Journal of Infrastructure, Policy and Development 2024, 8(9), 5893.
https://doi.org/10.24294/jipd.v8i9.5893

Article

A cross country analysis of financial development, trade openness, population and digitalization's impact on sustainable development

Wajiha Manzoor[1], Muhammad Bilal Mandahar[2], Hadia Mustafa[1], Muhammad Moazzam[3], Nabeel Safdar[3,*]

[1] Comsats University Islamabad, Islamabad Campus, Islamabad 44000, Pakistan
[2] Lahore Grammar School, Lahore 54000, Pakistan
[3] National University of Sciences and Technology Islamabad, Isamabad 44000, Pakistan
*** Corresponding author:** Nabeel Safdar, nabeel.safdar@nbs.nust.edu.pk

CITATION

Manzoor W, Mandahar MB, Mustafa, H., et al. (2024). A cross country analysis of financial development, trade openness, population and digitalization's impact on sustainable development. Journal of Infrastructure, Policy and Development. 8(9): 5893. https://doi.org/10.24294/jipd.v8i9.5893

ARTICLE INFO

Received: 19 April 2024
Accepted: 20 May 2024
Available online: 9 September 2024

Abstract: This study employs the Standard Error Estimation technique to investigate the connections between the digitalization of economy, population, trade openness, financial development, and sustainable development across 127 countries from 1990 to 2019. The findings revealed associations between financial development, population growth, trade openness, economic growth, Digitalization development, foreign direct investment (FDI), and sustainable development. Financial development negatively impacts sustainable development, suggesting that countries with advanced financial systems may struggle to maintain sustainability. Trade openness exhibits a negative association with sustainable development, implying that countries with open trade policies may face challenges in maintaining sustainability, possibly due to heightened competition or resource exploitation. These findings highlight the multifaceted relationship between economic factors and sustainable development, underscoring the importance of comprehensive policies and governance mechanisms in fostering sustainability amidst global economic dynamics.

Keywords: digitalization; trade openness; sustainable development; financial development

1. Introduction

Since the evolution of civilization, one of the critical considerations that has always sought socio-political prioritization is development. The human curiosity and inquisitiveness towards progression, along with the multi-tiered competitive ventures, have guided civilizations towards the developmental domain. Human interest in and curiosity towards movement alongside multi-layered cutthroat endeavors has directed civic establishments towards formative space. Nonetheless, at the same time, it has additionally mixed and enhanced the advancement between related aspects. In this thought, improvement has been explained by Manesh (2019) as a 'multi-faceted technique' that envelops the unpredictably many-sided modifications in the public eye and its positive characteristics as standards and monetary development that deliberately prompt previous imbalances and destitution decrease. Global commitments concerning Sustainable Development Goal–12 stress responsible consumption and production and reverberate that humankind needs to quit the economic progression at the cost of environmental degradation.

With humans' profound tendency toward advancement, these contemplations will be underpinned by manageable improvement in this association. Geels (2018) suggests that reasonable improvement has seen a multidisciplinary transitionary movement connected with the supportable advancement objective of dependable

utilization and creation. Geels (2018) likewise construes that this has come about because of the consolidated effect of multi-layered changes in cultural practices, cultural nature, culture, monetary models, and the significant organizations and mechanical movement. In this association, Loorbach et al. (2017) and Markard et al. (2012) elaborate on this movement as an upper deliberate and maintainable change that includes manageability at the creation and shopper levels alongside its different and complex relationships with people.

The Sustainable Development Index (SDI) by Hickle 2020 has measured human development's ecological efficiency, including five indicators: education, life expectancy, income, Carbon emissions, and material footprint. The SDI data for different countries showed development disparities that ranged from 0.156 to 0.85 in 2019. These differences shed light on the factors that inhibit the linkages between e-economics and environmentally sensitive growth—**Figure 1** Representing the SDI for different countries in 2019.

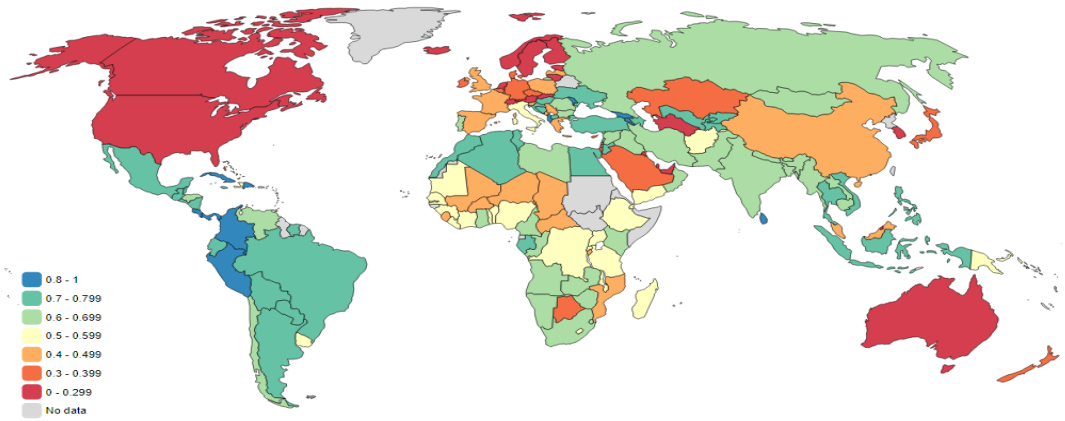

Figure 1. Representing the SDI for different countries in 2019 (source: Sustainable development index, 2019).

The Digitalization could spur growth by integrating social, economic, and environmental aspects. It promotes coordination of urban and rural development and facilitates a higher efficient economic development level and resource utilization efficiency. The use of different digital devices, i.e., e-commerce platforms, new ways of doing business, Artificial Intelligence, the Internet, and the Internet of Things supporting sustainability through the Digitalization is remarkable. In addition, it contributes to better deployment of resources, better decision-making, and sustainability in creating better operational and environmental survival environments for businesses. Luo et al. (2023) found that the Digitalization helped in green innovation when they observed a number of patents by using data from 278 cities in China between 2011 and 2018. Yang et al. (2022) found that the Digitalization has positive effects and has a valuable contribution to sustainable development by using data from 31 countries from 2013–2019.

