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Dynamic association between socio-economic, environmental and logistic operations: Evidence from SSA BRI host countries

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This study examines the connection among green logistic operations, countries-level economic, environmental, and social indicators in Sub-Saharan Africa (SSA) Belt and Road Countries. Using the system generalized method of moments (S-GMM) estimator, this study analyses annual data from 2008 to 2018 and offers three key findings. First, economic indicators China's foreign direct investment (FDI), trade openness and economic output) are positively associated with green logistic operations. Second, logistics are positively correlated with renewable energy while inversely correlated with carbon emissions. Third, social indicators are also directly associated with green logistic operations measured through health expenditure and institutional quality. Lastly, information communication technology also spurs green logistic operations. Manifestly, Chinese outbound FDI in SSA substantially improved the quality of their logistics in terms of infrastructure, cost, time, customs services, tracking, and the consistency of international shipments. These findings show that green logistics provide adequate infrastructure, and supply chain partners share information more frequently, increasing trade volume, growth potential, and environmental sustainability. Similar results are also endorsed using a feasible generalized least square (FGLS) estimator and suggest that SSA should take effective measures to improve their logistics operation.

KEYWORDS

energy-environment nexus, belt and road initiative, green energy technologies, environmental sustainability, SSA (Sub-Saharan Africa)

TABLE 1 Chinese FDI projects in Africa.

Country	Year	Project category	Project name	Investment amount	Chinese contractor	Project status
Djibouti	2015	Port	Doraleh multi-purpose Port	US $599 m	China Civil Engineering Construction Corporation (CCECC)	Operating
	2011	Standard Gauge Railway	Addis Ababa-Djibouti Railway	US $4 bn	China Railway Engineering Corporation (CREC)	Operating
Ethiopia	2015	Light Railway	Addis Ababa Light Rail	US $475 m	China Railway Group Limited Shenzhen Metro Group	Operating
	2007	Industrial zone	Ethiopia's Eastern industrial zone	US $900 m	Jiangsu Yongyuan Investment Co. Ltd	Operating
Egypt	2015	Industrial zone	Suez canal economic zone	US $1 bn	China's TEDA and other Chinese companies	Operating
	2015	Administrative Buildings	New Administrative Capital	NA	China State Construction Engineering Corporation (CSCEC)	Operating
Kenya	2014	Standard Gauge Railway	Mombasa-Nairobi Standard Gauge	US $3.6 bn	China Road and Bridge corporation	Operating
Nigeria	2011	Standard Gauge Railway	Abuja–Kaduna railway line	US $876 m	China Civil Engineering Construction Corporation (CCECC)	Operating
	2016	Railway construction	Lagos–Calabar railway line	US $13 bln	China Railway Construction (CRC)	Under construction (2021)
	2018	Standard gauge Railway	Lagos–Kano Standard Gauge Railway	US $6.68 bln	China Civil Engineering Construction Corporation (CCECC)	Under construction (2021)
Uganda	2013	Energy	Karuma Hydropower project	US $1.7 bn	Sinohydro Corporation Limited (EPC) Shandong Taik	Under Completion
Zimbabwe	2018	Transport	Harare Airport expansion	US $153 m	Jiangsu International	Under construction

Introduction

Global logistics is a critical component of global supply chain management (SCM). Freight transportation, material handling, information processing, inventory storage, and exchanging data among supply chain members involved in product movement are all covered under logistics management (Martel and Klibi, 2016). Due to its effects on economic, social, and environmental concerns, global logistics has garnered the attention of practitioners and scholars over the past few decades (Khan and Qianli, 2017a). To attain social, environmental, and economic benefits, several companies have incorporated sustainable initiatives into their supply chain operations. Green approaches typically increase system costs significantly due to poor consumer perception, a lack of government support, and unfavorable environmental rules and regulations (Khan et al., 2016; Halkos and Skouloudis, 2018). The Belt and Road Initiative (BRI), developing nations displayed considerable gaps in their trade and logistic infrastructure, which somewhat limited their economic development and caused many social and environmental concerns (Wiederer, 2018). The BRI is constructing dependable infrastructure and logistics throughout the undeveloped region (Swaine, 2015), which consists of seaports, dry ports, railway tracks, highways, and airport terminals establishing the way for sustainable growth and facilitating the trading process by making it quicker, more effective, and compatible (Huang, 2016). A special economic zones, Industrial parks and urban development are all components of the BRI projects, which are primarily focused on infrastructure development in the transportation, as well as IT mining, communications sectors and energy. After the official launch of BRI in 2013, the majority of projects received funding. Furthermore, 42 African nations are participating in the BRI initiative with a total investment of over US$33 billion. Africa is a crucial component of BRI due to its enormous demand for railways, highways, and energy. If we examine more closely at some of the projects, as illustrated in Table 1, we observe how the program included significant projects including constructing world-class airports, developing smart cities and financing in special economic zones, and.

In the past decade, scholars and practitioners have shifted their focus to the integration of economic, social, and environmental challenges that green logistic operations (GLOs) may solve (Khan et al., 2019; Yu W. et al., 2020). Material handling, information processing, freight transportation, warehousing, and information sharing with supply chain members involved in the commodities movement in GLOs (Martel and Klibi, 2016). GLOs are the center of economic activity, whereas poor logistics exacerbated environmental and social concerns caused by CO_2 emissions and climate change (Cousins et al., 2019; Rehman Khan and Yu, 2021). According to estimations by (The World Bank, 2018) 23%

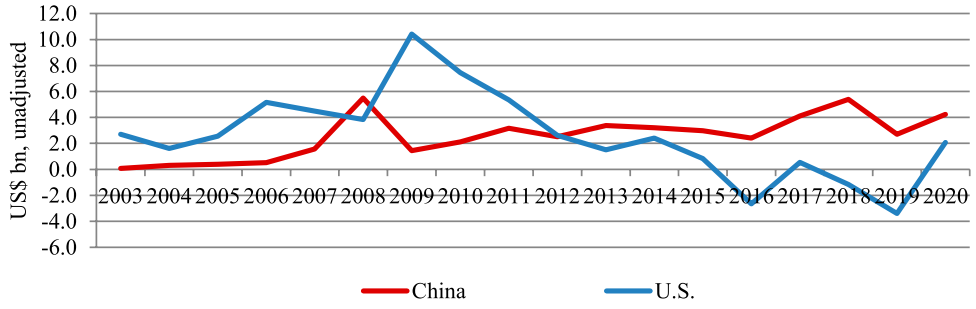

FIGURE 1
FDI flows from China and the United States to Africa between 2003 and 2020.

