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Article

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Advancing sustainable development goal 8 Targets: The role of institutional Quality, economic Complexity, and state fragility in G20 nations (2000–2023)

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ABSTRACT

As the global community nears critical milestones in achieving the Sustainable Development Goals (SDGs), the interplay of dynamic forces continues to reshape progress trajectories. This study explores the advancement of SDG 8 targets ("Decent Work and Economic Growth") through the lens of three increasingly prominent factors: institutional quality, economic complexity, and state fragility, focusing on the G20 nations from 2000 to 2023. Guided by an extensive literature review, three research questions, and nine hypotheses, this study formulates four empirical models aligned with four SDG 8 targets and employs the cross-sectionally augmented autoregressive distributed lags model, further validated through dynamic common correlated effects mean group estimators. The findings reveal that economic complexity, institutional quality, and renewable energy significantly enhance economic growth and labour productivity, while reducing unemployment, and CO_2 emissions. In stark contrast, state fragility and primary energy use exert detrimental impacts, underscoring the negative influence of macroeconomic instability and the persistent reliance of growth and labour productivity on primary energy sources, which intensify unemployment and CO_2 emissions. Additionally, globalisation, human development, environmental technologies, urbanisation, and foreign direct investment continue to positively influence growth and labour productivity while mitigating unemployment and CO_2 emissions. Under the combined influence of economic complexity, state fragility, and institutional quality, the findings validate the Environmental Kuznets Curve hypothesis, revealing a redefined turning point shaped by these metrics. Beyond this threshold, the environmental consequences of achieving SDG 8 targets are expected to abate, laying a critical foundation for the policy implications outlined in the study.

1. Introduction

As the global pursuit of the United Nation's Sustainable Development Goals (SDGs) accelerates, nations are swiftly approaching critical deadlines to eradicate poverty, reduce unemployment, and ensure decent work for all while safeguarding environmental sustainability (Melethil et al., 2025). By 2024, some progress has been achieved. For example, the global poverty rate has fallen from 10 % in 2015 to 8.6 % in 2023 (UNDP, 2025). Despite this, over 700 million individuals still live in extreme poverty, highlighting persistent challenges. While the global unemployment rate is reported at 4.5 %, regional disparities remain pronounced, with some areas grappling with alarmingly high levels of unemployment. On the environmental front, 15 % of terrestrial ecosystems and 7 % of marine areas have been designated as protected areas (UNSDG, 2024), but significant strides are needed to bolster conservation efforts. Renewable energy' now accounts for 29 % of global electricity generation, yet the remaining 71 % continues to rely on unsustainable energy resources, underscoring urgent need for transformation in household and industrial energy use. The 2024 United Nations' SDG Report (UNSDG, 2024) paints a sobering picture, with almost 50 % of the SDGs showing only marginal progress and over a third are either stagnating or regressing. The lingering effects of the COVID-19 pandemic, intensifying geopolitical tensions (Wang et al., 2024), and mounting trade barries between key global players nations (Zuo & Majeed, 2024) have stymied progress. As a result, an additional 23 million people have been thrust into extreme poverty, while more

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than 100 million people now face acute hunger compared to 2019 (Hunger & High, 2025). These setbacks are primarily driven by political instability, economic inequality, and persistent armed conflicts, exacerbating the plight of affected nations. Climate changes further compound the scenario, with 2023 marked as the hottest year on record and global temperature approaching the perilous threshold of 1.5 °C (Year, 2024).

Regional disparities in SDG achievements remain stark. European countries such as France, Germany, Finland, Sweden, Denmark, and the United Kingdom have recorded impressive scores of over 80 %, reflecting robust achievements (Lafortune et al., 2024). In stark contrast, sub-Saharan African countries, including Chad, South Sudan, and the Central African Republic, struggle with scores below 50 %. In Asia, nations like Japan, China, and South Korea continue to make steady headway, while countries like Afghanistan, Pakistan, India, and Yemen face mounting challenges due to conflict, political unrest, and unchecked population growth. Moreover, Australia, Canada, and the United States achieve scores of 77.5, 79.2 and 74.4, respectively, indicating moderate progress. However, significant challenges persist, particularly in effectively addressing climate change, promoting marine ecosystems, and ensuring responsible production and consumption (UNSDG, 2024; Canada, 2024).

Apparently, the G20 nations continue to grapple with significant challenges in meeting their SDG commitments within the stipulated timelines. These setbacks are further compounded by persistent state fragility and trade tensions in several member nations, which disrupt steady progress towards achieving the SDGs. Fragile states often endure reduced gross domestic product (GDP) growth and heightened economic instability, resulting in limited access to market and education, inadequate healthcare services, higher unemployment, and increased gender-based disparities and exclusions. Such fragility poses a particular impediment to the advancement of SDG 8, which focuses on inclusive and sustainable growth and decent work for all. Fig. 1 illustrates the trend of state fragility scores across G20 nations, with a minimum average score of 41.116 and a maximum average score of 41.30, and a projected slight decline to an average score of 40.55 in 2025. However, this score remains significantly high, continuing to disrupt progress towards SDG 8 targets. Furthermore, while real GDP has experienced a slight decline, its recovery trajectory in 2025 appears confined to regaining prior lagged values, offering little evidence of substantial forward momentum. Meanwhile, economic complexity, a critical driver of dynamic market forces, remain relatively unchanged, underscoring the need for targeted interventions to address fragility and foster sustainable economic resilience.

Although recent studies by Sianes et al. (2022), Mishra et al. (2024); Alfirević et al. (2023); Rasool (2023); Gupta and Vegelin (2016); Jia et al. (2021); Yap et al. (2023); Chen et al. (2024); Vera et al. (2022); Martín-Blanco et al. (2022); Elsamadony et al. (2022); Choudhary et al. (2025); Bashir et al. (2024); and Arner et al. (2020) have extensively examined the impacts of numerous traditional factors such as energy consumption, renewable energy, per capita GDP, financial development, FinTech, climate change, financial inclusion, governance, and poverty on SDG outcomes, existing literature significantly lacks a comprehensive focus on the role of emerging dynamic market forces. This gap is particularly evident in the context of SDG 8 targets, which require an ample understanding of how these dynamics reshape inclusive growth, labour productivity, unemployment, and environmental sustainability.

Building on this background, this study delves into the intricate influences of state fragility and economic complexity, uncovering their true impacts and magnitudes on the progress of SDG 8 within the G20 nations. By focusing on four core targets—sustainable growth, labour productivity, unemployment, and the environmental repercussions of progressing towards these targets—it primarily aims to provide a nuanced understanding of these challenges. To further enrich this analysis, it evaluates the role of existing institutional quality frameworks in enabling these nations to confront fragility and complexity while chartering a path toward achieving SDG 8 targets with resilience and inclusivity. To guide the research, four pivotal questions are posed: First, to what extent do state fragility, economic complexity, and institutional quality, alongside conventional drivers, impact economic growth? Second, how do these factors shape labour productivity? Third, what role do they play in influencing unemployment rates? Fourth, how do these variables affect environmental degradation, and do they redefine the Environmental Kuznets Curve hypothesis within the G20 nations? Answering these questions will yield valuable insights into the complex dynamics influencing progress towards SDG 8, offering a more contemporary, evidence-based understanding that can effectively guide policymakers in addressing challenges and capitalising on opportunities.

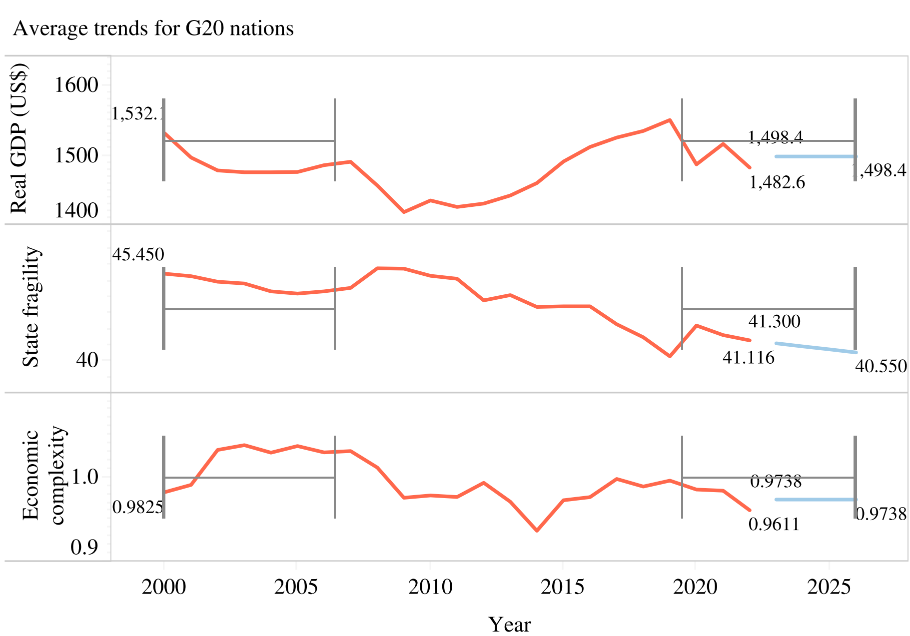

Fig. 1. Annual average trends of key dynamic market forces from 2000 to 2023. Notes: Real GDP is in trillion US$, State fragility ranges between 0 and 100, and economic complexity is in Standard International Trade Product Classification (SITP). Sources: The World Bank (WDI National Accounts Data), The Fund for Peace (Fragile State Index), and Organisation for Economic Cooperation and Development (OECD) (OECD, 2023) databases.

This investigation makes a novel contribution to the existing literature, enriching the contemporary body of knowledge from several critical perspectives. First, it offers a focused examination of SDG 8 targets, an area that has largely been underexplored in prior studies. By leveraging the most recent data and trends in progress toward achieving SDGs and applying advanced econometric techniques, this study provides actionable insights that can help policymakers capitalise on existing opportunities and address pressing policy-related challenges. Second, beyond accounting for the effects of traditional socioeconomic and sociodemographic indicators, this study integrates emerging dynamic market forces such as economic complexity and state fragility, which play pivotal role in reshaping existing market strategies aligned with SDG objectives. It does so in the presence of an innovatively constructed institutional quality index, developed through a comprehensive distance-based scoring methodology that captures all dimensions of good governance influencing SDG 8 targeted predictors. This approach underlines the gradual evolution of institutional quality in tandem with SDG 8 predictors, shedding light on specific policy areas that require immediate attention. Third, by validating the EKC hypothesis in the context of new metrics—state fragility, economic complexity, and institutional quality—the study identifies a revised turning point for sustainable and resilient economic growth, emphasising the critical contributions of institutional quality and economic complexity in reducing environmental degradation. This redefined perspective offers policymakers with actionable insights to align growth strategies with SDG 8 targets while fostering environmental sustainability.

The structure of the study is as follows: Section 2 reviews the latest empirical literature. Section 3 presents the data and variables. Section 4 outlines the methodologies used for analysis. Section 5 presents the results, followed by a comprehensive discussion in Section 6. Finally, Section 7 concludes the article.