Significant exploration has tracked areas of strength down among monetary and financial turn of events (Sadorsky, 2011). Existing writing has recommended that monetary development is a main thrust for financial development (Borio, 2011; Shahbaz et al., 2018), and monetary steadiness is significant for financial solidness (Shahbaz et al., 2018). This makes the money area a significant region for research.

Moreover, it may be contended that monetary improvement affects natural corruption (Haseeb et al., 2018). This implies that exploring the connections between monetary area tasks and natural degradation is also significant. In this present circumstance, worldwide associations, such as the UN, are expanding tension on their individuals and accomplices to carry out green money strategies (Campiglio et al., 2018). UN has additionally set SDGs that are reachable by 2030 (Fenner and Cernev, 2021). In this way, the UN's plan has featured the significance of a green turn of events and natural government assistance (Irshad et al., 2023a; Taghizadeh-Hesary and Yoshino, 2020).

Moreover, the Paris environment meeting significantly supports natural government assistance worldwide (Ji et al., 2021). One significant result is the advancement of ventures that uphold supportable action plans. This speculation is critical to meeting objectives (Thoma et al., 2021). They have proposed incorporating environment gambles into the board portfolio to assist with arriving at the objectives of the Paris environmental arrangement. Ahmed et al. (2022) explains the role of financial development and institutional quality in the green growth of South Asian economies from 2000 to 2018; results revealed that long-term co-integration between financial development and institutional quality drive factors in promoting green economic growth in the long run. Archer et al. (2023) investigated the relationship between financial outreach, innovation, and sustainable development in 34 African economies from 2010 to 2020. Their comprehensive study revealed that bank branch penetration has a significant positive association with sustainable development, while credit information sharing has a significant negative impact.

Moreover, financial outreach enhances economic sustainability but adversely affects environmental sustainability. Surprisingly, financial innovation is found to be negatively linked to sustainable development in Africa, potentially leading to unemployment. The relationship between inflation and sustainable development is complex and multifaceted. While inflation can stimulate economic activity in the short term, its long-term ramifications pose significant challenges to achieving sustainable development goals (Ogege, 2019). Exchange rates can have positive and negative impacts on sustainable development, depending on various factors such as the country's economic structure, trade policies, and the nature of its exports and imports (Yang et al., 2023).

Trade openness stimulates economic development, provides employment opportunities, improves resource availability, promotes innovation, reduces income disparity, contributes to environmental protection, and is vital in enhancing sustainable development. It connects goods and services and inputs markets to circulate freely and facilitate capital, energy, people, and knowledge flows. It may also boost various social and environmental aspects of sustainable development. Also, trade openness may foster the development of infrastructure, including transport networks, energy grids, and communications grids, that would enhance general well-being and, thus, sustainable development. Ongoing experimental investigations (Chien et al., 2023; Irshad et al., 2023b; Manzoor et al., 2021a; Meng et al., 2022; Nguyen and Phan, 2023; Wang et al., 2023) support likewise the adverse consequence of global exchange on the maintainable improvement of emerging nations. Subsequently, the effect of worldwide exchange on manageable

improvement in non-industrial nations can appear in different ways, habitually through three impacts (Dupuy and Agarwala, 2014; Nguyen and Phan, 2023), including:

1) Scale impact—as global exchange prospers, the economy and society are created, joined by an ascent in contamination outflows that adversely impact the climate.
2) Strategy impact—monetary development driven by global exchange expands earnings, expectations for everyday comforts, and requests for ecological quality, which prompts legislatures and enterprises to assume the liability of ordering the regulation and cultivating mechanical headways to moderate natural corruption, which emphatically affects feasible turn of events.
3) Structure impact—global exchange prompts specialization, driving specific nations to enjoy near benefits in the creation of additional dirtying merchandise and others enjoying relative benefits in less contaminating products.

FDI includes exchanging long-haul business capital between nations determined to achieve higher benefits. In this paper, we activate the exchange cost hypothesis to examine the connection between FDI and manageable turn of events. Exchange costs are the complete expenses of running a firm's monetary arrangement. These expenses happen while participating in the market for trading, purchasing, and selling data sources and results (Coase, 1937; Nguyen and Phan, 2023; Williamson, 1979). From the exchange cost approach, a financial backer will choose to include in an FDI to avoid exchange costs connected with the rising ecological costs in their nation of origin. Unfamiliar financial backers are generally intrigued exclusively by benefits, yet not in the climate of the host country. Thus, FDI could hurt the host nation's current circumstance, successfully forcing costs on its maintainable improvement endeavors (Manzoor et al., 2021b; Khan et al., 2024). Exact examinations support the adverse consequences of FDI on feasible advancement in emerging nations. Findings of Ahmed et al. 2023 in the USA context, Rana and Sharma (2020) in the Indian context, and Karimov (2020) in Turkey's context all demonstrate that FDI prompts an expansion in carbon emanations, consequently affirming the contamination sanctuary speculation, which sets a negative connection among FDI and the maintainable improvement of host nations. Gorus and Aslan (2019) find additionally that FDI inflows worsen contamination issues in a few MENA nations. Sbia et al. (2014) and Nguyen et al. (2019) notice that, without any eco-accommodating FDI technique in agricultural nations, uneven FDI fascination happens regarding speculation areas, fields, businesses, and venture scale; this lopsidedness results in low financial development, uplifted monetary disparity, emerging issues of natural contamination or exhaustion of non-sustainable assets. Besides, FDI can bring startling changes in culture, customs, and propensities, which are likewise aspects of feasible advancement inside agricultural nations. Supporting the adverse consequence of FDI, Bokpin (2017) concentrating on African nations, stressed that, in remiss command over FDI fascination, especially concerning advancements, the host nations can become stores for obsolete and outdated advances once brought into the homegrown market.