of fuel-based CO_2 emissions are attributable to transportation, whereas 7% of global CO_2 emissions are attributable to freight transportation (Arvis et al., 2018). In order to obtain social, economic, and ecological benefits, organizations are implementing green practices in their operational networks (Liu et al., 2017; Yu Z. et al., 2020; Shahzad et al., 2020). Green practices usually add significant expenses to the system due to insufficient environmental rules and customer awareness. When it comes to SCM, supply chain members play a variety of essential functions. These include government lawmakers, community activists, non-governmental organizations (NGOs), and international competitors. These criteria motivate companies to contribute to environmental sustainability at a certain level (Hassini et al., 2012). Conventional logistic operations require much fossil fuel, contributing to climate change and global warming (Hayami et al., 2015; Rehman Khan and Yu, 2021). Transportation and worldwide supply chain operations depend substantially on energy usage. Higher energy consumption is primarily driving the expansion of the logistics and transportation industry (Ullah et al., 2022b; 2022a).

Furthermore, it has been demonstrated that regulators have failed to develop appropriate policies to protect against environmental pollution, resulting in severe socio-environmental consequences. Earlier studies warned about increasing environmental risks and increased emissions creating a variety of health and ecological concerns, including allergy infections, asthma attacks, bronchitis, lung cancer and neurobehavioral disorders (Yildiz Çankaya and Sezen, 2019; Razzaq et al., 2020; Alinaghian et al., 2021). Global CO_2 levels have nearly doubled in the last five decades, according to the study (Herold and Lee, 2017), with 78% of total CO_2 ascribed to fossil fuel consumption (Field et al., 2014). The BRI countries have a poorer socioeconomic level, such as a lower per capita income (US$12,000), an immense contribution to global carbon emissions, i.e., 54%, and a substantial logistical infrastructure deficit, i.e., US$22.5 trillion (Pascha, 2018; Fan et al., 2019), which has attracted more than US$80 billion in Chinese foreign direct investment (FDI) in the last 5 years (Statistical bulletin of China's outward foreign direct). These Chinese investments are not only strengthening logistical infrastructure and boosting commerce and development (Liu et al., 2017), but they have also decreased CO_2 emissions by at least 48.69 Mt in the last 5 years by using renewable alternatives (Liu et al., 2017). According to Figure 1, China had invested 4.2 billion dollars FDI in Africa as of 2020. The amount of American FDI during that time was 2.1 billion dollars. Since China eclipsed the U.S. in terms of investment flows to the continent in 2013, this trend-higher Chinese than American FDI flows to Africa—has been noticeable.

Research gaps and objectives

While numerous previous studies have examined the relationship between the environmental and financial success of businesses and GLOs, few studies have investigated the relationship at the macro/international level. Previous research has predominantly employed business, microeconomic methods, survey-level analyses or industry. No research has been performed on the region-level investigation from Africa region (Khan et al., 2016), South Asian Association for Regional Cooperation Belt and Road Initiative, "BRI," the new buzzword previously known as OBOR (one belt one road). The Silk Road Economic Belt and Maritime Silk Road " (SAARC) countries (Khan et al., 2019), the United Kingdom (Khan and Qianli, 2017a), has chosen developed and developing nations (Rehman Khan et al., 2018), and European Union (EU) countries (Zaman and Shamsuddin, 2017; Rehman Khan et al., 2018).

The primary purpose of this research is to explore the relationship between social, economic and environmental indicators and logistics operations in a panel of Sub-Saharan Africa (SSA) countries from 2008 to 2018. This research is divided into five parts, including the introduction. The second section consists of a literature study and the formulation of hypotheses, while section three defines the proposed

methodology. Section four summarizes the findings and discussion. The fifth section presents the results and practical ramifications.

Literature review and hypotheses

Almost 2.6 billion people, primarily located in sub-Saharan Africa and developing regions of Asia, do not have constant electricity availability (China's Belt and Road Initiative: Implications in Africa, 2020). Around 2.5 billion individuals lack basic sanitary facilities around the world, and approximately 800 million individuals do not have access to water. Between one and five billion people lack adequate cellular service. Internet connectivity is available to just over 20% of individuals in underdeveloped nations. The BRI proposed by China offers a welcome change of direction. In these situations solving the infrastructure gap, one of the largest obstacles to economic success, seeks to increase economic expansion, reduce poverty, and link billions of people. It is not possible without infrastructure connectivity. Economic interchange is impossible without connectivity. Development is impossible without economic exchange. Infrastructure investment cannot exist without prosperity, and so the cycle continues. Africa has a massive demand for infrastructure funding. 600 million individuals in Sub-Saharan Africa do not have access to electricity now, and Africa's electricity sector alone will need $450 billion by 2030. Nearly $2 trillion in capital is expected to be required for the oil and gas sector between 2013 and 2035, according to estimates. Just to keep its current level of development, Africa is required to invest an additional $37 billion in maintenance and operation and an extra $38 billion annually in transportation. For the next 10 years, around $93 billion will be required to be committed to infrastructure development in Africa (Addaney, 2020). China's BRI is a response to the infrastructure deficit. Africa, with its rich mineral wealth, diversity of infrastructure chances, and convenient position, is an excellent fit for China's global infrastructure initiative, 'One Belt, One Road,' which aims to establish new maritime and land trade routes to assure fuel supplies, enhance international commerce, and boost Chinese company's products and services, a critical step for African economic growth, particularly modernization. One of China's main foreign and economic policy objectives, which is anticipated to have a large impact on Africa, is usually regarded as being this.

