000 to 2019 with yearly observation for advanced panel estimations.The preliminary finding raises the issues of cross-sectional dependency and slope heterogeneity; thus, we have applied the cross-sectional autoregressive distributed lag(CS-ARDL) model.The long-run findings confirm that technological innovations and green growth encourage environmental sustainability. Moreover, economic growth, green technological innovations, and government effectiveness have significantly promoted social development through higher employment opportunities. Similar results are also observed in the short run; however, the influence is more substantial in the long run. These findings imply that green growth, eco-innovations, and institutional governance are core drivers of SDGs in the long run.

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1. Introduction

Green Growth (GGR) fosters economic development and financial growth while ensuring the continuous availability of environmental services and natural resources for human well-being (OECD, 2021). GGR and sustainable economic growth are essential strategies for achieving sustainable development goals (SDGs). Economic growth can be attained with enhanced sustainability, and improved environmental quality is considered an essential policy under SDGs. To attain GGR goals, countries must set policies for reducing carbon emission levels. This is possible through technological innovation

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in energy production and the supply chain (Wiebe, 2022). In addition, GGR can be improved through green technology innovation (GTI) in the energy sector based on eco-friendly technologies (Su et al., 2020; Ullah et al., 2021). Technology innovation (TINO) will provide efficient energy production and utilisation, conserve natural resources, and minimise CO2 emissions (CEN). It allows simultaneous achievement of economic, ecological, and community goals and fosterssustainable industrial transformation. Technology advancement is critical to this transformation, and addressing environmental challenges will be difficult and costly without it. The OECD countries integrate green growth in their national and multilateral policy surveillance activities, including financial surveys, ecological performance evaluations, technology and capital market reviews, and the Green Cities Programs.

GGR is a vital strategy to achieve SDGs and human well-being in terms of employment (EMP). Environmental degradation and natural capital depletion can pose a threat to economic progress. However, minimal evidence of environmental degradation and economic expansion negatively influences. Some researchers argue that typical growth for developing nations is a better means out of poverty and a path to environmental sustainability. It is unclear whether a transition to green growth will produce the growth that developing countries require (Verkaart et al., 2019). Overall, GGR strategies have long-term impacts on environmental sustainability (Barbier, 2020). Governmental regulations also play a vital role in setting policies for achieving SDGs. Carbon emission levels determine the impact of GGR and the other factors of SDGs, including human TINO, CEN, GDP, and governmental effectiveness at the country level (GEF) (Sohag et al., 2019).

The central idea of the given research work is to contribute to the debate on effective governance at the country level (GEF) to attain SDGs, especially in the context of Agenda 2030 set by countries of the United Nations. The agenda states the global commitment towards sustainable development and environmental sustainability (United Nations, 2018). The dynamic role of GEF is mainly addressed through a normative point of view in the research studies (Visseren-Hamakers et al., 2021). All member states are called upon to integrate effective GEF into their national development and sustainability plans. Prior studies suggest that the correlation and complexity of SDGs need holistic, integrated, and logical regulations where public and private sectors need to implement and monitor reasonable governance goals (Khalid & Maidin, 2022). According to Bornemann and Weiland (2021), SDG governance must provide an enabling climate for collective action, hold actors responsible, and deal with growing complicated trade-offs across aspirations. Thus, by analysing GEF attributes in lower- and upper-income countries and their effectiveness in achieving SDGs, specific insights have been provided that will contribute to sustainable goals. Governance can be recognised in a country's specific areas of sustainable achievement (Taghvaee et al., 2022). Effective governance can aid by building a climate conducive to collaborative action, ensuring that all parties engaged are held responsible, and addressing growing complicated trade-offs between objectives (GGI, 2022). GEF has been referred to as the fourth pillar of sustainable development, alongside social, ecological, and economic aspects, because of its relevance in motivating efforts to accomplish the goals.

Achieving the SDGs requires tangible actions in several aspects, including TINO development (Cancino et al., 2018). TINO plays a vital role in the competitiveness of a country. It is also essential to cope with the issues posed by non-renewable production, social inequalities, and environmental degradation. According to United Nations Industrial Development Organization (UNIDO), innovations can integrate all the dimensions of sustainability. Globalisation has enabled the financial transfer of innovations from industrialised to underdeveloped countries. However, due to a lack of technological capacity and a country's capacity to promote innovative systems, this diffusion has not always translated into real opportunities for growth. In this context, liable inventions are required to reinforce the development of technology innovation. Regarding social development and employment opportunities, automation and technology bring innovative working methods, but replacing the workforce with machines also impacts the job market (Bekhet & Latif, 2018).

