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Developing and Validating Multidimensional Indices for Sustainability, FinTech Adoption, Green Finance, and Governance Quality

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ABSTRACT
The growing complexity of the world economic, technological, environmental, and institutional systems demands the use of evaluation tools that reflect the interrelationship character of sustainable development. The paper constructs and confirms four composite metrics FinTech Adoption, Green Finance, Sustainable Performance, and Quality of Governance through a wide range of internationally recognized indicators. FinTech Adoption is evaluated using the indicators of digital and traditional access to finance such as ATMs, use of the internet, mobile subscriptions, and commercial bank branch. Adjusted net savings, renewable energy use, and CO2 emissions represent the three components that form Green Finance, whereas economic, environmental, and social sub-dimensions constitute Sustainable Performance. The World Governance Indicators include Regulatory Quality, Rule of Law, Government Effectiveness and Political Stability, used to evaluate Governance Quality. To establish the reliability, adequacy and the structural coherence of the indexes, the research design utilizes correlation analysis, KMO test, Sphericity Bartlett test, Principal component analysis (PCA) and Cronbach alpha test. The data indicate high scores on the internal consistency and high factor loading, which proves the multidimensional indices as effective instruments to be used in comparative analysis. These built indices offer an integrated field of empirical study that enhances the insight into the interaction between FinTech creation, environmental financial framework, sustainable performance, and governance among nations and a considerable policy application to digital transformation approaches, climate financing, sustainability planning, and institutional reforms.

Keyword: Fintech Adoption, Green Finance, Sustainable Performance, World Governance indicators, PCA, KMO,

Introduction

The concept of sustainable performance has emerged as one of the main objectives in international policymaking as nations deal with the Internet revolution and climate change. Innovation in technologies particularly in the finance sector is transforming economies due to the revolution of ways individuals access financial services and how they engage on a digital platform. FinTech is regarded as an engine of inclusion, efficiency, and modernization, primarily in the less developed economies (Solarz &

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Swacha, 2021). Simultaneously, green finance is what is needed to address climate change and environmental damages as it urgently pushes nations to invest their funds in ecologically safe activities and low-carbon roadways (Wang & Zhi, 2021).

Sustainable performance nowadays is calculated through economic, environmental and social metrics as they provide more comprehensive information of national development (Yan et al., 2022). Contemporary developmental models put emphasis on nature stewardship, equitable social development and community ecological well being. Such holistic development is dependent on effective governance which formulates, applies as well as enforces inclusive and sustainable policies. The origin of sustainable development is commonly considered to be rule of law, political stability, institutional effectiveness, and regulatory performance that is known as governance quality.

When discussing FinTech, green finance, sustainability performance, and governance, researchers have examined them in isolation, not in combinations (Dhanabhakyam & Suresh, 2024; Zhang et al., 2025). There are very limited studies that integrate these dimensions into a cohesive framework demonstrating their interaction (Phan et al., 2020). In addition, most indices are not rigorously validated, dimension reduced, and consistent. This distance hinders the efforts of the researchers and policymakers who require cross-country comparisons or evidence-based interventions (Nguyen et al., 2022). To address this weakness, we have come up with four multidimensional composite indices based on internationally recognized proxies and tested them through the use of strong statistical measures. They are correlation analysis, tests on KMO and Bartlett, Principal Component Analysis, and Cronbach's Alpha (Hair et al., 2019; Hoffmann et al., 2008). The FinTech Adoption (FA), Green Finance (GF), Sustainable Performance (SP) and Governance Quality (WGI) indices offer a holistic and methodologically sound mechanism of evaluating development in technology, environment, socioeconomics and institutions (Arner et al., 2015; Sachs et al., 2023; Kaufmann et al., 2011). The combination of these indices is a complete system to measure the development of countries, identify their strengths and weaknesses, and make imperial policy decisions that further the spread of digitalization, climate sustainability, and institutional transformation (Hoffmann et al., 2008; United Nations, 2023).

Literature Review

FinTech Adoption

The use of FinTech has been used as one of the most important enablers to present-day financial ecosystems. It provides affordable, convenient and efficient services that increase financial inclusion and enable economic growth. Two principal drivers of FinTech adoption, mentioned in literature, include digital penetration (measured in Internet-use and mobile subscription), and financial-access structure, including ATM-machines and bank-branches (Sahay et al., 2020; Arner et al., 2020). Online financial skills and digital literacy are created through diffusion of the internet. Mobile subscriptions show they have a market that is experiencing mobile banking, digital payment, and apps. Although ATMs and bank branches are not a novel concept, they continue to be a significant proxy to location, particularly in developing areas where hybrid financial systems tend to be prevalent (Demirguc-Kunt et al., 2018).

