Journal of Social Sciences Research & Policy (JSSRP)

GISSR
Global Institute of Social Sciences Research

The Impact of Blue Economy on Sustainable Industrialization in Saarc Countries

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How to Cite This Article: Mansoor, H., Khan, D. D, Haq, D. I. U & Nawaz, A. (2025). The Impact of Blue Economy on Sustainable Industrialization in Saarc Countries. *Journal of Social Sciences Research & Policy. 3 (04), 01-14.*
DOI: https://doi.org/10.71327/jssrp.34.01.14

ISSN: 3006-6557 (Online)
ISSN: 3006-6549 (Print)

Vol. 3, **No.** 4 (2025)
Pages: 01-14

Key Words:
Blue Economy; Sustainable Industrialization; SAARC; South Asia; Economic Development; Marine Resources

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Abstract: *This study analyzes the impact of Blue Economy on sustainable industrialization among selected SAARC countries. A composite index was constructed for Blue Economy and Sustainable Industrialization. Trade Openness, Governance index and Foreign Direct investment were taken as controlled variables. The study spans over the period 2000 to 2023. Cross-sectional dependence test was used to determine the cross-sectional dependence along with Second-generation CIPS unit root tests and the Westerlund (2007) cointegration test. Subsequently, the CS-ARDL model is employed to estimate both short- and long-run dynamics. Findings suggest that the Blue Economy, trade openness, and governance exert a modest but positive effect on sustainable industrialization in the short run, while their impact becomes significantly stronger in the long run. Foreign Direct Investment shows a weak and negative influence in the short term—possibly due to crowding-out effects—but turns significantly positive over time, indicating delayed spillover benefits such as technology transfer and job creation. The error correction term, confirms nearly 28.5% of deviations is corrected each period. Together, these findings provide robust empirical support for integrating Blue Economy strategies into long-term industrial development planning across South Asia.*

Introduction

The South Asian economies are increasingly recognizing the importance of the Blue Economy as a strategic pillar for sustainable development. South Asia is home to a rich coastal and marine ecosystem, and many SAARC countries—including Bangladesh, India, Sri Lanka, and the Maldives—have begun to incorporate Blue Economy principles into their national development plans. For example, Bangladesh has launched its Blue Economy Cell to coordinate marine-based initiatives, while India's "Sagarmala" project aims to modernize port infrastructure and stimulate coastal industrial clusters. Sri Lanka, similarly, has invested in fisheries and port development to harness marine trade opportunities (Patil et al., 2018). Ecological Modernization Theory posits that environmental protection and economic development are not mutually exclusive; rather, technological innovation and institutional reforms can make industrial activities more sustainable (Mol & Sonnenfeld, 2000).In the SAARC region, Blue Economy initiatives such as cleaner shipping technology, sustainable aquaculture, and eco-tourism exemplify this synergy. EMT thus supports the hypothesis that investment in sustainable marine industries can lead to cleaner, more efficient industrialization pathways.

The concept of the Blue Economy has emerged as a transformative development model aimed at promoting economic growth, environmental sustainability, and social inclusion through the sustainable use of ocean resources. According to the World Bank (2017), the Blue Economy encompasses "the sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystems." It expands upon traditional maritime sectors such as fisheries, tourism, and maritime transport to include emerging areas like offshore renewable energy, aquaculture, and marine biotechnology (UNCTAD, 2021).Sustainable industrialization on the other hand is a model of industrial development that promotes economic growth and employment while minimizing environmental harm. Rooted in Sustainable Development Goal 9 (SDG-9), it emphasizes building resilient infrastructure, fostering innovation, and promoting inclusive and sustainable industrial growth (UNIDO, 2020). Indicators commonly used to measure sustainable industrialization include industrial GDP as a share of total output, employment in industry, and industrial emissions of CO_2 (OECD, 2019). Sustainable industrialization — as emphasized in SDG-9 — is not merely about expanding industrial output but about integrating social inclusiveness, environmental protection, and economic resilience. The Blue Economy aligns with this vision by promoting low-carbon, resource-efficient growth from marine-based sectors like fisheries, aquaculture, and maritime transport.