SDGs are more critical now than at all times. A total of 17 goals need to be accomplished under sustainable development. The research work is based on determining the factors affecting the accomplishment of SDGs and social development goals. GGR, TINO, GDP growth, and GEF are the determinants of SDGs and EMP opportunities in developing and developed nations. Economic growth (GDP) is also an essential factor that brings a decisive shift in SDG accomplishment as it is the 8th goal. The research states that unconditional growth in per capita GDP risks the development of sustainable goals. Thus, the association is also provided between GDP growth and SDGs that can bring environmental sustainability. The study includes a dynamic analysis of current literature on GGR, GEF, and TINO, along with indicators that can positively or negatively impact the given variables. This study contributes to the current knowledge on the importance of green development and governmental policies following the SDGs through empirical analysis. It also contributes to the analysis of TINO and GEF, which impacts societies' environmental sustainability and social development. The following section will provide a literature review, methodology, and empirical analysis.

2. Literature review

2.1. Green growth and environmental goals

GGR promotes economic development and growth while preserving natural resources. It assures environmental assets and resources vital for human wellbeing in social development goals or employment. To achieve GGR, it is essential to improve innovation and investment to provide sustained economic growth and help achieve environmental goals (CEN) (OECD, 2022). GGR and sustainable development has gained much importance in the last decade to achieve ecological goals while preserving natural assets. Abid et al. (2022) explored the dynamic association between green development and environmental sustainability. The interrelationship between the GGR and CEN is provided through a novel technique based on grey relational analysis. Findings of the study reveal that GGR is significantly integrated with CEN. However, in case of developing nations with enhanced consumption of fossil fuels, there is a need to foster the GGR to overcome the environmental challenges. Likewise, Hussain et al. (2021) proposed the

GGR strategy for achieving CEN. They investigate the impact of GGR on environmental factors in higher GDP economies employing the panel data between 2000 and 2020. Moreover, it also provides the impact of economic growth on GGR, which ultimately help countries to achieve CEN. Their findings show that green technology innovation (GTI) and economic growth improve the GGR, significantly reducing CO2 emissions in the long run. Nassani et al. (2019) explored the relationship between GGR and GHG emission rates by employing the data between 1970 and 2016 in Pakistan. The study implements the generalised method of moments (GMM) approach and endorsesthe Environmental Kuznets curve (EKC).

2.2. Green technology and environmental goals

Green technologies can help to minimise greenhouse gas emissions for environmental protection. Environmental patents also play a vital role in improving environmental sustainability. Compared to other types of innovation indicators, patent data have several advantages. They are readily available, quantifiable, impartial, and outcome-focused. They can also be differentiated, which is useful when studying environmental technology. However, not all inventions or advances are trademarked (OECD, 2019). Du, Li, and Yan determined TINO's impact on CO2 emission levels by employing panel data from 71 countries between 1996 and 2012. Their findings reveal that TINO does not significantly impact reducing carbon emissions for lower-income countries while reducing carbon emissions levels for higher-income countries. The study also suggests developing innovative mechanisms to eliminate CO2 emissions and improve environmental sustainability. Cheng et al. (2019) investigated the impact of environmental patents on carbon emission levels per capita, employing the data from BRICS economies between 2000 and 2013. It utilises the panel quantile regression approach and reveals that the development of environmental regulations increases the per capita carbon emission levels.

Bashir et al. (2020) investigated the impact of environmental patents and carbon tax on achieving sustainable development goals. The study analyses the data between 1995 and 2015 for OECD economies while employing the quantile regression and GMM approaches. The empirical research states that environmental patents negatively impact CO2 emissions. Furthermore, TINO improves environmental quality by reducing carbon emission levels. The study suggests changes in environmental policies to minimise degradation and enhance investment for GGR. Abedi and Moeenian's (2021) examine the role of environment patents and their impact on climate change mitigation in Middle East economies. Using multi-linear regression models, the findings show that environmental patents and increased TINO significantly impact climate change mitigation and improve environmental sustainability (Ullah et al., 2019).

2.3. Economic growth and environmental goals

You et al. (2022) explored the causal relationship between economic growth (GDP) and carbon emission rates by analysing the panel data for the period 1996–2015 for developing economies. They implement the Granger causality model and validate a bi-directional causalitybetween economic growth and carbonemissions. Moreover, a positive correlation exists between economic complexity and environmental sustainability. Li and Li (2020) constructed an econometric model to determine the impact of economic growth in per capita GDP on carbon emission levels for 30 provinces of China. The study employs a unified economy, energy, and environmental sustainability approach to develop a spatial econometric model. Their findings reveal that economic growth is responsible for enhanced emission levels in China.