Green Finance

Green finance is one of the important answers to climate change and environmental degradation. It is channelling funds to green infrastructure and renewable energy and green projects (Wang et al., 2023). Adjusted net savings represent environmental and

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economic sustainability in long term since resource depletion and pollution damages are included on national saving rates. The use of renewable-energy is a crucial indicator of the development of green-transitions, whereas the CO2 emissions are the universal standard of environmental influence. It has been empirically demonstrated that the green financing practice contributes to the reduction of emissions, enhancement of energy efficiency, and advancement of low-carbon technologies (Apergis & Payne, 2016). However, the research in green finance is usually divided so that comparing countries is not easy. Very minimal studies create composite indices combining ecological savings, renewable energy utilisation, and emissions, therefore there is need of a multidimensional, standardised measure.

Sustainable Performance

The triple bottom line (TBL) theory is the basis of the sustainable performance (Elkington, 1997). It deals with economic, environmental, and social spheres. The economic indicators that address stability and growth potential are economic indicators such as the GDP per capita, unemployment, and inflation. Ecological integrity and resource resilience is indicated by environmental flagons, including forest area, withdrawals of freshwater and PM 2.5 pollution. The well-being, inclusiveness and human development are well taken care of in the social indicators, life expectancy, health expenditure and political representation by women.

Many researchers point out that these aspects are linked, since environmental health and social stability tend to be the subjects of economic performance (Jan et al., 2021; Ikram & Akhtar, 2021). The exposure to risk in terms of sustainability in the long term of the countries of high ecological degradation is increased, whereas the support in society enhances the effectiveness of performance and resilience. Composite sustainability indices are increasingly demanded by the literature, whereas a lack of commonality between methods leading to inconsistencies in measurement (Sachs et al., 2023; Zhang et al., 2022). In this work, the inconsistencies are resolved by creating an index through the principal component analysis (PCA).

Governance Quality

The quality of governance defines institutional power, effectiveness of policies and national resilience. The World Governance Indicators (WGI), including the quality of regulatory, rule of law, governmental effectiveness and political stability are well utilized in order to measure the institutional performance (Kaufmann et al., 2011). Good governance enhances digitalization, growth of financial markets, sustainability of the environment, and social wellbeing.

Research indicates that good governance fosters economic expansion, lowers down corruption, increases the predictability of the regulations and aids the activities of the green finance (Zeng, 2019). Good institutions also assist the attainment of successful implementation of environmental regulations and climate policies which mediate the process of transition to sustainability. However, there are hardly any empirical studies which incorporate governance indicators in a composite index which has been authenticated through multivariate means.

The technological growth of FinTech is associated with increased access of financial services, reduced transaction and transaction costs, as well as increased economic inclusivity (Solarz & Swacha, 2021). Recent research has put greater emphasis on the contribution of FinTech to speeding up sustainable finance, fostering ESG investments, and green access to digital financing solutions (Zhang et al., 2022). Nevertheless, the

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absence of a common composite index of the use of FinTech is a hindrance to comparative study and comparative analysis over countries.

Research Gap Identification

Despite the comprehensive studies of FinTech, green finance, sustainable performance, and governance, as well as the existing gaps in research of their combination in terms of dynamics, it is evident that there is a significant gap in validated multidimensional indices that would include their interaction. Lack of PCA-composite scales restricts the benchmarking of across-country as well as the development of comprehensive sustainability models. This paper accomplishes these gaps through the empirical estimation of statistically tested indices of each domain in terms of internationally recognized proxies.

Methodology

The design used in the research, along with the data format employed in the study, is as follows:

This analysis is based on a set of panel data of 85 countries between 2004 and 2023. Panel data are a combination of cross-sectional variability (differences by country), as well as dynamics in the data (changes over time), which will increase the strength of indices. All the index construction procedures, including correlation analysis, KMO, the Bartlett test, PCA, and Cronbach Alpha, were carried out on pooled standardized values of every proxy in the complete panel, to eliminate year specificity. This is done according to the developed cross-country sustainability procedures (Sala et al., 2015; Moldan et al., 2012).

The source of data is World Bank, UN databases, World development indicators, and Worldwide Governance Indicators (WGI) repository. All variables were first transformed into standardized z -scores prior to analysis so that scale differences between proxies can be eliminated.

Variable Operationalization

The operationalization of variables will entail variables, such as the use or rejection of a contingent leadership approach.

