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Financial foundations for sustainability: how business sophistication, tax policy, and technology shape ESG in belt and road initiative countries

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Research Article

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Abstract

Non-technical summary. The research paper studies business sophistication, tax revenue policies, and ESG (Environmental, Social, and Governance) performance across 105 Belt and Road Initiative (BRI) countries spanning from 2013 to 2021. Key insights from the study underscore a positive association between business sophistication and ESG performance. This suggests that organizations leveraging advanced knowledge and innovation are better positioned to implement effective ESG strategies. Moreover, higher tax revenue is linked to better ESG, underlining a commitment to sustainability within the business landscape. Notably, Information, Communication, and Technology (ICT) emerges as a pivotal catalyst in augmenting ESG performance, particularly when integrated with business sophistication and tax revenue mechanisms.

Technical summary. This study examines the relationship between business sophistication, tax revenue policies, and ESG (Environmental, Social, and Governance) performance in 105 Belt and Road Initiative (BRI) countries from 2013 to 2021, focusing on the moderating role of Information, Communication, and Technology (ICT). Using advanced econometric methods like Two-Stage Least Squares (2SLS), two-step Generalized Method of Moments (GMM), and fixed-effect regression, the research also considers factors such as microfinance institutions, commercial bank financing, and the COVID-19 pandemic. The findings reveal a significant positive link between business sophistication and ESG performance, indicating that companies with advanced knowledge and innovation are more likely to implement successful ESG policies. Higher tax revenue is also positively correlated with ESG improvements, reflecting support for sustainability. ICT is crucial in enhancing ESG performance, especially when combined with business sophistication and tax revenue. Microfinance and commercial banking are vital in promoting ESG practices in BRI countries. Despite a temporary decline in ESG performance due to COVID-19, the study predicts a post-pandemic resurgence, emphasizing the need to foster an innovation culture for sustainable development.

Social media summary. There is a positive association between business sophistication, tax revenues, microfinance, ICT, and commercial banking, which are key drivers of better ESG performance in BRI countries.

1. Introduction

The term Environmental, Social, and Governance (ESG) was first introduced in the United Nations (UN) 'Who Cares Wins' report through a collaborative effort of various financial institutions in 2004 (UN report, 2004). Over the past three decades, the ESG concept has evolved into a crucial component of the sustainable development agenda. ESG sustainability adopts a comprehensive approach, evaluating both national and corporate operations based on three fundamental pillars: planet, people, and profit. Institutions emphasizing strong environmental practices strive to minimize ecological footprints and contribute to environmental preservation. The social facet of ESG sustainability centers on an institution's interactions with people as communities, employees, customers, and stakeholders. Governance evaluates how an institution is managed, encompassing assessments of corporate and national governance structures, accountability, diversity, transparency, ethics, and compliance with laws and regulations (Saleh & Maigoshi, 2024).

ESG considerations ensure that businesses operate responsibly from environmental and social perspectives, preserving resources and contributing to societal well-being. In recent years, the significance of ESG considerations has grown significantly in the global business

and investment landscape. This trend is propelled by various factors, including the increasing consideration of ESG factors by shareholding protection of investors and asset managers in their investment decisions. Recognition prevails that corporations demonstrating robust ESG performance are better positioned for long-term success and are more adept at mitigating risks associated with environmental and social issues. Concurrently, governments and regulators worldwide are enforcing stricter regulations and disclosure requirements related to businesses and ESG. This has resulted in business institutions being compelled to disclose their ESG performance, thereby intensifying focus on sustainability practices. Institutions and businesses are increasingly acknowledging that addressing ESG risks is imperative for ensuring long-term resilience (Baker et al., 2022; Dicuonzo et al., 2022; Lim, 2024; Liu et al., 2023). The increasing relevance of evaluating corporate and national performance in terms of its ESG impacts signifies a growing awareness. ESG factors, pivotal to national as well as corporate and business strategies, are seamlessly integrated into day-to-day government regulation and operations, motivating government effectiveness, indicating risks through accountability and transparency, and encouraging the pursuit of opportunities. Governance-related focuses, such as accountability, transparency, and regulatory aspects, are critical components of effective ESG strategies (Saleh & Mansour, 2024). Therefore, voluntary government and corporate reporting should encompass ESG factors, emphasizing links between environmental and social performance, and governance.

The concept of business sophistication is how conducive corporate institutions are to innovation activity. This business sophistication concept refers to and is based on knowledge workers, innovation linkages, and knowledge absorption. Businesses, in COVID-19, particularly in the period that occurred in 2019–2020, immediately following the global financial crisis, have begun to think not just about stabilizing but also about further enhancing their positions in the marketplaces in which they operate. The political system, the social and economic environment, and technological advancements can all affect an enterprise's degree of sophistication. Therefore, it is necessary to study the role of business sophistication (Ghimire et al., 2024). Moreover, business sophistication denoting the quality of business networks and operational strategies acts as a catalyst fostering social, economic, and environmental growth by enhancing market efficiencies, productivity, and profits. This improvement in operations and strategies is integral to heightened business quality (Dima et al., 2018).

Business sophistication concerns the quality of a country's overall business networks; therefore, this is particularly important for a country's development to a large extent. The quality of a country's business networks and supporting industries is important for strategies, greater opportunities, and sustainability (Salas-Velasco, 2018). The empirical study of Kirikkaleli and Ozun (2019) reveals that improvement in business sophistication triggers innovation capacity and supports macroeconomic stability. The quality of business networks and operational and strategic sophistication can facilitate international collaborations and access to new markets and technologies, which allows national and corporate policies to optimize their operations and innovate effectively. The promotion of ESG activities requires concerted efforts and relies on various factors, including fostering an innovation culture and nurturing business sophistication. Business sophistication, delineated by how conducive corporate institutions are to innovation, hinges on factors like knowledge workers, innovation linkages, and knowledge absorption. Post the global financial crisis, particularly in 2008, businesses are not only focused on stabilization but also on enhancing their market positions. The degree of sophistication is influenced by the political system, social and economic environment, and technological advancements, shaping an enterprise's strategic positioning.

Tax revenue policies play a pivotal role in shaping a society's economic and social trajectory (Chouaibi et al., 2022a), extending beyond the generation of government funds to wield influence over environmental, social, and economic (ESG) aspects. This section delves into the intricate connection between tax revenue policies and sustainability, scrutinizing their impact across various domains. Tax policies possess the potency to effectively promote eco-friendly behaviors and address environmental challenges. Notably, levies on carbon emissions, pollution, and resource extraction can dissuade detrimental practices, propelling the shift toward cleaner technologies and sustainable resource management. Furthermore, incentivizing the adoption of efficient technologies holds the potential to stimulate innovation and facilitate the development of a low-carbon economy, which leads to sustainability (Chien et al., 2021; Christmann, 2004; Yoon et al., 2021). In the realm of successful business expansion, Information, Communication, and Technology (ICT) innovation management assumes a crucial role by enhancing corporate competitiveness through the promotion of product and process innovation. The ability of businesses to navigate continuous shifts in the economic environment, ensuring profitability and expansion, hinges significantly on fostering ongoing innovation as a fundamental requirement.

ICT exerts a direct impact on economic growth through its role in promoting innovation, enhancing productivity (Gajdzik et al., 2021), and improving efficiency across various industries. Critical to the development of new industries, ICT simplifies corporate processes (Bilan et al., 2022) and boosts competitiveness (Gajdzik et al., 2021; Gurbanov et al., 2022). The effective and equitable application of ICT tools and technology plays a pivotal role in achieving sustainability goals and enhancing the domains of environment, society, and governance.