2. Literature review

2.1. Review methodology

While the existing body of literature offers extensive empirical investigations into various facets of SDG 8, findings often remain fragmented and mixed across diverse economies. To ensure a comprehensive and systematic understanding of the factors influencing SDG 8 outcomes, this study conducted a structured literature review following a rigorous methodological approach. The search process was executed across several reputable academic databases, including Scopus, Web of Science, JASTOR, Google Scholar, and PubMed. These platforms were selected due to their extensive coverage of peer-reviewed academic publications, particularly those addressing issues relevance to sustainable development, institutional quality, and economic growth. A structured search strategy was performed using targeted keywords and phrases directly aligned with the study's scope and objectives. These terms included: "SDG 8", "Decent Work and Economic Growth", "Institutional Fragility", "Institutional Quality", "Good Governance", Economic Complexity", "Economic Diversification", "Political Instability", "Environmental Kuznets Curve", "Employment", Labour Productivity", "Total Factor Productivity", "G20", "Environmental Quality", "Material Footprint", "Ecological Footprint", "Labour Hours", "Globalisation", and "Renewable Sources". To ensure a focused and relevant selection, Boolean operators (AND, OR, NOT) were applied to refine the search results and exclude irrelevant studies.

The inclusion criteria for selecting relevant studies were carefully defined to ensure academic rigour and thematic relevance. Only peer-reviewed empirical journal articles published between 1990 and 2025 were considered, capturing a comprehensive range of research spanning historical trends and contemporary development. The studies primarily focused on SDG 8 outcomes, such as economic growth, labour productivity, and unemployment. Additionally, research examining the environmental consequences of economic growth was also included to provide a broader understanding of the interconnections between growth and trajectories and sustainability. Studies were excluded if they were non-peer-reviewed (*e.g.*, opinion pieces, conference abstracts) or if they did not address either the direct or spillover impacts of socioeconomic indicators on SDG 8 outcomes.

The review highlights a significant gap in the literature: while there is an abundance of research examining various dimensions of SGDs through both qualitative or quantitative lenses, limited attention has been given to emerging phenomena such as state fragility, economic diversification, and the role of institutional setups in shaping progress toward SDG 8. This gap is particularly evident within the context of G20 nations, where varying institutional capacities and governance structures significantly influence economic outcomes. Although studies like Fonseca et al. (2020) have established links between different SDGs, the literature remains underdeveloped in capturing how these emerging phenomena affect progress toward achieving SDG 8. The subsequent subsections delve into the core themes and findings of the reviewed literature, with a particular emphasis on factors shaping SDG 8 progress.

2.2. Growth trajectories

Economic growth, a key component of SGD 8, is grounded in the neoclassical growth theory articulated by Solow (1956) and Swan (1956), which emphasises the role of capital accumulation, labour, and technological progress in driving economic growth. However, recent empirical studies have delved deeper into this relationship, incorporating additional drivers that impact economic dynamics. For instance, Chen and Xue (2024); Wang et al. (2024); Acemoglu et al. (2018); Garcia-Lazaro and Pearce (2023); Barr and Roy (2008); Stevy Sama et al. (2024); and Osakede et al. (2023) have analysed the role of labour, often proxied by the human development index, in shaping growth. Using both panel and country-specific data with diverse quantitative techniques, these studies collectively demonstrate the positive and enduring impact of labour on sustaining growth. Additionally, Huo et al. (2024) examined the interplay between financial innovation, technological advancements, and growth across a panel of developing economies (1990–2021) using the CS-ARDL model. Their findings reveal that financial and technological innovations contribute to balancing growth trajectories while advancing SDGs. Similarly, Shahbaz et al. (2022) investigated the asymmetric effects of financial development on growth in a panel of ten most financially developed nations, employing a threshold ARDL model with labour and capital as threshold variables. Their results underscore that financial development, conditional on labour and capital, asymmetrically sustain long-term growth. Moreover, studies by Lukhmanova et al. (2025); Hussein et al. (2025); Alsabhan and Alabdulrazag (2025); and Rahman et al. (2025) provide mixed evidence on the relationship between energy use and economic growth, varying significantly across economic contexts. Further contributions by Ratnawati (2020); Zheng et al. (2024), and Erlando (2020) employed regression and causality techniques to elucidate the link between growth and financial market performance, emphasising the market stability-growth nexus. While existing literature also identifies urbanisation (Huang & Jiang, 2017), institutional quality (Azimi, 2022), and foreign direct investment (Chee & Nair, 2010) as integral drivers of growth, there remains a significant gap understanding the implications of state fragility and economic complexity on sustainable growth within the existing institutional setups. To address this, the present study proposes the following hypotheses:

H_1: State fragility has a negative impact on growth sustainability.

H_2: Economic complexity has a significantly positive impact on economic growth.

2.3. Employment dynamics

Labour market theories, such as the Keynes (2018) and structuralist frameworks (Micklewright et al., 1989), underscore the critical role of macroeconomic stability, human capital, and effective policy interventions in fostering employment generation. This area has garnered considerable scholarly attention, particularly focusing on conventional predictors of unemployment dynamics. For example, Alshyab et al. (2021); Mehry et al. (2021); and Kim et al. (2019) respectively explored the impact of financial inclusion, investment, and liquidity on unemployment rates in emerging economies, employing advanced quantitative techniques. Their results collectively confirmed that financial and investment indicators significantly reduce unemployment. Erdem and Tugcu (2012) took a distinct approach by examining human capital development, proxied by education levels, in relation to unemployment rates in Türkiye through causality analysis. Their analyses reveal a bidirectional causality between human capital and unemployment, highlighting the importance of aligning educational initiatives with market demands. Similarly, Shaaibith et al. (2020) examined the growth-unemployment nexus in Iraq from 1999 to 2017 using a vector autoregressive model, concluding that economic growth substantially reduces unemployment. Banda et al. (2016) extended this analysis to South Asian nations (1994–2012), confirming that robust economic growth effectively mitigates unemployment rates. Siddikee et al. (2022) examined unemployment and growth dynamics across 14 developed and developing Asian nations within the SDG frameworks. Their findings highlight contrasting trends: developed nations exhibit consistent progress in reducing unemployment through growth sustainability, whereas developing nations, led by Türkiye, demonstrate inverse patterns, with growth failing to adequately address unemployment challenges. Another strand of literature, including studies by Rabiu et al. (2019); Sato and Zenou (2015); Chen et al. (2023); and Castells-Quintana and Royuela (2012) delves into the influence of population growth and urbanisation on unemployment. These analyses reveal that while population growth exacerbates unemployment, urbanisation tends to exert a mitigating influence by fostering job creations through industrial and economic clustering. While little is known, merging factors such as state fragility and economic complexity, under existing institutional frameworks, may yield divergent effects on employment dynamics. To explore this dimension, the study proposes the following hypotheses:

H_3: Economic complexity exerts negative impacts on unemployment.

H_4: State fragility negatively influences unemployment.

2.4. Labour productivity

Labour productivity, a central pillar of SDG 8, is theoretically anchored in classical production function developed by Solow-Swan (Solow, 1956) and extended by the endogenous growth model (Romer, 1994), which emphasises the pivotal role of innovation and human capital. Despite this importance, this area has received comparatively limited scholarly attention, with existing studies largely focusing on conventional drivers. For instance, Celik et al. (2024) explored the relationship between urbanisation and labour productivity across 6 African countries from 1991 to 2019, employing the CS-ARDL model. Their findings reveal a positive correlation and causal links between urbanisation and labour productivity. Kumar and Kober (2012) expanded the analysis by examining urbanisation, health, and education as determinants of labour productivity in a broader panel of countries. Their results underscore the significantly positive impacts of both health and urbanization on labour productivity. Likewise, Cörvers (1997) investigated the role of human capital in labour productivity within manufacturing firms across 7 EU member states. Using cross-sectional analysis, their findings indicate that moderate- and highly developed human capital positively influence labour productivity, whereas low levels of human capital development yield inverse effects. Nowak and Kijek (2016) provided further evidence by exploring Poland's agricultural sector, demonstrating that farms managed by highly educated farmers achieve significantly higher productivity levels, emphasising the role of human capital in labour productivity. Foreign direct investment (FDI) has also been identified as a key driver of labour productivity. Boghean and State (2015) analysed its effects on labour productivity through growth and technological transfers in EU countries between 2000 and 2012. Their regression analysis highlights that increased FDI, through skills and capital transfer, significantly boosts labour productivity. Similarly, Liu et al. (2001) examined FDI's impact across Chinese industries from 1996 to 1997, revealing that FDI in the form of human capital, capital intensity, and foreign presence in industries substantially enhances labour productivity. Malick (2013) analysed globalisation's impact on labour productivity in OECD nations from 1990 to 2011 using panel regression models. Their results demonstrate that globalisation, proxied by economic openness, exerts a significantly positive influence on labour productivity, suggesting that greater openness promotes higher productivity. While these studies provide valuable insights, the literature remains sparse regarding the impacts of emerging factors such as state fragility, economic complexity, and institutional quality on labour productivity. Addressing this issue, the study proposes the following three hypotheses:

H_5: State fragility negatively influences labour productivity.

H_6: Economic complexity is positively associated with labour productivity.

H_7: Institutional quality exerts a significantly positive impact on labour productivity.

2.5. Environmental integrity

The Environmental Kuznets Curve (EKC) hypothesis, introduced by Grossman and Krueger (1991), provides a theoretical lens to analyse the interplay between growth and environmental sustainability. Building on this foundation, recent empirical studies expanded the EKC narrative by incorporating additional predictors alongside economic output to examine this critical nexus. For instance, Suyanto et al. (2024) investigated the EKC hypothesis within G20 nations (1995–2015), incorporating institutional quality, government expenditures, and CO_2 emissions as key determinants. Their findings validated the EKC hypothesis and underscored the pivotal role of institutional quality in significantly curbing emissions. Conversely, Alakbarov et al. (2024), using panel data spanning 1992 to 2014, confirmed the EKC hypothesis but observed that the inclusion of energy consumption complicated the narrative, revealing that energy use does not invariably exacerbate CO_2 emissions across G20 group. In the same vein, Ozturk et al. (2023) analysed the EKC hypothesis from 1990 to 2020 using trade-adjusted material footprint, environmental governance, and green innovations within G20 nations. Their quantile regression results affirmed the EKC hypothesis, highlighting the significant contribution of environmental technologies in reducing material footprints. In a related study, Mar'I et al. (2023) examined financial and fiscal policy impacts on the EKC framework in G20 panel (1995 to 2019) with CO_2 emissions as the dependent variable. Their findings, derived from ARDL modelling, confirmed the EKC hypothesis and emphasised the need to redirect financial resources toward clean energy initiatives. Likewise, Li et al. (2022) explored the effect of conventional energy consumption on the CO_2 emissions-growth (1995 to 2018), using panel cointegration regression analysis. Their results validated the EKC hypothesis within G20 nations. While these studies collectively provide insights into the EKC hypothesis, they largely rely on conventional predictors and fail to integrate emerging metrics to redefine the EKC framework for G20 nations. This study seeks to fill this gap by incorporating economic complexity and state fragility alongside institutional quality to examine their combined influence on environmental outcomes. Accordingly, we propose the following hypotheses:

H_7: Both state fragility and economic complexity significantly influence CO_2 emissions.