FinTech Adoption (FA)

The digitization of the financial system and the presence of a conventional financial system are captured using 4 World Development Indicators which are used to measure FinTech adoption. Online financial services and mobile financial services are essential digital enablers, which are internet usage (FA2) and mobile cellular subscriptions (FA3). Density of ATMs (FA1) and branch of commercial banks (FA4) are the basic financial infrastructure which facilitates or leads the user to the digital platforms. The four proxies can collectively be used as a concise and comprehensive economic gauge in respect to the adoption of FinTech in the nations (Sarma & Pais, 2011; Park & Mercado, 2018; Asongu & Nwachukwu, 2017; Demirgüç-Kunt et al., 2018)

Green Finance (GF)

Three indicators of the environment-economic outcomes are employed by green finance, rather than the actual transversal of financial streams. True savings and using sustainable resources are adjusted net savings, including particulate-emission damage (GF1). Renewable energy usage (GF2) demonstrates the magnitude of clean transition on green investments. An inverse proxy is the CO2 emission without LULUCF (GF3), which is a

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measure of the efficiency of low-carbon investment activity. Combined, these indicators can be used to give a brief, result based comparison of green finance amongst economies (Becker & Ólafsdóttir, 2023; Apergis & Payne, 2016; Meo & Abd Karim, 2022)

Sustainable Performance (SP)

Sustainable Performance (SP) is an evaluation of the potential of a country to have equitable economical, environmental and social performance in the long duration. It has a three-pillar composite structure. The economic pillar (EcI) is used to test financial stability and productivity with reference to GDP per capita, unemployment and inflation (Jan et al., 2021; Ikram & Akhtar, 2021; Hussain et al., 2018). The ecological pillar (EnI) measures the ecological well being through the area of the forests, freshwater abstraction and PM 2.5 content (Shiklomanov & Rodda, 2003; Xiong & Dai, 2023; Keeler et al., 2012). Social pillar (SI) embodies the human well-being in terms of life expectancy, capita spending on health, and the number of women in national parliaments (Murphy, M. 2001; Dieleman et al., 2018; Hickel, 2020; Asfahani et al., 2023; Ferreira & Marques, 2021; Salinas Fernández et al., 2014) Combined, these indicators provide a whole picture overview of the performance of sustainable development on a country-by-country level.

Governance Quality (WGI)

The quality of governance would be measured using four dimensions of the Worldwide Governance Indicators which are the regulatory quality, the rule of law, government effectiveness and political stability (Kaufmann et al., 2011; Han & Khan, 2014). These dimensions reflect the effectiveness and integrity of institutions in a country, and the focus is put on transparency, accountability, and policy efficacy. The presence of strong governance enhances the application of fintech and green finance policies and makes them more efficient in promoting sustainable performance.

Index Construction Method

To analyse the data, our paper will build green finance, fintech adoption, governance indicators, and sustainable performance indexes. The process of constructions has three steps.

Step 1: Data Normalization

The Min-Max scaling was used to normalize all of the proxy variables to allow them to be comparable, as per (Mazziotta & Pareto, 2022; Sharma & Bandyopadhyay 2023). The formula here is:

$$X_{norm} = (X_i - X_{min})/(X_{max} - X_{min})$$

Negative impacting variables (e.g., CO2 emissions, unemployment, PM2.5 pollution, etc.) were scaled back (1 -Xnorm)

Step 2: PCA estimation of the weight.

Principal Component Analysis, which followed the normalization, established the contribution made by each proxy to its construct (Zheng et al., 2024; Ghanem, 2025; Zhang et al., 2024).

Step 3: Index Development.

By averaging, weighted by the weight of the proxies derived according to PCA, the indices were derived. The last deliverable was an integrated Sustainable Performance Index which integrates the environmental, social, and economic aspects.

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Index Validation

When multiple indicators are used to measure composite indicators, they must be validated in order to show that they are reliable representations of the underlying constructs. There are two uses of validation, (i) to determine the internal consistency between the constituent indicators, or (ii) to determine if the data are suitable to be measured as a single indicator. We used correlation analysis, Principal Component Analysis, Cronbachs alpha, and Bartlett test to perform the validation in this study (Zheng et al., 2024; Udeagha & Muchapondwa, 2023; Rusu & Oprean-Stan, 2025).

Results

Descriptive Statistics

The descriptive analysis means that there are great differences in countries as time progresses with varying degree of digital financial development, environment practices and quality of governance.