Meanwhile, the Belt and Road Initiative (BRI), a monumental international development project proposed by the Chinese government in 2013, stands as one of modern history's most ambitious initiatives. Also known as 'One Belt, One Road', the BRI aims to foster economic international cooperation, infrastructure development, and trade among Asian, European, African, and other countries. This initiative, subject to ongoing debate regarding its impact on geopolitics and global development, signifies China's strategic pursuit of regional influence and leadership. Through substantial investments in infrastructure and development projects, the BRI seeks to enhance China's soft power and economic leverage, positioning the nation as a global leader and expanding its geopolitical influence (Chen & Liu, 2022; Choudhury, 2021; Christawan et al., 2023). The role of business sophistication and tax revenue in ESG sustainability is important and has not been explored yet concerning the moderating effect of ICT in the BRI region.

Therefore, this study delves into examining the nuanced impact of business sophistication and tax revenue on the intricate dynamics of ESG with a critical focus on the moderating role of ICT in 105 BRI partner countries from 2013 to 2021.

This research stands out on multiple noteworthy contributions. Firstly, it sheds light on the vital role of business sophistication in enhancing ESG practices and offering innovative solutions to prevailing challenges. Notably, the concept of

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business sophistication is relatively unexplored within the multi-country dataset of BRI, making this study a pioneering effort that contributes fresh insights to the existing literature, enriching the knowledge of decision-makers. Secondly, the study underscores the significance of tax revenue in advancing ESG, recognizing its pivotal role in fostering investments and innovation culture. By emphasizing the interplay between tax revenue and ESG improvement, the research adds valuable literature and findings to the understanding of sustainable practices in BRI countries. Thirdly, the investigation goes beyond conventional analyses by exploring the moderating influence of ICT between independent and dependent variables. This approach acknowledges the transformative potential of technology in shaping ESG outcomes, providing a novel perspective on the interconnectedness of these variables with the support of innovation of diffusion theory. Fourthly, the study addresses existing gaps in the literature by incorporating additional factors such as microfinance and commercial bank credit, as contributors to ESG sustainability. By considering these elements, the research enriches the comprehension of the intricate factors influencing ESG practices in BRI countries. Moreover, the study exhibits contemporary relevance by conducting a thorough pre-post analysis of the COVID-19 era's impact on ESG sustainability. Employing advanced econometric methods, such as Two-Stage Least Squares (2SLS) and two-step Generalized Method of Moments (GMM), and adhering to robust testing methodologies like Pesaran's test, the research ensures methodological rigor. The use of a substantial dataset comprising 105 BRI partner countries from 2013 to 2021 underscores the comprehensive nature of the study. In essence, this study not only contributes substantially to the existing body of knowledge but also offers practical implications by providing policies for balanced and sustainable green growth to decision-makers and governments in BRI countries. Through its meticulous examination of a relatively new topic backed by the latest and comprehensive data, the study stands as a commendable effort to advance scholarly discourse and inform practical strategies for sustainable development in the BRI context.

The subsequent sections of this paper are structured as follows: the forthcoming section elucidates the methods and materials employed in this study, providing transparency on the research approach. Subsequently, the results and ensuing discussion unfold, delving into the intricate interconnections between business sophistication, tax revenue, and ESG within BRI countries. The final segment encompasses the conclusion, synthesizing the key findings and implications gleaned from the comprehensive analysis, thereby concluding the study on the multifaceted nexus of these pivotal factors in the context of BRI nations.

2. Material and methods

2.1 Research design

This study undertakes a comprehensive examination of the nexus between business sophistication, tax revenue, and ESG indicators within the BRI context. Covering the period from 2013 to 2021 across 105 BRI countries, this research employs a robust framework. The dependent variable, ESG, encompasses a nuanced index that spans environmental, social, and governance dimensions. Business sophistication and tax revenue serve as the independent variables, while the moderating role of the ICT index. Moreover, microfinance institutions financing, commercial banks financing, and the impact of COVID-19 enhance the analytical model as control factors. Environmental indicators include ecological sustainability and business performance, social indicators encompass resource distribution, human capital, and research index, and household consumption per capita, while the governance index integrates control of corruption, government effectiveness, political stability, regulatory quality, rule of law, and voice and accountability as well as shareholder rights and corporate investor protection score. Rigorous data for this investigation are sourced from reputable entities such as the World Bank, International Monetary Fund (IMF), the Global Innovation Index (GII; Cornell University, INSEAD, WIPO), and the V-Dem Dataset, ensuring a robust and credible foundation for analysis.

In this study, the independent variable, business sophistication, is gauged by assessing firms' receptivity to innovation activity, relying on three pivotal pillars: knowledge workers, innovation linkages, and knowledge absorption. The data, sourced from the GII (Cornell University, INSEAD, WIPO), forms a robust foundation (Ghimire et al., 2024). The primary hypothesis, H_1, posits that business sophistication exerts a significantly positive influence on ESG sustainability (Kirikkaleli & Ozun, 2019). Moving to the second independent variable, Tax Revenue to GDP is quantified as tax revenue, % of GDP, with data extracted from the WDI (Hicks, 1946). Hypothesis H_2 anticipates a significant and positive impact of tax revenue on ESG sustainability (Chien et al., 2021; Christmann, 2004; Yoon et al., 2021). The moderating role of the ICT index is assessed through metrics encompassing ICTs, ICT access, and ICT use, drawing from the GII. Hypothesis H_3 proposes a significant and positive impact of ICT on ESG sustainability (Nevado-Pena et al., 2019; Sinha, 2018; Ziemba, 2020). Further, alternate hypotheses H_{3a} and H_{3b} suggest that the moderating role of ICT significantly and positively affects the relationship between business sophistication and ESG sustainability and moderates the relationship between tax revenue and ESG sustainability, respectively. These hypotheses collectively form a robust framework for examining the intricate interplay between business sophistication, tax revenue, and ICT in influencing ESG sustainability.

Additional factors, namely microfinance institutions and commercial bank financing, are quantified by outstanding loans from microfinance institutions (% of GDP) and robust outstanding loans from commercial banks (% of GDP), respectively. The data for these variables are derived from the IMF database, ensuring reliability (Bongomin et al., 2020; Mahmood et al., 2014). The proposed alternate hypothesis, H_4, asserts that microfinance institutions exert a significantly positive influence on ESG sustainability. Simultaneously, commercial bank financing, as per the alternate hypothesis H4a, is expected to significantly and positively impact ESG sustainability. A crucial element incorporated into the study is a dummy variable for COVID-19, where a value of zero denotes the period before COVID (2013–2018) and one indicates the period since the onset of COVID (2019–2021). In light of existing literature and the profound impact of COVID-19 on global sustainability, the proposed alternate hypothesis H_5 posits that the pandemic has a detrimental effect on ESG sustainability, aligning with the understanding that COVID-19 significantly impedes sustainable development worldwide (Pandey & Pal, 2020; Prasad et al., 2020; Shaw et al., 2020). This comprehensive framework aims to scrutinize the multifaceted influences of microfinance institutions, commercial bank financing, and the COVID-19 factor on ESG sustainability within the broader context of business sophistication, tax revenue, and ICT.

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2.2 Data, and measurement

This research is conducted on a comprehensive sample of 105 partner countries associated with the BRI, with the detailed list provided in Appendix A for transparency and reference. The study meticulously examines data spanning from 2013 to 2021 for these 105 BRI countries, ensuring a robust timeframe for analysis. Additional details regarding the measurement of variables and their respective data collection sources can be found in Table 1, offering a comprehensive overview of the study's methodology. This deliberate and transparent approach not only enhances the credibility of the research but also provides stakeholders with a clear understanding of the dataset and methodologies employed, thereby contributing to the study's reliability and relevance.

2.3 Framework model econometric strategy

This paper undertakes a meticulous exploration of the intricate interplay between business sophistication, tax revenue, and ESG factors, conducting a comprehensive pre- and post-COVID analysis and incorporating ICT as a crucial moderating variable. The methodological rigor is evident in the two-step estimation process, utilizing 2SLS, and then robust with alternate variables as well as using a two-step system GMM and robust fixed effect. The underpinning of the research lies in a well-established theoretical model grounded in existing literature, with the conceptual framework thoughtfully illustrated in Figure 1. By integrating rigorous methodologies and a robust theoretical foundation, this paper endeavors to provide nuanced insights into the dynamic relationships shaping ESG outcomes, especially in the context of evolving business landscapes and the transformative impacts of the COVID-19 pandemic.