H_8: The EKC hypothesis holds valid under these emerging factors while accounting for institutional frameworks.

3. Data, variables, and sources

3.1. Data

This study utilises panel data for the G20 nations—(1) Argentina, (2) Australia, (3) Brazil, (4) Canada, (5) China, (6) European Union (EU), (7) France, (8) Germany, (9) India, (10) Indonesia, (11) Italy, (12) Japan, (13) South Korea, (14) Mexico, (15) Russian Federation, (16) Saudi Arabia, (17) South Africa, (18) Türkiye, (19) the United Kingdom, and (20) the United States—covering the years from 2000 to 2023. Focusing on this group is justified by four primary reasons. First, the G20 collectively accounts for over 80 % of global GDP, approximately three-quarters of international trade, and over 60 % of the global population, making it a significant proxy for the global economy (OECD, 2025). Second, these nations include both developed and emerging economies, allowing for insights into varied institutional setups, levels of development, and infrastructures (Azimi & Rahman, 2023). Third, they play a critical role in coordinating international economic and environmental policies, addressing global challenges and rendering solutions particularly insightful for policymakers around the world (Wang et al., 2024). Fourth, the bloc offers consistent and updated datasets for diverse variables used in the study, which makes the analysis robust and reliable. To avoid data duplication and unit overlap, the study excludes individual countries included in EU, such as France, Germany, and Italy, when treating EU as a collective entity. Consequently, the total number of units rounds to 44 (see Fig. 2), encompassing all entities that constitute the G20. This approach ensures the integrity and independence of the data used in the study.

3.2. Variables

The variables utilised in this study are carefully selected to align with core objectives of SDG 8, focusing on its four specific targets. Per capita GDP (PCG, constant 2015 US$), labour productivity (LP, ratio)—derived by dividing real GDP in constant 2015 US$ by hours worked per person—unemployment rate (UR, annual %), and CO_2 emissions (CO_2, metric tonnes per capita) serve as the dependent variables. These variables are also used as explanatory predictors in specific model specifications to capture intricate interrelations. To ensure analytical precision and contextual relevance, the explanatory variables are categorised into distinct dimensions. Macroeconomic variables include foreign direct investment (FDI) as a percentage of GDP, which reflects capital inflows, and trade openness, proxied by the globalisation index (GLO), ranging from 0 and 1, indicating the degree of integration with global trade and investment networks. The economic complexity index (ECI) is also incorporated to measure the diversity and sophistication of export structures. Positive values denote high complexity, negative values reflect low complexity, and zero signifies the absence of diversification. Socioeconomic variables include the stage fragility index (SFI), ranging from 0 (least fragile) to 1 (most fragile), and the human development index (HDI), a composite indicator of health, education, and income levels, also scaled between 0 and 1. The study further introduces a novel institutional quality index (IQI), constructed using a distance-based scoring method, which captures all dimensions of governance and range from 0 (low quality) to 1 (high quality). Energy and environmental variables encompass primary energy consumption (PE), measured in terawatt-hours, capturing the total energy usage, and renewable energy (RE), representing the share of renewable sources in total energy consumption. This analysis also integrates environmental-related technologies (ENT), measured as the percentage of green technology patents or innovations, which signify progress towards cleaner production processes and resources efficiency. These metrics are vital for understanding the energy transition, technological innovations, and environmental sustainability within G20 framework. Finally, the sociodemographic variable, urbanisation (URB), is calculated as the percentage of the total population residing in urban areas. It reflects urban development patterns and demographic dynamics, which are critical in shaping economic performance and societal outcomes.

3.3. Construction of IQI

To comprehensively capture the influence of all governance aspects on SDG 8 targets, the study constructs the institutional quality index (IQI) using six key metrics from WGI: control of corruption (CC), government effectiveness (GE), political stability (PS), the rule of law (RL), regulatory quality (RQ), and voice and accountability (VA)—each expressed as percentile ranks from 0 to 100. The IQI is developed using the inclusive methodology proposed by Sarma (2012), a robust framework for constructing a multidimensional index that offer several advantages over conventional techniques (Azimi et al., 2025). Unlike methods such as weighted averages and arithmetic means, which tend to oversimplify complex dimensions by assigning equal importance to all indicators, this approach effectively captures disparities in institutional performance both within individual indicators and across the countries (Azimi & Rahman, 2024). Moreover, compared to Principal Component Analysis (PCA) and Factorial Analysis (FA)—which primarily rely on statistical correlations and often reduce the complexity of governance dimensions to a few dominant factors—this distance-based scoring method considers the entire range of institutional performance. This methodology enhances sensitivity by capturing both best- and worst-case scenarios, offering a more nuanced reflection of institutional quality. Therefore, it is particularly effective in monitoring institutional convergence and divergence over time, an aspect that PCA and FA are less equipped to address due to their emphasis on static relationships (Azimi et al., 2023).

To construct IQI, we first normalise each dimension into a 0–1 scale, where 0 reflects the worst and 1 represents the best institutional quality, using the following equation:

$$d_{cj} = \frac{X_{cj}}{100} \tag{1}$$

where X_{cj} represents the percentile rank for country c in dimension j—that is, CC, GE, PS, RL, RQ, or VA. Next, we position each country c as a point in a 6-dimensional space $(d_{cj1}, d_{cj2}, \cdots, d_{cj6})$, where $d_{cj} \in [0,1]$ denotes country c's score on dimension j (Park & Mercado, 2015). The ideal point is $(1,1,1,1,1,1)$, which signifies the highest possible institutional performance across all six metrics. Subsequently, we compute the distance from the ideal point for each G20 nation by applying the Euclidean distance (D_{cj}) between the 6-dimensional space and the ideal point, as follows:

$$D_c = \sqrt{\sum_{j=1}^{6} (1 - d_{cj})^2} \tag{2}$$

When a country score $d_{cj} = 1$ in all six dimensions, $D_c = 0$. Conversely, if a country underperforms in one or several governance dimensions, the distance grows larger. To arrive at the IQI, we invert this distance into a 0–1 scale:

$$IQI_c = 1 - \frac{D_c}{\sqrt{6}} \tag{3}$$

where $\sqrt{6}$ is the maximum distance between the ideal point $(1,1,1,1,1,1)$ and the worst point $(0,0,0,0,0,0)$, in a 6-dimensional space:

$$\sqrt{\sum_{j=1}^{6} (1 - 0)^2} = \sqrt{6} \tag{4}$$

Here, $IQI_c = 1$ corresponds to $(d_{cj1}, d_{cj2}, \cdots, d_{cj6}) = (1,1,\cdots,1)$, *i.e.*, high institutional quality in all dimensions, whereas $IQI_c = 0$ corresponds to $(d_{cj1}, d_{cj2}, \cdots, d_{cj6}) = (0,0,\cdots,0)$, *i.e.*, poor institutional quality across all

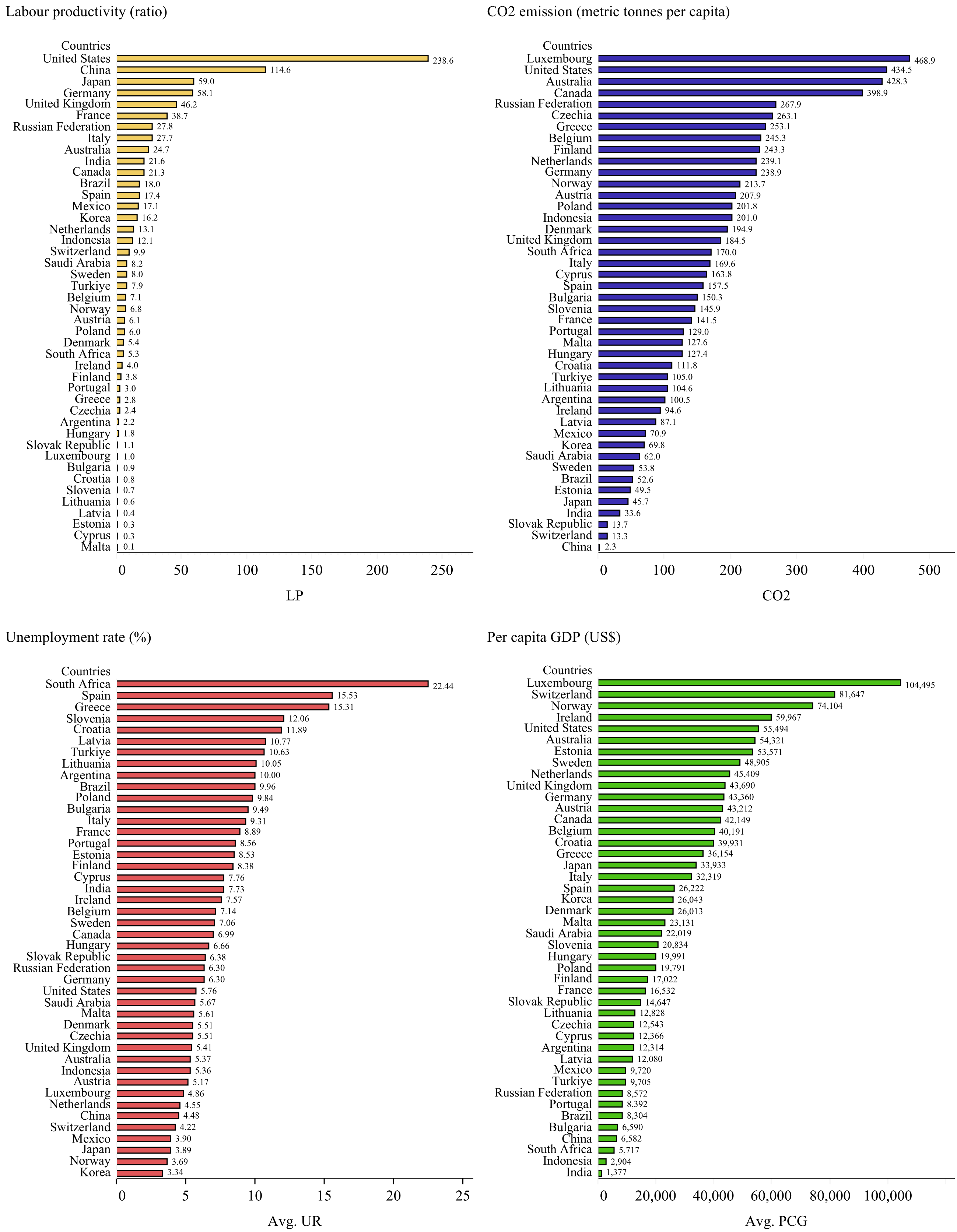

Fig. 2. Dependent variables' trends across the G20 nations. Note: Avg. represents average values of the indicators.

dimensions. This comprehensive approach captures the gradual evolution of IQI over time in G20 nations (Azimi et al., 2025).

3.4. Sources of compilation

Datasets on nominal GDP, the GDP deflator, per capita GDP, control of corruption, government effectiveness, rule of law, political stability, regulatory quality, voice and accountability, urbanisation, and FDI are obtained from the World Development Indicators (WDI) database of the World Bank Group. CO_2 emissions data are sourced from Our World in Data, curated by Ritchie and Roser (2020). HDI data are sourced from the United Nations Development Programmes (UNDP) sources (UNDP Human Development Index, xxxx). Globalisation index series is drawn from the KOF Swiss Economic Institute, developed by Gygli et al. (xxxx). The state fragility index dataset is retrieved from the Fund for Peace sources (). Finally, hours worked per person, environmental-related technologies, and the economic complexity index data are acquired from OECD resources ().