Hypothetically, financial development affects the supportable advancement of nations. In particular, in creating ones, financial development is often focused on as

the essential objective by superseding ecological worries as optional in the rich possibility (Eisenmenger et al., 2020). Thus, financial development adversely influences the climate and supportable improvement in non-industrial nations. For sure, the higher the monetary development, the quicker the utilization and utilization of public capital assets, the more waste individuals produce, and the weaker the climate. Solely after accomplishing the financial objectives, non-industrial nations focus on the climate issues that have happened in advancing their monetary development. Observational examinations support the previously mentioned viewpoint. Sethi et al. (2020) concentrated on the connection between monetary development and energy utilization on carbon dioxide discharges in India during 1980–2015; that is what their discoveries affirm: temporarily, financial development straightforwardly adds to natural corruption. Essentially, Churchill et al. (2018) and Moutinho et al. (2020) analyzing OPEC test, Gorus and Aslan (2019) and Shahbaz et al. (2019) with MENA tests, Meng et al. (2022) with BRICST test, Wang et al. (2023) with Chinese example, and Qiao et al. (2023), these examinations meet on similar results inside emerging nations, by supporting the idea of the natural Kuznets bend. This infers that monetary development is related to ecological corruption.

FDI has the potential to drive economic growth, its negative impacts on sustainable development cannot be overlooked. Through the lenses of dependency theory, environmental economics, and social justice, it is evident that FDI can lead to economic vulnerability, environmental degradation, social inequities, and cultural erosion. To harness the benefits of FDI while mitigating its adverse effects, host countries need robust regulatory frameworks, sustainable investment policies, and inclusive development strategies that prioritize the well-being of all citizens and the preservation of their natural and cultural heritage. Financial development can negatively impact sustainable development through Resource Curse Theory. Advanced financial systems often promote rapid industrialization and resource extraction, leading to environmental degradation and resource depletion, which hinder sustainability. Financial markets are sometimes driven by short-term profit motives rather than long-term sustainability goals, leading to overexploitation of resources and neglect of environmental concerns explained through Short-Termism.

Trade openness can drive economic growth, its potential negative impacts on sustainable development are profound. Economic dependency, environmental degradation, social inequality, weakened institutions, and cultural erosion are critical concerns that highlight the complex relationship between trade liberalization and sustainability. Policymakers must navigate these challenges carefully, ensuring that trade policies are aligned with the broader goals of sustainable development, encompassing economic stability, environmental protection, and social equity. Economic growth has traditionally been viewed as a key indicator of a nation's progress, often linked to improvements in living standards and overall prosperity. However, this paradigm is increasingly challenged by the principles of sustainable development, which emphasize the need to balance economic advancement with environmental protection and social equity. The inherent conflict between unbridled economic growth and sustainable development is rooted in several theoretical perspectives, including environmental economics, ecological economics, and social sustainability theories. The Demographic Transition Theory provides a framework

for understanding how population dynamics influence sustainable development. In early stages, high population growth exerts immense pressure on natural resources and the environment. As societies transition through the stages, the nature of labor supply shifts from agriculture to industry and services, impacting economic structures and development strategies. In later stages, stabilized population growth allows for the implementation of sustainable practices and technologies, reducing environmental pressures and contributing to long-term sustainability.

H1a: As financial direct investment increases it leads to lower the Sustainable Development due to environment degradation.

H2a: More exposure to trade openness without considering the environmental effects reduce sustainable development.

H3a: Without considering the environmental effect financial development has a negative impact on sustainable development.

H4a: Increase in population leads to more sustainable development.

H5a: Increase in the digitalization leads to more Sustainable development.

H6a: Increase in the growth of countries without considering the environmental destruction leads to lower the sustainable development.

Figure 2 Representing the theoretical framework of this paper.

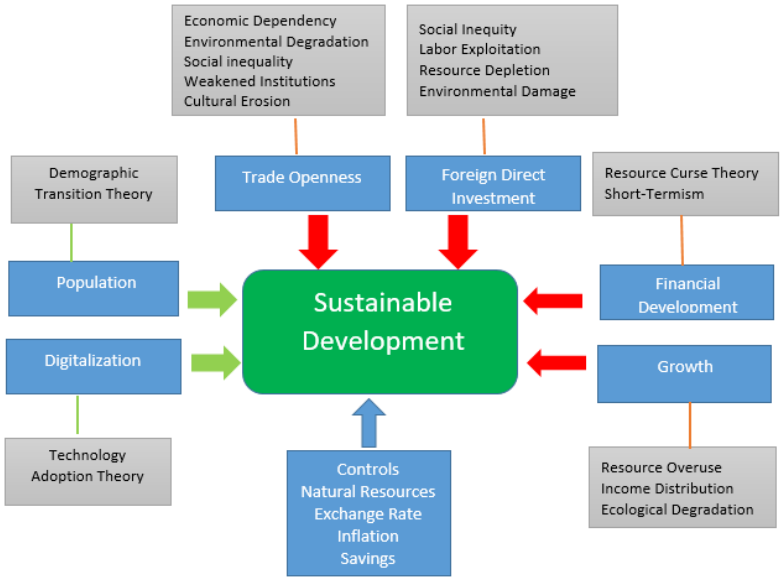

Figure 2. Representing the theoretical framework.

Through empirical analyses, this study provides an in-depth assessment of the role of the digitalization, trade, FDI, and financial development towards sustainable development. With the world becoming more technology-centered and interlinked, there is a need to establish how these issues affect sustainable development. In addition, this study utilized two facets of the financial development index to differentiate the impact of financial institutions and financial markets' perspectives on sustainable development.

2. Materials and methods

This study utilizes secondary data from different sources, including a panel data sample of 127 countries from 1990 to 2019. Countries were chosen based on data availability making unbalanced panel with 2580 observations. The variables (Appendix): Digitalization (DIGECO), trade openness (TO), gross domestic product (GDP), exchange rate (ER), foreign direct investment (FDI), population (POPT), inflation (INF), savings (SAV_GDP) and natural resources rent (NR) are gathered from World Bank statistics. While financial development index (FD)whose data was taken from the IMF and Hickel 2020 methodology is used in developing Sustainable Development Index (SDI). The detail description of variables is found in annexure A.