In the last 10 years, researchers have changed their attention to integrating environmental, social, and economic concerns that emphasize decreasing emissions and pollution (Yu W. et al., 2020; Hussain and Malik, 2020). Elkinjton developed the word "triple bottom line" (TBL) to describe this concept, which has since gained popularity (Elkinjton, 2007). TBL offers a framework for evaluating a company's economic, social and environmental effects. The sustainable performance of the nation can be evaluated using a similar theoretical framework. Industrial growth and global supply chain operations contribute to the nation's economic development. Nevertheless, this development is not sustainable in the absence of social and environmental problems caused by CO_2 and global warming (Jayaraman et al., 2012). Companies nowadays are implementing environmentally friendly practices in their operational systems, such as green storage, green sourcing, green transportation, ecological product design and green distribution to enhance economic, social and environmental sustainability (Ullah et al., 2021a, 2021b; Rehman Khan and Yu, 2021). Under the Supply chain, there has been much discussion about the correlation between energy demand and logistics. To attain a sustainable environment, the supply chain must utilize renewable resources (Centobelli et al., 2018). Zaman and Shamsuddin's Study found that logistics services primarily utilized resources and energy, significantly contributing to climate change and environmental destruction (Zaman and Shamsuddin, 2017). Cousins et al. proposed that industries use renewable resources and environmental design in their logistics activities to enhance sustainable biodiversity (Cousins et al., 2019). Green logistics services contribute to achieving environmental and socio-economic goals at the same time (Dev et al., 2020). The global energy consumption forecast for 2040 shows a consistent trend toward clean energy usage (Energy Information Administration, 2019). Renewable energy sources are relatively inexpensive, which encourages companies to employ them. Bhattacharya et al. noted that the only approach to reduce environmental consequences is to implement alternative energy solutions, which falls under the sphere of green regulations (Bhattacharya et al., 2016). Table 2 illustrates the overall LPI score for Sub-Saharan Africa (SSA) countries for 2 years, namely 2018 and 2012. The first ten nations have a high LPI score (South Africa with a 3.38 score in 2018 and a 3.67 score in 2012) with an average of 2.65 score, whereas the last ten countries have a low LPI score (Congo, Dem. Rep. with a score of 2.43 in 2018 and 2.21 as a score in 2012) with an overall LPI score an average of 2.28.

Association between countries' economic progress and supply chain management

Sustainable logistics operations highlight waste minimization and resource management, which is tightly connected to environmental protection and company economic growth (Arora et al., 2020; Mardani et al., 2020). At the state level, sustainable SCM techniques and green logistics operations have been strongly linked to trade potential and economic growth (de Medeiros and Ribeiro, 2017; Aldakhil et al., 2018; Khan et al., 2022a). Sustainability in SCM is expected to play a vital role in gaining market share, enhancing a company's financial performance, and boosting consumer satisfaction (Jayaraman et al., 2012; Yu Z. et al., 2020; Khan et al., 2021a). The supply chain efficiency of the nations involved and the achievement of inter-regional logistic collaboration is an important issue based on the demand for combined development across the BRI region. However, the BRI region's logistics

TABLE 2 Overall LPI score of SSA countries.

Country	2012	2018	Country	2012	2018
South Africa	3.67	3.38	Congo, Dem. Rep	2.21	2.43
Côte d'Ivoire	2.73	3.08	Sudan	2.1	2.43
Rwanda	2.27	2.97	Chad	2.03	2.42
Egypt, Arab Rep	2.98	2.82	Gambia, The	2.46	2.4
Kenya	2.43	2.81	Madagascar	2.72	2.39
Benin	2.85	2.75	Guinea-Bissau	2.6	2.39
Mauritius	2.82	2.73	Mauritania	2.4	2.33
Maldives	2.55	2.67	Lesotho	2.24	2.28
Djibouti	1.8	2.63	Liberia	2.45	2.23
Burkina Faso	2.32	2.62	Guinea	2.48	2.2
Cameroon	2.53	2.6	Gabon	2.34	2.16
Malawi	2.81	2.59	Central African Republic	2.57	2.15
Tunisia	3.17	2.57	Zimbabwe	2.55	2.12
Ghana	2.51	2.57	Libya	2.28	2.11
Comoros	2.14	2.56	Eritrea	2.11	2.09
Morocco	3.03	2.54	Sierra Leone	2.08	2.08
Nigeria	2.45	2.53	Niger	2.69	2.07
Congo, Rep	2.08	2.49	Burundi	1.61	2.06
Algeria	2.41	2.45	Angola	2.28	2.05
Togo	2.58	2.45			

performance is below the world average (Arvis et al., 2018). Two significant obstacles, customs efficiency and logistics infrastructure, were recognized (Ma et al., 2021) as restricting the overall performance of the LPI in the BRI region. Despite this, the majority of the BRI's funds are going into the development of infrastructure, which will considerably improve both the availability and quality of transportation systems throughout all BRI countries (Chen and Lin, 2018). BRI is assisting in eliminating protectionist policies and boosting the economy (Shahriar et al., 2019). It is also trying to enhance the use of green sources (Gu and Zhou, 2020). Economic progress in host countries has unquestionably depended on the efficiency of supply chains and logistical systems; nevertheless the logistics industry was also responsible for a significant amount of CO_2 emissions and contributed 13% of the total global CO_2 emissions (Khan et al., 2021d).

Similarly, worldwide logistics and transport activities, which promote international trade between nations, are a significant source of CO_2 (Herold and Lee, 2017). Logistics competence and infrastructure enhance economic growth significantly, and the supply chain promotes sector development and foreign direct investment (FDI) inflows (Khan and Qianli, 2017b). Traditional logistical procedures obstruct investment opportunities (Wanzala and Zhihong, 2016). The slow customs clearance procedure and fewer export prospects increase logistics and supply chain operational expenses. Implementing an efficient waste management system and sustainable practices, green logistic activities assist in dealing with climate change while also boosting the performance and profitability of companies (Hartmann et al., 2015; Khan et al., 2020). Green logistics operations encourage foreign investment and could be a powerful determinant of a sustainable environment (Zaman and Shamsuddin, 2017). These studies demonstrated that renewable energy resources and FDI are strongly and positively associated with green supply chain management. Furthermore, improved green logistic performance is linked to lower CO_2 and fuel usage. Higher values of logistics performance metrics at the global level encourage both imports and exports (Gani, 2017). Overall, GDP, trade, and FDI are all favorably connected with green logistic performance measures (Zaman and Shamsuddin, 2017; Khan et al., 2019). We formulate the following hypothesis based on the existing literature.