4. Specification and estimation procedures

SDG 8 accentuates “promoting inclusive, sustainable growth, full and productive employment, and decent work for all.” This goal entails multiple interrelated targets: fostering higher levels of productivity via diversification and technological advancement (Target 8.2), achieving full and productive employment (Target 8.5), reducing the proportion of youth not in employment or training (Target 8.6), and improving resource efficiency (Target 8.4). In essence, SDG 8 captures both the quantitative dimension of economic growth and employment, as well as the qualitative aspects of decent work, inclusiveness, and environmental responsibility. Given these multifaceted targets, this study develops four empirical models that comprehensively evaluate these dimensions.

4.1. Model I: Sustainable growth

Grounded in the Neoclassical Growth Theory of Solow (1956), this model emphasises labour, technology, and capital accumulation as core determinants of economic output. Building on this foundation, Romer (1990) highlights the transformative role of ENT and ECI spillovers in fostering sustainable growth. Accordingly, Model I integrates these factors to capture the sophistication of production structures and the adoption of cleaner, innovative processes within the growth trajectory. In addition to ENT and ECI, the model incorporates key macroeconomic and sociodemographic variables, including FDI, GLO, HDI, and URB, which collectively contribute to shaping economic performance. IQI and SFI are further included to account for the regulatory, political, and structural environments that sustain market performance, enhance entrepreneurial activities, and attract investment (Salman et al., 2019). Moreover, this model considers the critical role of resource consumption and efficiency, measured by PE and RE. These variables reflect G20′s efforts to reduce ecological impact and transition to cleaner systems, aligning with sustainable development imperatives (Chen et al., 2019; Magazzino, 2024). Given this context, Model-I can be expressed as follows:

$$PCG_{it} = \beta_1 + \sum_{j=1}^{9} \theta_j X_{it} + \delta_i + \varepsilon_{it} \tag{5}$$

where PCG represents the dependent variable, β_i represents the intercept, θ_i is the vector of coefficients for X_{it} which includes ENT, ECI, SFI, IQI, HDI, FDI, GLO, PE and RE. δ_i captures the unobserved country-specific effects, and ε is the error term.

4.2. Model II: Labour productivity

Labour productivity, a cornerstone of economic performance and a critical target of SDG 8, is rooted in the classical production function (Cobb & Douglas, 1928), which assesses the efficiency with which inputs are transformed into outputs. In this context, IQI and GLO emerge as pivotal factors. Robust IQI and high GLO mitigate rent-seeking behaviour and economic distortion, creating an environment conducive to the optimal allocation of labour resources (Adams-Kane & Lim, 2016). Simultaneously, low SFI ensures political and economic stability, further enhancing productivity dynamics. The role of ENT and HDI as synergetic drivers of productivity gains is well-documented in prior literature (Zilibotti et al., 1999). ENT fosters innovation and efficiency, while HDI equips the workforce with the skills and capacities required for higher productivity. ECI and FDI complement these factors by introducing managerial best practices, enhancing technological transfers, and promoting workforce efficiency. URB also plays a significant role by enabling access to a more skilled and concentrated labour pool, which facilitates knowledge sharing and innovation (Celik et al., 2024). Additionally, the transition from conventional energy sources to renewable energy (RE) directly impacts labour productivity by reducing production costs and fostering sustainable industrial practices. This underscores the growing importance of energy efficiency in shaping productivity outcomes. To encapsulate these dynamics, Model II is specified as follows:

$$LP_{it} = \beta_2 + \sum_{j=1}^{9} \theta_j X_{it} + \delta_i + \varepsilon_{it} \tag{6}$$

where LP indicates labour productivity as the dependent variable, β_2 is the intercept for Model II, X_{it} includes IQI, GLO, SFI, ENT, HDI, FDI, ECI, URB, and RE within this framework. All other notations maintain similar meaning as were explained in equation (5).

4.3. Model III: Employment and decent work

Rooted in the Keynesian labour market perspective (Keynes, 2018), unemployment is conceptualised as a result of mismatches between labour demand and supply, market frictions, and macroeconomic fluctuations. IQI emerges as a pivotal factor in enhancing labour market efficiency by enforcing contracts, protecting workers, and fostering equitable employment opportunities. Conversely, heightened SFI signals instability, deterring investment and stifling job creations. ECI promotes diversification into high-value industries, contingent upon the availability of a skilled workforce capable of meeting advanced production requirements. Simultaneously, ENT facilitates the creation of green jobs in renewable energy, circular economy, and other sustainable sectors. FDI and GLO further complement these dynamics by driving job creations in export-oriented sectors (Pal & Villanthenkodath, 2024) and fostering cross-border employment opportunities. HDI plays an amplifying role, enhancing the quality of and inclusiveness of employment through improved education and healthcare, aligning labour market demand with supply. However, rapid URB can exacerbate UR in metropolitan areas by straining infrastructure and mismatching labour supply with local opportunities (Pandey et al., 2024). Conversely, the adoption process to renewable sources, RE is expected to create job opportunities within sustainable sectors. To capture these dynamics within the framework of SDG 8, Model III is formulated as follows:

$$UR_{it} = \beta_3 + \sum_{j=1}^{9} \theta_j X_{it} + \delta_i + \varepsilon_{it} \tag{7}$$

where UR represents unemployment as the dependent variable, β_3 is replaced with β_2—the intercept, to maintain distinguished notations across models, and X_{it} includes IQI, SFI, ECI, ENT, FDI, GLO, HDI, URB, and RE within the framework of Model III. All other notations carry same meaning as stated earlier.

4.4. Model IV: Environmental impact

Balancing sustainable economic growth with environmental objectives is a cornerstone of the SDGs. The EKC hypothesis, proposed by Grossman and Krueger (1991), offers a theoretical framework for understanding the non-linear relationship between economic growth and environmental degradation. It posits an inverted U-shaped nexus between income and pollution, contingent upon key factors. Robust IQI and lower SFI foster the enforcement of stringent environmental governance, ensuring that growth aligns with ecological sustainability. ECI supports the reorientation of production toward advanced, less resource-intensive sectors (Liu et al., 2019), while ENT facilitates the decoupling of economic growth from emissions (Nkalu et al., 2020). FDI and GLO may exhibit dualistic impacts on emissions. In the absence of robust IQI, these factors may exacerbate pollution due to lax regulations (the "pollution haven" hypothesis) (Pata & Caglar, 2021). Conversely, under strong IQI, they can lead to the diffusion of cleaner technologies, fostering a "pollution halo" effect (Alshubiri & Elheddad, 2020). URB, however, presents mixed implications. While efficient urban planning and infrastructure can reduce emissions through scale efficiency, poorly designed urbanisation may escalate emissions due to overcrowding and inefficient production systems (Dogan & Turkekul, 2016). EP is expected to contribute positively to emissions, reflecting continued reliance on fossil fuels (Nathaniel, 2021), whereas RE plays a counterbalancing role in mitigating emissions (Pata, 2018). To examine the EKC hypothesis in the presence of new metrics, we specify the following equation:

$$CO_{2,it} = \beta_4 + \lambda_1 PCG_{it} + \lambda_2 PCG_{it}^2 + \sum_{j=1}^{9} \theta_j X_{it} + \delta_i + \varepsilon_{it} \tag{8}$$

where PCG^2 captures the quadratic term of income to account for the non-linear EKC relationship, β_4 is the intercept of Model IV, λ_1 and λ_2 are the coefficients for PCG and its squared term, θ_i is the vector of coefficients for other explanatory variables (X_{it}) such as IQI, SFI, ECI, FDI, GLO, ENT, URB, PE, and RE. The meaning of other vectors remains consistent with those previously defined. Collectively, these four models capture multiple aspects of SDG 8—including growth, productivity, employment, and environmental sustainability—while drawing upon appropriate economic theories. This foundation not only justifies the chosen specifications but also paves the way for empirical testing in the context of G20, where institutional and socioeconomic heterogeneities make these interactions insightful for policymakers.

4.5. Estimation procedures

Prior literature highlights several critical empirical challenges in analysing the relationships among predictors of sustainable development. Among the most pervasive issues are cross-sectional dependence (SCD), slope heterogeneity (SLH), and heteroskedasticity in residuals (Udeagha & Ngepah, 2023). Additionally, in certain contexts, coefficients bias arising from sample distortion further complicates empirical analysis. The presence of CSD, as well-documented in prior studies (Guerrero, 2006), is particularly problematic, undermining the reliability of conventional estimation techniques. While Fixed-effects (FE) and random-effects (RE) approaches remain widely used, they are not devoid of significant limitations. The FE model, for instance, simplifies heterogeneity by assuming homogeneity across units and removing time-variant effects, which inadequately addresses dynamics in the presence of SLH (Phillips & Sul, 2007). On the other hand, the RE method relies on stringent assumptions regarding the independence of individual-specific effects, often producing biased estimates under the rejection of homoskedasticity.

Although advanced panel estimators such as Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), Autoregressive Distributed Lags (ARDL), and the Generalised Method of Moment (GMM) offer alternative approaches, the selection of an appropriate method remain critical. For instance, while panel ARDL becomes inefficient under the rejection of the null hypothesis of no CSD, GMM estimators fails to adequately account for CSD. Given the empirical confirmation of both CSD and SLH within our dataset, standard FE and RE, alongside other conventional estimation techniques, fail to produce consistent and reliable coefficients (Huang et al., 2019). To address these limitations, this study adopts the Cross-Sectionally Augmented ARDL (CS-ARDL) model, developed by Chudik et al. (2016). The CS-ARDL model explicitly accounts for CSD by incorporating CS averages of both the dependent and explanatory variables. This method not only ensures robust coefficient estimation but also enables the simultaneous evaluation of short- and long-run coefficients, providing nuanced insights into the progress of SDG 8 targets. The general form of the CS-ARDL model used in this study is specified as follows:

$$y_{it} = \varphi_i y_{it-1} + \sum_{j=1}^{p} \lambda_{ij} X_{it-j} + \gamma_i \overline{y}_t \sum_{k=0}^{K} \zeta_{ik} \overline{X}_{tk} + \xi_i + \varepsilon_{it} \tag{9}$$

where y_{it} represents the dependent variables in the respective models (PCG, LP, UR, and CO_2), while X_{it} denotes the vector of explanatory variables (IQI, SFI, ECI, ENT, HDI, FDI, URB, and GLO). The model includes coefficients for the lagged dependent variable (φ_i) and the explanatory variables (λ_i), alongside coefficients for the cross-sectional averages of the dependent variable ($\overline{y}$) and explanatory variables ($\overline{X}$), denoted by γ_i and ζ_{ik}, respectively. These cross-sectional averages effectively account for CSD. Country-specific effects (ξ_{ik}) and idiosyncratic error terms (ε_{it}) are also incorporated to capture unobserved heterogeneity and stochastic variations. As a robustness check, the study employs the Dynamic Common Correlated Effects Mean Group (DCCEMG) model, an advanced extension of the CCEMG framework proposed by Pesaran and Smith (1995) for MG, Pesaran (2006) for CCE, and Chudik and Pesaran (2015) for DCCE. The DCCEMG model incorporates lagged y_{it-k}, enabling it to capture the dynamic relationships between the dependent and explanatory variables in the presence of CSD and SLH. Although this method does not offer short-run effects, its long run estimators are computed as $\beta_{long-run,i}\beta_i/(1-\varphi_i)$, where φ_i denotes the degree of y_{it} persistence. The DCCEMG method effectively accounts for the dynamic nature of the variables, remains robust to CSD through the inclusion of CS averages, and accommodates heterogeneity by allowing coefficients to vary across units. All statistical analyses are conducted using STATA/BE-18 software, while graphical representations are generated using the advanced visualisation tools of Tableau and OriginLab-2024.

