

Enhancing sovereign ESG in South Asia: the roles of digital penetration, globalization and natural resource dependency

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Abstract

Purpose – This study examines how natural resource dependency, digital penetration, and globalization relate to sovereign environmental, social and governance (ESG) performance – a proxy for national sustainability – across South Asian economies. It also considers the roles of urbanization and industrialization in shaping long- and short-term sustainability outcomes. The research aims to clarify how these structural and technological factors jointly influence national sustainability trajectories.

Design/methodology/approach – Using panel data from eight South Asian countries over 2000–2021, the study employs the panel mean group autoregressive distributed lag model to assess dynamic long- and short-run relationships. Robustness is verified with dynamic ordinary least squares and fully modified ordinary least squares estimations. Key variables include sovereign ESG performance, natural resource dependency, digital penetration, globalization, urbanization, and industrialization, capturing the economic, environmental and technological dimensions of sustainability.

Findings – The results show that natural resource dependency significantly undermines sovereign ESG performance, confirming the sustainability-based resource curse hypothesis. Industrialization and urbanization also exert negative effects, reflecting structural and environmental pressures. In contrast, digital penetration and globalization exhibit positive associations with ESG outcomes, consistent with their roles in enhancing governance transparency, institutional capacity and access to information.

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Originality/value – This study provides one of the first integrated analyses of digital penetration and natural resource dependency within a sovereign ESG framework for South Asia. It highlights how broader digital connectivity and global integration are associated with improved sustainability outcomes in resource-dependent economies. The findings offer evidence-based insights for policymakers seeking to strengthen institutional quality, diversify growth and promote sustainable development.

Keywords Sovereign ESG, Digital penetration, Natural resource dependency, PMG-ARDL, South Asia

Paper type Research article

1. Introduction

South Asia stands at a critical juncture in its development trajectory, marked by rapid economic growth, evolving social structures, and intensifying environmental pressures (Asadullah *et al.*, 2020). While natural resources have long underpinned economic progress, the region's continued reliance on resource-based growth has exposed it to numerous challenges, including economic volatility, environmental degradation, and widening social inequalities. These vulnerabilities increasingly constrain South Asia's potential to achieve the Sustainable Development Goals (SDGs) and long-term resilience (Ko and Lee, 2025; Pandey and Asif, 2022). Consequently, the region must transition toward a more diversified, sustainable, and knowledge-driven growth model capable of balancing environmental stewardship with economic development.

Amid this transition, digital penetration has emerged as a transformative force reshaping the region's economic and institutional landscapes. The rapid expansion of internet connectivity, mobile technologies, and data-driven tools is fostering transparency, efficiency, and inclusive participation in public policy and governance (Matthess and Kunkel, 2020). By enabling better resource management, promoting technology-driven innovation, and creating more knowledge-based industries, digital penetration has the potential to support sustainable development (Olawade *et al.*, 2024). Its capacity to enhance governance accountability and data transparency also suggests a promising pathway for strengthening the institutional foundations of sustainability.

However, natural resource dependence remains a persistent barrier to sustainable development. Economically, heavy reliance on extractive sectors exposes countries to fluctuations in global commodity prices, amplifying fiscal volatility and inhibiting structural diversification. Socially, the distribution of resource rents often favors elites, entrenching inequality and marginalizing vulnerable communities. Environmentally, resource extraction accelerates deforestation, biodiversity loss, and greenhouse gas emissions (Carrington *et al.*, 2023; Destek *et al.*, 2022). Moreover, weak institutions and rent-seeking behavior frequently undermine policy coherence and governance effectiveness (Waaje *et al.*, 2025). Together, these factors reinforce the so-called "resource curse," whereby short-term gains from resource wealth impede long-term sustainable progress. Recognizing these interrelated challenges underscores the importance of investigating how digital penetration and globalization relate to sustainability outcomes in resource-dependent economies.

The sovereign ESG (Environmental, Social, and Governance) framework developed by Jiang *et al.* (2022) and refined by Jiang *et al.* (2024) offers a valuable lens for evaluating sustainability at the national level. By integrating environmental stewardship, social well-being, and governance quality, the framework captures the multifaceted nature of sustainable development. This comprehensive approach is particularly relevant for South Asian economies, where digital connectivity, governance capacity, and environmental management converge to shape sustainability outcomes (Ma *et al.*, 2025). Examining sovereign ESG performance thus allows for a more nuanced understanding of how institutional, technological, and environmental factors interact to influence long-term national resilience.

Against this backdrop, this study investigates how digital penetration, globalization, and natural resource dependency relate to sovereign ESG performance across eight South Asian

economies—Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka—over the period 2000 to 2021. By integrating the sovereign ESG framework and applying the Panel Mean Group Autoregressive Distributed Lag (PMG-ARDL) method, the study assesses both long-run and short-run dynamics. This dual perspective is crucial for capturing how immediate policy changes interact with structural shifts in resource use and technological adoption over time.

Building on these foundations, the study makes three key contributions. First, it provides one of the earliest empirical examinations of digital penetration, globalization, and natural resource dependency within a national-level ESG framework, thereby integrating multiple dimensions of sustainability. Second, it extends ESG analysis beyond the firm level by adopting a sovereign perspective that captures countrywide environmental, social, and governance outcomes. Third, by focusing on South Asia—a region underrepresented in the sustainability literature—it offers new evidence from an emerging yet highly vulnerable economic context. Together, these contributions enhance understanding of how digital penetration and globalization are each associated with improved sustainability outcomes in resource-dependent economies.

The remainder of the paper is structured as follows. [Section 2](#) reviews the theoretical and empirical literature on digital penetration, natural resource dependency, and sovereign ESG performance. [Section 3](#) outlines the data sources, variable definitions, and econometric methodology. [Section 4](#) presents and discusses the empirical results, while [Section 5](#) concludes with key policy implications and directions for future research.

2. Literature review

2.1 Theoretical overview

The Resource Curse Theory, proposed by [Sachs and Warner \(2001\)](#), posits that nations endowed with abundant natural resources often experience slower economic growth, weaker institutions, and higher levels of environmental degradation than their resource-poor counterparts. This paradox arises because resource rents can create economic distortions, weaken incentives for diversification, and reduce institutional accountability. In the South Asian context, such vulnerabilities are clearly evident, as economies remain structurally dependent on extractive sectors that generate limited innovation and constrain productivity growth. These dynamics intensify when economic activity is overly concentrated and governance is fragile, consistent with the theory's prediction that institutional inefficiency and rent-seeking behavior limit long-term sustainability ([Corden and Neary, 1982](#); [Ross, 2015](#)).

While Resource Curse Theory highlights the risks of dependence, Institutional Theory ([North, 1990](#)) provides a complementary lens for explaining how sound institutional design can transform resource wealth into sustainable development. According to this perspective, the quality of institutions—reflected in transparency, the rule of law, and policy coherence—determines whether natural resources become a source of prosperity or stagnation. Well-functioning institutions help diversify economies, enforce environmental regulations, and channel resource rents toward productive and equitable outcomes. Where governance structures are strong, the negative mechanisms described by the resource curse can therefore be reduced or avoided. Within this institutional logic, digital penetration emerges as a modern pathway for institutional strengthening. As a transformative global megatrend, it promotes transparency, accountability, and administrative efficiency—prerequisites for long-term sustainability ([Goldfarb and Tucker, 2019](#)). By expanding access to information and communication technologies (ICTs), governments can reduce informational asymmetries, enhance regulatory oversight, and improve citizen participation in decision-making ([Li et al., 2026](#)). Through data-driven governance and real-time monitoring, digital penetration aligns with Institutional Theory's view that technological modernization can reinforce institutional adaptability, particularly in resource-dependent economies seeking to enhance structural efficiency.

To evaluate these relationships systematically, the Environmental, Social, and Governance (ESG) framework offers a comprehensive mechanism for assessing sustainability performance at the national level. Originally applied to corporate contexts (Friede *et al.*, 2015), ESG principles have evolved into a sovereign-level analytical tool that captures how environmental stewardship, social equity, and governance quality jointly contribute to sustainable progress. The sovereign ESG index developed by Jiang *et al.* (2022, 2024) extends this logic by providing a multidimensional measure consistent with the notion of “strong sustainability,” which prioritizes ecological integrity and institutional effectiveness over purely economic gains. Within this framework, Institutional Theory forms the conceptual foundation: sustainable outcomes depend on the strength of formal rules, governance systems, and public accountability mechanisms that guide environmental and social management.