The econometric investigation conducted in this study, spanning 105 BRI countries from 2013 to 2021, employs sophisticated techniques such as 2SLS and a two-step system GMM as well as a robust fixed effect, underscoring its methodological robustness. The strategic selection of 2SLS proves advantageous in addressing endogeneity concerns inherent in the analysis of the impact of BRI investments on diverse economic and social outcomes. With a substantial and diverse sample over an extended timeframe, the imperative to control unobserved heterogeneity becomes paramount, and the robust instrumental variable approach of 2SLS serves as a pivotal mechanism for mitigating this concern. Through the utilization of valid instrumental variables, this approach ensures the consistency and efficiency of parameter estimates, thereby fortifying the dependability of the study's outcomes. Given the dynamic nature of BRI countries over the 9-year period, 2SLS provides a systematic framework for handling endogeneity while accommodating individual and time-specific effects, establishing itself as an indispensable tool for a rigorous and reliable econometric analysis (Zahid et al., 2020).

The application of the two-step system GMM in this research presents several critical advantages. Given the substantial temporal dynamics and endogeneity challenges inherent in BRI initiatives, this method is exceptionally well-suited to address these complexities (Rehman et al., 2024). We use a dynamic system GMM where we do not know the distribution of the dependent variable. So, in this case, the incorporation of lagged dependent variables in the estimation process allows for the modeling of dynamic effects, a crucial consideration when scrutinizing the evolving relationships between BRI investments and economic, social, or infrastructural outcomes over time. Moreover, the two-step system GMM proves adept at accommodating unobserved heterogeneity by incorporating individual and time-specific fixed effects, thereby bolstering the precision of parameter estimates. Specifically designed for panel data, the two-step system GMM is effective in addressing issues such as endogeneity, overidentifying restrictions (measured through the Hansen test), measurement errors, and autocorrelation (Roodman, 2009; Tang et al., 2018). The method captures dynamic effects by introducing lags of the dependent variable and instruments (Hayakawa & Qi, 2020), and additional tests, like the variance inflation factor (VIF) test, are deployed to assess and address multicollinearity concerns.

The relationship between ESG and business sophistication and tax revenue is as follows.

$$\mathrm{ESG} = \mathrm{f}(\mathrm{BS},\ \mathrm{TR},\ \mathrm{ICT},\ \mathrm{MFC},\ \mathrm{CBC},\ \mathrm{COVID}) \tag{1}$$

2SLS equations are reported as follows. The instruments in the equation are tax burden, inflation, and financial globalization to obtain reliable results.

$$\mathrm{BS}i,\ t = \alpha 0 + \alpha 1\text{tax burden}i,\ t + \alpha 2\text{Inflation}i,\ t + \alpha 3\text{financial globalization}i,\ t + \varepsilon 1i,\ t\ \text{(First stage)} \tag{2}$$

$$\mathrm{TR}i,\ t = \gamma 0 + \gamma 1\text{tax burden}i,\ t + \gamma 2\text{Inflation}i,\ t + \gamma 3\text{financial globalization}i,\ t + \varepsilon 3i,\ t\ \text{(First stage)} \tag{3}$$

$$\mathrm{ESG}_{i,t} = \beta_0 + \beta_1(\mathrm{BS})_{i,t} + \beta_2(\mathrm{TR})_{i,t} + \beta_3(\mathrm{ICT})_{i,t} + \beta_4(\mathrm{BS}\times\mathrm{ICT})_{i,t} + \beta_5(\mathrm{MFC}) + \beta_6(\mathrm{COVID}) + \varphi\mathrm{t} + \varepsilon_{4i,t}\ \text{(Second stage)} \tag{4}$$

$$\mathrm{ESG}_{i,t} = \beta_0 + \beta_1(\mathrm{BS})_{i,t} + \beta_2(\mathrm{TR})_{i,t} + \beta_3(\mathrm{ICT})_{i,t} + \beta_4(\mathrm{TR}\times\mathrm{ICT})_{i,t} + \beta_5(\mathrm{MFC}) + \beta_6\ (\mathrm{COVID}) + \varphi\mathrm{t} + \varepsilon_{4i,t}\ \text{(Second stage)} \tag{5}$$

The robust test GMM validates the results. The following can be revised to incorporate the dynamic effect as a lag variable.

$$\mathrm{ESG} = \beta_0 + \beta_1(\mathrm{ESG})_{t-1} + \beta_2(\mathrm{BS}) + \beta_3(\mathrm{TR}) + \beta_4(\mathrm{ICT}) + \beta_5(\mathrm{MFC}) + \beta_6(\mathrm{COVID}) + e \tag{6}$$

$$\mathrm{ESG} = \beta_0 + \beta_1(\mathrm{ESG})_{t-1} + \beta_2(\mathrm{BS}) + \beta_3(\mathrm{TR}) + \beta_4(\mathrm{ICT}) + \beta_5(\mathrm{BS}\times\mathrm{ICT}) + \beta_6(\mathrm{MFC}) + \beta_7(\mathrm{COVID}) + e \tag{7}$$

$$\mathrm{ESG} = \beta_0 + \beta_1(\mathrm{ESG})_{t-1} + \beta_2(\mathrm{BS}) + \beta_3(\mathrm{TR}) + \beta_4(\mathrm{ICT}) + \beta_5(\mathrm{TR}\times\mathrm{ICT}) + \beta_6(\mathrm{MFC}) + \beta_7(\mathrm{COVID}) + e \tag{8}$$

In this study, ESG denotes the composite measure encompassing environmental, social, and governance indicators. Simultaneously, BS corresponds to business sophistication, ICTI signifies the ICT index, MFC represents microfinance institutions' credit, CBC stands for commercial banks' credit, and COVID designates a dummy

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Table 1. Data, measurement, and relationship of the variables

Variable name	Description	Hypothesis sign	Sources
Dependent variable			
ESG	PCA Index of Environmental, Social and Governance Indicators. *Environmental* indicators include ecological sustainability and environmental performance *Social* indicators equal resource distribution (the variable denotes the best estimate of the extent to which all social groups benefit from public spending and have equal access to education, healthcare, and the welfare state), human capital and research index, and household consumption per capita. *Governance index* (include the six indicators control of corruption, government effectiveness, political stability and absence of violence/terrorism, regulatory quality, rule of law, and voice and accountability) and shareholder rights and corporate investor protection score		World Bank; Global Innovation Index (Cornell University, INSEAD, and WIPO) (World Intellectual Property Organization); The V-Dem Dataset
Independent variables			
Business sophistication	The enabler pillar tries to capture the level of business sophistication to assess how conducive firms are to innovation activity. This index is based on three pillars, including *knowledge workers:* (knowledge-intensive employment %; firms offering formal training, % firms; gross domestic expenditure on R&D (GERD) performed by business, % GDP; GERD financed by business, %; females emp. w/adv. degrees, % tot. emp.) *Innovation linkages:* (university/industry research collaboration; state of cluster development; GERD financed by abroad, %; joint ventures JV-strategic alliance deals/bn PPP$ GD; patent families filed in 2+ offices/bn PPP$ GDP) *Knowledge absorption:* (intellectual property payments, % total trade; high-tech imports less re-imports, % total trade; ICT services imports, % total trade; FDI net inflows, % GDP; research talent, % in business enterprise) (Ghimire et al., 2024)	+	Global Innovation Index (Cornell University, INSEAD, and WIPO) (World Intellectual Property Organization)
Tax revenue to GDP	Tax revenue, % of GDP	+	WDI
Moderating variable			
ICT index	PCA index of information and communication technologies (ICTs), ICT access, and ICT use (Nevado-Pena et al., 2019; Sinha, 2018; Ziemba, 2020)	+	Global Innovation Index
Control factors			
Microfinance institutes financing	Outstanding loans from microfinance institutions (% of GDP) (Bongomin et al., 2020; Mahmood et al., 2014)	+	IMF (International Monetary Fund)
Commercial banks financing	Outstanding loans from commercial banks (% of GDP) (Bongomin et al., 2020; Mahmood et al., 2014)	+	IMF
Covid-19	Dummy variable zero before the COVID-19 year 2013–2018 and one since the start of COVID year (2019–2021) (Pandey and Pal, 2020; Prasad et al., 2020; Shaw et al., 2020)	–	Authors calculations

variable denoting the impact of COVID-19. The symbol μ is employed to represent the error term, i denotes the country, and t signifies the year in consideration within the econometric model.