Table 1

Descriptive Statistics of Variables Used in the Study

Variable Name	Observations	Mean	Std. Dev.	Minimum	Maximum
Fintech Adoption Index	1,700	0.3335	0.1632	0.0546	0.9469
Green Finance Index	1,700	0.5935	0.0778	0.3464	0.8815
WGI Index (Governance)	1,700	0.4965	0.2450	0.0145	0.9913
Sustainable Practices Index	1,700	0.5371	0.0997	0.2664	0.8361
Economic Index	1,700	0.4900	0.1082	0.1736	0.9064
Environmental Index	1,700	0.6301	0.1648	0.0190	0.9947
Social Index	1,700	0.5482	0.1667	0.0293	0.9357
Trade Openness (log, % of GDP)	1,700	0.9139	0.5619	0.2211	4.3733
FDI Inflows (log, % of GDP)	1,700	0.0533	0.2496	-4.4471	4.3179
Urban Population (proportion)	1,700	0.6295	0.1905	0.1651	1.0000

Table 1 contains descriptive statistics of 1,700 observations of 85 countries conducted between 2004 and 2023. FinTech Adoption Index has a middle range (mean) of 0.3335 (SD = 0.1632) which shows that technology is not evenly spread across countries as it would be expected based on (Sahay et al., 2020). The average figure is 0.5935; however, there is a large range (0.3464-0.8815) indicating that lots of countries continue to fall behind on the concept of sustainable finance (Zhang et al., 2022). Governance Quality Index (WGI) has an average of 0.4965 having a great spread (SD = 0.2450), which indicates a distinction in institutions (Kaufmann et al., 2011). The overall mean of the Sustainable Performance Index (SP) is 0.5371; an analysis of its sub elements demonstrates that the environmental performance (0.6301) is better than social (0.5482) and economic performances (0.4900) due to the increasing focus on the environmental

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policy globally (Wang and Zhi, 2021).

Correlation Analysis

Conceptual consistency and linear relationships were ensured with the generation of correlation matrices between each group of indicators. The preliminary step is the correlation analysis that investigates the pairwise relational linkage for proxies within each construct (FA1 to FA4 of FinTech Adoption; GF1 to GF3 of green finance; SPEcI1 to SPEcI3 of sustainable economic performance; SPSI1 to SPSI3 of environmentally sustainable performance; SPSI1 to SPSI3 of social sustainable performance and WGI1 to WGI4 of world governance indicators). Strong, statistically significant correlations are relevant to indicate that the measures of the indicators reflect related variables of the same concept (Hair et al., 2019). Nevertheless, high correlations can be a sign of redundancy.

Table 2

Pearson correlations among study variables

Panel A

FinTech adoption proxies

Variable	norm_atm	norm_iui	norm_mcs	norm_cbb
1. norm_atm	1.0000			
2. norm_iui	.63*** (.000)	1.0000		
3. norm_mcs	.43*** (.000)	.71*** (.000)	1.0000	
4. norm_cbb	−.48*** (.000)	−.35*** (.000)	−.30*** (.000)	1.0000

Panel B

Green Finance Proxies

Variable	norm_ans	norm_rec	norm_co2e
1. norm_ans	1.0000		
2. norm_rec	−.31*** (.000)	1.0000	
3. norm_co2e	−.11*** (.000)	.17*** (.000)	1.0000

Panel C

World Governance Indicators Proxies

Variable	norm_rq	norm_rl	norm_ge	norm_ps
1. norm_rq	1.0000			
2. norm_rl	.95*** (.000)	1.0000		
3. norm_ge	.95*** (.000)	.96*** (.000)	1.0000	
4. norm_ps	.78*** (.000)	.79*** (.000)	.76*** (.000)	1.0000

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Panel D

Sustainable Performance Proxies

Variable	norm_gdp	norm_ur	norm_icp	norm_fa	norm_fww	norm_aq	norm_le	norm_he	norm_ws
1. norm_gdp	1.0000								
2. norm_ur	.20*** (.000)	1.0000							
3. norm_icp	.31*** (.000)	−.03 (.175)	1.0000						
4. norm_fa	.07** (.004)	.03 (.183)	.12*** (.000)	1.0000					
5. norm_fww	.08** (.001)	.03 (.302)	.16*** (.000)	.23*** (.000)	1.0000				
6. norm_aq	.49*** (.000)	.02 (.460)	.28*** (.000)	.35*** (.000)	.37*** (.000)	1.0000			
7. norm_le	.64*** (.000)	.21*** (.000)	.42*** (.000)	.14*** (.000)	.03 (.184)	.46*** (.000)	1.0000		
8. norm_he	.93*** (.000)	.18*** (.000)	.31*** (.000)	.08*** (.001)	.08*** (.001)	.50*** (.000)	.61*** (.000)	1.0000	
9. norm_ws	.40*** (.000)	.06* (.014)	.13*** (.000)	.06* (.010)	.13*** (.000)	.37*** (.000)	.29*** (.000)	.43*** (.000)	1.0000