Nevertheless, digital penetration presents both opportunities and challenges for institutional and ecological transformation. It offers tools that enhance efficiency, innovation, and environmental awareness, but it may also exacerbate inequality, increase energy consumption, or widen digital divides if governance capacity is weak (Hilty and Aebischer, 2015; Norris, 2001). These trade-offs are particularly pronounced in South Asia, where rapid industrialization and urban expansion simultaneously strain natural systems and institutional capacities. Balancing economic modernization with environmental protection and technological inclusion therefore remains a central challenge for the region (Dodman *et al.*, 2012; Grossman and Krueger, 1995; Işık *et al.*, 2025a). Taken together, this theoretical synthesis suggests that while Resource Curse Theory underscores the pitfalls of resource dependence, Institutional Theory and digital penetration together identify potential pathways for strengthening institutional capacity and governance in resource-dependent economies. Collectively, they provide the conceptual foundation for understanding how expanding digital connectivity relates to improvements in sovereign ESG performance in resource-reliant contexts.

2.2 The effect of digital penetration on sustainable development

Digital penetration advances sustainable development primarily by strengthening institutional quality. Through improved transparency, data accessibility, and policy coordination, it enhances governance efficiency and accountability—mechanisms emphasized in Institutional Theory as fundamental to long-term development. In South Asia, where administrative inefficiency and regulatory fragmentation often undermine sustainability, wider digital connectivity improves oversight, reduces information asymmetry, and enables more coherent policy implementation. Empirical evidence supports these institutional dynamics. Mondejar *et al.* (2021) and Gupta and Rhyner (2022) show that the integration of digital systems in energy, agriculture, and resource management improves efficiency and resilience through better coordination rather than through technology alone. Lei *et al.* (2024) find that digital penetration increases green total factor productivity by promoting innovation and structural upgrading—key institutional improvements that facilitate sustainable growth. Ionescu Feleagă *et al.* (2023) demonstrate that countries with stronger digital connectivity perform better on the SDGs due to enhanced policy coherence and administrative capacity.

However, weak institutional settings can limit these benefits and generate adverse effects such as inequality, electronic waste, and high energy consumption (Roshid *et al.*, 2025; Varriale *et al.*, 2024). This underscores that the effectiveness of digital penetration depends on governance capacity—the central proposition of Institutional Theory. In resource-reliant economies, digital systems such as fiscal transparency platforms and permit-tracking databases improve accountability and help prevent rent mismanagement (Corden and Neary, 1982; Ross, 2015). Across South Asia, initiatives in digital governance and public administration have begun to enhance sustainability performance by embedding accountability within institutional processes. Digital penetration therefore promotes sustainable development not merely as a technological innovation but as an institutional

reform that strengthens governance, transparency, and policy integration across environmental, social, and economic domains (Roshid *et al.*, 2025).

H1. Digital penetration is positively associated with national ESG performance.

2.3 The effect of natural resource dependency on sustainable development

Natural resource dependency influences sustainable development through economic, institutional, and environmental channels. According to Resource Curse Theory, resource rents often undermine diversification and foster rent-seeking behavior, thereby weakening institutional quality and long-term governance capacity (Sachs and Warner, 2001). Within the framework of Institutional Theory, these outcomes occur because dependence on easily extractable wealth reduces incentives for institutional modernization, transparency, and policy coherence—conditions essential for achieving balanced sustainability. In South Asia, where fiscal institutions and administrative oversight remain fragile, these dynamics manifest in the form of fiscal volatility, corruption, and environmental degradation that constrain sovereign ESG performance. Resource booms, typically associated with the “Dutch Disease,” shift labor and capital toward extractive industries, crowding out manufacturing and innovation (Corden and Neary, 1982; Chen and Lee, 2023). This structural distortion perpetuates low productivity and suppresses technological adaptation—outcomes consistent with Institutional Theory’s proposition that weak institutional incentives impede dynamic learning and industrial upgrading. Asiamah *et al.* (2022) and Qamruzzaman (2025) show that the resulting concentration of rents creates governance asymmetries, enabling elites to capture resource revenues while weakening mechanisms of accountability. The erosion of institutional checks and balances, in turn, diminishes the state’s ability to manage social equity and environmental protection effectively.

The environmental consequences of resource dependency further reinforce institutional fragility. Destek *et al.* (2022) demonstrate that unsupervised extraction intensifies deforestation, pollution, and carbon emissions, thereby undermining the environmental pillar of the ESG framework. Weak environmental governance exacerbates these externalities, confirming Institutional Theory’s proposition that institutional performance determines how economies handle ecological stress. Empirical evidence across regions supports these systemic relationships: Erdogan *et al.* (2021) find that resource abundance heightens ecological pressure in resource-based economies; Zhang *et al.* (2025) show that higher resource rents expand the ecological footprint in emerging economies; and Ding (2023) identifies the “financial resource curse,” whereby rent dependence hinders financial development through poor regulatory quality. Collectively, these outcomes illustrate that the sustainability deficits linked to natural resource dependency are institutional in nature rather than purely economic. For South Asian economies, the persistence of resource-rent dependence exemplifies how weak institutions amplify vulnerability to global price shocks, environmental degradation, and governance inefficiency. Strengthening governance structures—through policy coordination and digital transparency mechanisms—remains essential for addressing the institutional failures driving the regional resource curse.

H2. Natural resource dependency is negatively associated with sustainable development performance.

2.4 Research on sovereign ESG index

Derived from its origins in ethical and responsible investment, the ESG concept represents an expansion of corporate social responsibility (CSR) practices and now serves as a foundational framework for promoting the sustainable growth of businesses (Wan *et al.*, 2023). Consequently, recent years have witnessed a proliferation of firm-level studies examining ESG performance (Alsayegh *et al.*, 2020; Gillan *et al.*, 2021). Despite ESG’s origins in the

business sector, there is mounting interest in applying its principles at the national level to assess how effectively governments promote sustainable development (Singhania and Saini, 2023). This shift has amplified attention to national ESG as an increasingly prominent topic among governments, the private sector, and academia (Mushafiq, 2023).

The World Bank (2025) developed a national ESG framework that identified indicators suitable for constructing a national-level ESG index. Building on this foundation, Jiang *et al.* (2022) employed an entropy-weight method based on the World Bank's sovereign ESG framework to develop a sovereign ESG index, which was later updated by Jiang *et al.* (2024) to cover 121 countries worldwide from 1990 to 2021. This advancement has spurred research on sovereign ESG performance (Ko *et al.*, 2025; Leung *et al.*, 2025; Niu, 2024).

A substantial body of literature has since explored the political and economic determinants of sovereign ESG performance, focusing on factors such as democracy (Leung and Ko, 2025), international sanctions (Liu *et al.*, 2024a, b), fiscal policy (Niu, 2024), economic shocks (Gazi *et al.*, 2024), and innovation (Long *et al.*, 2023). However, relatively limited attention has been paid to the role of digital penetration, particularly when examined alongside natural resource dependency. Most existing studies emphasize structural dimensions such as governance quality, economic stability, and institutional capacity, often overlooking how national-level digital connectivity might influence outcomes associated with resource reliance and ESG performance. Zheng *et al.* (2024a, b), however, demonstrate that ICT development enhances sovereign ESG performance by fostering green innovation and strengthening human capital. Overall, the literature underscores that diverse political, economic, and institutional factors shape a country's environmental, social, and governance outcomes. Yet, there is growing recognition that emerging drivers—particularly digital penetration—may play a pivotal role when considered together with traditional structural determinants and contextual factors such as natural resource dependency.

2.5 Literature gap, research objectives, and research contribution

First, much of the existing literature examines digital penetration and the resource curse in isolation, analyzing their independent effects on national development (e.g. Lei *et al.*, 2024; Sachs and Warner, 2001; Ross, 2015). However, the interconnections between these two factors remain underexplored. This study brings them together within a unified framework to investigate their combined relevance for national sustainability, thereby offering a deeper understanding of how technological and structural dimensions jointly relate to development outcomes. Unlike prior research that treats them separately, this study emphasizes their concurrent influence on national sustainability performance (e.g. Asiamah *et al.*, 2022; Zhang *et al.*, 2025).