Pauli (2010) played a pivotal role in conceptualizing the BE as a model that combines innovation, zero waste, and ecosystem balance while creating employment and promoting equity. His version of the BE drew attention to the untapped potential of marine ecosystems to deliver economic value without ecological harm. The transition from the traditional 'ocean economy' to the 'blue economy' thus represents a paradigmatic shift toward more sustainable development models. In the context of developing countries, particularly those with extensive coastlines, the Blue Economy offers significant potential for inclusive and green growth. It provides new sources of employment, enhances trade competitiveness through port connectivity, and supports food security through fisheries and aquaculture. As a result, it has become central to policy discourses in several coastal economies. There is growing recognition that Blue Economy sectors can contribute meaningfully to sustainable industrialization. Establishment of marine protected areas (MPA) helps in the protection of critical blue ecosystem that helps in the carbon sequestration (Leenhardt, 2015). Coastal and marine industries such as shipbuilding, fisheries processing, aquaculture, and offshore energy provide employment, stimulate exports, and promote localized industrial hubs (OECD, 2016). Empirical research on the relationship between the Blue Economy and industrial development remains limited. A few global and regional studies have explored the economic returns of ocean-based sectors but have not linked them explicitly with sustainable industrialization metrics. For instance, Colgan et al. (2017) emphasize the GDP contribution of ocean sectors, while Patil et al. (2018) highlight the potential for Blue Economy-led growth in Bangladesh. In the SAARC region, Blue Economy initiatives such as cleaner shipping technology, sustainable aquaculture, and eco-tourism exemplify this synergy supporting the hypothesis that investment in sustainable marine industries can lead to cleaner, more efficient industrialization pathways. Moreover, environmental protection and economic development are not mutually exclusive; rather, technological innovation and institutional reforms can make industrial activities more sustainable (Mol & Sonnenfeld, 2000, Rasheed et al., 2025). The blue economy has a key role to play in infrastructure development which involves constructing and enhancing facilities related to fisheries, transportation and tourism i.e. fish landing sites, processing plants and transport networks (Lagat & Handa, 2023). According to the UN Chronicle, “Coastal tourism is the largest market segment in the world economy, comprising five percent of the global GDP and six to seven percent of global employment” (Sain, 2015). However, studies rarely use multi-dimensional indices or panel data methods that could provide more nuanced and long-term insights.

In South Asia, there is a critical need to empirically examine how ocean resources and coastal sectors influence industrial transformation. Blue Economy activities are often seen as secondary to land-based industries, despite their potential to drive localized and low-carbon industrial growth. The integration of sustainable marine practices into national industrial strategies remains underdeveloped and underexplored in academic literature. Several notable gaps emerge in the current literature: Lack of regional focus: Most of the existing studies examine the Blue Economy at a national level or in global contexts. Limited econometric analysis: Many works are conceptual or descriptive, with limited use of statistical or panel data techniques to test the relationship between Blue Economy variables and industrial performance. Overlooked sustainability indicators: Industrial sustainability is often measured using single indicators like GDP or employment. A more comprehensive index that includes emissions and ecological dimensions is rarely used. Policy-practice disconnect: While many governments in South Asia emphasize the Blue Economy, there is little empirical evidence guiding how these policies affect industrial outcomes, particularly in terms of sustainability.

This study aims to address these gaps by constructing composite indices for the Blue Economy and Sustainable Industrialization and applying panel regression models to test the impact of Blue Economy on Sustainable Industrialization across SAARC countries. By employing a composite-index-based panel data approach, the study provides insights into how SAARC countries can better align marine-based sectors with their industrialization strategies. By identifying drivers and barriers, this study will provide actionable insights for policymakers, businesses, and regional organizations to harness maritime resources for sustainable growth. It emphasizes aligning economic development with ecological sustainability, addressing the unique challenges faced by ASEAN and SAARC countries. The findings will contribute to the global discourse on sustainable development, offering strategies to build resilient industries and infrastructure while preserving environmental integrity, ensuring equitable growth, and achieving long-term regional and global sustainability goals.