3. Results and discussion

3.1 Cross-sectional dependence (CSD) and second-generation unit root

The outcomes in Table 2, derived from cross-sectionally augmented Im, Pesaran, and Shin (CIPS) and cross-sectionally augmented Dickey-Fuller (CADF) analyses, reveal distinctive patterns. Tax revenue (TR) and ICT exhibit stationarity at the first difference, while ESG, BS, MIF, and CBF manifest stationarity at the level. Furthermore, Table 2's CADF data indicate that all other variables exhibit significance at the first difference, with ESG being stationary at the level. These CIPS and CADF results collectively reject the null hypothesis of the unit root test, favoring the alternative hypothesis, signifying that variables either exhibit stationarity at the level or accept the first difference at both levels. The detailed CIPS and CADF results are presented comprehensively in Table 2.

3.2 Results of descriptive, correlation, and VIF summary

Table 3 provides a comprehensive overview of descriptive statistics for the selected sample variables, encompassing 945 observations

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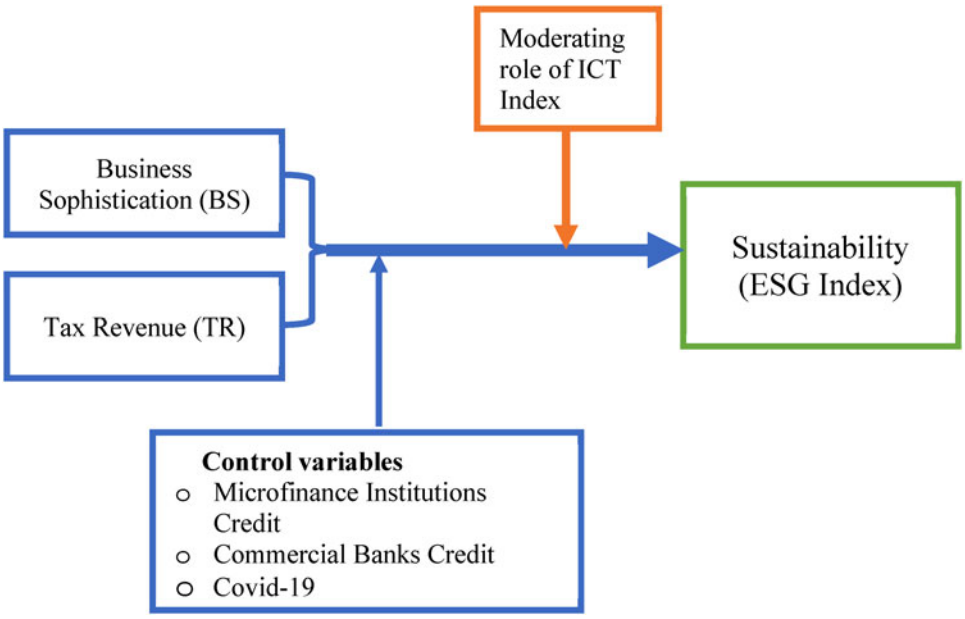

Figure 1. Theoretical framework.

Table 2. Cross-sectional dependence and second-generation unit root for CIPS and CADF

CSD						
Pesaran's test of cross-sectional independence			Fixed effect		Decision	
			79.595***		Refer to sec	
	CIPS			CADF		
Variables	At level	First difference	Decision	At level	First difference	Decision
ESG	−2.037***	–	I (0)	−2.040***	–	I (0)
Business sophistication	−0.753**	–	I (0)	−0.650	−2.449***	I (1)
Tax revenue to GDP	−0.142	0.138**	I (1)	0.314	2.609**	I (1)
ICT index	−1.073	−1.336**	I (1)	−0.544	−2.432**	I (1)
Microfinance institutes financing	0.095***	–	I (0)	0.824	−2.412**	I (1)
Commercial banks financing	0.092***	–	I (0)	0.815	−2.533**	I (1)

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

across 105 countries. Measures of central tendency, including mean and median, offer insights into the typical values, while indicators of data variability, such as maximum and standard deviation, confirm data reliability, providing a holistic view of the entire sample. The results suggest an average dispersion level in the sample, reflecting changes in values. This detailed information is presented in Table 3, combining descriptive and inferential statistical outcomes to enhance understanding.

Table 3. Results descriptive statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
ESG (PCA)	945	0.059	1.141	−4.195	2.688
BS (Log)	945	30.113	9.395	11.800	69.200
TR (Log)	945	0.102	0.925	−4.605	1.845
ICT (PCA)	945	0.442	0.847	−1.448	2.052
MIF (Log)	945	3.855	4.012	0.000	28.710
Covid-19 (dummy)	945	0.333	0.472	0.000	1.000

The paper conducted a thorough examination of the relationships among key variables through Pearson pairwise correlation analysis using the pwcorr command. The variables under consideration encompassed ESG, business sophistication (BS), tax revenue (TR), information communication technology (ICT), microfinance institutions credit (MIF), and the Covid-19 dummy variable. The findings reveal a noteworthy pattern: while the COVID-19 dummy exhibits a significantly negative correlation with ESG at the 1% significance level, all other variables showcase a robust positive correlation with ESG, also at the 1% significance level. These correlation results are instrumental in understanding the interplay between the variables and contribute valuable insights to the overall analysis (Table 4).

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Table 4. Results pairwise correlations

Variables		(1)	(2)	(3)	(3)	(5)	(6)
(1)	ESG	1.000					
(2)	BS	0.544***	1.000				
(3)	TR	0.201***	0.117***	1.000			
(4)	ICT	0.554***	0.471***	0.112***	1.000		
(5)	MIF	0.199***	0.040	−0.103***	0.272***	1.000	
(6)	Covid-19	−0.134***	0.102***	0.017	−0.154***	0.027	1.000

Note: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 5 presents the VIF analysis, a crucial step in ensuring the absence of multicollinearity within the study's sample. The VIF values for independent, moderating, and control variables were computed to assess the potential presence of multicollinearity. A VIF value exceeding five is typically indicative of multicollinearity issues with the corresponding variable (Hashmi et al., 2022). Fortunately, the analysis indicates that our dataset has no multicollinearity concerns, as all VIF values in Table 5 are well below the critical threshold of five (Sheraz et al., 2022). These findings enhance the reliability of the study's regression analysis by confirming that the included variables are not excessively correlated with each other, as shown in Table 5.

3.3 Findings for the nexus of business sophistication, tax revenue, and ESG sustainability: 2SLS, robust two-step system GMM, and fixed effect models

Table 6 presents the outcomes of the 2SLS main and robustness models of two-step system GMM and fixed effect, coupled with diagnostic tests that ensure the validity of the inferences. In column (1) of Table 6, the 2SLS primary model reveals noteworthy outcomes. Business sophistication (BS) exhibits a statistically significant and positive impact on ESG, boasting an 8.4% chance at a 1% significance level. This finding suggests that ESG performance tends to improve concomitantly with business sophistication based on the pillars of knowledge workers, innovation linkages, and knowledge absorption. Companies displaying greater business sophistication are more prone to successfully integrate and implement ESG policies, leading to increased sustainability, ethical business practices, and enhanced competitiveness and reputation. Conversely, tax revenue exerts a robust, significantly contributing influence on ESG, featuring a 97.4% chance at a 1% significance level. The heightened tax receipts may indicate a heavier tax burden on individuals and corporations, potentially resulting in reduced investments in sustainability projects and overall economic activity. Moreover, governments prioritizing revenue collection might occasionally compromise sustainability objectives, underscoring the delicate balance between financial and environmental priorities in Belt and Road partner countries.