Chen et al. (2020) investigated the impact of economic growth on carbon emission levels by employing the dynamic panel threshold model. The study uses panel data from 31 developing economies for a specific time interval. Research findings reveal that economic growth negatively impacts carbon emission levels in the case of low-income countries but has a positive impact in the case of high-income countries. A U-shaped correlation is established in the given study, which provides an evident causal relationship between the economic growth rate, per capita GDP, and emissions. The findings underscore transforming low-carbon technology to reduce emissions and achieve long-term economic growth. This could involve improving energy efficiency and switching from non-renewable to renewable energy sources. Li and Ouyang (2019) examined the dynamic impact of economic development on carbon emissions levels in China from 1978to 2015. The ARDL approach reveals that increased per capita income can significantly reduce carbon emission levels in long-run.

2.4. Governance and environmental goals

Leal Filho et al. (2019) exhibited the importance of good governance in curbing environmental degradation and maintaining sustainable development. Good governance in terms of political, economic, and institutional aspects are taken as conditional variables. They evaluate the impact of governance parameters on carbon emission in 20 MENA countries between 1996 and 2014. It implements the simultaneous-equation modelling method, which states that good institutional and political governance positively contributes towards sustainable development. Findings further state that governance allows nations to eliminate the negative impacts of CO2 emissions on overall development. Sarwar and Alsaggaf (2021) evaluated the impact of good governance indicators to curb carbon emissions by increasing environmental awareness among the public. There has been a rise in environmental degradation, which need to be addressed for sustainable growth under government policies and regulations. The study implements the 'Quantile Regression' (QR) approach for Saudi Arabia from 1970 and 2018. Empirical findings of the study reveal that effective governance leads to lower carbon emissions. Government intervention is required to improve regional governance and ensure climate vulnerabilities.

Zhang et al. (2022) determined a link between carbon emissions and institutional factors vital for improved GEF in policymaking and economic growth. Using BRICS data from 1996 to 2019, it determines that governmental stability negatively impacts carbon emission levels in the long run. It also states that institutional factors enhance CO2 emissions in the case of BRICS economies. Governments must strengthen the GEF factors to improve environmental sustainability. Climate change has become a global concern, and different countries are devising policies to mitigate its negative environmental impacts. Based on the mandate of the Kyoto Protocol, Hao et al. (2021) investigated the impact of GEF on CO2 emissions in South Asian economies, including India, Sri Lanka, Pakistan, and Bangladesh. The study analyses the panel data from 1996 to 2019 using advanced techniques. It confirms the cross-sectional dependence between given variables. A cross-sectional ARDL approach is also employed to determine GEF's long- and short-term impacts on carbon emission levels. Findings of the study reveal that GEF is found to be beneficial in reducing environmental degradation. Governments are advised to integrate foreign direct investment and environmental regulations to improve sustainable development technologies.

2.5. Green growth and social development goals

GGR policies are found to be improving the environmental quality along with improved economic growth. These aspects positively impact employment (EMP) by creating more jobs in various green economic sectors. In contrast, non-renewable strategies implemented by the government destroy the overall workforce (OECD, 2017). Green laws have as their primary goal the improvement of air quality. Failure to address major environmental issues will seriously affect the environment, people's health, and the economy. Climate change, poor air quality, and the erosion of the natural resource base impact all sectors of the economy, both directly and indirectly, and can hinder long-term growth forecasts.

Bowen et al. determine the green economy's impact on employment development (EMP). According to the US database, GGR can generate 19.4% of the jobs in the green sector. Green jobs vary in their' greenness,' with only a few employments consisting entirely of green duties, implying that the term 'green' should be viewed as a continuum rather than a binary trait. While transitioning to indirectly green occupations is more accessible than directly green jobs, greening is likely to involve transformations of the same magnitude and scope as present job transformations. Network analysis suggests that the green economy has considerable potential for short-run growth if job transitions are effectively managed. Baş (2021) studied the impact of green development on EMP while explaining the conditions of green EMP and GGR for Turkey. Moreover, the potential of EMP is determined by the renewable energy sector and the development of new EMP opportunities. Findings of the study reveal that GGR has significantly positive impacts on the creation of EMP in the green sector.

2.6. Green technology and social development goals

Green technology allows countries to harness energy from natural resources through innovative means that do not harm the environment. It can also reduce carbon emission levels, improve energy utilisation, and provide environmental sustainability. Moreover, it is considered that social development is not possible without TINO and GGR (Sun et al., 2022). Based on the importance of TINO for social development goals, Li and Zhu (2019) stated the valued contribution of environmental patents to attain sustainability. Using panel data of Chinese manufacturing organisations from 2011 to 2017, it confirmed a positive impact of TINO on the EMP. Moreover, varying ownership structures in enterprises can negatively impact TINO on EMP based on increased stringency on environmental protection and technical density. Thus, countries must devise various TINO systems for environmental protection and develop more jobs in the green sector.