H1: Green logistics activities are associated with positive macroeconomic factors.

Association between macro-environmental variables and supply chain management

Green logistics operations offer the chance to preserve the environment from the adverse effects of standard none-green SCM techniques. Green logistics techniques considerably increase enterprises' environmental and socioeconomic

performance by conserving resources in company operations (Khan et al., 2021b; Rehman Khan and Yu, 2021). The sustainable logistics operations approach significantly decreases process waste, lower production charges, enhances efficiency, protects the ecosystem, and enhances the economic performance of the company (Zhu and Sarkis, 2004; Narasimhan and Schoenherr, 2012; Razzaq et al., 2021). Freight transportation and related supply chain operations will severely influence the global environment if sufficient green policies are not implemented (Yu Z. et al., 2020). Logistics operations and transportation are indeed the primary cause of pollution and climate change (Dey and Cheffi, 2013). Companies that have begun implementing green logistics and supply chain operations to increase efficiency must also overcome the complexities of performance assessment and associated executive choices (Khan et al., 2022b).

By implementing sustainable SCM techniques, companies can reduce their operational effect on the environment by approximately 80% (Büyüközkan and Çifçi, 2011). Green procurement Green supply chain and logistics practices were measured in Pakistan using five concepts: green information systems, environmental policy, green procurement, green manufacturing, and customer cooperation (Khan and Qianli, 2017a). Their research demonstrated that green supply chain management strategies improve a company's environmental efficiency. Yu et al. suggested that a company's goodwill and market share would increase if it planned for sustainable environmental approaches as part of its strategic planning (Yu W. et al., 2020). Green logistics and supply chain methods contribute to waste reduction, energy saving, and a more sustainable environment by lowering CO_2 emissions (Luthra et al., 2016; Herold and Lee, 2017; Hussain and Malik, 2020). Green SCM operations contribute to environmental sustainability based on Chinese market data (Lai and Wong, 2012). Green practices including the use of renewables in SCM and logistics activities are encouraged by consumer demand and regulatory organizations. Recent research revealed that the consumption of renewable energy could have a favorable impact on the economy, even at slower rates of economic growth (Dogan et al., 2020). Tirkolaee et al. revealed that global logistics activities significantly impact environmental protection, mainly determined by fossil fuel and energy usage (Tirkolaee et al., 2020). Sustainable and green logistics methods show a good and significant link with renewable energy consumption (Khan and Qianli, 2017b). Green approaches in logistics activities have a significant impact on sustainable growth and environmental stewardship. A large body of research has shown that inadequate logistics operations are responsible for a significant amount of CO_2 emissions, endangering global health and the environment. It cannot be resolved without taking proper measures, such as establishing stringent eco-friendly technology and legislation, rewarding businesses to embrace green efforts, and raising consumer awareness (Wanzala and Zhihong, 2016; Nawaz et al., 2020; Shahzad et al., 2020; Khan et al., 2021c). Based on the preceding investigations, the following hypothesis is developed:

H2: Green supply chain management approaches are associated with higher levels of environmental sustainability.

Association between macro-level social determinants of supply chain management

Governing and enforcement authorities regulate domestic and international logistic operations. As a result, the effectiveness of logistics activities was determined mainly by the quality of institutions, which somewhat assisted domestic goods movement through an effective national transit system and allowed cross-border commerce through the connection of international and domestic supply chain logistics activities (Arvis et al., 2018North, 1990). The political situation, law and order, criminality, violence, and terrorism prevention, as well as formal and informal corruption in host nations, are all measures of the quality of institutions. "Institutions are indeed the laws of the game in a nation, or, more technically, the humanly conceived limits that define human interaction in the economic environment," according to these researchers (North, 1990; Wegenast, 2013; Seabra and Flores, 2016) found that customs authorities are the most dishonest, purposefully delaying shipment clearance to demand more bribe money in underdeveloped countries. They even explored fabricating documentation in order to clear unlawful shipments. As a result, corruption reduces investor confidence and reduces a country's competitiveness for worldwide trade and FDI (Wegenast, 2013).

Globally, these researchers (Wong and Tang, 2018) analyzed the primary factors of logistic performance. They discovered that solid political systems and anti-corruption measures considerably enhance the logistics efficiency of host nations. Sales growth and the economic climate are influenced by the host country's socioeconomic factors (Bach and Allen; Doh et al., 2012). Arvis et al. observed that corruption reduces and affects the effectiveness of all logistic operations (Arvis JF, Saslavsky D, Ojala L, Shepherd B, Busch C, Raj A and 2016). These studies investigate similar empirical findings; on the other hand, they discovered that a high score on green supply chain performance measures is associated with a low level of corruption (Helble et al., 2007; Uca et al., 2016). A higher level of democracy, political stability, and regulatory quality enhance supply chain performance significantly (Guner and Coskun, 2012). Consistent regulations that allow logistics companies to operate formally and successfully in a country are associated with more excellent

political stability. Political turbulence and ethnic conflict in the MENA and Ukraine, for example, have put worldwide supply chains in danger and cause commercial instability. Most companies have a negative effect on society because of the essential characteristics of their activities (water and air pollution) (Zaman and Shamsuddin, 2017; Khan et al., 2020). Traditional logistics activities produced unrelenting pollution, while other business activities resulted in health and environmental issues. Asthma, Premature deaths, neurobehavioral disorders, mesothelioma, bronchitis, pulmonary liver cancer, other forms of cancer, and respiratory diseases are some of the most common dangers (Khasnis and Nettleman, 2005; McMichael et al., 2008; Maji et al., 2018). Rodriguez et al. stated that achieving long-term political stability can help alleviate social issues (Rodríguez et al., 2014). Companies have been focusing on corporate social responsibility (CSR) in the last decade to reduce their negative impacts on living animals (Yu Z. et al., 2020; Shahzad et al., 2020). The signaling hypothesis information inconsistencies can be eliminated by communicating information with peers in the business. Companies in developing countries, in especially, must indicate their approach to CSR in the context of poor policies and institutions (Rodríguez et al., 2014). In order to serve society, Visser explained that the company's social responsibility would include health care, promotion of political reforms, and the preservation of historic cultural traditions (Visser, 2009). Logistics operations are the major contributors to CO_2, but green practices positively reduce social and environmental problems (Aldakhil et al., 2018). Furthermore, green business and logistics practices can assist policymakers in the control of a range of illnesses, such as lung infection, asthma, and a variety of neurological disorders caused by contaminated air. Rehman et al. concluded that green logistic activities reduce socio-environmental problems in terms of reduced public health costs (Rehman Khan et al., 2018). Based on the above researches, the following hypothesis has been developed:

H3: Greater use of sustainable practices in logistics activities will significantly reduce social concerns.