Table 5. Variance inflation factor: results for the multi-collinearity test

Dependent: ESG	VIF	1/VIF
BS	1.325	0.755
TR	1.039	0.962
ICT	1.477	0.677
MIF	1.125	0.889
Covid-19	1.08	0.926
Mean VIF	**1.209**	.

In addition, microfinance institutions (MFI) exert a robust positive impact on ESG, featuring a coefficient of 7.1% constructive change at a 1% significance level. This outcome underscores the beneficial influence of microfinance institutions on fostering sustainable and ethical business practices, emphasizing their pivotal role in achieving ESG goals, particularly in the realms of environment, social responsibility, and governance. On a different note, the dummy variable of COVID-19 exhibits a negative impact on ESG, with a coefficient value of −0.545 and a 1% significance level. This finding implies that ESG performance experienced a temporary decline due to the pandemic's disruptive effects on financial stability, governance procedures, and social and environmental activities.

The diagnostic tests in column (1) of Table 6 affirm the results' reliability, validity, and inference. Notably, the R^2 value is 0.636 for the primary model, indicating that the chosen independent variables possess substantial explanatory power, elucidating a significant portion of the variance in the dependent variable. The Sargen test p-value is 0.886, with an exceeding 5%, signifying the validity of the over-identifying restrictions and the model's reliable instrumentation. In the under-identification test (Anderson canonical correlation LM statistic), the value registers as 10.288, accompanied by a χ^2 p-value below 5%, implying an ample dataset from the selected instruments for accurate parameter estimation. Furthermore, the endogeneity test of endogenous regressors yields a value of 88.907, with a p-value below 5%, indicating an absence of endogeneity issues in the model. These diagnostic indicators collectively affirm the reliability and validity of the results, as summarized in Table 6.

Robustness check column (2) of Table 6 presents the results of the 2SLS robustness model with alternate variables, while column (3) demonstrates the two-step system GMM and column (4) confirms the robust fixed-effect model outcomes reinforcing the robustness and consistency of the main model findings. Notably, business sophistication (BS) continues to exert a strong and positive impact on ESG at a 1% significance level, mirroring the outcomes of the main 2SLS, system GMM, and fixed-effect models. Tax revenue (TR) positively influences ESG at a 1% and 5% significance level, aligning with the main 2SLS, system GMM, and fixed-effect model's results. Additionally, commercial banking finance (CBF) emerges as a robust variable, significantly impacting ESG, paralleling the impact of microfinance institutions (MFI) in the primary 2SLS model. This underscores the

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Table 6. Results of business sophistication, tax revenue effect on ESG sustainability: 2SLS and robust system GMM

	(1)	(2)	(3)	(4)
	2SLS main model	2SLS alternate variables robust model	Sys-GMM robustness check	Robust fixed effect
Dependent variables	ESG index	ESG index	ESG index	ESG index
ESG (Lag)			0.402***	
			(0.026)	
Business sophistication (BS)	0.084***	0.076***	0.083***	0.062***
	(0.019)	(0.019)	(0.009)	(0.008)
Tax revenue to GDP (TR)	0.974***	0.914**	0.434***	0.271***
	(0.376)	(0.368)	(0.165)	(0.095)
Microfinance institutes financing (MIF)	0.071***		0.040***	0.067**
	(0.015)		(0.012)	(0.033)
Commercial banks financing (CBF)-robust		0.047***		
		(0.010)		
ICT index (ICT)		0.166**		
		(0.078)		
Covid-19	−0.545***	−0.484***	−0.592***	−0.483***
	(0.083)	(0.091)	(0.038)	(0.050)
Constant	−2.632***	−2.469***	−2.380***	−1.921***
	(0.478)	(0.495)	(0.258)	(0.260)
Year effect	Yes	Yes	Yes	
Observations	932	932	829	
Sargan	0.0207	0.134	256.75	
Sargan *p*-value	0.886	0.714	0.345	
Underidentification test (Anderson canon. corr. LM statistic)	10.288	10.110		
χ^2 (2) *p*-value	0.0058	0.0064		
Weak identification test (Cragg–Donald Wald *F* statistic)	13.43	13.43		
Stock–Yogo weak ID test critical values: 10% maximal IV size	Pass	Pass		
Endogeneity test of endogenous regressors	88.907	58.357		
χ^2 (2) *p*-value	0.0000	0.0000	0.0000	
Prob > *F*	0.0000	0.0000	0.0000	0.0000
AR-1 (*p*-value)				
AR-1 (*p*-value)			−3.849 (0.1354)	
Difference-in-Hansen tests of exogeneity of instrument subsets: GMM instruments for levels difference (null *H* = exogenous)			5.99 (0.200)	
Instruments			27	
R^2	0.636			0.3867
Sigma_u				0.6099
Sigma_e				0.6875
rho				0.4404
Groups	105	105	105	105

Note: Standard errors in parentheses ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.
Note: Instrumented: BS, TR; included instruments: ICT, MIF Covid; excluded instruments: tax burden, inflation and financial globalization.

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pivotal role of commercial banking financing in promoting ESG principles and fostering ethical and sustainable corporate behavior, much like microfinance institutions. The dummy variable for COVID-19 indicates a significantly negative impact on ESG, aligning with the results of the primary model. Furthermore, robust ICT in column (2) positively affects ESG, exhibiting a 5% significance level, consistent with the primary 2SLS model. This positive influence underscores the role of technology-driven solutions in addressing social and environmental challenges, contributing to good governance, and supporting ethical and sustainable corporate practices. The instruments employed in the equation – tax burden, inflation, and financial globalization – contribute to the reliability of the results. Notably, the diagnostic test results mirror those of the primary 2SLS model, affirming the robustness and validity of the primary model results through alternate variables 2SLS, system GMM, and fixed-effect methods.

3.4 Moderating and interaction term effect of ICT among business sophistication, tax revenue effect, and ESG sustainability: 2SLS and system GMM

Table 7 delineates the 2SLS and two-step system GMM results, shedding light on the moderating influence of ICT between independent variables and dependent variables. The first two columns (1 and 2) show the 2SLS models in which the independent variable business sophistication (BS) manifests a positive and significant impact on ESG, with significance levels of 5 and 1%, respectively. Moreover, another independent variable, tax revenue, exhibits a positive impact on ESG at a 5% significance level in column (1) but becomes insignificant in column (2). This implies that heightened tax revenue corresponds to advancements in ESG performance. This suggests that entities subject to higher taxation are more inclined to invest in social responsibility, environmental sustainability, and sound governance.

Notably, the moderating variable ICT exerts a positive and significant impact on ESG in column (1) at a 5% significance level and in column (2) at a 1% significance level. Meanwhile, the first interaction term, BS×ICT, demonstrates a robust positive impact on ESG at a 1% significance level in column (1). Before the introduction of the interaction term in column (1), BS was positive at a 5% significance level, and ICT was positive at a 1% significance level. However, their interaction yields a markedly positive impact on ESG, with a 91.3% change at a 1% significance level. This outcome underscores the importance of synergizing cutting-edge technology with astute management techniques to achieve enhanced ESG performance. Particularly significant for the institutions and nations dedicated to addressing ESG challenges and delivering value to investors and society, the result underscores the advantages of blending technological innovation with corporate acumen to propel ethical behavior and sustainability.