The generalized model for this study is stated as follows.

$$SDI_{it} = \beta_0 + \beta_1(SDI_{it\text{-}1}) + \beta_2(LNDIGIECO_{it}) + \beta_3(LNTO_{it}) + \beta_4(FD_{it}) + \beta_5(LNNR_{it}) + \beta_6(LNGDP_{it}) + \beta_7(LNFDI_{it}) + \beta_8(LNINF_{it}) + \beta_9(LNER_{it}) + \beta_{10}(LNPOPT_{it}) + \beta_{11}(LNSAV\_GDP_{it}) + \varepsilon_{it}$$

where *i* and *t* refer to country and time respectively and LN refers to the natural log, while,

SDI = Sustainable Development Index
DIGECO = Digitalization
TO = Trade Openness
GDP = Gross Domestic Product
ER = Exchange Rate
FDI = Foreign Direct Investment
POPT = Population Total
INF = Inflation
SAV_GDP = Savings
NR = Natural Resources Rent

This research used data from different countries, and the fixed model is appropriate for many reasons. The basic assumption in the analysis is that within every single country, Digitalization, trade openness, financial development, and foreign direct investment inflows.

3. Results and discussion

The descriptive statistics are tabulated in **Table 1**, which shows the mean, standard deviation, minimum, and maximum of all variables used in study without logarithmic form.

Table 1. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
SDI	2580	0.596	0.163	0.085	0.85
FD	2580	0.342	0.233	0.03	1
DIGECO	2580	62.612	51.471	0	212.453
TO	2580	78.438	43.449	11.855	425.363
NR	2580	5.181	8.521	0	66.06
GDP	2580	4.699×10^{11}	1.656×10^{12}	4.870×10^{08}	2.138×10^{13}

Table 1. (*Continued*).

Variable	Obs	Mean		Std. Dev.	Min	Max
ER	2580	558.474	2127.726	0	23050.242	
FDI	2580	5.061	17.183	0	449.081	
INF	2580	11.256	69.089	0.012	2240.169	
POPT	2580	56,416,247	1.746×10^{08}	194,177	1.408×10^{09}	
SAV GDP	2580	22.301	9.522	0.103	67.902	

Table 2 explains the correlation matrix and the significance level in parenthesis, which offers some insights into how different variables in a sample are interrelated. The SDI shows negative relationships with most variables except ER and INF. Also, all correlations among independent variables are less than 0.45, showing no Multicollinearity among predictors. Therefore, the correlation matrix depicts an intricate picture of the relationship between the given economic and developmental factors, which can be used to study and interpret them better.

Table 2. Correlation matrix.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) SDI	1.000										
(2) FD	−0.336	1.000									
	(0.000)										
(3) DIGECO	−0.079	0.365	1.000								
	(0.000)	(0.000)									
(4) TO	−0.126	0.139	0.217	1.000							
	(0.000)	(0.000)	(0.000)								
(5) NR	−0.125	−0.224	−0.018	0.010	1.000						
	(0.000)	(0.000)	(0.365)	(0.603)							
(6) GDP	−0.265	0.435	0.116	−0.184	−0.097	1.000					
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)						
(7) ER	0.066	−0.107	0.009	0.040	0.068	−0.044	1.000				
	(0.001)	(0.000)	(0.640)	(0.040)	(0.001)	(0.024)					
(8) FDI	−0.085	0.085	0.101	0.288	−0.028	−0.037	−0.015	1.000			
	(0.000)	(0.000)	(0.000)	(0.000)	(0.155)	(0.060)	(0.436)				
(9) INF	0.054	−0.049	−0.100	−0.063	0.014	−0.021	−0.011	−0.020	1.000		
	(0.006)	(0.013)	(0.000)	(0.001)	(0.467)	(0.277)	(0.568)	(0.299)			
(10) POPT	−0.009	0.140	−0.056	−0.215	−0.044	0.395	0.021	−0.046	0.012	1.000	
	(0.662)	(0.000)	(0.005)	(0.000)	(0.025)	(0.000)	(0.286)	(0.018)	(0.526)		
(11) SAV_GDP	−0.108	0.243	0.131	0.267	0.360	0.061	0.029	−0.032	−0.009	0.236	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.146)	(0.102)	(0.638)	(0.000)	

They modified the Wald test for group-wise heteroscedasticity checks for a substantial variance differentiation between groups or entities within a dataset. The test statistic, very high (Chi2 = 49416.83), and *p*-value = 0.0000, provide strong evidence to reject the null hypothesis. Therefore, group-wise heteroskedasticity is

present in the data. Breusch-Pagan/Cook-Weisberg test for heteroskedasticity is also tabulated in **Table 3** with (Chi2 = 67.25) and *p*-value = 0.0000, suggesting heteroskedasticity is present in the data. The Wooldridge autocorrelation test evaluates if the serial correlation exists in the panel data's residuals. The *F* statistic of 181.721 and the associated *p*-value of 0.000 support a significant rejection of the null hypothesis. Hence, the residuals of the panel data model possess autocorrelation, implying that there is a correlation of errors over.

Table 3. Diagnostic test results of heteroscedasticity and autocorrelation.

Test	Test Statistic	*p*-Value	Presence
Modified Wald test for group-wise heteroskedasticity	Chi2 = 49416.83	0.0000	Yes
Breusch-Pagan/Cook-Weisberg test for heteroskedasticity	Chi2 = 67.25	0.0000	Yes
Wooldridge test for autocorrelation in panel data	*F* Statistic = 181.721	0.0000	Yes

In addition, the Cross-sectional dependence test suggested by Pesaran (2004) is reported in **Table 4**. **Table 4** shows that all variables are significant at the 1% level. The result indicates that there is a solid cross-sectional dependence on the data of this study.

Table 4. Diagnostic test results of cross-sectional dependence.