Literature Review

For coastal and developing economies, particularly in the ASEAN and SAARC regions, the interplay between marine-based economic activities, industrial growth, and infrastructure resilience is not just a development opportunity but also a matter of national and regional stability (Voyer et al., 2018; Roy, 2019). ASEAN nations such as Indonesia, Vietnam, and the Philippines rely heavily on fisheries, aquaculture, and maritime transport, while SAARC countries like Bangladesh, Sri Lanka, and the Maldives face a dual challenge of sustaining ocean-based resources and building industries that can withstand economic and environmental shocks (Pauly & Zeller, 2016; OECD, 2019). The Blue Economy has been widely recognized for its potential to foster inclusive and sustainable economic growth by tapping into sectors such as fisheries, shipping, marine biotechnology, and renewable ocean energy (Lee et al., 2020; Silver et al., 2015). Meanwhile, sustainable industrialization — as outlined in Sustainable

Development Goal 9 — emphasizes creating industries that are competitive yet environmentally responsible (UNIDO, 2020, Sajid et al., 2024). Complementing both is the idea of resilient infrastructure, which ensures that physical systems such as ports, energy grids, and transport networks can adapt to environmental stressors, technological disruptions, and socio-economic transitions (Thacker et al., 2019; UNEP, 2021).

Against this backdrop, understanding how these three pillars interact is vital for designing integrated policy frameworks. This literature review begins with a theoretical background to anchor these concepts in economic and sustainability theory, before turning to empirical studies that examine the links between the Blue Economy, industrial development, and infrastructure resilience at regional and national levels. The chapter seeks to clarify whether these linkages are complementary, reinforcing each other to create sustainable growth, or if they present trade-offs that require policy negotiation. Aprizal et.al, (2025) undertook a comprehensive systematic review using the PRISMA methodology, analyzing 57 peer-reviewed articles from Scopus to map the research landscape on sustainable development and the Blue Economy. They found that marine tourism, marine spatial planning, and fisheries management are dominant research themes. However, emerging topics such as the integration of digital technologies, block chain-based traceability in seafood supply chains, and “doughnut economics” (Raworth, 2017) approaches are gaining attention. Doughnut economics reframes development goals by emphasizing social foundations while respecting planetary boundaries, offering a fresh paradigm for balancing marine resource use with environmental thresholds. Their review also highlighted persistent gaps, particularly in ensuring equitable access to blue technologies in developing nations and in evaluating the robustness of marine governance frameworks.

Szirmai (2012) analyzed the industrialization trajectories of developing countries from 1950 to 2005, concluding that manufacturing remains a primary driver of job creation, productivity gains, and GDP growth. Similarly, Haraguchi et. al, (2017) argued that industrial development is not just about output expansion but also about embedding innovation, technology adoption, and sustainable practices within production systems. This aligns with the BE’s potential to integrate environmentally responsible industrial models into long-term growth strategies. Rapid industrialization in China and India has lifted hundreds of millions out of poverty (Chen & Ravallion, 2004), while South Korea and Taiwan achieved similar results through a mix of export-oriented policies, land reforms, and heavy investment in human capital (Amsden, 1989). By contrast, countries such as Mexico and Brazil have experienced growth volatility and deepening inequality due to skill-biased industrialization and uneven reform processes (Ravallion & Datt, 1996; Mansoor et al., 2018). These cases demonstrate that while industrialization can drive economic transformation, the benefits are not automatically distributed—policies must actively promote equity.

Analyses of structural transformations across regions consistently reveal a “hump-shaped” trajectory between industrial production and per capita income—economies initially experience industrial-driven growth, followed by a transition toward service-oriented expansion (Aggarwal, 2021; IMF, 2007). In South and Southeast Asia, this pattern manifests through robust development in labor-intensive manufacturing sectors (textiles, food processing, metals), coupled with emerging high value–added services, substantiating a dynamic dual-sector growth model (Huq & Huq, 2025). Asia’s successful path contrasts sharply with Sub-Saharan Africa, where manufacturing’s share in value added has remained modest (roughly 10%), while Asia has increased its industrial value added to over 23%, contributing significantly to productivity gains and economic growth (Higuchi, 2019; Jha & Afrin, 2021). These regional disparities underline the need for context-specific Blue Economy strategies: ASEAN and SAARC countries could pursue industrially anchored Blue Economy expansion alongside targeted service development, whereas Sub-Saharan Africa requires foundational industrial policy interventions to overcome its structural limitations.