Second, existing research tends to focus narrowly on specific components of sustainability—most often environmental sustainability—while paying relatively little attention to broader social and governance dimensions (e.g. Destek *et al.*, 2022; Erdoğan *et al.*, 2021). By employing the sovereign ESG (Environmental, Social, and Governance) framework, this study adopts a multidimensional lens that simultaneously captures environmental, socioeconomic, and governance dynamics (Jiang *et al.*, 2022, 2024). This broader approach enables a more holistic assessment of how digital penetration and resource dependency jointly relate to sustainability outcomes, thereby addressing gaps in earlier research that focused on single dimensions in isolation. Third, much of the existing empirical evidence on digital penetration and sustainability centers on advanced economies, particularly OECD and G7 countries (e.g. Gillan *et al.*, 2021; Alsayegh *et al.*, 2020), while regions such as South Asia remain understudied. South Asia is especially significant given its rapid economic growth, high dependence on natural resources, and expanding digital infrastructure—conditions that make it an essential context for evaluating how digital access aligns with sustainable development (e.g. Roshid *et al.*, 2025).

In addressing these gaps, this study makes three main contributions. First, it examines digital penetration and the resource curse within a unified empirical framework. Second, it investigates sustainability through a comprehensive sovereign ESG approach that encompasses environmental, social, and governance dimensions. Third, it focuses on the underexplored South Asian context, providing region-specific insights. Using the ARDL approach and panel data from eight South Asian countries (2000–2021), the research offers empirical evidence on the associations among digital penetration, resource dependency, and sovereign ESG performance. The findings yield valuable implications for policymakers seeking to leverage digital access to promote sustainable, inclusive, and resilient development across the region.

3. Materials and methods

3.1 Data and variables

The primary variable employed in this study is the sovereign ESG (Table 1) index developed and updated by Jiang *et al.* (2024), which provides a comprehensive measure of sustainability performance across 121 countries over a thirty-year period. This dataset—accessible through the Pacific Rim Sustainable Development Association (PRSDA) at <https://prsdaframer.website/dataset/data/esg-aggregates>—multiple sustainability indicators to enable systematic cross-country and longitudinal evaluations of sovereign ESG performance. Originally introduced by Jiang *et al.* (2022) and refined by Jiang *et al.* (2024) based on the World Bank (2025) Sovereign ESG Framework, the sovereign ESG index integrates the environmental, social, and governance dimensions of sustainability within a unified methodological design. It differs from corporate-level ESG approaches by assessing state-level performance and reflecting national policy effectiveness, institutional quality, and long-term development outcomes. The index provides consistent coverage from 1990 to 2021 and applies an entropy-based weighting method that assigns greater importance to more informative indicators, thereby enhancing objectivity and comparability across countries and over time.

The sovereign ESG index comprises three major pillars: environmental, social, and governance. The environmental pillar, accounting for approximately 42% of the total index, evaluates carbon emissions, renewable energy utilization, resource management, and biodiversity protection. The social pillar, contributing about 30%, captures social well-being through indicators such as education, healthcare, labor rights, and income equity. The governance pillar, representing roughly 27% of the composite score, measures political stability, transparency, accountability, and institutional effectiveness. For full details of the indicators and the construction of the variable, please refer to Jiang *et al.* (2024). All indicators are normalized to ensure comparability and are combined through entropy-derived weights. This methodological structure ensures that countries exhibiting greater cross-sectional variation in particular dimensions exert a stronger influence on the composite score, thereby better reflecting the heterogeneity of sustainability performance across nations. The dataset addresses missing values using interpolation techniques to maintain temporal consistency and comparability. By harmonizing data sources and measurement standards over three decades, the sovereign ESG index offers a coherent, transparent, and robust foundation for analyzing regional sustainability trajectories and institutional dynamics in comparative perspective.

The key independent variables include natural resource dependency (NRS), digital penetration (DGN), globalization (GOB), urbanization (URB), and industrialization (INDS). Natural resource dependency, measured as total natural resource rents (% of GDP), captures the extent to which a country's economy relies on extractive sectors and serves as a central indicator for assessing vulnerability to the resource curse mechanism. Digital penetration, represented by the percentage of individuals using the internet, reflects the diffusion of digital access and technological connectivity within an economy—an important factor enhancing governance capacity, transparency, and social inclusion. Globalization, derived from the KOF

Table 1. Data and variables

Variables	Code (log form)	Definition and details	Unit of measurement	Data source
ESG (Environmental, social, and governance)	LESG	Sovereign ESG Index (LESG) – a composite national-level measure integrating environmental, social, and governance pillars. It aggregates standardized indicators—such as carbon emissions, renewable energy use, education, health, and institutional quality—into a single entropy-weighted score capturing overall sustainability performance	Index score (0–1, entropy weighted); a higher score indicates a higher level of sustainable development, while a lower score indicates weaker ESG performance	Jiang et al. (2024)
NRS (Natural resource dependency)	LNRS	Total natural resource rents as a percentage of GDP, capturing the degree to which a country’s economy relies on extractive industries such as oil, gas, coal, and minerals. This measure reflects the scale of resource-based income generation relative to total output and is used as a proxy for exposure to the resource-curse mechanism	% of GDP	WDI (2024)
GOB (Globalization)	LGOB	The overall KOF Globalization Index encompassing economic, social, and political integration. It reflects the extent of a country’s global interconnectedness through trade openness, cross-border investment, information flows, and participation in international institutions. Higher globalization levels generally indicate greater exposure to international norms, technology transfer, and institutional learning that can influence national sustainability outcomes	Index score (0–100); a higher score indicates greater global integration, while a lower score represents weaker international connectedness	KOF Globalization Index (2024)
DGN (Digital penetration)	LDGN	Number of individuals using the internet as a percentage of total population. It measures digital access and technological diffusion within the economy, indicating the extent of connectivity and potential for digital transformation	% of population	ITU (2024)
URB (Urbanization)	LURBA	Urban population as a percentage of total population, representing the scale of demographic transition toward urban centers. It captures the spatial, infrastructural, and environmental dimensions of urban growth and modernization	% of population	WDI (2024)
INDS (Industrialization)	LINDS	Industry (including construction) value added as a percentage of GDP. It reflects the level of structural transformation and productive capacity within the economy while highlighting potential sustainability trade-offs linked to emissions and resource use	% of GDP	WDI (2024)

Globalization Index, reflects the degree of economic, social, and political integration with the global system, thereby facilitating technology transfer, institutional learning, and the diffusion of sustainable policy frameworks. Urbanization, measured as the share of the population residing in urban areas, captures the scale of demographic transition, infrastructure pressures, and environmental challenges associated with urban expansion. Finally, industrialization, defined as the share of industry (including construction) in total value added, represents structural economic transformation that can strengthen productive capacity but may also introduce sustainability trade-offs through increased resource consumption and emissions.

3.2 Theoretical framework and model specification

The study examines the Resource Curse Hypothesis to explore why countries in South Asia that depend on natural resources may exhibit poor sovereign ESG performance. Several studies support the resource curse hypothesis (Asif *et al.*, 2020; Khan *et al.*, 2020). The underlying premise of the resource curse hypothesis is that abundant natural resources may hinder economic growth in resource-rich countries (Pan *et al.*, 2021). Beck *et al.* (2008) suggest that the abundance of resources in the mining and energy sectors discourages investment in the financial sector, thereby weakening it overall. Moreover, because of the large stock of natural assets, these resources are often underutilized, creating instability and leading to economic weaknesses generally referred to as the resource curse. However, some resource-rich countries have successfully managed to transform resource wealth into sustainable outcomes through stronger institutions and technological progress (Sharma and Paramati, 2022; Wang *et al.*, 2021). The following provides the structured empirical foundation for analyzing the associations between digital penetration, globalization, and sovereign ESG performance while considering the roles of natural resource dependency, urbanization, and industrialization.