Materials and methods

A panel of SSA BRI host nations is chosen for this study. The study displays the connection between economic (Eco), environmental (Env), social (Soc), and digital (ICT) aspects and green logistics performance indicators (LPI). Through the development of physical infrastructure (roads, motorways, rail lines, port facilities, inland containers, and airports) and the enhancement of logistic quality (delivery time, efficiency), Chinese FDI promotes and advances the logistical performance of the BRI host nations both quantitatively and qualitatively (Ye and Haasis, 2018). Very few researchers doubt that supply chain and transportation activities promote growth in the economy. Nevertheless, without green laws and green activities, it creates several environmental and social problems. Since Chinese FDI finances and enhances GLOs throughout the BRI region, this study linked global logistics operations with economic, environmental and social variables at the national level. The following fundamental equation is developed based on our hypotheses.

$$LPI_i = a_i + \beta_1 Eco_i + \beta_2 Env_i + \beta_3 Soc_i + \vartheta_i + \varepsilon_i. \quad (1)$$

In the fundamental equation, LPI represents a cumulative green logistics performance index with more than six logistic performance parameters. Chinese outbound FDI (actual Chinese outbound FDI stocks in BRI host countries), TO (trade openness percentage of GDP), and GDP (real GDP per capita USD constant 2010) are among the economic healthiness metrics that are denoted by Eco in the above Eq. 1. CO_2 emission (metric tons of carbon emissions per person) and the share of renewable energy consumption out of overall energy utilization are examples of environmental indicators displayed by Env in the above Eq. 1. Institutions quality (weighted index; public and private institution quality, institutional transparency and mismanagement, business cost of wrongdoing, crime, and terrorist acts) and HS (Per capita health expenditure) are examples of social indicators that are denoted by Soc in the above Eq. 1. ICT is added to control digital transformation in SSA measured by % of the population using Internet sourced from World Development Indicators. BRI host nation is represented by, the information that is specific to a country and constant with the passage of times such as geography is represented by ϑ_i , and a_i in the equation represents the constant term.

Data from SSA BRI host Countries covering 11 years from 2008 to 2018 is used in this study. The data for Chinese outward FDI has been obtained from the statistical bulletin of China collected annually from the weighted intuitional quality; the index is obtained from World Bank Global Competitiveness Index. All the other data are obtained from Work Bank Logistics Performance Dashboard. Since the data for all nations are obtained from the same sources, data are in a standardized format (same measuring unit and scale of the data). Additionally, by following these authors (An et al., 2021), all model variables—aside from indexes—are converted into logarithms (2020). The below equation examines the performance of green logistics activities.

$$LPI_{it} = a_{it} + \beta_1 Eco_{it} + \beta_2 Env_{it} + \beta_3 Soc_{it} + \vartheta_i + \varepsilon_{it}. \quad (2)$$

Eq. 2 is expanded and replaces the independent variables (Eco, Env, Soc) with relevant sub-variables (see Eq. 3).

$$LPI_{it} = a_{it} + \beta_1 \, Ln\, FDI_{it} + \beta_2 \, Ln\, TO_{it} + \beta_3 GDP_{it} + \beta_4 \, CO2_{it} + \beta_5 REC_{it} + \beta_6 HS_{it} + \beta_7 \, INST_{it} + \beta_8 ICT_{it} + \vartheta_i + \varepsilon_{it}. \quad (3)$$

In Eq. 3, the LPI index denotes the aggregate green logistics performance index, which comprises six distinct

logistic performance indicators. FDI, TO, GDP, CO_2, REC, HS, INST, ICT represent Chinese outward FDI and trade openness in Eq. 3. Economic expansion, CO_2 emissions, sustainable energy consumption, expenditure on health, cumulative service quality index, and production value-added are all measured in different ways. The host country is represented by *i* in the equation, while *t*, a, and β, represent time, constant term, coefficient of parameters, ε error term, and ϑ_i represent a particular effect about a county, respectively. Typically, heteroscedasticity, auto-correlation, endogeneity, and induced estimate mistakes and issues with panel data are inherent. These issues do not exist in modeling techniques such as fixed effect (FE), random effect (RE), and ordinary least squares (OLS) (Ibrahim and Law, 2014). The first issue is a serial correlation, which is defined as the correlation between an error term and a model variable caused by an error term that is linked to other model variables (Attari et al., 2016). Heteroskedasticity, which manifests when the variance of the error components varies between observations, is the second issue with the panel data (Simpson, 2012). The correlation between the parameters and the error term can also indicate the endogeneity problem (Khan et al., 2019).

The system generalized method of moments (S-GMM) is the best suitable tool for dealing with dynamical developments, inverse causation, and endogeneity. The S-GMM estimator is appropriate for testing hypotheses since the real estimate is distorted by explanatory factors connected with the error component. Arellano and Bond strongly advise using lagged endogenous variables as explanatory factors (arellanobond91). As a result, the S-GMM transformed fundamental equation is written as:

$$\mathrm{Lyi,t} = \alpha 1 + \gamma \mathrm{yi,t-1} + \beta \mathrm{Xi,1} + \delta \mathrm{i} + \lambda \mathrm{t} + \mu \mathrm{i,t}. \quad (4)$$

The *X* represents the collection of variables in the model; the δi reports the omitted country-specific effects, λ represents the period-specific effects. The omitted country-specific risk is eliminated by taking the difference between endogenous variables and lagged endogenous variables

$$\mathrm{yi,t-yi,t-1} = \alpha 1\,(\mathrm{xi,t-1-xi,t-2}) + \beta\,(\mathrm{Xi,t-Xi,t-1}) + (\lambda \mathrm{t} - \lambda \mathrm{t-1}) + (\mu \mathrm{i,t-\mu i,t-1}). \quad (5)$$

The estimation becomes biased due to the lagged endogenous variable yi,t−1−yi,t−2 correlates with the error μi,t−μi,t−1 (arellanobond91) (Khan et al., 2019). The S-GMM estimator corrects the term of disturbance by using the lagged level of the independent variables as instruments since they are independent and not auto-correlated (arellanobond91).