In column (2), the second interaction term, TR×ICT, exhibits a significantly positive impact on ESG at a 5% significance level. Prior to the introduction of the TR×ICT interaction term in column (2), TR was positively insignificant, and ICT was significantly positive at a 5% significance level. The interaction between TR and ICT enhances their combined influence on ESG, indicating a 78.4% chance that leveraging ICT capabilities strategically to boost tax revenues positively impacts ESG. These findings underscore the critical role of tax-funded financial resources in advancing sustainability and ethical behavior. Moreover, this suggests that technology optimizes the utilization of these resources, thereby enhancing accountability and transparency in ESG-related initiatives. The results imply that effective fiscal management, coupled with cutting-edge technological capabilities, can fuel positive ESG outcomes.

Furthermore, MIF demonstrates a significantly positive influence on ESG at a 5% significance level in column (1) and a 1% significance level in column (2). Hence, findings underline the considerable impact of microfinance institutions on promoting sustainable and ethical business practices and endorse the findings of Saleh et al. (2022) that institutions financing with shareholding investors as owners play a crucial developmental role. Additionally, COVID-19 significantly negatively impacts ESG at a 1% significance level in both columns (1 and 2) models. Therefore, the adverse effect of the COVID-19 pandemic on ESG underscores the challenges posed to sustainable development by global crises, emphasizing the need for resilient strategies in the face of external shocks.

The diagnostic tests in columns (1 and 2) of Table 7 confirm the results' reliability, validity, and inference. The R^2 values of 0.648 and 0.592 in both columns demonstrate that the selected independent and moderating variables possess a reasonably robust variance as the models' fitness. The Sargen test p-values are 0.2154 and 0.1657, respectively, suggesting that over-identifying limitations are invalid, affirming the reliability of the model's instrumentation. Furthermore, the under-identification test (Anderson canon. corr. LM statistics) values χ^2 p-values are less than 5%. This implies that there are ample data from the selected instruments to accurately estimate the parameters. Additionally, the endogeneity test of endogenous regressors yields values indicating an absence of endogeneity problems, which means there is no endogeneity problem in the models. The diagnostic tests collectively underscore the reliability and validity of the results presented in Table 7.

Table 7 also presents the results of the robustness model using the two-step system Generalized Method of Moments (Sys-GMM-Robust). Columns (3 and 4) showcase the results of the 2SLS robustness check with a two-step system GMM. The findings underscore the dynamic nature of ESG, as indicated by the lag coefficient value at a 1% significance level. This emphasizes the persistence and temporal dependencies within the ESG framework. This highlights the persistence and time-dependent characteristics of ESG, suggesting that past values influence its current state. The findings of the system GMM underscore the robustness of the indirect moderating channel's main model results. In both robustness check columns, BS and tax revenue confirm similar findings regarding the impact of ESG aligning with the primary model's results. Tax revenue (TR) has a positively insignificant impact on ESG, as shown in column (3), suggesting that the relationship between tax revenue and ESG is less clear or less pronounced in this specific interaction. While this finding differs from some previous models, it underscores the nuanced nature of the relationship between tax revenue and ESG and the importance of considering contextual factors. This robustness across different model specifications reinforces the conclusion that business sophistication is crucial in positively contributing to ESG outcomes. Moreover, increased tax revenue may have a detrimental impact on sustainable and ethical business practices.

Moreover, the ICT demonstration confirms a positive and significant impact on ESG in columns (3 and 4), mirroring the primary model's results for the indirect channel. The interaction term BS×ICT manifests a robust, significantly positive impact on the ESG level in column (3), consistent with the primary

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Table 7. Results of moderating and interaction term effect: 2SLS-IV and robust system GMM

	(1)	(2)	(3)	(4)
	2SLS main model		Sys-GMM robust model	
Dependent variables: ESG	BS×ICT	TR×ICT	BS×ICT	TR×ICT
ESG (Lag)			0.876***	0.836***
			0.232	0.225
Business sophistication (BS)	0.324**	0.296***	0.297***	0.306***
	0.148	0.104	0.109	0.098
Tax revenue to GDP (TR)	0.657*	0.274	0.698**	0.286
	0.389	0.215	0.316	0.235
ICT index (ICT)	0.529***	0.416**	0.494***	0.442***
	0.104	0.198	0.114	0.141
BS×ICT	0.913***		0.954***	
	0.263		0.259	
TR×ICT		0.784**		0.823***
		0.318		0.271
Microfinance institutes financing (MIF)	0.213**	0.147*	0.245*	0.165**
	0.091	0.078	0.126	0.079
Covid-19	−0.588***	−0.428**	−0.541**	−0.501**
	(0.226)	0.197	0.246	0.196
Constant	−0.984**	0.765**	−0.974***	0.862***
	0.317	0.306	0.334	0.310
Year effect	Yes	Yes	Yes	Yes
Observations	932	932	828	828
R^2	0.648	0.592		
Sargan	5.657	3.5443	4.5487	3.4897
Sargan *p*-value	0.2154	0.1657	0.2034	0.1264
Underidentification test (Anderson canon. corr. LM statistic)	26.457	9.546		
χ^2 (2) *p*-value	0.000	0.007		
Weak identification test (Cragg–Donald Wald *F* statistic)	9.545	12.7654		
Stock–Yogo weak ID test critical values: 10% maximal IV size	Pass	Pass		
Endogeneity test of endogenous regressors	17.765	32.43		60.018
χ^2 (2) *p*-value	0.0019	0.0000		
Wald χ^2	174.68	198.645	54,332	316.16
Prob > χ^2	0.0000	0.0000	0.0000	0.0000
Durbin (score) χ^2 (*p*-value)	70.371 (0.000)	60.757 (0.000)	61.3606 (0.000)	53.297 (0.000)
Wu–Hausman *F* (3,1323)	19.876 (0.000)	23.546 (0.000)	21.288 (0.000)	18.373 (0.000)
AR-1 (*p*-value)			−6.543 (0.0000)	−5.765 (0.0000)
AR-2 (*p*-value)			−5.672 (0.342)	−4.7694 (0.298)
Instruments			31	32
Hansen (*p*-value)			22.532	21.743
Hansen *p*-value difference-in-difference			24.654	23.152
Groups	105	105	105	105

Note: Standard errors in parentheses ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

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model. Before the interaction of BS×ICT in column (3), BS was positively significant, and ICT was positively substantial. The interaction's strong, significantly positive effect on ESG underscores the importance of combining business sophistication and information communication technology to enhance ESG outcomes. The consistency of these results with the primary models highlights the reliability and robustness of the findings. Column (4) of Table 7 reveals that the interaction term TR×ICT demonstrates a significantly positive impact on ESG, akin to the primary model's findings for the indirect channel. This emphasizes how strategic utilization of ICT capabilities to bolster tax revenues can positively impact ESG outcomes. This consistency in results underscores the importance of technological advancements in promoting ESG principles. Findings confirm that microfinance is vital in advancing ESG principles, akin to the primary model's results for the indirect channel. This finding emphasizes the significant role that microfinance institutions play in fostering sustainable and ethical business practices, particularly in the realms of ESG, such as environment, social responsibility, and governance. Additionally, COVID-19 confirms a significantly negative impact on ESG. These results align with the primary model's outcomes for the indirect moderating channels, indicating that the COVID-19 pandemic has adversely affected ESG performance.

The diagnostic tests of system GMM in columns (3 and 4), including the lag structure, further support the reliability and validity of the results. The diagnostic test results in columns (3 and 4) are consistent across investigative tests which further reinforces the reliability and validity of the indirect channel's main model results. All diagnostic tests presented in Table 7 affirm the adherence of the estimated model to the prerequisites for dependable inference. The p-value for AR2 substantiates the appropriateness of the two-step Sys-GMM approach, while the p-value for AR1 signals an absence of autocorrelation within the residuals. Post-tests further corroborate the instrument's integrity, with Hansen and Sargan tests fortifying its reliability. F-statistics and Wald-χ^2 metrics illuminate the model's fitness. The collective diagnostic outcomes in Table 7 underscore the assurance of accuracy and dependability in estimating. These diagnostic tests show confidence in the robustness of the 2SLS main and robust models, along with the Sys-GMM robust results.