$$ESG = f(NRS, GOB, DGN, URB, INDS) \quad (1)$$

In this context, sovereign ESG refers to Environmental, Social, and Governance performance; NRS denotes natural resource reliance; GOB represents globalization; DGN stands for digital penetration; URB refers to urbanization; and INDS indicates industrialization. Globalization can enhance social and governance standards by introducing international norms and accountability mechanisms; however, it may not adequately safeguard the environment without strong regulatory frameworks. In addition, technological advancement can promote positive institutional change by increasing government transparency, expanding service accessibility, and supporting environmental monitoring and control efforts (Işık *et al.*, 2025b). Digital penetration can also be positively associated with sovereign ESG performance (Chen *et al.*, 2024), reflecting how improved connectivity and digital access contribute to better social inclusion, transparency, and environmental management. Similarly, urbanization can strengthen social support systems and governance structures, although poor urban planning can exacerbate environmental degradation (Kapoor *et al.*, 2025). Industrial development, for instance, can stimulate economic expansion and benefit communities through job creation and improved infrastructure; however, without effective regulation, it can increase pollution and energy consumption. Together, these factors are modeled as parallel determinants of sovereign ESG performance rather than interactive mechanisms.

$$LESG = \beta_0 + \beta_1 LNRS + \beta_2 LGOB + \beta_3 LDGN + \beta_4 LURB + \beta_5 LINDS + \varepsilon_i \quad (2)$$

Here, the intercept is denoted by β_0 , and β_1 to β_5 represent the coefficients of the explanatory variables. Equation (2) expresses the variables in logarithmic form rather than in their conventional levels. The use of logarithms is common in econometric analysis because it helps linearize nonlinear relationships, making them easier to interpret and estimate (Al Balushi and

[Yusoff, 2025](#)). The model thus estimates how each variable is statistically associated with sovereign ESG performance, without implying causal or moderating effects. For South Asian nations, greater digital penetration, globalization, and urbanization may be associated with improved institutional capacity and sustainable development outcomes. Understanding this theoretical framework can assist policymakers in strengthening these parallel linkages and ensuring that natural wealth supports sovereign ESG-aligned pathways.

3.3 Empirical strategy

According to the analysis of panel data and longitudinal relationships, South Asian countries may face several econometric challenges, including mixed-order stationarity, slope heterogeneity, and cross-sectional dependence (CSD). Given the high degree of economic interconnection among these nations, the study first applies the CSD test, followed by a cointegration test for longitudinal analysis. Most South Asian economies are developing, although their growth rates vary considerably. The next step involves examining slope homogeneity. The combined modeling process includes testing for cross-sectional dependence and slope homogeneity, as well as performing second-generation stationarity and cointegration tests. Considering the presence of CSD, heterogeneity, and non-stationarity, the cointegration tests proposed by [Westerlund \(2007\)](#) are employed.

After completing these diagnostic assessments, the study evaluates whether the PMG-ARDL approach effectively captures the long-run relationships among the variables. The model estimates the long-run and short-run associations between sovereign ESG performance, digital penetration, globalization, and natural resource dependency, rather than interactive or moderating effects. The results are further validated using DOLS and FMOLS estimations, which confirm the robustness of the main findings. This multi-step methodological framework ensures that both dynamic interactions and long-term equilibrium associations among sovereign ESG, digital penetration, and natural resource dependency are rigorously examined, thereby aligning the empirical strategy with the study's objective of capturing short- and long-run sustainability dynamics across heterogeneous South Asian economies. As illustrated in [Figure 1](#), the study follows a structured estimation process that begins with variable selection, proceeds through model diagnostics and estimation, and concludes with robustness assessments and policy implications.

3.3.1 Cross-sectional dependence test. To evaluate whether similar entities, such as nations and firms, are interrelated, panel data analyses often rely on Pesaran's CSD test. Given the potential for biased results and misleading conclusions, awareness of this dependence is essential. Multiple factors contribute to the presence of cross-sectional dependence (CSD), including unobserved common factors, economic and geographical integration, implicit fluctuations, and spillover effects ([Raihan et al., 2024](#)). To address this issue, the study follows the recommendation of [Pesaran \(2004\)](#) and applies a CSD assessment. The test performs effectively regardless of whether the number of cross-sections (M) exceeds the time dimension (T) or vice versa. The test statistic for Pesaran's CSD test is expressed by the following formula:

$$CSD = \sqrt{\frac{2}{M(M-1)}} \left(\sum_{i=1}^{M-1} \sum_{k=i+1}^M \sqrt{T_{ij}} \hat{\omega}_{ik} \right) \quad (3)$$

In this model, the sample is represented by M, and time by T. Moreover, $\hat{\omega}_{ik}$ signifies the estimated pairwise correlation between residuals of nations i and k based on the sample. Testing cross-sectional dependence at the outset allows the model to account for regional interconnectedness, improving the reliability of the results.

3.3.2 Slope homogeneity test. A panel data analysis is incomplete without testing for slope homogeneity, which ensures that the relationships between the independent and dependent

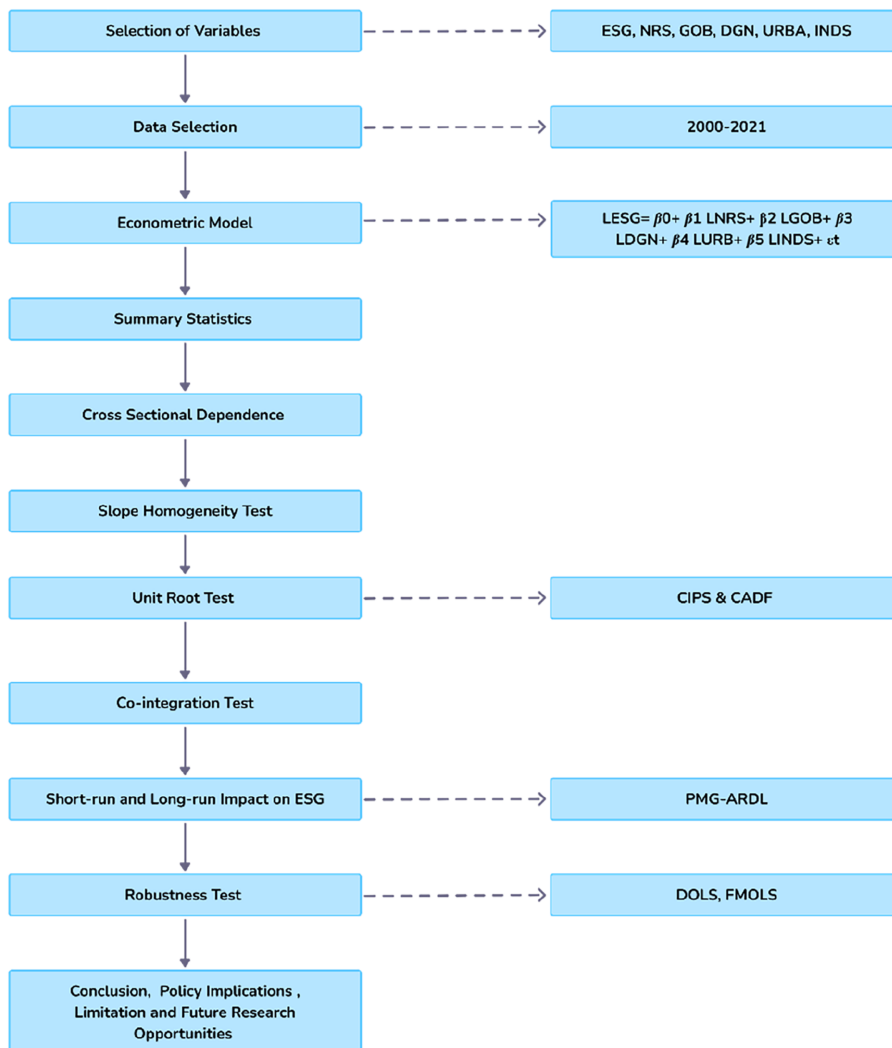


Figure 1. The flow of the estimation approach

variables are consistent across sample units. The assumption of homogeneity is satisfied if the coefficients remain uniform for each cross-sectional unit; otherwise, the coefficients are heterogeneous. Evaluating slope homogeneity is crucial because certain estimation procedures—such as unit root, cointegration, and long-run estimations—may yield inaccurate results in the presence of slope heterogeneity (Ahmad *et al.*, 2024). To address this concern, the study employs the slope-homogeneity test. The DELTA statistics form the basis of this test and can be represented by Equations (4) and (5). This step ensures that national differences in structural and institutional contexts are appropriately captured, which is vital for modeling the heterogeneous nature of South Asian economies.