Blundell and Bond pointed out that the outcomes of the difference S-GMM may not provide real estimations, which is a limitation of this study methodology (Blundell and Bond, 1998). The exceptionality may be caused by the small sample size and continuous endogenous and exogenous factors in the data, making the instrument used to quantify them unreliably (Masron and Subramaniam, 2019). The best approach to address the problem is S-GMM (Ibrahim and Law, 2014). Arellano suggested a second common transformation (Arellano and Bover, 1995), S-GMM, which addresses the issues of autocorrelation, endogeneity, unseen panel results, and the dynamic characteristic of logistic performance indicators. The system estimators create S-GMM type instruments using the lags of the endogenous variables and the first variation of all the exogenic variables as standard instruments (Roodman, 2009). This method works better with smaller sample numbers and shorter time dimensions. For more extensive panels and shorter time dimensions (11 years), both the estimators S-GMM and Feasible Generalized Least Square (FGLS) are viable options (Khan et al., 2019). To simultaneously address the concerns of correlation, endogeneity, and heteroscedastic property, the study initially uses pooled OLS (P-OLS), FE, and RE approaches, followed by FGLS and S-GMM methodology. Although these estimators are capable of dealing with heterogeneity issues, BRI nations have a variety of features.

The FGLS estimator can handle the issues of autocorrelation and heteroskedasticity (Judge GG, Hill RC, Griffiths WE, Lütkepohl H, 1988; G.S.Maddala, 1992). The FGLS models do not support cross-sectional correlation but accept heteroskedasticity (Davidson et al., 1995; Green et al., 2012). Furthermore, the FGLS models are effective and better suited for larger sample sizes, which aids in resolving the serial correlation and heteroscedastic issues (Rao and Griliches, 1969). To Control the year-fixed effect using a time dummy variable throughout estimations is another way to deal with the auto-correlation issue. If the endogeneity problem is not handled correctly, then the potential endogeneity and reverse causation between operational logistics and economic expansion indicators can result in inaccurate estimations. For instance, the reverse causality between economic growth and logistic operations. Higher economic growth leads to higher logistic operation. Similarly, higher logistic operation leads to higher economic growth. This results in reverse causality bias. Furthermore, supply chain operations may be influenced by their own latency. The use of dynamic estimators is the sole way to handle the potential effects of lag factors on logistic operations.

Empirical results and discussion

Both dependent and independent variables have a positive mean (see Table 3). A range indicates a higher to lower value of logistic performances from 5 to 1. The value 5 indicates the highest logistic performance and the lower performance is indicated by a value of 1. A higher green logistics result is

TABLE 3 Descriptive Statistics for a panel of states from the SSA countries.

	LPI	FDI	To	GDP	CO_2	REC	HS	INST	ICT
Mean	2.90	13.16	4.32	7.71	6.80	2.38	4.91	−1.027	12.50
S. D	0.49	2.43	0.68	1.25	6.73	1.29	1.31	0.460	6.43
Min	1.69	7.42	−1.68	5.43	0.10	0.10	1.83	−2.101	0.12
Max	3.92	20.21	5.11	9.25	45.30	3.94	7.63	−0.548	59.21
Obs	473	473	473	473	473	473	473	473	473

Source: Authors estimations.

TABLE 4 Empirical results of panel SSA from S-GMM, FE and RE estimators.

Variables	S-GMM	FE	RE
Lag (LPI)	0.420*** (3.515)	—	—
FDI (Eco)	0.011* (1.701)	0.049*** (3.251)	0.016** (2.231)
TO (Eco)	0.013 (1.231)	0.039*** (3.37)	0.007 (1.501)
GDP (Eco)	0.359*** (4.393)	0.174*** (4.102)	0.412*** (3.971)
CO_2 (Env)	−0.001 (1.291)	−0.005*** (3.841)	−0.001* (1.705)
REC (Env)	0.074*** (3.97)	0.201*** (3.322)	0.087*** (3.506)
HS (Soc)	0.031* (1.905)	0.089*** (3.125)	0.029** (2.832)
INST (Soc)	0.068** (2.196)	0.211** (2.269)	0.016* (1.893)
ICT (Digital)	0.164*** (3.645)	0.135** (3.214)	0.167** (2.211)
Constant	9.40*** (3.522)	9.414 (1.201)	−0.546* (1.703)
Year Fixed Effect	Yes	—	—
Arellano bond test AR-1	0.000	—	—
Arellano bond test AR-2	0.213	—	—
Hansen (*p* value)	0.201	—	—

Entries in Parentheses denote robust normal errors. The symbol *** represents 1% significance level, ** represents 5% significance level, and * represents significance level.

associated with sound and better economic actions that enhance GDP and Trade especially Chinese FDI. The standard deviation and positive means of CO_2 may be reduced with the substitute of REC which has a significant impact on environmental sustainability and HS. Additionally, a reduction in health costs will result from employing sustainable energy sources in public transportation and supply chains. The institutional strength of the host nation creates an atmosphere that is favorable for promoting trade and logistical operations, which has a beneficial knock-on effect on the host nations environmental, social, and other financial indices. Notably, the sub-samples mean value shows that nations with more significant Chinese FDI have more robust green logistics operations while increasing GDP, trade, and eco-friendly value.