Variables	Pesaran (2004) CD-test	*p*-Value
SDI	25.291	0.000
FD	127.678	0.000
LNDIGECO	294.897	0.000
LNTO	54.743	0.000
LNNR	77.82	0.000
LNGDP	282.542	0.000
LNER	96.619	0.000
LNFDI	45.666	0.000
LNINF	66.2	0.000
LNPOPT	178.032	0.000
LNSAV_GDP	14.304	0.000

Table 5 explained coefficients with sustainable development index as the dependent variable with Column 1 pooled OLS regression, Column 2 as panel fixed effect, Column 3 with panel year fixed effect, Column 4 with random effect model, and Column 5 reported results obtained through Driscoll and Kraay Standard Error Estimation (SCC) regression models. Driscoll and Kraay's standard error (SCC) technique is used to address the issues of heteroscedasticity, autocorrelation, and cross-sectional dependence in data. In addition, the tabulated Variance Inflationary factor (VIF) is checked, and all values of VIF are less than 10, showing no Multicollinearity among predictors. All the techniques give consistent results; the Hausman test supports fixed effect as an appropriate technique because the

coefficient difference is not a systematic Chi2 value of 96.40 with 0.0000 significance.

Table 5. Comparing results for sustainable development index as dependent variable using different techniques.

	(1)	(2)	(3)	(4)	(5)
VARIABLES	**Pooled OLS**	**Fixed Effects**	**Fixed Effects**	**Random Effects**	**SCC**
L.SDI	1.000***	0.932***	0.924***	0.984***	0.932***
	(0.00286)	(0.00688)	(0.00759)	(0.00392)	(0.0232)
FD	−0.00301	−0.0423***	−0.0225**	−0.0138***	−0.0423***
	(0.00396)	(0.00855)	(0.00921)	(0.00530)	(0.0141)
LNDIGECO	8.79×10^{-5}	0.000949**	0.00252***	0.000265	0.000949
	(0.000233)	(0.000410)	(0.000631)	(0.000255)	(0.000680)
LNTO	−0.00297**	−0.00629**	−0.00710***	−0.00269*	−0.00629**
	(0.00120)	(0.00259)	(0.00270)	(0.00161)	(0.00276)
LNNR	0.000242	0.00112	−0.000391	0.000100	0.00112
	(0.000253)	(0.000695)	(0.000730)	(0.000349)	(0.000685)
LNGDP	−0.00424***	−0.00583***	−0.0126***	−0.00331***	−0.00583***
	(0.000641)	(0.00143)	(0.00213)	(0.000837)	(0.00180)
LNER	-5.77×10^{-5}	0.000425	0.000918*	−0.000138	0.000425
	(0.000176)	(0.000542)	(0.000528)	(0.000262)	(0.000552)
LNFDI	−0.000283	−0.000658	−0.000712	−0.000372	−0.000658
	(0.000395)	(0.000516)	(0.000509)	(0.000447)	(0.000775)
LNINF	−0.000173	−0.000334	−0.000369	−0.000204	−0.000334
	(0.000414)	(0.000491)	(0.000505)	(0.000455)	(0.000496)
LNPOPT	0.00433***	0.0234***	0.0307***	0.00407***	0.0234***
	(0.000575)	(0.00537)	(0.00583)	(0.000810)	(0.00554)
LNSAV_GDP	-8.21×10^{-6}	0.000199	0.00180	0.000105	0.000199
	(0.000979)	(0.00137)	(0.00134)	(0.00113)	(0.00101)
Constant	0.0471***	−0.163*	−0.107	0.0396**	−0.163
	(0.0116)	(0.0859)	(0.108)	(0.0159)	(0.0996)
Observations	2246	2246	2246	2246	2246
Country FE	NO	YES	YES	NO	YES
Year FE	NO	NO	YES	NO	NO
Adj R2	0.986	0.922	0.928	0.926	0.927
Number of Countries		127	127	127	127

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

Table 5 Driscoll and Kraay Standard Error Estimation (SCC) results are the appropriate technique with a coefficient of −0.0423 for financial development, which indicates a negative effect of financial development across countries on the sustainable development of any country. These results suggest that increased financial development harms sustainable development, implying that countries with more advanced financial systems might struggle to maintain sustainability. At the

same time, population has a positive significant relationship, implying that sustainable development is attained with more population with 0.0234 enhancement per unit change. These results indicate that an increase in population is associated with higher levels of sustainable development, suggesting that larger populations might drive initiatives and economies toward more sustainable practices.

These results also indicated a significant negative association between trade openness and sustainable development, with a coefficient of −0.00629, implying that the more countries are open towards trade, the less sustainable development is. Countries with more open trade policies might experience challenges maintaining sustainable development, possibly due to heightened competition or resource exploitation. Also, more growth countries are less on sustainable development due to a negative significant coefficient. Higher economic growth might negatively impact sustainable development, possibly due to increased resource consumption or environmental degradation associated with rapid economic expansion. The Digitalization variable has a positive insignificant impact on sustainable development.

Also, countries with more foreign direct investment inflows are less on sustainable development due to a negative insignificant coefficient. While it may seem intuitive to correlate increased FDI with decreased sustainability due to resource exploitation and environmental degradation concerns, the reality is far more complex. Several factors contribute to this dynamic. Firstly, the nature of FDI varies widely across sectors and industries, with some investments promoting sustainability through technology transfer, knowledge spillovers, and adopting environmentally friendly practices. Conversely, FDI in resource-intensive sectors may exacerbate environmental degradation if not properly regulated. Secondly, the effectiveness of regulatory frameworks and governance structures significantly influences the impact of FDI on sustainable development. Weak regulations or inadequate enforcement may fail to mitigate adverse environmental and social externalities associated with FDI, while robust regulatory mechanisms can help ensure that investments align with sustainability goals.

Table 6 Compare results by stepwise introducing different facets of financial development in the primary model. We used two different facets of the financial development index, the Financial Institutions Index (FI) and the Financial Markets Index (FM), for further detailed analysis of the role of markets and institutions in sustainable development. **Table 6** results revealed that the coefficient for financial markets and financial institutions are consistently negative and statistically significant at the 1% level, meaning an increase tends to have a detrimental effect on sustainable development. Countries with more advanced financial systems, markets, and institutions might struggle to maintain sustainability.

Table 6. Comparing results for sustainable development as dependent variable using different facets of financial development.