Methodology

This purpose of the study is to find the impact of Blue Economy on Sustainable Industrialization in SAARC region with specific countries namely: Bangladesh, India, Pakistan, and Sri Lanka using panel data covering the period 2000 to 2022, depending on data availability across countries. Data for dependent and independent variables was collected from source like World Bank (2025) and Fraser Institute (2025). The dependent variable, Sustainable Industrialization (SI)**,** and Blue economy (BE), the main key independent variable are measured using a composite index from three indicators i.e. Industrial Value Added, Industrial Employment, CO_2 emission per unit of output and Fisheries and Aquaculture Production, Marine protected area, and value added from agriculture, forestry and fisheries respectively. Both of the indices were formed using principal component analysis (PCA) technique. Along with this variable other control variables i.e. Trade Openness (TRD) taken as percentage after obtaining its value as ratio of the summation of exports and imports and dividing it by the Gross Domestic Product (GDP), Foreign Direct Investment (FDI) taken as % of GDP, Governance Index (GOV) with scale 1 to 10, value close to 1 indicates the weak governance and value close to 10 indicating the effectiveness of government institutional performances, are also taken to avoid the biasedness in analysis. Description of the variables is listed in the Table 1. The functional relationship among the dependent and independent variables can be expressed as under.

$$SI = f(\,BE, TRD, FDI, GOV) \;..... (1)$$

The econometric model that reflects the relationship between dependent and independent variables is as follows.

$$\text{Ln}SI_{it} = \alpha + \beta_1 \ln BE_{it} + \beta_2 \ln TRD_{it} + \beta_3 \ln FDI_{it} + \beta_4 \ln GOV_{it} + \varepsilon_{it} \quad (1)$$

Where SI,BE,TRD,FDI, and GOV are Sustainable Industrialization, Blue Economy, Trade Openness, Foreign Direct Investment and Governance while the term ln is taken for logarithm, i is the respective cross-sectional unit and t is the time effect. Variable description is given in the Table 1.

Table 1. Description of Variables

Variable	Description	Unit	Source
SI	SUSTAINABLE INDUSTRIALIZATION: Computed from the following components: (i) Industrial GDP. (ii) Industrial Employment (iii) CO2 emission	Index (i) percentage of GDP (ii) % of total employment (iii) % of total fuel combustion	World Bank (2025)
BE	Blue Economy: Computed from the following components: (i) Agriculture Forestry and Fisheries. (ii) Marine Protected Areas (iii) Aquaculture Production	Index (i) Value added (%) (ii) % of territorial waters (iii) Metric tons	World Bank (2025)
TRD	Trade Openness Indicator. The sum of exports and imports divided by GDP	Constant US$ 2015	World Bank (2025)
FDI	Foreign Direct Investment	Net inflows (% of GDP)	WDI (2025)
GOV	GOVERNANCE Index	Index Scale (1-10)	Fraser institute (2025)

Since South Asian countries have many ecological, biological, and cultural similarities. Thus, we may possibly have a case of cross-sectional dependence (CSD), and slope heterogeneity (SH). The very first step was to check to check for the presence of (CSD) and (SH). In case these two terminologies exist then the formal panel data unit root tests are no longer applicable as these techniques tests may produce estimates that are biased, incomplete or inaccurate therefore second generation tests, and cointegeration tests are appropriate for this work when the CSD and SH problem is verified. After verifying the SH and CSD problems, the cross-sectional IPS or CIPS (Peasaran, 2007) unit root test was employed. The analysis utilized panel cointegeration tests as proposed by Westerlund (2007) this test considers (CSD), heterogeneous effects, as well as non-stationary issues. The CS-ARDL approach was utilized in the investigation considering all of these tests that are necessary (Rasheed et al., 2023) . The issue of CSD is exacerbated by factors such as energy crises, trade crises, financial etc. Consequently, the CS-ARDL has the potential of addressing CSD, and slope homogeneity issues.

Panel data models assumes that error terms are unit free, however in some cases it is also possible that error terms are correlated along cross-sections and we might have a case of CSD (Rasheed et al., 2023). This approach differs from auto-correlation and heteroscedasticity since the correlation matrix is no longer a unit matrix. The Pesaran CD test (Pesaran, 2004,), is mostly and widely used as it is considered the suitable test to identify CSD problem.

$$CD = \frac{\sqrt{2}T}{\sqrt{F(F-1)}} \left(\sum_{i=1}^{F-1} \sum_{j=i+1}^{F} \widehat{\sigma_{\iota,J}}\right) \quad (3)$$

From eq (2) T is the length of the period while F represents the sample size while $\widehat{\sigma_{\iota,J}}$ is the correlation of the entities which is shown as under in equation (3)

$$\widehat{\sigma_{\iota,J}} = \frac{\sum_{s=1}^{F} e_{it} e_{jt}}{\left(\sum_{s=1}^{F} e_{it}^2\right)^{1/2} \left(\sum_{s=1}^{F} e_{jt}^2\right)^{1/2}} \quad (4)$$

From eq (3), $\widehat{\sigma_{\iota,J}}$represents the correlation between the error terms.