$$\Delta = \sqrt{M \left(\frac{M^{-1} S\% - P}{\sqrt{2P}} \right)} \quad (4)$$

$$\Delta_{adj} = \sqrt{M \left(\frac{M^{-1} S\% - P}{\sqrt{\frac{2P(t-p-1)}{T+1}}} \right)} \quad (5)$$

3.3.3 Panel unit root test. Due to the presence of cross-sectional dependence (CSD) in the data, the study refrains from employing first-generation unit root tests, as they could lead to incorrect inferences. Instead, advanced second-generation unit root techniques are applied to detect stationarity. Among these, the CIPS and CADF tests provide consistent results even under CSD (Zheng *et al.*, 2024b). To compute the CIPS statistic, the cross-sectional average of the CADF statistic is used, as proposed by Pesaran (2021). Unlike conventional tests, these methods account for cross-sectional dependence by averaging each indicator's lag and first-difference estimates across nations (Iqbal *et al.*, 2024). Confirming the order of integration validates the use of the PMG-ARDL model, which is designed for panel datasets containing a combination of I(0) and I(1) series.

$$\Delta y_{it} = \alpha_i + \delta_i y_{it-1} + \rho_i \bar{y}_{t-1} + \sum_{k=1}^q \partial \Delta y_t + \varepsilon_{it} \quad (6)$$

Where, $\bar{y}_{t-1}$ and Δy_t are average for lagged and first difference of each cross-sectional series.

$$CIPS = \frac{1}{N} \sum_{i=1}^N t_i \quad (7)$$

3.3.4 Panel cointegration test. The Westerlund (2007) panel cointegration test is employed to determine whether a long-run equilibrium association exists among sovereign ESG, natural resource dependency, and digital penetration. Unlike conventional tests, this approach accounts for both cross-sectional dependence and heterogeneity, offering robustness for practical economic analysis. Based on structural dynamics and error-correction modeling, the test provides four statistics (Gt, Ga, Pt, and Pa) to evaluate whether cointegration holds for some or all cross-sections.

$$G_a = \frac{1}{N} \sum_{i=1}^N \frac{\alpha'}{SE(\alpha_i)} \quad (8)$$

$$G_t = \frac{1}{N} \sum_{i=1}^N \frac{T\alpha_i}{\alpha_i(1)} \quad (9)$$

$$P_t = \frac{\alpha'}{SE(\alpha)} \quad (10)$$

$$P_a = T\alpha \quad (11)$$

In this context, Gt and Ga represent group statistics, while Pt and Pa represent panel statistics. Evidence of cointegration implies that stable long-run associations exist among the variables rather than short-term fluctuations.

3.3.5 PMG-ARDL model. By integrating cross-sectional dependence (CSD) and accommodating mixed integration orders, this study applies the second-generation Pooled Mean Group–Autoregressive Distributed Lag (PMG-ARDL) technique to explore the long-run panel cointegration associations among the selected variables. This technique is robust, effectively addressing key econometric challenges such as endogeneity, serial correlation, and heterogeneity (Ansari *et al.*, 2023).

The PMG-ARDL estimator allows short-run parameters to vary across countries while maintaining a common long-run relationship, ensuring both flexibility and efficiency. It is particularly suitable for examining long-run associations instead of causal mechanisms, as the current model does not include interaction terms between variables. The long-run parameters are evaluated using the standard t and F tests following Pesaran *et al.* (1999).

$$\Delta Y_{l,it} = \alpha_{li} + \beta_{li} Y_{l,it-1} + \sum_{l=2}^q \beta_{li} X_{l,it-1} + \sum_{n=1}^{k-1} \gamma_{lij} \Delta Y_{l,it-n} + \sum_{n=0}^{j-1} \sum_{l=2}^k \gamma_{lij} \Delta X_{l,it-n} + \varepsilon_{li,t} \quad (12)$$

Here, Y_l refers to the dependent variable and X_l are independent variables where $l = 1, 2, 3, 4$. ε_{it} and Δ are residual and first difference operators, respectively. We obtain the following long-term ARDL model for sovereign ESG as the dependent variable:

$$\begin{aligned} \Delta LESG_{it} = & \alpha_{1i} + \beta_{1i} LESG_{i,t-1} + \beta_{2i} LNRS_{i,t-1} + \beta_{3i} LGOB_{i,t-1} + \beta_{4i} LDGN_{i,t-1} \\ & + \beta_{5i} LURBA_{i,t-1} + \beta_{6i} LINDS_{i,t-1} + \sum_{n=1}^k \gamma_{1i} \Delta LESG_{i,t-n} + \sum_{i=0}^j \gamma_{2i} \Delta LNRS_{i,t-n} \\ & + \sum_{i=0}^j \gamma_{3i} \Delta LGOB_{i,t-n} + \sum_{i=0}^j \gamma_{4i} \Delta LDGN_{i,t-n} + \sum_{i=0}^j \gamma_{5i} \Delta LURBA_{i,t-n} \\ & + \sum_{i=0}^j \gamma_{6i} \Delta LINDS_{i,t-n} + \varepsilon_{1i,t} \end{aligned} \quad (13)$$

Where, μ_i , i and t represent fixed effect, countries, and time, respectively. Furthermore, the following is the short-run relationship that takes error correction models into account:

$$\begin{aligned} \Delta LESG_{it} = & \sum_{n=1}^{k-1} \theta_{1in} \Delta LESG_{i,t-n} + \sum_{i=0}^{j-1} \alpha_{2in} \Delta LNRS_{i,t-n} + \sum_{i=0}^{j-1} \alpha_{3in} \Delta LGOB_{i,t-n} \\ & + \sum_{i=0}^{j-1} \alpha_{4in} \Delta LDGN_{i,t-n} + \sum_{i=0}^{j-1} \alpha_{5in} \Delta LURBA_{i,t-n} + \sum_{i=0}^{j-1} \alpha_{6in} \Delta LINDS_{i,t-n} \\ & + \mu_{1i} ECT_{1,it-1} + \varepsilon_{1i,t} \end{aligned} \quad (14)$$

3.3.6 Robustness check. Nevertheless, relying on a single type of panel estimator is not advisable, as it may lead to biased or inconsistent results (Dong *et al.*, 2020). Accordingly, this study employs the Fully Modified Ordinary Least Squares (FMOLS) estimator, originally proposed by Phillips and Hansen (1990), and the Dynamic Ordinary Least Squares (DOLS) estimator, introduced by Kao and Chiang (2000), to enhance the robustness of the panel cointegration analysis. Compared with the PMG-ARDL approach, these methods differ in several important respects. The FMOLS technique is a non-parametric estimator capable of addressing endogeneity, serial correlation, and cross-sectional heterogeneity (Pedroni, 2000). It serves to verify the results of the cointegration tests while correcting for potential issues

related to autocorrelation and heteroskedasticity across both time and cross-sectional dimensions. In contrast, the DOLS approach is a parametric estimator that estimates long-run relationships among variables by incorporating first-differenced leads and lags of the regressors (Perone, 2024). A key advantage of the DOLS method is its capacity to integrate variables of differing integration orders within the cointegrated framework (Pesaran, 2007). By incorporating temporal information on each explanatory variable, this estimator effectively mitigates problems of small-sample bias, endogeneity, and autocorrelation (Begum *et al.*, 2020).

Within the scope of this study, the FMOLS and DOLS estimators are used not to identify causality or moderating effects but to verify the stability and strength of the long-run associations observed among sovereign ESG performance, digital penetration, globalization, and natural resource dependency. The estimators provide complementary evidence supporting the PMG-ARDL findings that these variables are statistically associated in the long run, while recognizing that the analysis captures correlation-based relationships rather than interaction or offsetting effects. Thus, the comparison of FMOLS, DOLS, and PMG-ARDL results ensures that the estimated associations are robust, stable, and not sensitive to the choice of estimator.