Table 4 summarizes the results of the S-GMM, and FE, RE estimators. The subsequent discussion based on the estimation results of the S-GMM model. The S-GMM results are explained. The Chinese FDI significantly improves the host country's GLOs in three economic indicators. By increasing 1%, Chinese FDI enhances cumulative LPI by 0.011 percent, at a 10% significant level. This finding supported the fundamental aims of BRI, which is urged to enhance host nations' logistical performance in order to reduce trade obstacles (Wiederer, 2018; Ruparathna and Hewage, 2015; Huang, 2016; Ye and Haasis, 2018). With the strengthening of logistic infrastructure and the removal of logistic operations limitations, TO and GDP both increase dramatically (Shahriar et al., 2019). This also suggests that poorer logistic performance metrics equate to lower GDP and TO values. These results are also consistent with previous research (Wanzala and Zhihong, 2016; Yune et al., 2016; Du and Zhang, 2018; Khan et al., 2019). This research stressed that inefficient customs clearance processes and enormous greenhouse gasses and toxic wastes from logistical activities greatly hindered trade potential. According to these Authors (Rehman Khan and Yu, 2021), logistics operations substantially impact a firm's performance, which helps to increase overall performance. Green logistics operations are strongly associated with a firm's financial performance, according to these

researchers (Barysienė et al., 2015; Benitez-Amado et al., 2015). Furthermore, green logistics methods boost the per capita income of the host country (Khan and Qianli, 2017b). Another study by the researchers (Zhu et al., 2012) found that adopting green methods in the supply chain and transportation industry not only slows environmental deterioration but also enhances business economic implementation. Similarly, the study (Khan et al., 2019) from SAAR nations discovered a favorable association between FDI, TO, GDP, and green logistics operations.

Under the effect of logistical performance metrics, the study employs two indicators for environmental health: CO_2 emissions and renewable energy usage. Table 4 shows that CO_2 is strongly and adversely linked with logistic performance metrics. A 1% increase in green logistics performance reduces CO_2 emissions by 0.001 percent. This finding implies that inadequate logistics operations add to more significant CO_2 emissions due to non-green logistics and supply chain activities. Inadequate execution of sustainable and eco-friendly logistics activities, for instance, transportation facilities, increases non-renewable usage, resulting in massive CO_2 emissions and various environmental problems. According to the authors (Leigh and Li, 2015), using bioenergy and REC in the supply chain management process can help to mitigate environmental threats such as environmental damage and global climate change.

Table 4 illustrates that renewable energy consumption is strongly associated with GLOs, with a 1% increase in REC, improving LPI to 0.074 percent at the 1% significance level. This finding shows that REC has effectively conserved energy, which has improved logistic operations. According to the International Energy Agency (IEA), worldwide CO_2 emissions from transportation climbed by 0.6 percent in 2018 compared to 1.6 percent in 2016, highlighting that in the international SCM the importance of productivity improvement and ecological logistic operations. This also suggests that bad logistical operations are associated with less renewable energy consumption and *vice versa*. Abid et al. stated that renewable energy sources and bioenergy would assist in maintaining ecological beauty while also accelerating economic progress (Abid et al., 2012). Implementing green energy regulations is a critical first step toward establishing green logistical operations. Without the specific assistance of elected leaders and eco-friendly rules, the business communal cannot implement them in their logistical and economic activities. Acknowledging environmental limitations, bioenergy is a viable alternative to fossil fuels and can convert logistical operations into commercial activity (Datta et al., 2015). Previous research studies on the other hand concluded that bioenergy and renewable energy sources do not have a bright future in the absence of adequate state support and environmental laws for tax incentives and subsidies on these initiatives (Mafakheri and Nasiri, 2014; Khan et al., 2016). Aside from previous arguments, Li emphasized that green and sustainable energy resources can alleviate ecological damage; firms can gain a competitive edge by using biofuels and renewable energy in transportation and logistics activities, resulting in higher customers loyalty and a positive reputation in the global economy, which boosts international trade (Li, 2014). The findings show that green logistic accomplishment significantly influences sustainable growth by decreasing CO_2 emissions and implementing an alternate policy shift to renewable energy.

TABLE 5 Empirical results of panel SSA from FGLS estimators.

Variables	Model-1	Model-2	Model-3
FDI (Eco)	0.151** (2.55)	0.119*** (3.33)	0.010* (1.61)
TO (Eco)	0.041*** (2.41)	0.064** (2.149)	0.011 (1.31)
GDP (Eco)	0.269** (4.15)	0.429*** (4.12)	0.248** (4.42)
CO_2 (Env)		0.005 (1.15)	−0.011 (01.99)
REC (Env)		0.191*** (3.71)	0.091*** (4.10)
HS (Soc)			0.021
			(1.12)
INST (Soc)			0.059**
			(2.23)
ICT (Digital)			0.158*** (3.56)
Constant	10.014 (1.501)	−0.615** (2.32)	7.30* (1.65)

Without a doubt, the logistic performance is substantially impacted by nations' hosting BRI and the quality of private institutions, such as customs approval, competency, and logistics feature. Table 3 results confirm a significant positive association between the quality of institutions and green logistics operation: a 1% increase in the host nation's quality of institutions increases LPI by 0.068%, respectively, at a 5% significance. ICT and HS have a positive association on LPI, implying that greater ICT and HS are associated with higher logistic performance. The HS coefficient is positive in comparison to the assumption, which could explain why central BRI developing nations spend on health relatively lower, life expectancy is lower than average due to lower social and economic position, while population growth, food insecurity, and poverty are relatively high all of these contribute to increased health problems triggered by lower public health expenditure (Chan et al., 2019). Nevertheless, a negative link exists between health spending and the quality of logistics in certain places. Burrell investigated how CO_2 emissions and other greenhouse gases in enterprises and businesses have a negative impact on our world, notably human health difficulties caused by air pollution (Burrell, 2006). Asthma, hypertension, eye infection, severe lower respiratory infections in youngsters, and lung problems are all rising due to lousy transportation infrastructure (Dekker et al., 2012; Khan et al., 2020). The same results were found from Models FE and RE.

TABLE 6 Summary of Hypotheses decision across a panel of SSA countries.

Hypothesis	Description	Decision
H1	There is a positive correlation between LPI and macro-economic indicators	Accepted
H2	There is a positive correlation LPI and greater environmental sustainability	Accepted
H3	There is a positive relation between LPI and social indicators	Accepted

Source: Authors' estimation.

To check the efficacy of proposed models we have used FGLS (Table 5) for the robustness. First we have used Model 1 considering Eco variables, the result are consistent, further in Model 2, we have added the Env variables, and the results are same. In Model 3 we have added Soc and ICT variables and found that the direction of relation are same.