A very important diagnostic test in the panel data is to check for the slopes heterogeneity crosswise through cross-sectional units. Assuming homogenous slopes coefficients in the panel data analysis that involve economies like SAARC nations can often result in model misspecification and biased inference (Pesaran & Smith, 1995). Such assumption can overlook country-specific responses driven by institutional, developmental and policy differences. So in order to address this, the Delta (Δ) and the adjusted Delta Δ_{adj} tests are employed, developed by Pesaran and Yamagata (2008). Such second generation tests evaluate the null hypothesis of homogenous slopes against the alternative hypothesis of heterogeneous slopes. The test statistics are constructed as follows.

$$\Delta = \sqrt{J} * \left(\frac{\frac{1}{N}\sum_{i=1}^{N} t_i - k}{\sqrt{2k}}\right) \text{ and } \Delta_{adj} = \sqrt{J} * \left(\frac{\frac{1}{N}\sum_{i=1}^{N} t_i - 2k}{\frac{\sqrt{2k(T-k-1)}}{\sqrt{T+1}}}\right. \quad (5)$$

From the above formula k is the number of regressors, t_i is the individual slope coefficient test statistic for i^{th} unit and N is the number of crossectional units while T is the time dimension. The adjusted version of this test improves reliability in panels with moderate T by correcting for small-sample bias. A statistically significant result provides strong evidence for heterogenous slopes and rejects the null hypothesis of homogeneous slope indicating that variation in regressor varies across the countries which justifies the use of estimators that allows for individual and country specific slope- coefficients such as Cross-Sectional Autoregressive Distributed Lag model (CS-ARDL) proposed by Chudik and Pesaran (2015) while the Pooled Mean Group (PMG) and Mean Group (MG) estimators developed by Pesaran and Smith (1995). Both of these methods accounts for cross-sectional dependencies and structural asymmetries, yielding more robust log-run and short-run estimates. As far as this study is concerned, the evidence of heterogeneity slopes reinforces the empirical strategy of using heterogeneous panel estimators that align with the economic realities of diverse SAARC countries and boost the credibility of policy implications drawn from the analysis.

In terms of slope heterogeneity and cross-sectional dependency, the standard or first generation unit root tests and cointegeration methods such as Pedroni (2001) and Kao et al. (1999) will produce misleading results. The current research study presents a second generation unit root test CIPS as proposed by Pesaran (2007) to test if the relevant variables are stationary in the presence of CSD and slope heterogeneity. This test (CIPS) has been emerging with increasing prominence in recent literature because of its highly summarized power in addressing cross-sectional dependence across cross-sections and heterogeneity (Rafique et al., 20240. Its null hypotheses assumes that the series has a unit root can be rejected when the variables are integrated at first difference instead of level. This test also gives a pathway to proceed with a cointegeration test after any parameters have been established. The accompanying illustration demonstrates why a cross-sectional average of it is needed when attempting to estimate CIPS:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} t_i\,(N,T) \qquad (6)$$

Due to the existing evidence of CSD, heterogeneity, and non-stationarity in the dataset, a heterogeneous estimation approach was used to determine cointegeration. Westerlund and Edgerton's (2008) approach incorporates differences in slope, coefficient of determination, and correlated errors. This study employed a second-generation panel cointegration approach to investigate if any association existed among the variables of interest which provides accurate estimations of the cointegeration properties of cross-sectionally dependent heterogeneous panel datasets when they are applied to these datasets. Furthermore, when conducting the test against cointegeration among the four panels included in this study, it provided error-corrected statistics as well. The equations below explain this test.

$$G_t = \frac{1}{N}\sum_{1=1}^{N}\frac{T\alpha_i}{\alpha_i(1)} \;\;,,\;\; G_s = \frac{1}{N}\sum_{1=1}^{N}\frac{\alpha_i}{SE(\alpha_i)} \;,,\; P_t = \frac{\alpha}{SE(\alpha)} \;,,\; P_s = T\alpha \qquad (7)$$