4. Results and discussion

4.1 Summary statistics and preliminary testing

This summary comprises 176 observations for each variable presented in Table 2. The mean value of LESG is 0.554, while LNRS has a low mean of −0.609. South Asian countries exhibit a relatively high average score of 13.96 for LDGN. Regarding dispersion, LDGN shows the highest standard deviation (3.08), whereas LURBA displays the lowest variability, with a standard deviation of 0.30. Variables such as LNRS, LGOB, LURBA, and LINDS are negatively skewed, while LESG and LDGN are approximately symmetrical. The distribution of LINDS is leptokurtic, with a high kurtosis value of 6.74, indicating the presence of numerous outliers, while the kurtosis values of the other variables are close to those of a mesokurtic distribution. The Jarque–Bera test strongly suggests that LNRS and LINDS deviate from normality, a pattern largely supported by most of the remaining variables. These findings highlight significant structural heterogeneity among South Asian economies, reinforcing the justification for employing a panel estimation framework capable of capturing cross-country differences in institutional and developmental characteristics.

All log-transformed variables exhibit significant cross-sectional dependence, as indicated by *p*-values below 1% in Table 3, thereby leading to rejection of the null hypothesis. This finding suggests that changes occurring in one country can trigger corresponding reactions in other nations within the South Asian region. The identification of such interlinkages implies

Table 2. Summary statistics of the variables

Statistic	LESG	LNRS	LGOB	LDGN	LURBA	LINDS
Mean	−0.554032	−0.608545	3.796046	13.96484	3.306092	4.122442
Median	−0.566074	0.065308	3.849330	14.19786	3.389089	4.436734
Maximum	−0.442003	9.164111	4.137603	20.30002	3.761386	5.147494
Minimum	−0.674791	−5.958430	3.159403	6.200113	2.595031	0.000000
Std. Dev	0.051052	2.025831	0.243750	3.082697	0.299192	1.038244
Skewness	0.109250	−1.329056	−0.720254	−0.203191	−0.525248	−1.832726
Kurtosis	2.487134	3.745495	2.849484	2.349437	2.058915	6.740383
Jarque-Bera	2.279005	55.88969	15.38325	4.314774	14.58733	201.1240
Probability	0.319978	0.000000	0.000457	0.115627	0.000680	0.000000
Observations	176	176	176	176	176	176

Table 3. Results of the cross-sectional dependence test

Variables	CD statistics	p-value
LESG	21.39***	0.000
LNRS	12.80***	0.000
LGOB	21.89***	0.000
LDGN	19.08***	0.000
LURB	21.12***	0.000
LINDS	3.00***	0.002

Note(s): *** $p < 0.01$

that the region comprises highly connected economies, making the application of second-generation panel data methods both appropriate and necessary. This observed interdependence also aligns with the integrated economic and environmental connections documented in regional studies such as [Ko and Lee \(2025\)](#) and [Gazi et al. \(2024\)](#).

Both the Delta and adjusted Delta statistics show p -values of 0.000 in [Table 4](#), confirming significance at the 1% level. Accordingly, rejection of the null hypothesis indicates that the slope coefficients are not constant across all countries. This result underscores variations in structural and institutional dynamics among South Asian economies, thereby reinforcing the heterogeneity assumption underlying the PMG-ARDL approach.

After confirming the presence of cross-sectional dependence and slope heterogeneity, [Table 5](#) applies the CIPS and CADF unit root tests to assess the stationarity properties of the variables. The results show that LNRS, LGOB, and LDGN are stationary at level $I(0)$, while LESG, LURBA, and LINDS become stationary only after first differencing, $I(1)$. Specifically, the CIPS and CADF statistics for LNRS and LGOB are significant at conventional levels even in level form, indicating stationarity, whereas LESG, LURBA, and LINDS are non-stationary at level but achieve stationarity upon first differencing. LDGN shows mixed results under the two tests but is considered stationary at level based on overall evidence.

Table 4. Results of the slope homogeneity test

H0: Slope coefficients are homogeneous	Delta	p-value
Adj	7.122 8.625	0.000 0.000

Table 5. Panel unit root test

Variables	CIPS $I(0)$	$I(1)$	CADF $I(0)$	$I(1)$	Decision
LESG	-1.817	-4.313***	-0.981	-3.982***	$I(1)$
LNRS	-2.254**	-3.634***	-2.761***	-4.981***	$I(0)$
LGOB	-2.831***	-4.510***	-3.091***	-4.091***	$I(0)$
LDGN	-1.769	-3.728***	-0.770	-3.918***	$I(0)$
LURB	-1.518	-4.543***	-1.082	-3.007***	$I(1)$
LINDS	-1.699	-4.434***	-0.981	-5.081***	$I(1)$

Note(s): *** $p < 0.01$, ** $p < 0.05$

This combination of integration orders, with both I(0) and I(1) series, justifies the use of the ARDL framework for model estimation, as it minimizes the risk of spurious regression associated with purely non-stationary data. Moreover, the coexistence of mixed integration levels supports the adoption of the PMG-ARDL specification, consistent with the dynamic panel modeling approach proposed by [Pesaran et al. \(1999\)](#), which is appropriate for analyzing sustainable growth relationships across heterogeneous panels.

[Table 6](#) summarizes the results of the panel cointegration tests. The findings provide strong evidence against the null hypothesis of no cointegration, indicating that LESG, LNRS, LGOB, LDGN, LURBA, and LINDS share a stable long-run equilibrium relationship across South Asian economies. All four statistics (Pt, Pa, Gt, and Ga) are highly significant, with negative values and *p*-values below conventional thresholds, confirming the existence of cointegration among the log-transformed variables. The establishment of cointegration across dimensions such as digital penetration, globalization, urbanization, industrialization, and resource dependency emphasizes a persistent and interdependent linkage with sovereign ESG performance. This long-run equilibrium reinforces the integrated analytical framework grounded in Resource Curse Theory and Institutional Theory, illustrating how technological and institutional dynamics jointly shape sustainable growth outcomes through complementary rather than offsetting mechanisms.

4.2 Long run and short run test

The results presented in [Table 7](#) and illustrated in [Figure 2](#) indicate that both long-run and short-run factors are significantly associated with sovereign ESG performance (LESG) in South Asian countries. The long-run coefficient for LNRS (−0.140, *p* < 0.01) shows a strong negative association between natural resource dependency and national sustainability. A 1% increase in natural resource rents is linked to a 0.14% lower sovereign ESG index, suggesting that economies more reliant on natural resources tend to exhibit weaker environmental, social, and governance performance. This association corresponds with the resource curse hypothesis, which links extractive sector dependence to diminished institutional quality and monitoring capacity ([Auty, 2004](#)). Similar associations have been observed by [Souza Barbosa et al. \(2023\)](#) and [Naomi and Akbar \(2021\)](#), who report that resource reliance correlates with reduced transparency and governance effectiveness in developing economies.

In the short run, the coefficient for D(LNRS) = −0.282 (*p* < 0.10) also indicates a negative association between changes in resource exploitation and ESG outcomes. Immediate shifts in extraction intensity or resource price booms correspond with temporary declines in sustainability performance through fiscal volatility and environmental stress ([Neo et al., 2025](#); [Wu et al., 2024](#)). These patterns reinforce Resource Curse Theory ([Sachs and Warner, 2001](#)), illustrating persistent links between natural resource dependence and reduced sustainability, both over time and across short-term fluctuations.