4. Discussion based on hypothesis findings

The application of 2SLS, the two-step system GMM, and robust fixed-effect methods using comprehensive panel data analysis for 105 BRI countries spanning from 2013 to 2021 represent a sophisticated and robust methodology. This approach is instrumental in revealing relationships, mitigating endogeneity concerns, capturing dynamic effects, and accommodating the multifaceted factors involved. As a result, it significantly enhances our comprehension of the ramifications of the BRI on a global scale. The consistent validation of results across all robust check models further bolsters the reliability and credibility of the findings obtained from the 2SLS and system GMM direct and indirect moderating models.

The outcomes of all models unequivocally establish the substantial impact of business sophistication on ESG. Consequently, the alternate hypothesis H_1 is accepted, as business sophistication is statistically significant and positively influences ESG (sustainability). The findings align with the conclusions drawn by Dicuonzo et al. (2022) and Lim (2024), asserting that enhanced business sophistication enhances a corporate and national institution's capacity to engage with and address the concerns of stakeholders, ultimately leading to improved national ESG outcomes and practices. The study's second alternate hypothesis, H2 outcomes, reveals a noteworthy impact of tax revenue on ESG, substantiating the hypothesis that tax revenue positively endorses ESG sustainability. The findings endorse the Chouaibi et al.'s (2022a, 2022b) theme that underlines the potential for taxation policies not only to generate revenue for governments but also to play a positive role in fostering conscious corporate business practices and social responsibility and increase the collection of tax revenue and practices adoption in emerging markets. Furthermore, the findings of business sophistication and tax revenue hypothesis imply that the robust dynamic nature of ESG sustainability performance necessitates a holistic approach encompassing well-defined policies, the effectiveness of knowledge workers, innovation linkages, knowledge absorption, management practices, employee involvement, transparent stakeholder communication, and a genuine dedication to sustainability and ethical conduct. The findings endorse the stakeholder theory, and theoretical contributions are noteworthy, reflecting the understanding that businesses operate within an intricate network of stakeholders, such as knowledge and innovative employees, customers, and investors, helping to increase the tax revenue to build the broader society seeking knowledge and ESG sustainability.

Moreover, from the agency theory perspective, business sophistication serves as a mechanism aligning the interests of diverse knowledge stakeholders, including managers and shareholders, with the overarching aim of enhancing ESG sustainability. It can be explored as an instrumental tool for mitigating agency problems and fostering sustainable practices. Additionally, through business sophistication in pursuit of ESG sustainability, the resource-based view (RBV) is aligned with the collection of taxes, and this study's findings suggest that the corporate world and institutions can gain sustainable competitive advantages by leveraging unique and valuable resources. This RBV supports the notion that businesses and national institutions, by enhancing sophistication in knowledge workers, innovative linkages at the corporate level, and knowledge absorption in areas, align with ESG principles based on the business environment, social impact, and corporate governance practices in the BRI region. The BRI can enhance and foster greater sustainability, contributing substantively to the overarching goals of an ambitious regional development strategy. The validated hypothesis underlines the critical importance of championing sophisticated concepts such as knowledge and innovative business practices as a catalyst for advancing ESG sustainability within the Belt and Road framework.

Moving forward, the third alternate hypothesis, H3, asserting that ICT significantly and positively impacts ESG (sustainability), is validated as we found a significantly positive influence of ICT on ESG. Additionally, the examination of the interaction term BS×ICT reveals a significant and positive effect on ESG, leading to the acceptance of alternate hypothesis H_{3a}, emphasizing the moderating role of ICT as significantly enhancing the relationship between business sophistication and ESG (sustainability). Moreover, our findings also support alternate hypothesis H_{3b}, highlighting that ICT significantly moderates the relationship between tax revenue and ESG (sustainability). This suggests that the impact of tax revenue on ESG is positively influenced by the moderating role of ICT, contradicting conventional beliefs. The traditional understanding posits that higher tax revenue may adversely affect ESG due to potential resource misallocation or regulatory constraints on businesses. However, our results

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suggest that effective leveraging of tax revenue through ICT moderation can promote ESG sustainability. Specifically, ICT-targeted taxes can incentivize businesses to reduce their carbon footprint, adopt eco-friendly practices, and invest in sustainable technologies, aligning with business environment and business sustainability principles. This shift in behavior, driven by the interplay of taxation policies and ICT, contributes significantly to the broader goal of ESG sustainability. Our findings are aligned with ICT diffusion theory by supporting the developmental process, as proposed by Belhadi et al. (2023) and Gurbanov et al. (2022) by suggesting that ICT emerges as a pivotal enabler, facilitating corporate and national businesses in collecting, managing, and reporting ESG data effectively. This enhances transparency and automates sustainable practices, and furthermore endorses that ICT practices facilitate communication and collaboration, empowering businesses to engage with stakeholders and optimize their ESG initiatives.

The results of our study affirm hypothesis H_4, establishing that control variable microfinance institutions exert a significant and positive effect on ESG (sustainability). Therefore, this study accepts the alternate hypothesis H_4 by suggesting the pivotal role played by microfinance institutions in fostering business environment, social, and governance practices within the context of the BRI partner countries from 2013 to 2021. Hence, findings endorse that the positive impact observed aligns with the practical understanding that microfinance loans promote financial inclusion, and entrepreneurship has the potential to empower communities to adopt environmentally and socially responsible practices. In the realm of BRI projects, affiliated banks providing financing assistance can play a crucial role in fostering new business development. This aligns with recommendations from (Choudhury, 2021; Christawan et al., 2023; Pingchao, 2023), emphasizing that BRI project financing partnerships hold the potential to stimulate regional innovation and enhance the overall sustainability of ESG practices in BRI partner nations. Our findings reveal a significant negative impact of the COVID-19 before and after period dummy variable on ESG (sustainability), leading us to accept hypothesis H_5 that COVID-19 depicts a meaningful and adverse effect on ESG sustainability on a global and BRI partner countries scale. Hence, outcomes confirm the dynamic nature of ESG's greater implications for audit and accountability and endorse the findings (Saleh & Mansour, 2024). This study also endorses integrated reporting as recommended by Bhatia and Thawani (2024) by endorsing and using ESG practices as integrated reporting practices best align with the practical reality and past literature where the pandemic has disrupted supply chains, affected labor practices, and introduced economic uncertainties, thereby exerting a detrimental influence on ESG sustainability. This empirical finding suggests the pivotal role of external shocks and crises in shaping sustainability outcomes, emphasizing the critical need for adaptability and resilience of business sophistication, tax policies, and ICT innovation to effectively navigate unforeseen challenges.

5. Conclusion and policy implications

This study aims to investigate the business sophistication and tax revenue role in shaping ESG concerning the moderating role of ICT in BRI countries with a particular focus on the pre- and post-COVID periods. The dependent variable, ESG, is gauged through the ESG index, encompassing Environmental, Social, and Governance Indicators. The independent variables are business sophistication and tax revenue, while the moderating role of the ICT index is considered. Additionally, control variables such as microfinance institutions financing, robust through commercial banks financing, and a dummy variable for COVID-19 are incorporated. The latter assumes a value of zero for the years preceding the onset of COVID-19 (2013–2018) and one for the years since its initiation (2019–2021). This comprehensive framework allows for a nuanced examination of the multifaceted dynamics between these key variables in the context of the 105 BRI countries from 2013 to 2021.