Overall group mean statistics are represented by the letters G_t and G_s & cointegeration statistics are represented by the letters P_t and P_s. The null hypothesis is that the variables are independent with the optional hypothesis that they are cointegrated. This research employs a newly developed method cross –sectional auto-regressive distributed lagged model (CS-ARDL) in order to account for the cross-sectional dependence and heterogeneity. This research utilized the Panel Cointegration test created by Westerlund (2007) in order to determine if there exists a long-run relationship over time. For both long-term and short-term assessments, we employed the CS-ARDL test introduced by Chudik and Pesaran (2015). Compared to traditional dynamic and static panel models like MG, CCEMG, and AMG, this test proves to be more dependable and efficient, saving both time and resources. These methods tackle issues like non-stationarity, mixed-order integration, SH, and CSD that often go unnoticed (Noor et al., 2024). Ignoring common components that aren't currently observed can lead to inaccurate estimates, so it's crucial to consider these factors. Mathematically CS-ARDL can be written as under.

$$H_{i,t} = \sum_{I=0}^{Q_w}\gamma I, iW_{i,t-1} + \sum_{I=0}^{Q_z}\beta I, iZ_{i,t-1} + e_{i,t} \qquad (8)$$

From above equation the extended form can be acquired by taking the average cross section of all the regressors that accommodated issue of unfitting inference concerning the threshold effects existence produced by CSD (Chudik & Pesaran, 2015).

$$H_{i,t} = \sum_{I=0}^{L_w}\gamma I, iW_{i,t-1} + \sum_{I=0}^{L_z}\beta I, iZ_{i,t-1} + \sum_{I=0}^{\alpha_x}\alpha' i, I\overline{X}_{t-1} + e_{i,t} \qquad (9)$$

From the above equation the averages of selected dependent and the independent parameters are given as:

$$X^{\wedge}{}_{t-1} = \overline{X}_{i,t-1}\overline{Z}_{i,t-1} \qquad (10)$$

In the above equation $L_w, L_z, and\ L_x$ presents variable lags. Along with this $H_{i,t}$ and $Z_{i,t}$ represents dependent and independent variables respectively where $\overline{X}$ represents average cross section in order to cater to the spillover effects (Liddle, 2018). The long-run coefficients are predicted by short-run coefficients in the CS-ARDL. The mean group estimator and the long-run coefficients are indicated respectively as follows.

$$\widehat{\emptyset}_{MG} = \frac{1}{N}\sum_{i=1}^{N}\widehat{\emptyset}_{\iota} \qquad (11)$$

$$\widehat{\emptyset}_{CS-ARDL,i} = \frac{\sum_{I=0}^{P_z}\beta_{I,i}^{pw}}{1-\sum_{I=0}1}\widehat{\gamma_{I,\iota}} \qquad (12)$$

Following mean group and long-run coefficients, the short-run coefficients are as under.

$$\Delta H_{i,t} = \emptyset_i\left[\,H_{i,t-1} - \vartheta_i Z_{i,t}\right] - \sum_{I=1}^{a_{w-1}}\gamma_{I,i}\Delta_I H_{i,t-1} + \sum_{I=1}^{a_{ws-1}}\beta_{I,i}\Delta_I Z_{i,t} + \sum_{I=0}^{a_x}\alpha'_{i,}I\bar{X}_{t-I} + \varepsilon_{i,t} \quad (13)$$

From the above equation

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

$$\widehat{\emptyset}_i = -(1-\sum_{I=1}^{a_w}\hat{\gamma}_{I,t})$$

$$\vartheta_i = \frac{\sum_{I=0}^{a_z}\beta_{I,i}^{aw}}{\hat{\delta}_i}$$

$$\frac{\wedge}{\vartheta_{MG}} = \frac{1}{N}\sum_{i=1}^{N}\hat{\vartheta}$$

The CS-ARDL along with variables used in the study can be written as under.