Table 1
Summary statistics.

Variables	Mean	Standard Deviation	Minimum	Maximum
PCG	29433.940	22906.564	756.704	112417.88
LP	0.823	1.671	0.001	10.384
UR	7.814	4.497	1.805	28.838
CO_2	6.854	4.847	0.058	26.003
IQI	0.878	0.205	0.000	1.000
SFI	43.643	19.132	12.700	89.200
ECI	0.993	0.748	−1.110	2.820
PE	2697.830	6055.95	18.510	47427.56
RE	14.083	14.169	0.000	72.329
ENT	8.321	5.66	0.620	53.850
HDI	0.835	0.109	0.291	0.967
FDI	9.306	40.206	−360.353	452.221
URB	73.008	15.239	21.637	98.153
GLO	76.936	9.666	43.582	91.141

5. Results

5.1. Preliminary analysis

Table 1 provides an in-depth statistical overview of the variables used in this study, reflecting significant heterogeneity across G20 nations. PCG has a mean of \$29,433.9, with a standard deviation \$22,906.5, highlighting substantial variation in per capita income levels. It ranges from \$756.7 to \$112,417.8, capturing disparities across both developed and emerging economies. LP averages \$0.82 of real GDP generated per hour worked, with values spanning from \$0.001 to \$10.38. This reflects a wide productivity gap across the panel. UR ranges from 1.80 % to 28.83 %, with a mean value of 7.81 %, signifying notable differences in employment dynamics among G20 nations. CO_2 exhibit a mean of 6.878 metric tonnes per capita, ranging from 4.84 to 26.0 metric tonnes per capita. IQI ranges from 0, indicating institutional underperformance in some nations, to 1, highlighting best institutional practices among some others, a mean value of 0.87, which is above average benchmark. SFI averages 43.64, ranging from 12.7 to 89.2, highlighting high fragility across some nations in the panel. ECI achieves a mean of 0.99, spanning from −1.11 to 2.82, underscoring opportunities for enhancing export diversification and sophistication. ENT accounts for an average of 8.32 %, ranging from 0.62 % to 53.85 %, reflecting varying levels of technological innovations in sustainability. HDI records a mean of 0.83, fluctuating from 0.29 to 0.96. FDI demonstrates considerable variability, with a mean of 9.3 %, ranging from −360.35 % to 452.2 %. URB averages 73 %, ranging from 21.63 % to 98.15 %. Lastly, GLO averages 76.93, extending from 43.58 to 91.14, encapsulating varying degrees of global integration across G20 nations. RE averages 14.08 %, with values ranging from 0 (observed in Saudi Arabia between 2000 and 2007) to a maximum of 72.32 %. The substantial standard deviation of 14.17 % indicates significant disparities in the adoption of renewable energy sources among G20 nations. Similarly, PE has a mean value of 2,697.83 terawatt-hours, spanning from a minimum of 18.51 to a maximum of 47,427.56 terawatt-hours. This wide range reflects a continued reliance on primary energy sources across the G20 economies.

Fig. 2 illustrates the average values of 24 years (2000–2023) for the key variables associated with SDG 8 targets—the dependent variables in this study—across the panel of G20 nations. The data highlights that South Africa consistently exhibits the highest UR over the study period, followed by Spain and Greece, while South Korea records the lowest UR. Luxembourg leads in PCG, whereas India registers the lowest. In terms of LP, the United States ranks highest among G20 nations, followed by China and Japan, with Malta recording the lowest LP. The analysis of average CO_2 emissions between 2000 and 2023 positions Luxembourg as the largest emitter ($\mu = 468.9$), with its peak occurring in 2006 at 26 metric tonnes per capita. The United States, Australia, and Canada follow Luxembourg, consistently generating more than 10 metric tonnes per capita. Interestingly, China, despite being a major global emitter in recent years, shows the lowest average of the last 24 years. To complement the findings presented in Fig. 2, Fig. 3 provides annual averages for these critical variables, offering a more granular view of their recent and expected future temporal trends toward SDG 8 targets.

Fig. 3 illustrates key trends from 2000 to 2023, with linear projected values for 2024 and 2025. Specifically, PCG shows a consistent upward trajectory, rising from an average of \$33,644 to \$45,534 in 2023, with a projected increase to an average of \$48,213 by 2025 among G20 nations. LP shows minor fluctuations but an overall upward trend, increasing from an average of 0.82 in 2000 to 0.83 in 2023, and is anticipated to reach an average ratio of 0.85 by 2025. UR displays significant variability, declining from an average of 8.27 % in 2000 to 5.96 % in 2023. However, projections suggest a temporary rise to an average of 6.23 % in 2024, followed by a further decline to an average of 5 % in 2025 across the G20 nations. Lastly, CO_2 emissions have also decreased notably, falling from an average of 7.29 metric tonnes per capita in 2000 to 5.98 metric tonnes per capita in 2023. Projections indicate a slight increase to an average of 6.07 metric tonnes per capita in 2024, before decreasing again to an average of 5.81 metric tonnes per capita in 2025.

Subsequently, we assess the correlation among the panel variables in

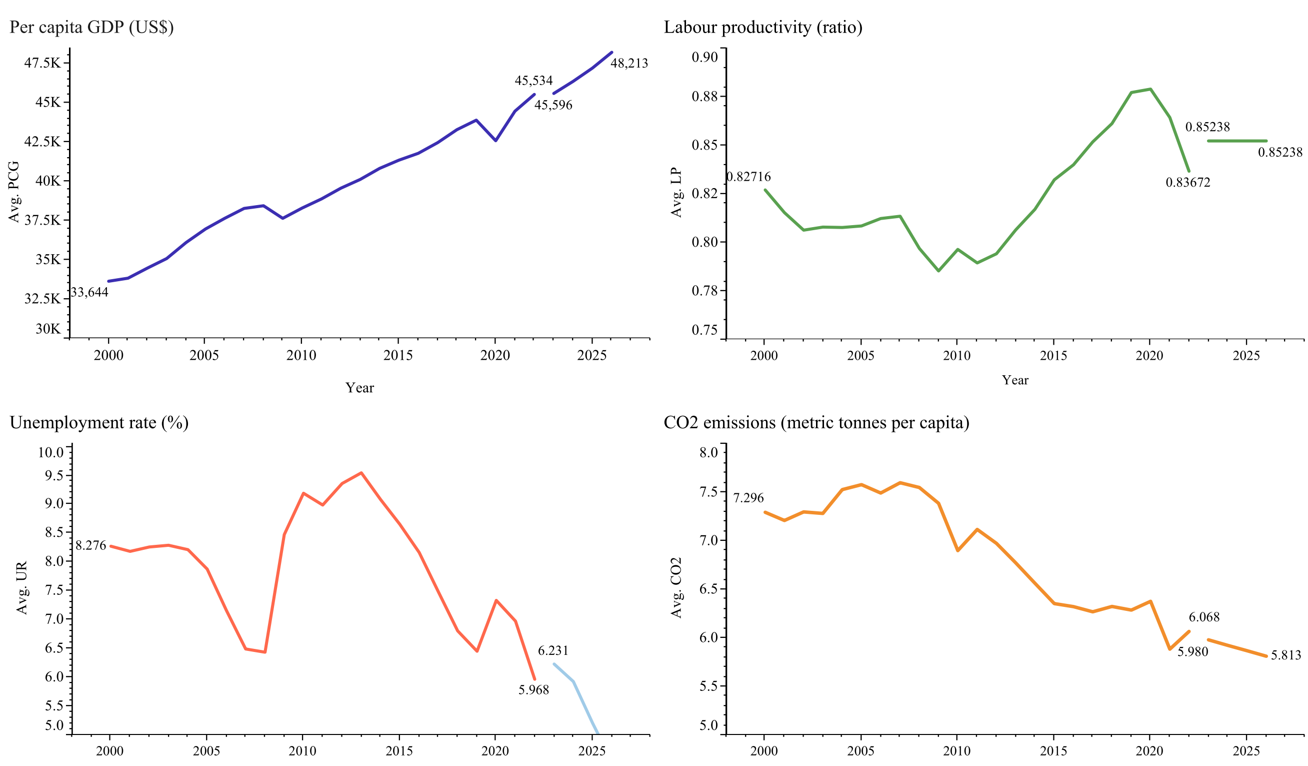

Fig. 3. Annual averages of the key variables. Note: Avg. represents average values of the indicators.

a pooled manner (*i.e.*, without distinguishing between model specifications), with the results detailed in Table 2. This analysis is conducted to identify multicollinearity among the predictors, following the established threshold of < 0.85, as proposed by Elith et al. (2006). While pooled together, the results demonstrate that none of the indicators exceed the critical threshold of 0.85, thereby confirming the absence of multicollinearity.

To ensure an appropriate model specification—particularly given the shared economic structures among most G20 nations—we extend our analysis to investigate the cross-sectional dependence (CSD) properties of the variables. This is achieved using Pesaran's (2004) test, which is well-suited for detecting CSD across variables with varying orders of integration, requiring "no a priori" assumption about the presence of CSD. The results are reported in Table 3 reject the null hypothesis of no CSD at the 1 % significance level for all the augmented variables, highlighting the presence of cross-sectional interconnectedness among them.

Additionally, to account for the variations among variables—as initially warranted by results in Table 1—we examine their slope heterogeneity (SLH) through the methodology proposed by Pesaran and Yamagata (2008), while recognising the relevance of specific regressors within the models presented in equations (5)–(8) (*e.g.*, Models I to IV). The findings in Table 4 reveal pronounced SLH across Models I, III, and IV, indicating significant variability in the relationships between the dependent and independent variables. In contrast, no evidence of SLH is detected in Model II, suggesting that the interactions captured by this model exhibit a relatively uniform behaviour.

Furthermore, to inform the accurate selection of an estimation procedure, this sub-section concludes with the implementation of two additional tests: the panel unit root and panel cointegration analysis. The observations presented in Tables 3 and 4 collectively suggest that conventional methodologies would be inadequate for capturing the true properties of variables under the influence of SCD and SLH. Consequently, we employ the cross-sectionally Im, Pesaran, and Shin (CIPS) panel unit root test, proposed by Pesaran (2007), and the panel cointegration model, developed by Westerlund (2007). These methodologies are particularly well-suited for detecting stationarity and long-term relationships in datasets characterised by CSD and SHL. Table 5 delineates the outcome of the CIPS test, reinforced by the cross-sectionally augmented Dickey and Fuller (CADF) method, performed at both levels $I(0)$, and first differences $I(1)$. The optimal lag length, determined via the Akaike Information Criterion (AIC), is set to 2. The findings consistently reveal that most variables exhibit non-stationarity at levels, transitioning to stationarity at first differences. Exceptions to this pattern include IQI, ENT, and FDI, which manifest stationarity at levels $I(0)$. These results underscore the mixed integration properties of the variables, warranting the utilisation of cointegration test to identify their long-run relationships.