	(1)	(2)	(3)
VARIABLES	**SCC**	**SCC**	**SCC**
L.SDI	0.932***	0.941***	0.931***
	(0.0231)	(0.0229)	(0.0229)
FI	−0.0219**	−0.0262**	
	(0.00915)	(0.00987)	
FM	−0.0215**		−0.0233***
	(0.00807)		(0.00821)
LNDIGECO	0.000942	0.000590	0.000942
	(0.000674)	(0.000750)	(0.000678)
LNTO	−0.00626**	−0.00682**	−0.00719**
	(0.00285)	(0.00294)	(0.00290)
LNNR	0.00113	0.00110	0.000942
	(0.000687)	(0.000744)	(0.000637)
LNGDP	−0.00577***	−0.00499**	−0.00798***
	(0.00181)	(0.00196)	(0.00173)
LNER	0.000422	0.000839	0.000367
	(0.000539)	(0.000638)	(0.000588)
LNFDI	−0.000657	−0.000969	−0.000476
	(0.000787)	(0.000859)	(0.000780)
LNINF	−0.000339	−0.000366	−0.000206
	(0.000482)	(0.000450)	(0.000488)
LNPOPT	0.0233***	0.0213***	0.0265***
	(0.00538)	(0.00509)	(0.00586)
LNSAV_GDP	0.000203	0.000296	0.000298
	(0.00100)	(0.00102)	(0.00104)
Constant	−0.163	−0.157	−0.166
	(0.0997)	(0.0993)	(0.103)
Observations	2246	2246	2246
Number of groups	127	127	127
Country FE	YES	YES	YES
Year FE	NO	NO	NO
Adj R2	0.927	0.926	0.927

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

4. Discussion

The regression analysis results shed light on the intricate relationship between various economic and demographic factors and sustainable development. The findings reveal a nuanced picture; wherein certain variables exert significant influence while others exhibit less discernible effects. Firstly, the negative and

statistically significant coefficient associated with financial development underscores a potential challenge: as financial systems become more sophisticated, there may be a tendency for sustainability efforts to face obstacles in alignment with Archer et al. (2023) and Nguyen and Phan (2023). The efforts to foster sustainable development must carefully navigate the complexities of financial structures to ensure they align with sustainability goals. Conversely, the positive and significant relationship between population growth and sustainable development implies that larger populations may drive initiatives and economies toward more sustainable practices. However, the negative association between trade openness and sustainable development raises concerns, suggesting that countries with open trade policies may encounter difficulties in maintaining sustainability, potentially due to increased competition or resource exploitation in alignment with Meng et al. (2022) and Chien et al. (2023).

Similarly, the negative coefficient for GDP growth highlights the dilemma faced by rapidly growing economies, wherein the pursuit of economic expansion may inadvertently undermine sustainability efforts, as Wang et al. (2023). Interestingly, the Digitalization variable does not significantly impact sustainable development based on the variables considered in the analysis, indicating a need for further exploration into the intersection of digital innovation and sustainability in alignment with Luo et al. (2023). Overall, these findings underscore the multidimensional nature of sustainable development and emphasize the importance of crafting holistic policies that balance economic growth with environmental and social considerations to foster enduring sustainability.

5. Conclusion

The complex interconnection of the Digitalization, trade openness, financial development, and sustainable development was elaborated on in this research. Our research uncovered areas of strength for a connection between the manageable turn of events and the development of the computerized economy as a head main thrust. With the advanced change in numerous nations, the utilization of innovation in the public monetary texture, without a doubt, makes it feasible for the improvement of supportability markers to be pointedly increased. The requirement for improving computerized foundation and proficiency if one economy supported improvement. Surprisingly, trade openness, usually perceived as an engine of economic growth, was negatively related to sustainable development. These conflicts with standard assessment and feature the significance of approaches that make global exchange traditionalist to naturally feasible goals. A harmony between being financially open and naturally capable is necessary for a manageable worldwide future.

Notwithstanding, in our examination, there was a significant negative connection between monetary development and monetary turn of events. It then prompts checking on, for example, how monetary frameworks help or beat practical tasks down. Spellbinding insights and a connection framework helped gain an underlying handle on information scattering designs between factor relations. Especially the backward connection between the advanced economy and the SDI expanded inquiries that the scientists evaluated through the pooled OLS, fixed

impacts, irregular impacts, and SCC. The relapse results reliably featured the computerized economy's negative coefficient across various models, stressing its likely effect on maintainable development.

Here are some policy recommendations regarding the study, such as implementing policies to promote and encourage digital entrepreneurship with incentives to small businesses and start-up entrepreneurs utilizing digital technologies to generate green products. Put resources into programs that advance computerized education and inclusivity by furnishing individuals with the essential capacities and apparatuses for exploiting the advanced economy, accomplishing through instructive undertakings and local area-based outreaches. Coordinate maintainability provisions with worldwide exchange agreements that point toward convincing associational states not to penetrate the green guidelines and good work standards. Monetary receptiveness should remain closely connected with the world's goal of supportability. Concoct arrangements pointed toward expanding monetary incorporation to allow more individuals to enter monetary administrations. Microfinance projects and electronic financial administrations are examples. Tart carbon offset programs connected with global exchange, wherein firms engaged with worldwide exchanges will be urged to balance their fossil fuel byproducts with reasonable natural drives.

Author contributions: Conceptualization, NS, WM, MM and HM; methodology, NS, MM and HM; software, WM and MM; validation, WM, HM and MBM; formal analysis, NS, WM, MM and MBM; investigation, WM and HM; resources, NS, WM and MM; data Scuration, WM and MBM; writing—original draft preparation, NS, WM, HM, MM and MBM; writing—review and editing, NS and WM; visualization, WM, HM and MM; supervision, NS; project administration, WM, and NS; funding acquisition, MBM. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

References

Ahmad, K., Irshad Younas, Z., Manzoor, W., et al. (2023). Greenhouse gas emissions and corporate social responsibility in USA: A comprehensive study using dynamic panel model. Heliyon, 9(3), e13979. https://doi.org/10.1016/j.heliyon.2023.e13979

Ahmed, F., Kousar, S., Pervaiz, A., et al. (2022). Do institutional quality and financial development affect sustainable economic growth? Evidence from South Asian countries. Borsa Istanbul Review, 22(1), 189–196. https://doi.org/10.1016/j.bir.2021.03.005