$$\Delta SI_{i,t} = \emptyset_i\left[SI_{i,t-1} - \vartheta_1 BU_{i,t-1} - \vartheta_2 TRD_{i,t-1} - \vartheta_3 FDI_{i,t-1} - \vartheta_1 GV_{i,t-1}\right] + \sum_{p=1}^{p}\partial_p\,\Delta SI_{i,t-p} + \sum_{q=0}^{q}\{\rho 1_q\Delta BU_{i,t-q} + \rho 2_q\Delta TRD_{i,t-q} + \rho 3_q\Delta FDI_{i,t-q} + \rho 4_q\Delta GV_{i,t-q}\} + \delta\overline{SI}_{t-I} + \sigma_1\overline{BU}_{t-I} + \sigma_2\overline{TRD}_{t-I} + \sigma_3\overline{FDI}_{t-I} + \sigma_4\overline{GV}_{t-I} + \varepsilon_{i,t}.(14)$$

In CS-ARDL model the term ECT (-1) is represented by $\emptyset_i$ and shows whether the economy is approaching equilibrium. The results conducted based on these tests are discussed in the next section.

Results and Discussion

A total of five variables were used in this study with three variables being taken as indices i.e. SI, BE, GV, while TRD was taken as the ratio and FDI was taken as share of total GDP. All of the variables were converted to log form. Table 2 provides the descriptive summary/statistics of the variables as its highlights the key features and characteristic of the variables used in the study. On the average the value of SI and BE was found to be 0.551 and 0.558 respectively with highest value of SI being 0.91 and lowest value of 0.18 was recorded across South Asian countries. Similarly the maximum and minimum values of BE across the region were found to be 0.75 and 0.03 respectively. Results of which are given as under in Table 2.

Table 2. Descriptive Statistics of Variables.

Variables	Mean	Minimum	Maximum	St.Dev
SI	0.551	0.183	0.917	0.144
BE	0.558	0.034	0.753	0.141
TRD	10.68	9.761	11.830	0.565
FDI	1.151	0.095	3.620	0.664
GOV	0.192	0.023	0.373	0.095

Since the dataset in this study includes SAARC nations over an extended period of time, a cross-sectional dependence (CSD) test is performed as an essential preliminary diagnostic. Therefore, it is crucial to investigate whether there is cross-sectional dependence among the panel dataset's residuals in order to guarantee the results' robustness . Standard CSD tests, including the Friedman, Breusch-Pagan, and Pesaran CD tests, are used for this purpose. The Pesaran cross-sectional dependence test was used to determine the cross-sectional dependence in all series of this study. The results are as under in table 3.

Table 3. Cross- Sectional dependency test

Variable	CD-test	P-value
LSI	9.09	<0.01
LGV	7.07	<0.01
LBE	8.03	<0.01
LTRD	10.38	<0.01
LFDI	4.04	<0.01

Since the CD test result demonstrates the existences of cross-sectional dependence (with p-value less than 0.05), therefore, CIPS second generation panel unit root test was used to examine the stationarity of series. From the table 3 it is evident that all variables are stationary at first difference. Hence we conclude that variable are free from unit root providing us the pathway to conduct panel cointegeration test results which will be followed by second generation cross-sectional dependence ARDL test to examine the long and short run association between variables (Rasheed et al., 2022).

Table 4. CIPS Unit Root Test

Variable	CIPS value		p-value	Conclusion
	At level	At 1st diff		
LSI	0.394	-2.092**	<0.05	I(I)
LGV	-1.74	-2.874*	<0.01	I(1)
LBE	1.493	-2.845*	<0.01	I(1)
LTRD	-1.641	-4.030*	<0.01	I(1)
LFDI	-1.090	-3.846*	<0.01	I(1)

Note: * , ** represents significance at 1% and 5% level respectively.

The crossectional dependency test is followed by cointegeration test, in our case we explored Westerlund (2007) test for cointegeration since the other tests Kao et al. (1999); Pedroni and Pedroni (2001); McCoskey and Kao (1998); Larsson et al. (2001); Pedroni (2004) were unable to estimate the suitable results. Before conducting panel cointegeration test the study undergone slope (or coefficient) heterogeneity test using the Pesaran and Yamagata (2008). The results presented in table 4 reflect the presence of slope homogeneity since the p-value is highly significant means the slopes are homogenous across the cross-sections. The results are given as under.