Furthermore, the Westerlund (2007) test results, employing the AIC to determine the optimal lag length of 2, confirm robust evidence of cointegration across all four models at both group-specific and panel-specific levels, as summarised in Table 6. For Models I to IV, the null hypothesis of no cointegration is consistently rejected at the 1 % significance level. These findings underscore the presence of stable long-term relationships between the dependent variables and their respective explanatory variables. Notably, the heterogenous cointegration identified by the Gt and Ga statistics across models—recently corroborated by SHL test for Models I, III, and IV—and the homogeneous cointegration captured by the Pt and Pa statistics highlights the varying nature these relationships within individual units and groups. These findings reinforce the need for employing analytical approaches that account for CSD and structural differences within the G20 panel.

5.2. Baseline results

Table 7 presents the CS-ARDL estimation results for Models I to IV. In Model I, where PCG serves as the dependent variable, the findings reveal that a 1-unit improvement in IQI increases PCG by \$567.05 in the short run and \$566.07 in the long run, underscoring the role of strong institutional foundations in amplifying sustainable economic growth. ENT positively impacts PCG, with a 1 % increase contributing \$76.04 in the short run and \$77.29 in the long run, reflecting the economic benefits of sustainable technologies. FDI also has a positive impact, with a 1 % increase raising PCG by \$62.93 in the short run and \$101.15 in the long run. The effect of ECI is particularly pronounced, where a 1-unit improvement precipitates a \$793.37 surge in PCG in the short run and \$800.62 in the long run. Conversely, SFI exhibits negative impacts on PCG, with a 1-unit increase reducing it by \$145 in the short run and \$149.37 in the long run, highlighting the economic vulnerability associated with state fragility. PE positively influences PCG. A terawatt-hour increase in PE leads to a \$493.18 increase in PCG in the short run and \$111.49 in the long run, accentuating the significant explanation of existing growth trajectories within the G20 nations. While RE increases \$55.014 = in the short-term, it increases to \$219.34 in the long-term, reflecting the impact of adopting sustainable sources in enhancing growth. A 1-unit increase in HDI enhances PCG by \$432.69 in the short run and \$459.06 in the long run. GLO contributes positively to PCG, with a 1-unit increase yielding \$74.29 in the short run and \$81.01 in the long run. URB amplifies PCG, with every 1 % rise contributing \$179.42 in the short run and \$190 in the long run. The error-correction term (ECT) shows that deviations from long-run equilibrium adjust at a rate of 40 % per year.

For Model II, both short- and long-run effects reveal the critical role of the explanatory variables in influencing LP. In the short run, a 1-unit increase in IQI enhances LP by 0.016 units, and this effect grows substantially in the long run to 0.08 units. ECI has significant impacts, with a 1-unit improvement raising LP by 0.131 in the short run and 0.29 in the long run. ENT also contributes positively, with a 1 % increase

Table 2
Matrix of correlations.

Variables	PCG	LP	UR	CO_2	IQI	SFI	ECI	ENT	HDI	FDI	URB	GLO	PE	RE
PCG	1.00													
LP	0.11	1.00												
UR	−0.27	−0.17	1.00											
CO_2	0.38	0.23	−0.06	1.00										
IQI	0.18	−0.05	−0.03	0.13	1.00									
SFI	−0.59	0.03	0.20	−0.28	−0.22	1.00								
ECI	0.34	0.24	−0.25	−0.01	0.10	−0.51	1.00							
ENT	−0.14	−0.29	0.02	0.06	−0.09	0.22	−0.38	1.00						
HDI	0.55	−0.17	−0.07	0.41	0.32	−0.57	0.16	0.06	1.00					
FDI	0.02	−0.08	−0.03	0.02	−0.04	0.01	−0.17	0.20	0.05	1.00				
URB	0.28	−0.12	−0.12	0.39	0.13	−0.24	−0.13	0.15	0.60	0.12	1.00			
GLO	0.59	−0.03	−0.17	0.32	0.36	−0.75	0.47	−0.24	0.72	0.03	0.33	1.00		
PE	0.13	0.09	−0.06	0.49	−0.09	0.26	0.10	−0.33	−0.20	0.29	0.30	−0.08	1.00	
RE	0.04	0.01	0.11	−0.03	0.17	−0.01	0.38	0.15	0.16	0.46	0.05	0.10	−0.17	1.00

Table 3
CSD results.

	PCG	LP	UR	CO_2	IQI	SFI	PE
CD-test statistics	113.52***	20.58***	27.85***	15.18***	81.59***	27.97***	39.87***
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Abs-corr	0.700	0.499	0.384	0.672	0.640	0.576	0.499
	ECI	ENT	HDI	FDI	URB	GLO	RE
CD-test statistics	2.60***	29.24***	142.44***	16.71***	92.88***	137.29***	10.35***
p-value	0.009	0.000	0.000	0.000	0.000	0.000	0.000
Abs-corr	0.545	0.260	0.945	0.231	0.867	0.911	0.338

Notes: *** rejects the null hypothesis of no CSD at the 1% level.

Table 4
SLH results.

	Model I: PCG	Model II: LP	Model III: UR	Model IV: CO_2
Delta	14.415***	1.006	11.969***	13.298***
p-value	0.000	0.314	0.000	0.000
Adj-delta	19.586***	1.367	16.262***	18.806***
p-value	0.000	0.172	0.000	0.000

Notes: *** rejects the null hypothesis of slope homogeneity at the 1% level.

Table 5
Panel unit root results.

	Optimal lags length	CIPS test I (0)	I (1)	CADF test I (0)	I (1)
PCG	2	−1.188	−2.907***	1.483	−4.271***
LP	2	−1.829	−3.638***	3.099	−8.130***
UR	2	−1.189	−3.570***	−1.331	−6.007***
CO_2	2	−1.847	−4.883***	1.411	−11.657***
IQI	2	−3.051***	−4.979***	−3.006***	−11.657***
SFI	2	−1.030	−4.190***	5.035	−8.046***
ECI	2	−1.023	−4.286***	−1.140	−14.583***
ENT	2	−3.434***	−5.355***	−5.914***	−15.994***
HDI	2	−1.621	−4.248***	0.272	−8.075***
FDI	2	−3.582***	−5.683***	−5.454***	−18.768***
PE	2	−1.110	−3.992***	−1.409	−7.053***
RE	2	−0.856	−3.219***	−0.087	−5.107***
URB	2	−1.094	−3.451***	−1.299	−7.184***
GLO	2	−1.274	−3.710***	−1.781	−7.960***

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. CIPS critical values at the 1%, 5%, and 10% levels are −2.23, −2.11, and −2.04, respectively.

Table 6
Panel cointegration results.

	Model I: PCG	Model II: LP	Model III: UR	Model IV: CO_2
Gt	−3.669***	−10.044***	−8.910***	−7.315***
Ga	−4.002***	−10.305***	−9.831***	−6.128***
Pt	−4.791***	−3.648***	−4.570***	−8.207***
Pa	−4.298***	−4.355***	−4.990***	−7.326***

Notes: *** rejects the null hypothesis of no cointegration at the 1% significance level. Gt: Group-specific for individual unit, Gt: Group-specific for aggregate, Pt: Panel-specific pooled, and Pa: Panel-specific aggregate.

improving LP by 0.01 units in the short run and 0.02 units in the long run. In contrast, SFI reduces LP, with short- and long-run effects of −0.022 and −0.013, respectively. PE positively impacts LP, with a 1 terawatt-house increase rising it by 0.017 and 0.028 units in the short- and long-run, respectively. Comparatively, RE exerts a higher positive impact on LP, increasing it by 0.038 and 0.078 units in the short- and long-run, respectively, for every 1 % increase. While GLO does not have short run effects, it amplifies PCG by 0.085 units in the long run, reflecting the gradual impact of GLO on LP. Furthermore, URB has a modest positive impact, contributing 0.026 unit in the short run and 0.033 unit in the long run. Likewise, FDI improves LP, with a 1 % increase enhancing it by 0.009 units both in the short- and long-run. The ECT is negative and significant, suggesting that 51 % of deviations from equilibrium are corrected annually.

For Model II—UR used as the dependent variable—the results indicate that while GLO and URB do not exhibit short run effects, all other augmented variables significantly influence UR both in the short- and long-run. Specifically, a 1-unit improvement in IQI reduces UR by 2.70 percentage point in the short run, with its effect slightly increases to 2.791 percentage point in long run. ENT has short- and long-run effects of −0.068 and −0.071 percentage points, respectively, for every 1 % increase, reflecting its job creation potential in green sectors. ECI is similarly impactful, with a 1-unit improvement decreasing UR by 0.30 percentage points in the short run and 0.33 percentage points in the long run. In contrast, SFI exacerbates UR, with short- and long-run effects of 0.247 and 0.26 percentage points for a 1-unit increase, highlighting the destabilising effects of fragility. RE decreases UR, with a 1 % rise causing a 0.506 percentage point decrease in the short run and 1.09 in the long run. HDI decreases UR, with a 1-unit increase leading to 1.414 and 1.467 percentage points decrease in UR in the short- and long-run, respectively. URB also reduces UR by 0.392 percentage points in the short run and 0.215 in the long run. The ECT suggests that 47 % of deviations from equilibrium are corrected annually.

Model IV validates the EKC hypothesis, showing that CO_2 initially rise with income but decline after a critical threshold. This is reflected in the positively significant coefficient for PCG (11.194) and the negative coefficient for PCG^2 (−0.0001), indicating an inverted U-shaped relationship between growth and expansion. Therefore, a redefined turning for G20 nations would be $\left(TP_{it} = \frac{11.194}{2\times(-0.0001)} = \$55,972\right)$. Moreover, IQI has significant negative effects, reducing CO_2 by 1.103 metric tonnes per capita in the short run and 1.169 in the long run for every 1-unit increase. ENT and FDI contribute to emissions reductions, with ENT decreasing CO2 by 0.050 metric tonnes per capita in the short run and 0.052 in the long run for every 1 % increase, while FDI reduces emissions by 0.024 metric tonnes per capita only in the long run. SFI does not have short run effects; however, it increases CO_2 by 0.029 metric tonnes per capita in the long run. ECI and HDI, while negative, do not exhibit short run effects. ECI reduces CO_2 by 0.230, while HDI curbs it by 0.609 metric tonnes per capita. GLO and URB both are impactful, with GLO reducing CO2 by 0.048 metric tonnes per capita in the short run and 0.044 in the long run, and URB mitigating it by 0.642 metric tonnes per capita in the short run and 0.689 in the long run. Additionally, PE continues to positively contribute to CO_2 emissions in the bloc. A terawatt-hour increase in PE leads to a 0.903 metric tonnes per capita increase in CO_2 emissions in the short run and 0.148 in the long run. Conversely, RE negatively influences CO_2 emissions, with a 1 % increase resulting in a 1.117 and 1.442 metric tonnes per capita decrease in CO_2 emissions in the short- and long-run, respectively.