Marin and Vona (2019) determined climate policies' impact on job creation in 14 European economies. The study implements the shift-share variable estimating approach to analyse the data between 1995 and 2011 for the industrial sector of Europe. Empirical findings of the study reveal a partial correlation between the given variables. Moreover, TINO benefits EMP and skill development in a long-term relationship. TINO has generally termed a job creator and its positive impacts on a sustainable environment. Environmental regulations also improve innovative technologies that positively influence growth and EMP creation. Jens (2020) argued that introducing cleaner process improvements rather than product-based ones can increase employment. The idea implies that greener technologies contribute to potential savings, which improves a competitive edge in the industry, resulting in an increased share of the technology market. Environmental innovations are any innovations that have a positive impact on the environment. Thus, even though the related innovative efforts did not seek to improve the ecosystem, it is feasible that they will be classified as green.

2.7. Economic growth and social development goals

Economic growth is termed as a prerequisite for increased EMP and production. An increase in per capita GDP sets the goal of developing EMP rates and a skilled workforce. Khare (2019) explored the impact of GDP on Indian social development goals and argues that economic opportunities can be created through inclusive growth in all sectors, including products and services. Soleh and Suwarni (2021) stated that higher economic growth positively impacts the development of the EMP and encourages the workforce for enhanced productivity. The study analyses the inclusive EMP growth employing the workforce growth in different provinces of Indonesia. The study uses the descriptive analysis method to measure inclusive growth in the Indonesian economy. Findings of the study reveal that economic growth is still not inclusive in developing the EMP rate in most provinces based on the panel data between 2011 and 2019. In addition, human capital plays a vital role in developing the GDP growth rate and thus creates more EMP opportunities.

Khan et al., (2019) analyse the impact of GDP growth on EMP in the context of developing nations while employing the panel data between 1996 and 2018. The study employs two proxies, including education expenses and expectancy, to determine human capital development. It also employs the variables of agricultural development, capital information, and manufacturing as control variables. They implement the random and fixed-effect models and find that economic growth has a significant positive impact on EMP opportunities in developing nations. The impact of GDP growth on creating productive jobs is determined by the pace of development and the efficiency with which growth is translated into productive EMP. The latter is determined by several factors, including the makeup of growing sectors and development's capital/ labour intensity. In most cases, there is a need to expand both the number of jobs and performance and earned income (ILO, 2021). Kinyondo and Pelizzo showed that GDP growth contributes towards EMP creation and opportunities in the context of Tanzania. They employed official data from local government offices of Tanzania and confirmed the cointegrating relationship between given variables.

2.8. Governance and social development goals

The customs and structures by which a country's political power is exercised are governance. The GEF encompasses selecting, monitoring, and replacing administrations, the ability of the government to devise and implement appropriate policies, and citizens and the state's respect for the institutions that control social and economic relations (World Bank, 2022). Keeping governance mechanisms in the significant context of social development, Agunowei and Blanchard (2022) investigated the role of GEF, policies, and politics in EMP generation and sustainable economic growth. The study reveals that poor policies, governance, and corrupted government can negatively impact EMP. Theyargue that governmentintervention is negatively associated with growth and employment in of Nigeria.

Shabbir et al. determined the short- and long-run relationship between economic growth through good governance and EMP rate in South Asian economies. They employ the panel vector correction technique to develop a cointegration between EMP rate governance policies implemented by the government. The study employs the data collected from WGI and WDI from 1994 to 2016. The correlation stability is also tested through forecast variance decomposition and impulse response functions. The study's empirical findings reveal a significantly positive relationship between the given variables. Furthermore, financial credit activities negatively impact the EMP rate in these economies. Bidirectional causality is also determined between GEF and EMP rate using the Granger causality approach. Good governance appropriately manages the state's economic, social, and development aspects based on available natural resources. GEF also seeks to protect the rights of people and provide them with equal EMP opportunities. It also highlights public management, development framework, transparency, and data flow.

3. Research methods

Initially, we examined the cross-sectional dependence between the study variables. This is because various macroeconomic factors can create cross-sectional dependence where such issues mainly lead to errors in the empirical findings, specifically in the study coefficients. Moreover, the presence of CD has been investigated along with the heterogeneity in the slope coefficients. One of the most valuable methods for expressing the relationship between independent and dependent variablesis the cross-sectional autoregressive distributed lag (CSARDL) estimation. As stated earlier, this

Table 1. Variables of the study.