Globalization exhibits a positive association with sustainability performance. A 1% increase in the globalization index corresponds to a 0.116% increase in sovereign ESG scores (*p* < 0.01). This relationship suggests that greater integration into international systems is

Table 6. Panel cointegration test

Statistic	Value	Z-value	<i>p</i> -value
P _t	−4.870***	−1.092	0.000
P _a	−6.901***	−2.821	0.000
G _t	−2.871**	−2.201	0.048
G _a	−3.091**	−1.982	0.018

Note(s): ****p* < 0.01, ***p* < 0.05

Table 7. PMG-ARDL model

Variable	Coefficient	Std. error	t-statistic	Prob.*
<i>Long run equation</i>				
LNRS	−0.140***	0.0514	−2.7249	0.0074
LGOB	0.116***	0.0362	3.2077	0.0017
LDGN	0.145***	0.0305	4.7612	0.0000
LURBA	−0.033***	0.0138	−2.3863	0.0085
LINDS	−0.098***	0.0444	−2.2093	0.0090
<i>Short run equation</i>				
COINTEQ01	−0.127***	0.0216	−5.8670	0.0000
D(LNRS)	−0.282*	0.1390	−2.0305	0.0606
D(LGOB)	0.033**	0.0154	2.1455	0.0144
D(LDGN)	0.201***	0.0513	3.9169	0.0000
D(LURBA)	−0.177**	0.0836	−2.1177	0.0265
D(LINDS)	−0.014	0.0214	−0.6529	0.5151
Error correction term (ECT)	−0.127***	0.0216	−5.8670	0.0000
Constant	−0.118***	0.0235	−5.0217	0.0000

Note(s): *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

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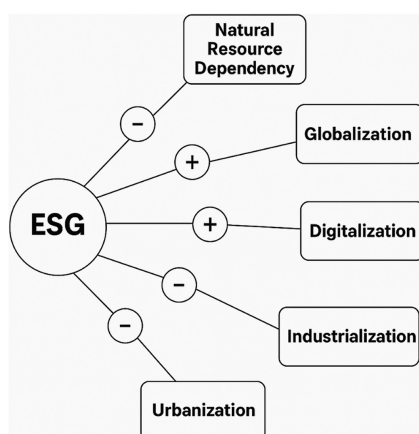


Figure 2. Impact of explanatory variables on ESG performance

linked to higher sustainability standards and stronger institutional practices. Countries that are more globally connected tend to adopt policies consistent with international governance norms and sustainability frameworks (Gazi *et al.*, 2024; Abu Afifa *et al.*, 2025). The short-run association, $D(LGOB) = 0.033$ ($p < 0.05$), further indicates that short-term increases in global participation align with contemporary improvements in ESG performance. According to Işık *et al.* (2024a, b), international exposure and cross-border engagement correlate with greater alignment between domestic and global expectations for environmental and social performance. Within an institutional framework, globalization and governance capacity evolve together rather than countering other structural dependencies.

Digital penetration also shows a significant positive association with sovereign ESG performance in both the long and short run. In the long run, a 1% increase in digital penetration corresponds to a 0.145% improvement in sustainability ($p < 0.01$). The short-run coefficient, $D(LDGN) = 0.201$ ($p < 0.01$), indicates that near-term increases in digital connectivity are

likewise associated with stronger ESG outcomes. These results imply that broader digital access is linked to greater transparency, participation, and information sharing (Leung *et al.*, 2025; Hao *et al.*, 2025). Prior research, including Zheng *et al.* (2024a, b) and Işık *et al.* (2024a, b), shows that digital communication systems correlate with improved governance responsiveness and accountability. Within South Asia, digital penetration is thus positively correlated with sustainability performance but does not necessarily alter or compensate for the structural effects of resource dependency; instead, it operates as an independent pathway of institutional association.

Urbanization is negatively associated with sustainability indicators. The long-run coefficient for LURBA (-0.033 , $p < 0.01$) points to a relationship in which faster urban growth corresponds with weaker sovereign ESG performance. This association aligns with urban-stress perspectives emphasizing governance and infrastructure constraints in rapidly urbanizing regions (Handoyo and Anas, 2024). In the short run, $D(LURBA) = -0.177$ ($p < 0.05$) indicates that short-term increases in urban populations coincide with immediate declines in ESG performance, reflecting pressures on infrastructure and environmental management (Malik and Sharma, 2024). Urbanization and sustainability thus exhibit a continuing negative association rather than reflecting any adjustment or counterbalance to other developmental dynamics (Dodman *et al.*, 2012).

Industrialization also shows a negative long-run association with sustainability performance. The coefficient for LINDS (-0.098 , $p < 0.01$) implies that higher industrial activity is associated with lower ESG scores, consistent with the pollution-haven perspective, which links industrial expansion to increased environmental and institutional stress (Wu *et al.*, 2024; Liu *et al.*, 2024a, b). In the short run, $D(LINDS) = -0.014$ ($p > 0.50$) is not statistically significant, suggesting no immediate association between short-term industrial fluctuations and ESG performance. This aligns with Yang *et al.* (2024), who find that sustainability outcomes relate more to structural industrial composition than to short-term output changes.

Overall, the results indicate that resource dependency, globalization, digital penetration, urbanization, and industrialization each maintain distinct and statistically significant associations with sovereign ESG performance in South Asia. The statistically significant error-correction term (-0.127 , $p < 0.01$) reflects a stable long-run relationship, implying that the variables share a long-term equilibrium pattern rather than demonstrating causal adjustment mechanisms. The findings illustrate enduring and parallel associations among technological, institutional, and structural dimensions of development, persisting alongside continued resource dependency.

4.3 Robustness test

The results from the FMOLS and DOLS estimations presented in Table 8 highlight the associations between key determinants and sovereign ESG performance across South Asia. The negative coefficients for LNRS in both FMOLS (-0.0108) and DOLS (-0.00884) confirm that dependence on natural resources is associated with lower national sustainability performance. This finding indicates that economies relying more heavily on resource-based revenues tend to exhibit weaker institutional and environmental outcomes, reinforcing the interpretation that resource dependence coincides with continued structural and sustainability constraints.

Globalization (LGOB) shows a positive and statistically significant association with sovereign ESG performance, with values of 0.160 in DOLS and 0.0547 in FMOLS. These results suggest that greater openness to global trade, cooperation, and policy exchange corresponds with higher sustainability performance, reflecting the coexistence of stronger institutional practices and exposure to global governance norms.

Digital penetration (DGN) also shows a generally positive association with sovereign ESG performance, with coefficients of 0.0101 ($p < 0.01$) in DOLS and 0.0778 (not significant) in FMOLS. This pattern indicates that higher digital connectivity is linked with better

Table 8. Robustness checkEnvironmental
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Variables	(1) DOLS	(2) FMOLS
LNRS	−0.00884*** (0.00211)	−0.0108*** (0.00132)
LGOB	0.160*** (0.00773)	0.0547*** (0.0130)
DGN	0.0101*** (0.00146)	0.0778 (0.0923)
LURBA	0.0467*** (0.00652)	0.0849*** (0.0136)
LINDS	0.00193 (0.00295)	−0.00188 (0.00115)
Constant	−1.187*** (0.0227)	−1.030*** (0.0246)
Observations	176	176
Number of groups	8	8
R-squared	0.980	0.9172

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

sustainability outcomes on average, although the FMOLS result shows some variability across panels and time. Digital penetration appears to coincide with greater transparency and coordination capacity but should not be interpreted as evidence of offsetting the structural impacts of resource dependency.

Urbanization (LURBA) exhibits a positive association with ESG performance, recording 0.0467 ($p < 0.01$) in DOLS and 0.0849 ($p < 0.01$) in FMOLS. This finding suggests that where urban growth takes place within relatively stable institutional frameworks and infrastructure systems, higher levels of urbanization correspond with improved social and environmental performance. The results remain descriptive and do not imply that urbanization reduces existing sustainability pressures. Industrialization (LINDS) shows statistically insignificant coefficients in both estimators, indicating that industrial expansion during the study period has not been associated with measurable national sustainability improvements. This result is consistent with continuing environmental and governance challenges faced by industrial sectors in the region.

The negative and statistically significant constant terms across both estimators point to structural and institutional limitations that remain linked with lower overall ESG performance. Combined, the FMOLS and DOLS results align with the direction and significance of the PMG-ARDL estimates, indicating consistent long-run associations between the explanatory variables and sovereign ESG performance. Based on Resource Curse Theory (Sachs and Warner, 2001) and Institutional Theory (North, 1990), these findings illustrate parallel associations among resource dependency, globalization, digital penetration, and institutional characteristics, without implying that digital or global integration mitigates the effects of resource dependence.

5. Conclusion

This study examines how sovereign ESG performance—a comprehensive indicator of national sustainability—responds to variations in natural resource dependency, globalization, digital penetration, urbanization, and industrialization across South Asian economies. Using the PMG-ARDL methodology, supplemented by FMOLS and DOLS robustness estimations, the analysis provides strong evidence of both long-run and short-run associations among these variables. The findings show that greater dependence on natural resources is consistently

associated with weaker sovereign ESG performance, indicating that resource-driven growth corresponds with lower environmental sustainability and weaker governance effectiveness. In contrast, globalization and digital penetration display positive and statistically significant associations with sovereign ESG outcomes, suggesting that increased international integration and digital connectivity correspond with stronger performance in the environmental, social, and governance dimensions through enhanced information exchange, policy innovation, and institutional transparency.