Table 7
The CS-ARDL estimates.

	Model I: PCG		Model II: LP		Model III: UR		Model IV: CO_2	
	Coefficients	t-statistics	Coefficients	t-statistics	Coefficients	t-statistics	Coefficients	t-statistics
ΔIQI	567.05***	3.24	0.016***	3.16	−2.709**	−2.48	−1.103***	−4.52
ΔENT	76.04*	1.81	0.012***	2.74	−0.068*	−1.92	−0.050*	−1.68
ΔFDI	62.93**	2.13	0.009***	3.85	−0.085**	−2.03	−0.019	−1.30
ΔSFI	−145.01**	−2.04	−0.022*	−1.80	0.247***	4.16	0.023	1.22
ΔECI	793.37***	2.80	0.131**	2.08	−0.301***	−5.27	−0.184	−0.68
ΔHDI	432.69**	2.11	0.504***	4.90	−1.414**	−2.12	−0.595	0.09
ΔGLO	74.29*	1.69	0.061	0.25	−0.023	−0.16	−0.048**	−2.35
ΔURB	179.42***	3.66	0.026***	2.69	−0.392	−0.53	−0.642**	−2.47
ΔPE	493.18***	2.98	0.017***	4.57	–	–	0.903***	4.26
ΔRE	55.014***	5.49	0.038*	1.94	−0.506***	−3.77	−1.117**	−2.10
ΔPCG							11.190	0.69
ΔPCG^2							−0.0002	−0.51
Constant	300.84***	10.49	1.822***	6.04	1.059***	9.27	0.417***	6.33
ECT (−1)	−0.404***	−3.37	−0.511***	−5.20	−0.466***	−2.99	−0.610***	−5.04
IQI	566.07***	3.43	0.084***	10.12	−2.791***	−2.77	−1.169***	−4.04
ENT	77.29***	2.74	0.019***	3.53	−0.071***	−3.76	−0.052***	−2.73
FDI	101.15***	2.86	0.009***	3.60	−0.094***	−2.81	−0.024***	−2.92
SFI	−149.37***	−3.22	−0.013***	−4.64	0.266***	3.45	0.029***	3.99
ECI	800.62**	2.15	0.299**	4.89	−0.336***	−3.11	−0.230**	−2.10
HDI	459.06**	2.24	0.620***	3.03	−1.467**	−2.35	−0.609***	−5.00
GLO	81.01***	3.40	0.085*	1.82	−0.031***	−3.01	−0.044***	−2.84
URB	190.00***	3.01	0.033**	2.43	−0.215***	−4.09	−0.689***	−3.67
PE	111.49***	4.32	0.004***	4.01	–	–	0.148***	3.98
RE	219.34***	2.94	0.078***	4.49	−1.099***	−2.75	−1.442***	−2.98
PCG							11.194***	−2.97
PCG^2							−0.0001***	−4.57
Post-estimations								
F-statistics	9.04***		11.29***		9.44***		10.15***	
R-squared	0.57		0.61		0.65***		0.67***	
Groups	44		44		44		44	

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

5.3. Robustness checks

To ensure the reliability and robustness of the results derived from the CS-ARDL model, as presented in Table 7, the study employs the DCCEMG model as a robustness test, with its results reported in Table 8. The statistical findings from the DCCEMG model across Models I to IV

Table 8
Dynamic CCEMG estimates.

	Model I: PCG		Model II: LP	
	Coefficients	Bootstrap p-values	Coefficients	Bootstrap p-values
IQI	619.22*** (4.33)	0.000	0.021*** (4.41)	0.000
ENT	82.35*** (3.19)	0.000	0.015*** (4.32)	0.000
FDI	79.65*** (4.10)	0.000	0.011*** (2.99)	0.002
SFI	−152.22*** (−2.87)	0.006	−0.024*** (−3.50)	0.000
ECI	811.46*** (5.32)	0.000	0.147*** (2.86)	0.005
HDI	488.27*** (4.40)	0.000	0.615*** (3.06)	0.001
GLO	80.11*** (3.26)	0.000	0.090*** (2.91)	0.009
URB	202.02*** (4.00)	0.000	0.031*** (4.27)	0.000
PE	244.00*** (3.66)	0.000	0.027*** (3.38)	0.000
RE	231.49*** (4.25)	0.000	0.080** (2.14)	0.043
Constant	455.01*** (8.39)	0.000	1.108*** (11.45)	0.000
R-squared	0.66		0.59	
F-statistics	11.47***		9.16***	
	Model III: UR		Model IV: CO_2	
	Coefficients	Bootstrap p-values	Coefficients	Bootstrap p-values
IQI	−2.83** (−2.32)	0.044	−1.200*** (−5.01)	0.000
ENT	−0.080*** (−4.45)	0.000	−0.048*** (−2.87)	0.006
FDI	−0.097*** (−3.10)	0.000	−0.016*** (−3.49)	0.000
SFI	0.271* (1.92)	0.069	0.037*** (4.02)	0.000
ECI	−0.334*** (−3.49)	0.000	−0.202*** (−5.10)	0.000
HDI	−1.465*** (−2.98)	0.006	−0.710*** (−3.44)	0.000
GLO	−0.033*** (−2.77)	0.009	−0.045*** (−2.90)	0.005
URB			−0.654*** (−2.93)	0.005
PE			0.153** (2.16)	0.037
RE	−0.974*** (−3.39)	0.000	−1.572*** (−5.01)	0.000
PCG			11.099*** (3.06)	0.000
PCG^2			−0.0001*** (−2.84)	0.007
Constant	0.909*** (7.13)	0.000	1.022*** (9.23)	0.000
R-squared	0.59		0.62	
F-statistics	10.34***		7.09****	

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

exhibit consistent long-run coefficients that align closely with those obtained from the CS-ARDL model. While slight differences in the magnitude of the effects are observed, these variations can be attributed to the superior ability of the CS-ARDL model to disentangle the true relationships between the explanatory and outcome variables. Nonetheless, the high degree of consistency between the two models confirms the robustness of the results, providing a solid foundation for proceeding to the empirical discussion in the subsequent section.

6. Discussion

SDG 8 reflects a global commitment to promoting sustained, inclusive, and sustainable economic growth, fostering productive employment, and ensuring decent work for all. This study scrutinises the fulfillment of this commitment within the G20 nations, recognised as pivotal actors in championing SDGs. Employing a multidimensional approach, the analysis is framed around four distinctive axes. First, it evaluates the adequacy of existing institutional setups within the G20 to support the targets of SDG 8. Second, it interrogates the nexus between labour productivity and the realisation of decent work for all. Third, it investigates whether unemployment trends are attenuated by key determinants or aggravated by state fragility, economic complexity, and institutional quality. Four, it examines the alignment of the G20′s environmental commitments with resource consumption outcomes, focusing on the interplay of economic growth, complexity, state fragility, and institutional frameworks in driving progress toward SDG 8. Drawing on the most recent datasets, this study employs advanced econometric models to unearth the dynamic relationships among these predictors. Innovatively, the study introduces a comprehensive institutional quality index, encompassing the critical dimensions of governance and institutional frameworks, which serve as a cornerstone for advancing SDG 8 objectives.

To address these objectives, we formulated four empirical models, yielding profound and nuanced insights. The results reveal that institutional quality index (IQI) serves as a cornerstone for sustaining growth trajectories, amplifying labour productivity, minimising unemployment rate, and mitigating CO_2 emissions—all of which are the essential drivers to achieve SDG 8 and environmental sustainability. The findings demonstrate that as IQI strengthens, growth not only endures but evolves in a more sustainable and resilient form. At the heart of this trajectory is the robustness of institutional frameworks, which underpin inclusive and enduring economic growth, higher labour productivity, lower unemployment, and reduced CO_2 emissions through the governance efficacy, regulatory quality, protection of property rights, political stability, and market freedoms. These frameworks create a stable environment for heightened economic activity while ensuring equitable participation and innovations to support the achievement of SDG 8 targets. Recent empirical evidence, such as those by Bruinshoofd (xxxx); Olaniyi and Oladeji (2021); Singh and Pradhan (2022); Nirola and Sahu (2019); Azimi (2022); Fengju and Wubishet (2024); Ayana et al. (2024); Degbedji et al. (2024); Abban et al. (2025); and de Almeida et al. (2024) lends strong support to these findings, documenting similar patterns across diverse economic contexts in both the developed and developing nations.

Our findings underscore the significant and multifaceted impact of the state fragility index (SFI) on SDG 8 targets. The results reveal that heightened SFI undermines economic growth and labour productivity while simultaneously exacerbating unemployment and environmental degradation. These effects arise from systemic constraints that fragility imposes on economic market activities, including restricted investment flows and pervasive monetary overhang in the country. Political instability often a byproduct of fragility, further destabilises labour markets, increasing unemployment and reducing the efficacy of economic policies (Degbedji et al., 2024). Additionally, fragile states often lack the governance mechanisms required to enforce sustainable development practices, contributing to accelerated environmental degradation and resource depletion. The cyclical nature of fragility creates a feedback loop, where fragility not only impedes immediate development but also erodes the foundations necessary for future resilience. This aligns with findings from studies such as Loayza and Ranciere (2006); Ye and Zeng (2024); and Kwablah and Amoah (2022), which similarly underscore how fragility diminishes market performance, deters environmental outcomes, and contracts economic growth.

The results highlight that economic complexity index (ECI) emerges as a crucial driver of SDG 8, demonstrating its ability to amplify economic growth, enhance labour productivity, reduce unemployment, and mitigate environmental degradation. These effects can be attributed to the increasing sophistication of production and trade structures, which foster innovation, diversification, and value-added industries. By enabling economies to move beyond reliance on low-complexity, resource-based activities, ECI promotes more resilient and inclusive growth trajectories. These findings align with those of Tabash et al. (2024); Can and Ahmed (2023); Kirikkaleli et al. (2023); Sarsar and Echaoui (2024); Cadman and Maraseni (2012); Geng and Fan (2023) and Mora and Olabisi (2023), who also highlight the transformative role of diversification in driving sustainable development. Likewise, these dynamics reflect the indispensable alignment of human capital development with SDG 8 targets.

The analysis underscores human development index (HDI) as a critical determinant, influencing growth, labour productivity, unemployment, and environmental outcomes. As HDI improves, economic growth not only accelerates but also becomes more resilient and sustainable over the long term. This is attributed to the enhanced capacity of an educated, skilled, and healthy workforce to drive innovation, foster diversification, and attract investment. Higher HDI levels directly bolster labour productivity by equipping individuals with the skills and capacities required to contribute more effectively to economic output, fostering inclusiveness and reducing inequalities. Conversely, the increase in HDI exerts a dampening effect on unemployment rate, as improved education and health outcomes align labour market demand with supply, reducing structural mismatches and frictional unemployment. Moreover, higher HDI levels contribute to a significant reduction in CO_2 emissions, reflecting the transition towards cleaner, knowledge-based economies that are less reliant on carbon-intensive industries. This environmental benefit is driven by the adoption of advanced technologies, greater public awareness of environmental issues, and strengthened institutional capacity to implement and enforce sustainability policies. These results align with the findings of Opoku et al. (2022); Arfanuzzaman (2016); Rahman and Alam (2021); Garza-Rodriguez et al. (2020); Curea and Ciora (2013); Zhang and Wu (2022); Phillips (2023); and Jain and Nagpal (2019), who similarly documented the favourable effects of HDI on sustainable development.