Variable name	Abbreviation	Measurement	Source
Environmental goals	CEN	CO2 emissions (metric tons per capita)	World Bank
Social development goals through employment	EMP	Total employed workforce in a given year	World Bank
Green growth	GGR	Adjusted net savings, including particulate emission damage (% of GNI)	World Bank
Green technology	TINO	Environmental patents as % of total patents	OECD
Economic growth	GDP	Current USD	World Bank
Governance in terms of governmental effectiveness at the country level	GEF	Indicators as per WGI, ranging from −2.5 to 2.5	WGI database

Source: Author's estimations.
Note: G7 countries selected for this study.

research entitles carbon emission and employment as two of the key-dependent variables to reflect the title of social and environmental development goals. Moreover, key explanatory variables are green technology innovations, green growth, governance, and economic growth. The details of the study variables are given in Table 1. The worldwide governance indicators (WGI) provide individual and aggregate governance factors for more than 200 nations from 1996 to 2020. It includes different governance dimensions: accountability and voice, regulatory quality, political stability, the rule of law, corruption control, and governmental effectiveness. These composite indicators are based on the responses of many businesses, citizen, and expert survey respondents from developed and developing nations. They are based on data from over 30 survey institutions, political organisations, non-governmental organisations, international organisations, and private sector companies (World Bank, 2022).

3.1. Variable details

More specifically, Eqs. 1 and 2 cover the traditional equation for expressing the relationships between the stated variables.

$$CEN_{i,t} = f\ (GGR_{i,t},\ TINO_{i,t},\ GEF_{i,t}) \tag{1}$$

$$EMP = f\ (GDP_{i,t},\ TINO_{i,t},\ GEF_{i,t}) \tag{2}$$

The cross-sections in the above two equations have been presented through 'i' in where the time duration of 2000–2018 has been covered through 't'.

Eqs. 3 and 4 show the regression form of Eqs.1 and 2.

$$CEN_{it} = \beta_{1it} + \beta_{2it}GGR_{it} + \beta_{3it}TINO_{it} + \beta_{4it}GEF_{it} + \alpha_i + \delta_{it} \tag{3}$$

$$EMP_{it} = \beta_{1it} + \beta_{2it}GDP_{it} + \beta_{3it}TINO_{it} + \beta_{4it}GEF_{it} + \alpha_i + \delta_{it} \tag{4}$$

The autoregressive distributed lag (ARDL) model is defined as Eq.5. However, Eq. 5 was used for each repressor the cross-section average and extended into Eq. 6

$$W_{i,t} = \sum_{i=0}^{pw} \varphi_{i,t} W_{i,t-1} + \sum_{i=0}^{pz} \gamma_{i,t} Z_{i,t-1} + \varepsilon_{i,t} \tag{5}$$

The cross-section average reduced the CSD effects.

$$W_{it} = \sum_{i=0}^{pw} \varphi_{i,t} W_{i,t-1} + \sum_{i=0}^{pz} \gamma_{i,t} Z_{i,t-1} + \sum_{i=0}^{px} \alpha_i \overline{X}_{t-1} + \varepsilon_{i,t} \tag{6}$$

where

$$\overline{X}_{t-1} = (\overline{W}_{i,t-1}, \overline{Z}_{i,t-1})$$

W_{it} is used for the consumption-based carbon dioxide emission per capita as an endogenous or dependent variable, whereas $Z_{i,t-1}$ indicates all independent variables, such as green technology innovation and renewable energy. Moreover, $\overline{X}_{t-1}$ is the average of both exogenous and endogenous variables to mitigate the issue of CSD due to the effects of spill-over; however, P_w, P_z, and P_x demonstrate each variable lag.

The long-run coefficients' value is estimated from the coefficients of the short run in the CS-ARDL test. The mean group estimator and the long-run coefficient are as under:

$$\hat{\pi}_{CD-ARDL,i} = \frac{\sum_{I=0}^{pz} \hat{\gamma}_{Ii}}{1 = \Sigma_{I=0}} \hat{\varphi}_{I,t} \tag{7}$$

The mean group is as follows:

$$\hat{\bar{\pi}}_{MG} = \frac{1}{N} \sum_{i=1}^{N} \hat{\pi}_i \tag{8}$$

The estimated short-run coefficients are as follows:

$$\Delta W_{it} = \vartheta_i [W_{i,t-1} - \pi_i Z_{i,t-1}] - \sum_{i=0}^{pw-1} \varphi_{i,t} \Delta_i W_{i,t-1} + \sum_{i=0}^{pz} \gamma_{i,t} \Delta_i Z_{i,t-1} + \sum_{i=0}^{px} \alpha_i \overline{X}_t + \varepsilon_{i,t} \tag{9}$$

where

$$\Delta_i = t - (t-1)$$

$$\hat{\tau}_i = -\left(1 - \sum_{i=0}^{pw} \hat{\varphi}_{i,t}\right) \tag{10}$$

$$\hat{\pi}_i = \frac{\sum_{i=0}^{pz} \hat{\gamma}_{i,t}}{\hat{\tau}_i} \tag{11}$$

Table 2. Results of cross-sectional dependence analysis.