Urbanization and industrialization contribute to structural transformation and economic modernization, but their unregulated expansion places considerable pressure on environmental systems and social welfare. Since industrialization exhibits negative long-run associations with national sustainability, a transition toward cleaner, low-carbon, and resource-efficient industrial strategies appears necessary. Taken together, the findings highlight the tension between economic growth and sustainability in developing regions. From a policy perspective, the results underscore the importance of reducing reliance on extractive industries, strengthening digital infrastructure, and integrating sovereign ESG principles into long-term development planning. Balancing digital and global integration with environmental stewardship will be essential if South Asia is to advance toward resilient, inclusive, and sustainable growth.

6. Policy recommendations

Advancing sustainable development in South Asia requires focusing on what is achievable within the fiscal and institutional limits that characterize much of the region. Many South Asian countries struggle with narrow tax bases, high debt burdens, and administrative weaknesses, making it unrealistic to pursue multiple large-scale sustainability initiatives simultaneously. Policy priorities therefore need to be sequenced by cost-effectiveness and institutional readiness. The most immediate and affordable reforms are those that strengthen governance and fiscal accountability, as these underpin all other sustainability measures. Improving transparency in the management of natural resource revenues and expenditure offers particularly strong returns relative to cost. Establishing independent oversight mechanisms, publishing revenue data, and reducing rent-seeking behavior can improve trust and budget stability even without major financial commitments. Redirecting a modest portion of resource rents to renewable energy, rural electrification, and watershed conservation would deliver measurable environmental gains. External concessional finance—such as the Green Climate Fund, the Global Environment Facility, and regional development banks—could be leveraged to cover upfront investments while limiting pressure on domestic budgets.

After basic fiscal and governance reforms are established, expanding digital penetration represents a logical next step. Digital systems can improve tax collection, public procurement, and environmental monitoring while remaining relatively low-cost compared with traditional infrastructure projects. Governments could start with targeted e-governance tools—such as online budget portals, land registries, or emissions reporting platforms—that improve coordination without extensive capital requirements. Gradually, these systems can evolve into integrated national platforms for social services, education, and resource management. The main costs lie not in hardware but in training civil servants and ensuring reliable Internet infrastructure. Shared public–private investment models, donor-supported digital cooperation programs, and mobile-service tax revenues can all contribute to sustainable financing. Yet, trade-offs exist: prioritizing digital reforms may divert funds from physical infrastructure, meaning that governments must carefully balance short-term social needs with longer-term institutional efficiency.

Over the medium term, the most resource-intensive reforms will arise from urbanization and industrialization. Low-income South Asian countries should not attempt wholesale urban transformation but instead prioritize targeted, cost-sensitive measures that amplify existing infrastructure. For instance, enforcing energy-efficiency codes and pollution standards

typically costs less than building new facilities, while gradually expanding public transport through concessional loans can improve mobility without exacerbating inequality. Industrial policy must likewise balance competitiveness with ecological goals—for example, phasing out the most pollution-intensive industries while incentivizing cleaner manufacturing capacity through tax relief and technical assistance. Meanwhile, deeper integration into global trade and environmental regimes can unlock financing and technology transfer opportunities, but each agreement carries compliance obligations that must be weighed against fiscal capacity. Selective participation—in renewable energy trade mechanisms, green supply chains, or carbon-finance partnerships—will offer the greatest payoff without overstretching institutions.

Ultimately, South Asian development strategies must recognize that sustainability is not only an environmental or moral imperative but an economic one shaped by fiscal realism. Immediate gains will come from inexpensive but high-impact governance and digital reforms that improve efficiency and transparency; structural shifts toward low-carbon industry and urban resilience must follow as fiscal capacity grows. Policymakers should treat sustainability finance as a gradual reallocation process, where every expenditure—whether in resource management, infrastructure, or trade—is evaluated for its long-term institutional and environmental return. Such a sequenced approach transforms sustainability from an aspirational agenda into a feasible policy pathway for even the lowest-income countries in the region.

7. Limitations and future research directions

While this study provides empirical insights into the relationships among natural resource dependency, digital penetration, globalization, and sovereign ESG performance in South Asia, several limitations should be acknowledged.

First, the analysis is confined to South Asian economies, which limits the generalizability of the findings. Differences in economic systems, governance quality, and technological capacity across regions suggest that the observed relationships may not hold uniformly in other contexts. Extending similar analyses to regions such as Sub-Saharan Africa or Latin America would help determine whether these dynamics are applicable across a broader set of developing-country settings characterized by different institutional and resource structures.

Second, the study relies on macro-level national data drawn from aggregate sources such as the World Development Indicators (WDI), the KOF Globalization Index, and ITU digital statistics. Although these datasets are comprehensive and internationally harmonized, they obscure subnational variation that could yield additional insights. Differences in regional governance capacity, digital infrastructure, and natural resource management within countries may substantially shape sustainability outcomes but remain unobserved in cross-country analysis. Future research could therefore incorporate subnational or spatial panel data to account for local heterogeneity and provide a more granular understanding of how sustainability dynamics evolve within national boundaries.

Third, although the PMG-ARDL estimator is appropriate for heterogeneous panels with mixed orders of integration, it assumes linear and additive relationships among the variables. The present model does not include interaction terms between natural resource dependency and other variables, such as digital penetration or globalization; therefore, the results capture only independent associations rather than moderating or offsetting effects. Future research could incorporate interaction terms (e.g. $\text{LNRS} \times \text{LDGN}$ and $\text{LNRS} \times \text{LGOB}$) into advanced versions of the model to test whether digital penetration or globalization condition or reduce the magnitude of the resource dependency effect on ESG performance. Including such interaction tests would help determine whether higher levels of digital and global integration can partially diminish the negative influence of extractive dependence on sustainability.

Fourth, digital penetration in this study is measured solely by the number of internet users—an indicator that captures connectivity but not the broader multidimensional attributes

of digital transformation. Internet access alone provides a partial perspective on technology adoption and excludes qualitative aspects such as infrastructure robustness, affordability, digital literacy, e-governance maturity, ICT investment, and regulatory efficiency. Because digital penetration encompasses not only access but also capacity and effective institutional usage, future research should incorporate a composite index reflecting these additional dimensions to better capture its full contribution to sovereign ESG performance.

Fifth, the reliability of data may be affected by political and institutional instability experienced in parts of South Asia during the study period. In Afghanistan, prolonged conflict and the eventual Taliban takeover in 2021 disrupted governance systems, curtailed institutional transparency, and weakened the continuity of national reporting mechanisms. Similarly, Sri Lanka's civil war (2000–2009) and its challenging post-conflict reconstruction phase created periods of significant institutional strain and policy volatility. Although these episodes of instability are not directly captured in our empirical estimation, they may have influenced the consistency and accuracy of economic, social, and governance indicators across the region, potentially introducing measurement errors and temporal biases. Future studies should therefore interpret data from these periods cautiously and, where possible, cross-validate national statistics with alternative international or third-party datasets to enhance reliability.

Finally, sovereign ESG performance captures sustainability primarily through environmental, social, and governance pillars, while the economic dimension is represented only indirectly. Key aspects such as macroeconomic stability, technological readiness, and fiscal resilience are not explicitly modeled despite their central importance for long-term sustainability. Future research could therefore expand the sovereign ESG framework into an enhanced E + ESG (EESG) index—Economics plus Environment, Social, and Governance—as proposed by [Ma et al. \(2025\)](#), integrating economic strength as a distinct but complementary sustainability dimension ([Doodoo et al., 2025](#)). Incorporating variables such as institutional capacity, innovation potential, and climate adaptation readiness would allow for a more multidimensional assessment of national sustainability performance.

Overall, the study provides evidence of consistent, additive, and independent associations among natural resource dependence, globalization, and digital penetration with sovereign ESG performance in South Asia. The framework offered here lays the groundwork for future research that includes interaction terms and nonlinear approaches to more fully test whether and how digital and global integration might moderate the negative sustainability effects of resource dependency.

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