When compared to wealthy nations, the majority of BRI developing countries have poorer institutional quality. Political upheaval, military domination or dictatorship, extremism, conflicts, inadequate government control, bad legislation, and terrestrial disputes threaten political stability, economic prosperity, and environmental laws in most BRI host nations (Duan et al., 2018). Earlier studies suggested that political stability for longer durations and effective institutional governance may only serve to increase nations' economic success while also improving the efficiency of eco-friendly policies (Bush et al., 2015; Datta et al., 2015; Nawaz et al., 2019). Overall, the Nations hosting BRI have poor logistical set-up and poor customs efficacy due to inefficient apparatus and unskilled personnel (Arvis et al., 2018).

Furthermore, most operations handled by hand are the leading cause of interruptions in the end-to-end clearing procedure. Moreover, the culture of bribery and corruption is expected mainly in South Asian emerging Belt and Road Initiatives host countries, namely Pakistan, India, and Bangladesh (Quazi, 2014). In some instances, customs officials purposely delay the customs approval procedure in order to collect the bribe money. Boluk proposed that lack of efficiency in customs procedures, inadequate transportation structure, damaging logistics vehicles, and bribery restricted potential business with European economies (Bölük and Mert, 2015). It also harms a country's image worldwide by using unsustainable practices and looser eco-friendly regulations in its worldwide logistics operations. Zawaydeh revealed that logistics sectors contribute considerably to the host country's economic health (Zawaydeh, 2017). It is mostly due to increased energy and CO_2 emissions which have far-reaching consequences for environmental sustainability, human illnesses, and rising global temperature. The logistics performance of BRI host nations has dramatically improved since the initiative's beginning in 2013. Infrastructure-based Chinese external FDI contributes to the development of logistics and transportation set-up along the path of BRI (Du and Zhang, 2018). Though the development is encouraging, enhancement in the fundamental institutional quality, as well as logistical quantity in terms of transportation-related facilities to attain organic progress, is still mainly required. Table 6 shows the three hypotheses that are accepted and examined in the underlying study, suggesting that there is a positive relation between the BRI host nations' economic, environmental, and social growth.

These findings support the underpinnings of the TBL concept theoretically. TBL is a background for examining organizations' social, ecological, and monetary performance of a business. We extended this hypothesis by establishing a relationship between TBL variables and GLOs at the country's level using a macro level in BRI host nations. Approval of TBL assumptions opens a new route for legislators to develop government plans and generate long-term growth. It may be used as a basis for analyzing industrial-level issues on a nationwide scale in order to incorporate the entire influence of a country's performance.

Conclusion

The Belt and Road Initiative (BRI) is a new "world strategic vision" that aims to improve linkages between China's underdeveloped western province and other underdeveloped countries in Central Asia through a series of logistical infrastructure and transportation projects (Cai, 2017). The BRI developing host nations have severe logistic infrastructure deficits, which limit their economic and trade progress while also causing social and environmental issues. As a result, the correlation between green logistics operations, social, environmental, and economic indices of countries, and the BRI are analyzed in this study. The function of logistics services in promoting environmental, social and economic activities is debatable from the viewpoint of contemporary supply chain management. Other essential aspects in logistic operations, including institutional quality, public health, environmental degradation, and social difficulties complicate this subject even further. As a result, utilizing the FGLS and S-GMM estimators, this research investigates the correlation between green logistics operations and environmental, social economic, and ICT indicators.

According to the results, Chinese external FDI dramatically enhances the quality of all logistics activities in BRI host nations. Poor green logistic performance measures in terms

of trade and transportation-related equipment, customs procedures performance, logistics operations quality, and competitive prices shipping result in increased CO_2 as a result of higher fossil fuel usage in the Supply chain management, which not only pollutes the environment but also harms people's health. The adoption of renewable sources of energy and sustainable and environmental procedures considerably enhances the quality of all logistics activities, thereby mitigating environmental and social problems and boosting the economic growth of host nations. Additionally, trade liberalization is favorably connected with the effectiveness of the customs clearance procedure, shipment cost, duration, delivery efficiency, and better information-sharing among supply chain members. It is thought that improved green logistic performance encourages trade and commercial activity contributing to economic growth. The quality of institutions considerably enhances all green logistic performance parameters. Industrial value-added and population health spending, on the other hand, are positively connected with more extraordinary logistic performance measures; nevertheless, the findings vary significantly in regions. Higher green supply chain effectiveness of cargo cost, delivery and tracking, transport facilities, and customs clearance is adversely connected with healthcare costs in SSA. Finally, more significant quality green logistics activities are favorably associated with environmental sustainability (lower CO_2 and higher REC), social determinants (institutions and health) and economical health parameters (FDI, GDP, and TO). The findings suggest that solid institutions help host countries develop economically and socially. Furthermore, by including REC and green logistics in the Supply chain management, environmental pollution can be reduced. Winkelhaus and Grosse, 2020, Yasin, 2020.

Policy recommendations

The research's outcomes could be used to establish sustainable logistics policies and rules that will contribute to advancing sustainable initiatives on a national level. The BRI reduces the gap in the infrastructure supporting the logistics sector, which boosts green logistics performance, trade, GDP, FDI and employment. In the Belt and Road region, it can therefore be used as a tool for reducing poverty and promoting environmental sustainability. A lack of sequestered logistic infrastructure hampers a country's long-term development. In order to promote Chinese infrastructure-based FDI, which can potentially result in several technological spillovers for recipient countries, BRI host nations must develop policies that encourage it. Additionally, the logistics operations are driven by energy consumption. As a result, energy conservation (sustainable sources) guided by innovation in logistics activities can reduce pollution, regulate global warming, and save flora and fauna. Greater socio-environmental sustainability can be facilitated by an ecologically friendly and green logistics network, which can also give businesses an advantage in the global market and improve their reputation there. The alignment of all these goals requires a solid institutional foundation, which brings us to our final point.

Limitations and future direction

Nevertheless, this research aims to connect logistics activities and economic, social, environmental and ICT′ aspects. Although this analysis uses China-specific regional investment, it can only examine national variables across Belt and Road host SSA countries. Due to its narrow focus, this paper explores a global logistics activities; future studies should focus on environmental science and pollution Redirected to investigate national logistics activities and their effects on socioeconomic variables at the aggregate/national level.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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