Variable	Test Statistics
GGR	19.256***
TINO	22.258***
GDP	29.517***
GEF	26.507***
CEN	33.652***
EMP	21.236***

Note: ***, **, and * explain the level of significance at 1%, 5% and 10%, respectively, whereas the values are in parentheses contains P-values.
Source: Author's estimations.

$$\hat{\hat{\pi}}_{MG} = \frac{1}{N}\sum_{i=1}^{N}\hat{\pi}_i \tag{12}$$

4. Results and discussion

Cross-sectional dependence has been investigated and presented findings in Table 2. The null hypothesis for the CD test indicates no existence of CD, whereas H1 rejects it with significant test statistics. The findings reflect that green growth, technologicalinnovation, gross domestic product, governmental effectiveness, carbon emission, and employment have reflected their significant results at 5%; thus, rejecting H0 and accepting the presence of CD across the panel

The investigation of CD in the panel data leads to checking for the unit root properties. Table 3 presents the Pesaran (2007) unit root test results in the presence of CD. This research also applies Bai & Carrion-I-Silvestre (2009) panel unit root test, which integrates trends in the data with structural breaks. The results in Table 3 report that the null hypothesis has not been rejected for the absence of stationarity at a level (Bai & Carrion-I-Silvestre, 2009). Moreover, the data is stationarity at levels in Pesaran (2007) test. Thus, the consideration of the first difference was quite evident in the implication of Bai & Carrion-I-Silvestre (2009).

For investigating the slope heterogeneity in the study coefficients, our study mainly applies the modified version of Swamy's test based on the key suggestion of Pesaran and Yamagata (2008). They investigate the trends in slope homogeneity in the panel data estimations. The results are shown in Table 4 for considering both dependent variables; carbon emission and employment for environmental and social development goals. The findings show that test values for CEN in terms of delta tilde and delta tilde adjusted were 53.580 and 66.254, respectively. Similarly, for model 2, Table 3 indicates thetest statistics (52.558 and 61.258) are significant at 1%. These results confirm the presence of heterogeneity in the slopeparametersin both models.

Using Westerlund and Edgerton (2008) cointegration test, the findings (Table 5) confirm a long-run cointegrating relationship between model variables in case of no break, mean shift, and regime shift categories. It is inferred that H1 is accepted; hence panel cointegration exists in both models. Hence researchers are moving towards both long-run and short-run estimations.

The long-run CS-ARDL results in Table 6 (Column 2) show a significant and negative relationship between green growth and CEN emission, provided that the

Table 3. Results of Unit root test with & without structural break Pesaran (2007).

	Level I(0)			First Difference I(1)		
Variables	CIPS	M-CIPS			CIPS	M-CIPS
GGR	−4.587***	−3.147**			–	–
TINO	−2.998***	−5.010**			–	–
GDP	−3.629***	−3.669**			–	–
GEF	−3.124***	−5.548**			–	–
CEN	−5.268***	−4.510**				
EMP	3.558***	−3.625**				
Bai & Carrion-I-Silvestre (2009)						
	Z	P_m	P	Z	P_m	P
GGR	0.369	0.239	20.363	−3.357***	4.357***	53.028***
TINO	0.227	0.138	19.826	−5.538***	6.339***	68.357***
GDP	0.307	0.208	18.526	−4.257***	3.652***	59.076***
GEF	0.162	0.179	21.578	−6.159***	4.357***	59.103***
CEN	0.159	0.528	25.205	−5.639***	3.528***	61.205***
EMP	0.258	0.357	31.525	−4.528***	3.985***	48.529***

Note: The significance level is determined by 1%, 5%, and 10% indicated through ***, ** and *, respectively.
Source: Author's estimations.

Table 4. Results of slope heterogeneity analysis.

Statistics: DV: CEN (Model 1)	Test value (P-value)
Delta tilde	53.580*** (0.000)
Delta tilde Adjusted	66.524*** (0.000)
Statistics: DV: EMP (Model 2)	Test value (P-value)
Delta tilde	52.558*** (0.000)
Delta tilde Adjusted	61.258*** (0.000)

Note: ***, ** & * explain the level of significance at 1%, 5% and 10% respectively, whereas the values are in parentheses contains P-values.
Source: Author's estimations.

Table 5. Results of Westerlund and Edgerton (2008) panel cointegration analysis.