Archer, C., & Idun, A. A.-A. (2023). Financial outreach, financial innovation, and sustainable development in Africa. Environmental Science and Pollution Research, 30(26), 69393–69415. https://doi.org/10.1007/s11356-023-27304-7

Bokpin, G. A. (2017). Foreign direct investment and environmental sustainability in Africa: The role of institutions and governance. Research in International Business and Finance, 39, 239–247. https://doi.org/10.1016/j.ribaf.2016.07.038

Borio, C. (2011). Rediscovering the Macroeconomic Roots of Financial Stability Policy: Journey, Challenges, and a Way Forward. Annual Review of Financial Economics, 3(1), 87–117. https://doi.org/10.1146/annurev-financial-102710-144819

Campiglio, E., Dafermos, Y., Monnin, P., et al. (2018). Climate change challenges for central banks and financial regulators. Nature Climate Change, 8(6), 462–468. https://doi.org/10.1038/s41558-018-0175-0

Chien, F., Paramaiah, C., joseph, R., et al. (2023). The impact of eco-innovation, trade openness, financial development, green energy and government governance on sustainable development in ASEAN countries. Renewable Energy, 211, 259–268. https://doi.org/10.1016/j.renene.2023.04.109

Churchill, S. A., Inekwe, J., Ivanovski, K., et al. (2018). The Environmental Kuznets Curve in the OECD: 1870–2014. Energy Economics, 75, 389–399. https://doi.org/10.1016/j.eneco.2018.09.004

Coase, R. H. (1937). The Nature of the Firm. The Nature of the Firm. Economica, 4(16), 386–405. Portico. https://doi.org/10.1111/j.1468-0335.1937.tb00002.x

Dupuy, L., & Agarwala, M. (2014). International trade and sustainable development. Handbook of Sustainable Development. https://doi.org/10.4337/9781782544708.00038

Eisenmenger, N., Pichler, M., Krenmayr, N., et al. (2020). The Sustainable Development Goals prioritize economic growth over sustainable resource use: a critical reflection on the SDGs from a socio-ecological perspective. Sustainability Science, 15(4), 1101–1110. https://doi.org/10.1007/s11625-020-00813-x

Fenner, R., & Cernev, T. (2021). The implications of the Covid-19 pandemic for delivering the Sustainable Development Goals. Futures, 128, 102726. https://doi.org/10.1016/j.futures.2021.102726

Geels, F. W. (2018). Disruption and low-carbon system transformation: Progress and new challenges in socio-technical transitions research and the Multi-Level Perspective. Energy Research & Social Science, 37, 224–231. https://doi.org/10.1016/j.erss.2017.10.010

Gorus, M. S., & Aslan, M. (2019). Impacts of economic indicators on environmental degradation: Evidence from MENA countries. Renewable and Sustainable Energy Reviews, 103, 259–268. https://doi.org/10.1016/j.rser.2018.12.042

Haseeb, A., Xia, E., Danish, Baloch, M. A., et al. (2018). Financial development, globalization, and CO_2 emission in the presence of EKC: evidence from BRICS countries. Environmental Science and Pollution Research, 25(31), 31283–31296. https://doi.org/10.1007/s11356-018-3034-7

Hickel, J. (2020). The sustainable development index: Measuring the ecological efficiency of human development in the anthropocene. Ecological Economics, 167, 106331. https://doi.org/10.1016/j.ecolecon.2019.05.011

Irshad, A. R., Safdar, N., & Manzoor, W. (2023). Predicting Efficiency of Innovative Disaster Response Practices: Case Study of China's Corporate Philanthropy. Sustainability, 15(3), 2031. https://doi.org/10.3390/su15032031

Irshad, A. R., Safdar, N., Younas, Z. I., et al. (2023). Impact of Corporate Governance on Firms' Environmental Performance: Case Study of Environmental Sustainability-Based Business Scenarios. Sustainability, 15(10), 7775. https://doi.org/10.3390/su15107775

Ji, X., Zhang, Y., Mirza, N., et al. (2021). The impact of carbon neutrality on the investment performance: Evidence from the equity mutual funds in BRICS. Journal of Environmental Management, 297, 113228. https://doi.org/10.1016/j.jenvman.2021.113228

Karimov, M. (2020). An Empirical Analysis of the Relationship among Foreign Direct Investment, Gross Domestic Product, CO_2 Emissions, Renewable Energy Contribution in the context of the Environmental Kuznets Curve and Pollution Haven Hypothesis Regarding Turkey. European Journal of Engineering and Formal Sciences, 4(1), 110. https://doi.org/10.26417/ejef.v4i1.p110-123

Khan, M. A, Safdar, N., & Manzoor, W. (2024). Financial Reporting Quality and Investment Efficiency: A Transnational Evidence Pakistan Journal of Commerce and Social Sciences. 18(2), 285-305

Loorbach, D., Frantzeskaki, N., & Avelino, F. (2017). Sustainability Transitions Research: Transforming Science and Practice for Societal Change. Annual Review of Environment and Resources, 42(1), 599–626. https://doi.org/10.1146/annurev-environ-102014-021340

Luo, S., Yimamu, N., Li, Y., et al. (2022). Digitalization and sustainable development: How could digital economy development improve green innovation in China? Business Strategy and the Environment, 32(4), 1847–1871. Portico. https://doi.org/10.1002/bse.3223

Manzoor, W., Safdar, N., & Mahmood, H. Z. (2021). A gravity model analysis of international migration from BRIC to OECD countries using Poisson Pseudo-maximum likelihood Approach. Heliyon, 7(6), e07357. https://doi.org/10.1016/j.heliyon.2021.e07357

Manzoor, W., Safdar, N., & Mahmood, H. Z. (2021b). Research on Economic Development of BRIC Countries Concerning Globalisation, Trade and FDI. Indian Journal of Economics and Business, 20(2).