The globalisation index (GLO) is shown to have profound implications for achieving SDG 8 targets. The results indicate that GLO plays a pivotal role in enhancing economic growth in the short term while laying the foundation for sustainable growth in the future. GLO also increases labour productivity, reduces unemployment, and mitigates environmental degradation. These outcomes can be attributed to globalisation's capacity to facilitate access to global markets, promote cross-border investment flows, and enable the exchange of innovative technologies, human capital, and knowledge. Increased exposure to international markets also incentivises firms to adopt efficient production processes and invest in workforce capacity building initiatives, leading to higher output per worker and more competitive economies. The findings also suggest the GLO contributes to mitigating environmental degradation by facilitating access to cleaner and more sustainable technologies. Global trade and investment flows often introduce stricter environmental standards and practices in host nations, especially when engaging with environmental conscious trading partners. These results align with empirical findings of Beri et al. (2022); Awad and Saadaoui Mallek (2023); Heimberger (2022); Ayana et al. (2024); Sethi et al. (2020); Nguyen et al. (2023); Hasan (2019); Al-Malki et al. (2024);

Primbetova et al. (2022); Pal and Villanthenkodath (2024); Figge et al. (2017); Rehman et al. (2021); and Degbedji et al. (2024), who found the crucial role of globalisation on sustainable trajectories.

Within this analysis, primary energy consumption (PE) emerges as a significant obstacle to realising the core objectives of SDG 8, particularly sustainable growth, labour productivity, and environmental sustainability. The findings reveal a persistent and positive association between PE and economic growth, labour productivity, and environmental degradation, underscoring the continued reliance on conventional energy sources. Conversely, renewable energy (RE) exhibits a comparatively modest positive impacts on SDG 8 targets, with its influence strengthening over the long term. This dynamic highlight the critical importance of transitioning to sustainable sources as a pathway to achieving the comprehensive goals of SDG 8. Recent empirical studies like those by Raza and Shah (2018); Alam and Adil (2019); Wang et al. (2016); Kasman and Duman (2015); and Pata and Caglar (2021) lend statistical supports to these findings. Furthermore, when CO_2 emissions are treated as the outcome variable, the results validate the EKC hypothesis, indicating that emissions initially rise with economic growth but begin to decline after surpassing a critical income threshold (new turning point = \$55,972) for the group; however, this value may differ across individual nations constituting G20 nations. This dynamic underscore the dual challenge: while growth trajectories in G20 nations contribute to emissions in the long run, achieving turning point of the EKC requires strategic interventions aligned with SDG 8 goals, such as promoting green technologies, institutional quality, economic complexity, and renewable energy. The adverse relationship between CO_2 emissions and SDG 8 outcomes stem from inefficiencies in carbon-intensive industries, increased healthcare and infrastructure costs, and regulatory burdens that deter investment. Over the long term, the cumulative effects of environmental degradation, such as rising emissions and resource depletion, erode the foundational structure of sustainable economic development. These findings are consistent with the works of Ahmad and Zhao (2018); Peng et al. (2022); Chen et al. (2019); Dong et al. (2018); Stamatiou and Dritsakis (2019); and Li et al. (2023), who similarly emphasise the critical need for transitioning to low-carbon economic systems to reconcile growth objectives with environmental sustainability.

Moreover, our findings highlight the significant influence of environmental-related technologies (ENT) on SDG 8 targets. ENT facilitates the adoption of technological innovations, whether through in-house development or imports, which are crucial for fostering resource efficiency and supporting the transition to greener and cleaner economic systems. This dual capability contributes significantly to economic sustainability, improving labour productivity, and reducing industrial emissions. By integrating cleaner and techno-efficient production methods, ENT boosts labour productivity, allowing economies to achieve higher output while minimising environmental impact reducing wastage of time and materials. ENT plays a transformative role in mitigating environmental degradation by decoupling growth from emissions and resource depletion, consistently driving reductions in CO_2 emission levels. Beyond its environmental benefits, ENT fosters job creation in emerging green industries, including renewable energy, waste management, and eco-friendly manufacturing, aligning seamlessly with SDG 8′s focus on decent and inclusive work opportunities. These results are consistent with the works of Chen and Lei (2018); Rahman et al. (2022); Abid (2022); Obobisa et al. (2022); Santra (2020); Amin et al. (2023); Hu (2023); Liu et al. (2023); Khan et al. (2023); Aytun et al. (2024); Xiong (2023); and Wu and Zhang (2022), who collectively demonstrate the efficacy of environmental technologies on sustainable development.

Based on the results, urbanisation (URB) and foreign direct investment (FDI) have substantial implications for economic growth, labour productivity, unemployment, and CO_2 emissions, all critical dimensions of SDG 8. In particular, the findings reveal that URB significantly drives economic growth across the G20 nations. This effect is attributed to the efficacy of controlled and well-managed urban planning, which fosters industrial expansion through improved infrastructure, greater resource efficiency, and enhanced market accessibility. Furthermore, the results indicate that URB enhances labour productivity in both the short- and long-terms. This is driven by the agglomeration of industries and the concentration of human capital, which facilitates knowledge sharing, skills development, and improved access of labour to job markets. Additionally, URB proves effective in mitigating CO_2 emissions under sustainable urban frameworks. Urbanised populations tend to exhibit more awareness and sensitivity to environmental sustainability, adopting practices that reduce emissions, such as the use of public transport, waste recycling systems, and more energy-efficient technologies. Similar findings are documented in recent empirical studies, including those by Ahmad and Zhao (2018); Sarwar et al. (2024); Wikurendra et al. (2024); Bishwajit (2014); Arouri et al. (2014); Zhang et al. (2023); Gross and Ouyang (2021); Sato and Zenou (2015); Ahmed et al. (2020); and Bertinelli and Zou (2008).

Similarly, the results reveal that FDI positively influences economic growth both in the short and long terms within the G20 nations. This is linked to the fact that FDI facilitates greater capital injection and integration of local communities into global value chains, thereby accelerating economic performance. For instance, Ayenew (2022) and Jugurnath et al. (2016) suggest that FDI is an effective tool to fuel economic growth through effective market stability, adopting better technological and skills transformation in addition to the flow of capital. FDI enhances labour productivity by competitive market dynamics, access to more capital, and creates more job opportunities through investment activities. This results in the enhancement of human capital capacity and a significant reduction in unemployment rate. Similar findings are offered by studies conducted by Jugurnath et al. (2016); Beri et al. (2022); Nketiah-Amponsah and Sarpong (2019); Nguyen (2020); Özek (2020); and Iliuta and Ram (2005).

7. Conclusions and policy implications

The G20 serves as a cornerstone of global efforts to achieve the SDGs; however, these ambitions demand robust, strategically informed inputs, often overlooked in existing literature, which predominantly focus on fragmented aspects of SDG drivers rather than SDG-specific targets. Deviating from common literature, this research delves into the progress of SDG 8 targets, identifying contemporary challenges and opportunities through an innovative approach. Focusing on four core SDG 8 targets—sustainable growth, labour productivity, unemployment, and environmental implications—this study explores the effects of institutional quality, economic complexity, and state fragility, alongside other conventional drivers, on these outcomes. Drawing on panel data from 2000 to 2023 for G20 nations, the study constructs a novel institutional quality index based on six governance dimensions through a distance-based scoring method. For analysis, it employs the cross-sectionally augmented autoregressive distributed lags (CS-ARDL) model, validated by the dynamic common correlated effects group mean estimators.

The results from the CS-ARDL model reveal that robust institutional quality, economic complexity, environmental-related technologies, and renewable energy are pivotal drivers in advancing SDG 8 targets, significantly contributing to increased economic growth, enhanced labour productivity, reduced unemployment, and lower CO_2 emissions in both the short- and long-terms. Conversely, state fragility demonstrates a markedly adverse behaviour, as heightened fragility leads to declines in economic growth and labour productivity, while unemployment and CO_2 emissions rise substantially across both time horizons. Traditional variables, including human development index, foreign direct investment, globalisation index, and urbanisation exhibit consistent positive impacts on the primary SDG 8 targets—economic growth and labour productivity, albeit with varying magnitudes between the short- and long-terms. However, primary energy consumption underscores a persistent environmental burden tied to contemporary economic growth, labour productivity, and CO_2 emissions. Our findings validate the Environmental Kuznets Curve (EKC) hypothesis, suggesting a revised turning point influenced by new factors. Only after this inflection point ($55,972), considering these specific factors, can the environmental impacts of sustainable growth begin to decline, setting the stage for the policy implications discussed in the subsequent sub-section.

7.1. Policy implications

Our findings provide several critical policy implications for the G20 nations, though we only focus on the implications of the emerging metrics alongside the revised EKC dynamics, which are crucial for immediate attention. Firstly, strengthening institutional quality emerges as vital for fostering inclusive and sustainable economic growth. Policies must prioritise effective governance reforms, emphasising regulatory quality, political stability, comprehensive anti-corruption measures, and an inclusive rule of law, which can enhance economic resilience, labour productivity, and environmental management. Secondly, economic complexity highlights the need for further industrial diversification into knowledge-intensive and high-value sectors. This can be achieved through targeted investments in research and development, trade policies on high-value goods and services, and skill development initiatives to align the workforce with the demands of complex industries. Thirdly, addressing existing state fragility requires stabilising political systems, enhancing social safety nets, and incentivising capital investments in fragile countries to break the feedback loops. Third, the validation of the revised EKC hypothesis suggests that achieving its turning point necessitates strategic interventions, including accelerated adoption of green and eco-friendly technologies, integration of climate goals with existing economic policies, and the promotion of resource-efficient practices in a wider manner.

7.2. Study's limitations

This study like all other empirical research, faces two notable limitations. First, while advanced econometric methods such CS-ARDL and DCCEMG are applied to capture empirical challenges such as cross-sectional dependence and heterogeneity of the employed panel, the analysis did not account country-specific progress towards SDG 8 targets. it does not conduct a detailed country-specific analysis due to space and scope limitations. Future research could benefit from focusing on individual G20 nations to uncover country-specific dynamics and provide more targeted policy recommendations. Such an approach would allow for a deeper understanding of regional disparities in SDG 8 progress and enable the formulation of more tailored interventions. Second, although the study incorporated new metrics to examine their impacts on 4 out of 12 SDG 8 targets, it only proposed a direct effect framework. Future studies may enhance this understanding by exploring the indirect and moderated effects of these predictors on these specific SDG 8 targets and include more targets.

CRediT authorship contribution statement

Mohammad Naim Azimi: Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation. **Mohammad Mafizur Rahman:** Writing – review & editing, Validation, Supervision, Investigation, Conceptualization. **Tek Maraseni:** Writing – review & editing, Validation, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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