Test for DV: CE (Model 1)	No break	Mean shift	Regime shift
Zφ(N)	−6.520***	−4.598***	−6.309***
Zτ(N)	−3.997***	−6.025***	−5.487***
Test for DV: EMP (Model 2)	No break	Mean shift	Regime shift
Zφ(N)	−7.598***	−7.159***	−8.075***
Zτ(N)	−5.664***	−5.267***	−6.418***

Note: *** shows significance at 1%.
Source: Author's estimations.

green growth in G7 countries reduces environmental issues. More specifically, the selected countries reported an overall decline of 0.512% because of a 1% change in green growth. Compared to traditional growth models, green growth depends on renewable energy sources with minimum environmental influence. Additionally, green growth promotes all those activities through which the adverse impact on nature would be lower. Existing literature has been observed with theoretical and empirical findings but with a limited contribution. For instance, Hao et al. (2021) focus on environmental taxes and green growth to explore carbon emissions through advanced panel techniques. The results have reported that both linear and non-linear trends in green growth help reduce carbon emissions. Recently, Dogan et al. (2022) applied quantile regression estimations to check the role of green growth at different

Table 6. Long-run results.

Model 1 (Environmental)	Coefficients (T-values)	Model 2 (Social)	Coefficients (T-values)
GGR	−0.512***	–	–
	(−3.516)	–	–
TINO	−0.365***	TINO	0.187***
	(−6.675)		(4.247)
–	–	GDP	0.638***
–	–		(5.225)
GEF	0.129	GEF	0.257**
	(1.038)		(2.068)

Note: ***, ** & * explain the level of significance at 1%, 5% and 10% respectively, whereas the values are in parentheses contains t-values.
Source: Author's estimations.

carbon emission levels. The results reflect that at all three stages of quantiles (low, medium, and higher), the coefficients for green growth are significantly negative for carbon emission.

Second, the results confirm that technological innovations help in achieving environmental goals measured through low environmental pollution. More specifically, the coefficient size for the TINO is 0.365, which implies that a 1% change in TINO is linked with a reduction of 0.365% in the CEN for the selected economies. Many technological innovations have been observed in recent years due to changing market and environmental needs. Most of these innovations are environmentallyfriendly and have lower environmental impacts on carbon and other greenhouse gas emissions. Therefore, developed and developing economies are putting their efforts into replacing traditional technologies, precisely energy sources, to reduce the adverse environmental impacts. These negative environmental impacts result in environmental sustainability issues and poor living standards. Meanwhile, considering the literature supporting the productive nexus between technological innovations and environmental goals, various studies have shown their theoretical and empirical support. Likewise, Shan et al. (2021)claim that after COP21, various stakeholders are putting their significant efforts into controlling adverse environmental outcomes. These efforts are helpful towards carbon neutrality. Their study focuses on the Turkish economy while entitling the role of green technology innovations towards carbon neutrality. Empirical findings support that renewable energy and ecological innovations support controlling environmental contamination in the form of low carbon emissions. Sun et al. (2021)explore environmental proxies to check whether the role of eco-innovation is significant or not. Moreover, the EKC curve has been tested where the results confirm the significantly negative influence of ecological innovations on different proxies of the environment. Yunzhao (2022) explores emerging seven (E7) economies while modelling the role of eco-innovations, renewable energy, and environmental taxes in reducing carbon emissions. They find that eco-innovations and environmental taxes help to reduce carbon emission in the selected countries. Many recent studies, such as Sun et al. (2021), Wang et al. (2020), and Paramati et al. (2021) support the negative influence of green/ecological innovations oncarbon emission in different regions.`

In Table 6, the results also report that governmental effectiveness is positive but insignificantly impacts CEN. One of the key reasons behind this insignificant association between governance and CEN is that the selected economies are in an emerging phase where many governance-related issues are yet to be resolved. Moreover, the effectiveness of governance is found to be more efficient in developed countries thanin developing/emerging ones. However, contrary to our findings, Sarwar and Alsaggaf (2021) focus on the region of Saudi Arabia while taking a range of governance measures to examine their influence on carbon emission reduction. Their results confirm that governmental effectiveness and regulatory quality significantly reduce carbon emissions in Saudi Arabia.Likewise, Sarpong and Bein test the association between governance mechanisms and carbon emissions for oil-producing and non-oil-producing economies. Their results show a negative and significant nexus between governance and carbon emission for oil-producing economies, whereas there is a positive linkage between non-oil-producing economies. Besides, Omri and Mabrouk (2020) and de Oliveira et al. (2019) also endorsed the significant association between governance and sustainable development goals.