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. Research Policy, 41(6), 955–967. https://doi.org/10.1016/j.respol.2012.02.013

Meng, Y., Wu, H., Wang, Y., et al. (2022). International trade diversification, green innovation, and consumption-based carbon emissions: The role of renewable energy for sustainable development in BRICST countries. Renewable Energy, 198, 1243–1253. https://doi.org/10.1016/j.renene.2022.08.045

Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. Cogent Social Sciences, 5(1). https://doi.org/10.1080/23311886.2019.1653531

Moutinho, V., Madaleno, M., & Elheddad, M. (2020). Determinants of the Environmental Kuznets Curve considering economic activity sector diversification in the OPEC countries. Journal of Cleaner Production, 271, 122642. https://doi.org/10.1016/j.jclepro.2020.122642

Nguyễn, H. V., & Phan, T. T. (2023). Impact of economic growth, international trade, and FDI on sustainable development in developing countries. Environment, Development and Sustainability. https://doi.org/10.1007/s10668-023-04060-9

Nguyen, H. V., Phan, T. T., & Lobo, A. (2019). Debunking the Myth of Foreign Direct Investment toward Long-Term Sustainability of a Developing Country: A Transaction Cost Analysis Approach. Sustainability, 11(17), 4569. https://doi.org/10.3390/su11174569

Ogege, S. (2019). Analysis of the Impact of Inflation, Interest Rate and Exchange Rate on Economic Development. International Journal of Commerce and Finance, 5(1), 121-132.

Qiao, H., Kang, Y., Yan, J., et al. (2023). What role does trade expansion play in the natural resource sustainability of highly resource-consuming countries? Testing Moderating Role of Exports and Innovation. Resources Policy, 82, 103424. https://doi.org/10.1016/j.resourpol.2023.103424

Rana, R., & Sharma, M. (2020). Dynamic Causality Among FDI, Economic Growth and CO_2 Emissions in India With Open Markets and Technology Gap. International Journal of Asian Business and Information Management, 11(3), 15–31. https://doi.org/10.4018/ijabim.2020070102

Sadorsky, P. (2011). Financial development and energy consumption in Central and Eastern European frontier economies. Energy Policy, 39(2), 999–1006. https://doi.org/10.1016/j.enpol.2010.11.034

Sbia, R., Shahbaz, M., & Hamdi, H. (2014). A contribution of foreign direct investment, clean energy, trade openness, carbon emissions and economic growth to energy demand in UAE. Economic Modelling, 36, 191–197. https://doi.org/10.1016/j.econmod.2013.09.047

Sethi, P., Chakrabarti, D., & Bhattacharjee, S. (2020). Globalization, financial development and economic growth: Perils on the environmental sustainability of an emerging economy. Journal of Policy Modeling, 42(3), 520–535. https://doi.org/10.1016/j.jpolmod.2020.01.007

Shahbaz, M., Balsalobre-Lorente, D., & Sinha, A. (2019). Foreign direct Investment–CO_2 emissions nexus in Middle East and North African countries: Importance of biomass energy consumption. Journal of Cleaner Production, 217, 603–614. https://doi.org/10.1016/j.jclepro.2019.01.282

Shahbaz, M., Nasir, M. A., & Roubaud, D. (2018). Environmental degradation in France: The effects of FDI, financial development, and energy innovations. Energy Economics, 74, 843–857. https://doi.org/10.1016/j.eneco.2018.07.020

Sustainable development index. (2019). Sustainable development index. Available online: https://www.sustainabledevelopmentindex.org/ (accessed on 3 May 2023).

Taghizadeh-Hesary, F., & Yoshino, N. (2020). Sustainable Solutions for Green Financing and Investment in Renewable Energy Projects. Energies, 13(4), 788. https://doi.org/10.3390/en13040788

Thomä, J., Murray, C., Jerosch-Herold, V., et al. (2019). Do you manage what you measure? Investor views on the question of climate actions with empirical results from the Swiss pension fund and insurance sector. Journal of Sustainable Finance & Investment, 11(1), 47–61. https://doi.org/10.1080/20430795.2019.1673142

Wang, R., Laila, U., Nazir, R., et al. (2023). Unleashing the influence of industrialization and trade openness on renewable energy intensity using path model analysis: A roadmap towards sustainable development. Renewable Energy, 202, 280–288. https://doi.org/10.1016/j.renene.2022.11.035

Williamson, O. E. (1979). Transaction-Cost Economics: The Governance of Contractual Relations. The Journal of Law and Economics, 22(2), 233–261. https://doi.org/10.1086/466942

Yang, J., Wan, Y., & Shen, S. (2023). Research on the impact of exchange rates and interest rates on carbon price changes in the context of sustainable development. Frontiers in Ecology and Evolution, 10. https://doi.org/10.3389/fevo.2022.1122582

Yang, Q., Ma, H., Wang, Y., et al. (2022). Research on the influence mechanism of the digital economy on regional sustainable development. Procedia Computer Science, 202, 178–183. https://doi.org/10.1016/j.procs.2022.04.025

Appendix

Table A1. Definitions of Variables.

Variables	Description	Acronyms	Data Source
Digitalization	Mobile cellular Subscriptions (per 100 people)	DIGIECO	WDI
Trade Openness	Imports of goods and services (% of GDP) Exports of Goods and services (% of GDP)	TO	WDI
Financial Development Index	Financial Institutions Access Index Financial Institutions Depth Index Financial Institutions Efficiency Index Financial Institutions Index (FI) Financial Markets Access Index Financial Markets Depth Index Financial Markets Efficiency Index Financial Markets Index (FM)	FD	IMF
Sustainable Development Index	Life Expectancy(years) Expected years of schooling Mean years of schooling GNI per capita 2017$ PPP CO_2 emissions per capita (tones) Mat. Footprint per capita (tones)	SDI	For methodology and rationale, see Hickel 2020
Exchange Rate	Official exchange rate (LCU per US$, period average)	ER	WDI
Foreign Direct Investment	Foreign direct investment, net inflows (% of GDP)	FDI	WDI
Innovation	Patent applications, residents[IP.PAT.RESD]	INN	WDI
Population	Population growth (annual %)	POPT	WDI
Inflation	Inflation, GDP deflator (annual %)	INF	WDI
Natural Resource	Total Natural resource rents (% of GDP)	NR	WDI
Savings	Gross savings(% of GDP)	SAV_GDP	WDI
Gross Domestic Product	GDP (Current US$)	GDP	WDI