The study employed the 2SLS and subsequently robust checked with alternate variables, two-step system GMM, and fixed-effect method. The findings reveal compelling insights into the relationships among key variables. Business sophistication and ESG exhibit a positive and statistically significant association. Conversely, tax revenue demonstrates mixed outcomes as significantly positive in the direct channel and, however, positively insignificant with an interaction term. ICT emerge as a significantly positive influence on ESG. The interaction term BS×ICT displays a significantly positive impact on ESG, emphasizing the importance of the joint impact of business sophistication and ICT in enhancing sustainability. Similarly, the interaction term TR×ICT exhibits a notably positive influence on ESG, suggesting the moderating role of ICT in the relationship between tax revenue and sustainability. Microfinance institutions (MFI) wield a substantial positive impact on ESG. Moreover, the inclusion of commercial banking finance (CBF) as a robust variable showcases its significant positive contribution to ESG. The dummy variable representing COVID-19 portrays a negative impact on ESG, illustrating the adverse effects of the pandemic on sustainability during the specified period. This comprehensive analysis provides valuable insights into the nuanced dynamics within the context of the BRI countries.

The outcomes suggest a positive trajectory in the ESG sustainable performance and business sophistication of BRI countries. The study suggests that corporate and national institutions with more focus on knowledge workers, innovation linkage, and knowledge absorption link with the successful implementation of better management and efficiency in the business environment, social responsibility, and corporate governance (ESG) policies. The alignment of business sophistication pillars such as knowledge worker, innovation linkage, and knowledge absorption with tax collection policies and ICT practices with ESG principles not only enhances sustainability but also fosters ethical business practices, ultimately bolstering competitiveness and reputation of global initiatives like Belt and Road. Furthermore, the findings indicate a positive association between tax revenue and ESG performance in BRI countries. Higher taxation, imposed by government policy-making institutes, correlates with increased support for environmental sustainability, social responsibility, and effective governance (ESG) to boost national sustainability through tax revenue generation. This national-level corporate commitment contributes to enhanced ESG outcomes, portraying taxation as a potential driver for positive social and business environment impacts on business sustainability.

The ICT access and use practices significantly positively contribute to ESG. Technological solutions are showcased as effective tools in addressing businesses' social and environmental challenges, as well as promoting good corporate governance at the national level. The interaction between ICT and business sophistication is identified as a significant contributor to ESG, emphasizing the synergy between technological innovation and strategic management for improved business sustainability

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outcomes. Moreover, the study highlights the positive impact of the interaction between ICT and tax revenue on ESG. This can play a pivotal role of technology in maximizing the use of corporate tax-funded resources, improving accountability, and enhancing transparency in ESG-related initiatives at the national, regional, and global levels in BRI partner countries. Additionally, the study advocates for an innovation culture and the promotion of innovative thinking in business. This emphasis on fostering a culture of innovation aligns with the evolving landscape of ESG practices, where innovative solutions play a crucial role in addressing emerging challenges and driving sustainability. The call for innovation underscores the dynamic nature of ESG considerations and the need for adaptive and forward-thinking approaches in BRI countries' business practices. Overall, the findings highlight the importance of information technological innovation, use, access, and strategic management practices in advancing ESG performance within the context of BRI countries.

Microfinance institutions emerge as key contributors to sustainable and ethical business practices in BRI countries, suggesting a pivotal role in achieving ESG goals, particularly in the realms of social responsibility and corporate governance. Microfinance loans' positive influence on ESG outcomes aligns with their emphasis on responsible financial practices and ethical corporate behavior in entrepreneurial development in BRI partner countries. Similarly, the study highlights the instrumental role of commercial banking financing in advancing ESG principles within BRI countries. Substantial financial influence wielded by these institutions is recognized for its markedly beneficial effects on society's national development. This emphasizes the significant impact financial institutions can have on promoting responsible business practices and fostering positive ESG outcomes.

The study further observes a temporary decline in ESG sustainability following the disruption caused by the COVID-19 pandemic. The upheaval affected tax collection and business practices, which hurt financial stability, governance procedures, and social and environmental activities. However, it anticipates a revival of ESG activities post-COVID-19, signaling a potential resurgence in momentum. The findings contribute to the resilience of ESG initiatives and the capacity for recovery after external shocks. The findings suggest the pivotal role of business sophistication, tax income, ICT moderation, microfinance institutions, and commercial banking funding in fostering ESG performance within BRI countries. The findings emphasize the multifaceted nature of factors influencing ESG outcomes in the BRI region, providing valuable insights for firms, financial institutions, and policymakers seeking to enhance the sustainability and ethical dimensions of business activities such as knowledge workers, innovation linkage, and knowledge absorption.

Moreover, the study endorses cultivating an innovative culture at the corporate and national level in global projects like BRI countries' partnerships as a crucial element in advancing ESG objectives. The emphasis on innovation aligns with the dynamic and evolving nature of sustainability practices, highlighting the need for adaptive and forward-thinking approaches. The call for an innovative culture underscores the role of creativity and ingenuity in addressing emerging challenges and driving positive ESG outcomes within the BRI framework.

Overall, this study's findings carry significant implications for national and corporate stakeholders, including businesses, financial entities, and policymakers, aiming to elevate the standards of sustainability and ethics across business activities in the global BRI region. This study was limited to 105 Belt and Road region countries as business sophistication data were obtained from the GII, which comprised 132 countries in total since 2013, and our sample regional BRI also started in 2013. Overall, 148 countries partner with BRI; however, due to data availability and participation in GII reports, the best available dataset is for 105 countries. The multifaceted approach presented in the study highlights the interconnectedness of various factors and the need for a comprehensive strategy to drive positive ESG performance in the evolving landscape of BRI countries. Therefore, future studies can explore the topic in more depth with other regions and at the income group level. The literature on business sophistication is limited; therefore, future studies should focus on the control and treatment group study using digital innovation as a shock to better depict the policy implications for a sustainable future.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used Grammarly Software (https://app.grammarly.com/) to avoid errors in the English language. After using this tool/service, the author(s) reviewed and edited the content as needed and took full responsibility for the publication's content.

Availability of data and material

The data are available upon request.

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Code availability. Codes and search queries are available upon request.

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Appendix A: List of BRI sample countries

Sr.	Country	Sr.	Country
1	Albania	54	Malta
2	Algeria	55	Mauritania
3	Angola	56	Malaysia
4	Argentina	57	Morocco
5	Armenia	58	Moldova
6	Austria	59	Montenegro
7	Azerbaijan	60	Mongolia
8	Bangladesh	61	Mozambique
9	Bahrain	62	Namibia
10	Belarus	63	New Zealand
11	Benin	64	Nepal
12	Bosnia and Herzegovina	65	Niger
13	Botswana	66	Nigeria
14	Bolivia	67	Nicaragua
15	Brunei Darussalam	68	Oman
16	Bulgaria	69	Pakistan
17	Burundi	70	Panama
18	Cabo Verde	71	Papua New Guinea
19	Cameroon	72	Peru
20	Chile	73	Philippines
21	China	74	Poland
22	Cambodia	75	Portugal
23	Cote d'Ivoire	76	Qatar
24	Cook Islands	77	Romania
25	Costa Rica	78	Russian Federation
26	Croatia	79	Rwanda
27	Cyprus	80	Saudi Arabia
28	Czech Republic	81	El Salvador
29	Dominican Republic	82	Senegal
30	Ecuador	83	Seychelles
31	Egypt, Arab Rep.	84	Singapore
32	Estonia	85	Slovak / Slovakia Republic
33	Ethiopia	86	Slovenia
34	Ghana	87	Sri Lanka
35	Georgia	88	Somalia
36	Greece	89	Serbia
37	Hungary	90	South Africa
38	Indonesia	91	Tajikistan
39	Iran, Islamic Rep.	92	Tanzania
40	Italy	93	Thailand
41	Jamaica	94	Togo
42	Kazakhstan	95	Trinidad and Tobago
43	Kenya	96	Tunisia
44	Korea, Rep.	97	Turkey
45	Kuwait	98	Uganda
46	Kyrgyz Republic	99	Ukraine
47	Lao PDR	100	United Arab Emirates
48	Latvia	101	Uruguay
49	Lebanon	102	Uzbekistan
50	Lithuania	103	Vietnam
51	Luxembourg	104	Zambia
52	Madagascar	105	Zimbabwe
53	North Macedonia		

(*Continued*)

Appendix A: (*Continued.*)

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