Table 5. Result of Slope Homogeneity Test

	Delta	P-value
	7.25	0.000
Adj.	8.20	0.000

Following the CIPS unit root test and slope homogeneity test the study conducted panel cointegeration test presented by Westerlund (2007). Result given in the table below shows and confirms the presence of long run association among the variables since the p-value of lbe, lto, and lcf is (0.0350), (0.0228), and

(0.095) respectively which support to reject the null hypothesis of no cointegeration. The results are as under in Table 6.

Table 6. Westerlund Cointegeration test.

	Lbe		lto		Lcf	
	t-stats	p-value	t-stats	p-value	t-stats	p-value
LSIND	-1.8123	0.0350	-1.9998	0.0228	-1.3086	0.095

The short run and long run association between the dependent variable (SI) and independent variable (BE) along with other control variables has been examined by the CS-ARDL model and provides insightful evidence on the dynamic relationship between the blue economy and sustainable industrialization in the context of South Asian countries. Table 7 presents the results of CS-ARDL. From the results of CS-ARDL presented in the table above it can be concluded that sustainable industrialization has a significant positive relation on its past values. The blue economy (dlblu) and trade openness (dltro), governance (lgov) exerts a modest but positive effect on sustainable industrialization in the short run suggesting that these factor may nurture sustainable industrialization albeit with limited robustness but this relationship tends to be more effective in the long run as evident. Conversely, foreign direct investment (lfdi) possesses a negative and near significant contribution, reflecting short-term volatility or displacement of domestic investment in the short run while it has a considerably stronger and statistically significant impact on the dependent variable indicating that FDI may take time to generate industrial spillovers, such as technology transfer and job creation in the long run. The error correction term is negative and statistically significant indicating that in each period a total of 28.5% deviation from the equilibrium are corrected, thus concluding that the model is stable in the long run as evident from the Table 7.

Table 7. CS-ARDL Test Results

		Short Run Estimates		
Variable	Coefficient	Std.Error	T-stats	P-value
L.LSIND	0.108*	0.031	3.446	<0.01
DLBLU	0.160***	0.092	1.738	<0.08
DLTRD	0.166***	0.088	1.877	<0.06
DLFDI	-0.027**	0.013	1.999	<0.05
DLGOV	0.495***	0.260	1.898	<0.06
ECT	-0.285**	0.134	-2.124	<0.03
		Long Run Estimates		
LBLU	0.205*	0.072	2.859	<0.01
LTRD	0.232**	0.113	2.058	<0.05
LFDI	0.359**	0.179	2.008	<0.05
LGOV	2.064*	0.890	2.317	<0.02

*, **, *** denotes significance level of 1%,5% and 10% respectively.

Conversely, foreign direct investment (lfdi) possesses a negative and near significant contribution, reflecting short-term volatility or displacement of domestic investment in the short run while it has a considerably stronger and statistically significant impact on the dependent variable indicating that FDI may take time to generate industrial spillovers, such as technology transfer and job creation in the long run. The error correction term is negative and statistically significant indicating that in each period a total of 28.5% deviation from the equilibrium are corrected, thus concluding that the model is stable in the long run.

Policy recommendations

The empirical results indicate that the Blue Economy has a positive (0.205875) and statistically significant ($p = 0.0062$) impact on sustainable industrialization in the long run, while its short-run effect is weaker but still positive (coefficient = 0.160199, $p = 0.0890$). This suggests that long-term investments in blue economy (particularly aquaculture production, agriculture-forestry-fishery, and marine protected areas) can play a transformative role in enhancing industrial GDP, generating industrial employment, and reducing environmental degradation. Accordingly, SAARC nations should develop policies that promote sustainable aquaculture and fisheries, offer financial and technological support to blue primary sectors, and encourage industrial integration through processing and export of marine-based products. The expansion and scientific management of marine protected areas (MPAs) will further sustain marine biodiversity, which supports industrial raw materials and enhances ecological stability.

The positive long-run effect of governance and trade openness implies that institutional frameworks and trade infrastructure are essential for converting blue sector growth into sustainable industrial output. Therefore, policies should align Blue Economy expansion with climate objectives by supporting low-carbon industrial practices, such as solar-powered aquaculture or bio-based manufacturing, which contribute to the inverse CO_2 emissions component of the SI index. Creating coastal industrial employment hubs, especially in regions with blue sector potential, can amplify the observed industrial employment effects. By leveraging the long-term structural relationship between Blue Economy and Sustainable Industrialization, SAARC countries can build a development pathway that is economically inclusive and environmentally resilient.

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