Model 2 (Table 6) considers employment as a social development indicator and tests for technological innovation, gross domestic product, and governmental effectiveness. The result shows that innovations in green technologies significantly promote employment opportunities in sample countries. More specifically, a 1% change in such technologies has confirmed an overall creation of 0.187% in employment. It demonstrates that green innovations helpachieve sustainable development goals both from environmental and social perspectives. The positive and significant relationship between technological innovations and employment also covers the economic impact of the former on the latter. This relationship has been justified in earlier studies. Aldieri and Vinci (2018) empirically test the economic impact of eco-innovations measured through employment. Kunapatarawong and Martínez-Ros (2016) have also tested a similar nexus between green innovations and employment dynamics. Their findings confirm a strong and significant positive association between employment and ecological innovations.Aldieri et al. (2019) have tested whether the nexus between green innovation and employment is an opportunity or a threat and confirm that environmental spill-overs are positively linked with employment. Licht and Peters take a sample of 16 European economies and support the positive role of green innovations in creating employment opportunities.

Economic growth has several advantages, among which the creation of employment in the economy is under the significant attention of researchers. In the present study, Table 6 covers that the coefficient for GDP determining employment among G7 economies is highly positive and significant. More specifically, the size of the coefficient was 0.638, which reflects that a 1% spur in economic growth stimulates employment by 0.638%. This significant and positive nexus between economic growth and employment implies that more production of goods and services in any economy requires more input in the form of labour and human capital. More job opportunities are created in different sectors of the economy. Herman (2011)and Meyer and Meyer (2017) support the positive association between economic growth and employment. Lastly, the coefficient for government effectiveness and employment shows that a 1% change in GEF tends to increase employment by 0.257%, which is aligned with prior studies.

Table 7. Short-run results.

Model 1 (Environmental)	Coefficients (T-values)	Model 2 (Social)	Coefficients (T-values)
GGR	−0.119**	–	–
	(−2.039)	–	–
TINO	−0.118***	TINO	0.083***
	(−4.667)		(3.932)
–	–	GDP	0.152***
–	–		(4.082)
GEF	0.189	GEF	0.118***
	(1.010)		(6.524)
ECM	−0.180**	ECM	−0.213***
	(−2.410)		(-3.528)

Note: ***, ** & * explain the level of significance at 1%, 5% and 10%, respectively, whereas the values are in parentheses contains P-values.
Source: Author's estimations.

The short-run relationship between independent and outcome variables has been reported in Table 7. The results exhibit that green growth and technological innovations help to promote sustainable goals, whereas an insignificant relationship between CEN and GEF exists. At the same time, the direction of the coefficients while considering employment as the second dependent variable reflects that technological innovation, economic growth, and government effectiveness help achieve more social development in the form of high employment; hence the short-run association also justifies the similar findings. Lastly, both models' error correction term (ECM) is significantly negative, confirming a convergence towards long-run steady-state equilibrium with 18% and 21% annual adjustment rates.

5. Conclusion and future directions

This research contributes to the current literature while investigating the effects of green growth, technological innovation, and governmental effectiveness in dealing with sustainable development goals measured by reducing carbon emissions and increasing employment opportunities. Moreover, it also examines whether economic growth, ecological innovations, and governmental effectiveness help achieve social developmentmeasured through employment. Based on the econometric findings, it is observed that:

- There is significant evidence for the long-run association between green growth, technological innovations, and carbon emission, providing that both explanatory variables help achieve environmental sustainability while lowering the CEN.
- Governmental effectiveness showsa positive but insignificant association with environmental sustainability.
- Byconsidering social development through employment, the results confirm that economic growth and ecological innovations are direct sourcesof employment opportunities in the long run.
- The short-run estimations also confirm similar findings where the role of green growth and eco-innovations is negatively significant, reducing carbon emissions. However, taking the employment and second dependent variables, our results

reflect that economic growth, eco-innovations, and government effectiveness are the key stimulators of social development.

These findings suggestgovernments and policymakers in G7 economies should continue focussing on green economic growth and ecological innovations in addressing climate vulnerabilities and ensuring employment opportunities. Substantial efforts are required to convert the traditional growth models into sustainable outcomes, along with significant spending for promoting and innovating environmental technologies. In this regard, green growth and eco-innovations may shift industrial structures into more sustainable patterns while reducing the dependency on traditional energy sources and offering new business opportunities. An integrated policy of green growth would help in achieving both social and environmental goals in the long run.

There are a few limitations of this study. First, current research only considers a limited number of explanatory variables while considering two of the sustainable development dimensions. It neglects the role of environmental regulations, green investment and related products, financial innovations, and financial developmentinexamining the trends in sustainable development goals. Second, only seven emerging economies have been selected as samples. Third, cross-sectional comparisons among different economies are also missing in this research. Future studies may consider these limitations as current recommendations.

Disclosure statement

No conflict of interest has been reported by the authors.

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