Correlational analysis shows that there are some noteworthy trends. FinTech adoption proxies indicate that there are very high interrelations of all measures, the highest relationship is between internet use and mobile banking ($r = .71$, $p < .001$). The only variable that is correlated negatively with the ATM, internet, and mobile banking usages is credit bureau coverage, which reveals that the increase in the coverage of credit information may drive the decrease in the use of these channels. The relationships between green finance proxies are mostly weak but significant, and moderate. The relation between renewable energy consumption and both adjusted net savings and CO2 emission is negative (r =.17, p <.001) whereas with CO2 emission reduction is positive (r =.17, p =.001) which indicates the possibility of having trade-offs. The indicators of governance show almost equal strong positive correlations ($r = .76$, $p = .001$) of internal coherence of regulatory quality, rule of law, government effectiveness, and political stability. Sustainable proxies of performance demonstrate that the GDP has a strong relationship with health expenditure (r =.93, p =.001) and life expectancy (r =.64, p =.001), where correlation shows the interdependence between economic and social wellbeing. There are also more moderate positive associations between the economic and social indicators and the environment factors, which suggests a tendency that the purity of the environment is the by-product of wider socio-economic benefits.

Sampling Adequacy

Kaiser–Meyer–Olkin (KMO) Test

KMO values ≥ 0.60 indicate sampling adequacy for PCA.

Bartlett's Test of Sphericity

The acceptable significance of chi-square (<0.05) value indicates that correlations are high enough. Along with KaiserMeyerOlkin (KMO) measure of the sampling adequacy

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which measures whether the sampling is adequate to aggregate to factors, the Test of Sphericity is also routinely employed (Kaiser, 1974).

Table 3

Kaiser–Meyer–Olkin (KMO) Measure and Bartlett's Test of Sphericity for Construct Validity

Construct	Variables Included	KMO (Overall)	Bartlett's Test χ^2 (df)	p-value	Sampling Adequacy Interpretation
FinTech Adoption	fa1_atm, fa2_iui, fa3_mcs, fa4_cbb	0.6679	2,535.72 (6)	< .001	Mediocre – acceptable for factor analysis
Green Finance	gf1_ans, gf2_rec, gf3_co2e	0.6489	2224.56 (3)	< .001	Mediocre – acceptable for factor analysis
Governance	wgi1_rq, wgi2_rl, wgi3_ge, wgi4_ps	0.8515	11,000 (6)	< .001	Excellent – highly suitable for factor analysis
Sustainable Performance	speci1_gdp, speci2_ur, speci3_icp, speni1_fa, speni2_fww, speni3_aq, spsi1_le, spsi2_he, spsi3_ws	0.7438	6,486.31 (36)	< .001	Good – appropriate for factor analysis

KMO and Bartlett were used to determine suitability of data to measure each construct in factor analysis. FinTech adoption construct was medium mediocre 0.6679, which is acceptable (Kaiser, 1974; Bartlett, 1954). The test by Bartlett $\chi^2(6)$ is very significant (2,535.72, $p<.001$), which proved that there was enough inter-variable correlation. The construct of Green Finance produced a KMO value of 0.5489 (moderate adequacy) and a significant Bartlett test $\chi^2(3) = 2{,}224.56$, $p<.001$) and indicated that its indicators correlated significantly. There was a high level of interrelationships that was evidenced by the good sampling adequacy (KMO=0.8515) and highly significant Bartlett test $\chi^2(6) =11000$, $p<.001$). A good KMO of 0.7438 was attained by the Sustainable Performance construct, and the test of Bartlett $\chi^2(36) = 6{,}486.31$, $p<.001$) was significant, which confirmed the great shared variance.

Principal Component Analysis (PCA)

Principal Component Analysis (PCA) can help reveal the underlying variable's structure and check to see whether they will be loaded heavily on one factor (Jolliffe, 2011). The strategy is particularly useful in the study of economy and sustainability research as the concept of FinTech Adoption, Green Finance, and Sustainable Performance, are multidimensional. The use of reliability and factor analysis will make sure that every composite index is theoretically consistent, as well as statistically strong prior to the use in further econometric estimation.

Table 4

Pannel A - Principal Component Analysis for Fintech Adoption Indicators

Variable	Component 1	Component 2	Component 3	Component 4

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Variable	Component 1	Component 2	Component 3	Component 4
norm_atm	0.517	−0.230	0.729	0.385
norm_iui	0.560	0.328	0.104	−0.754
norm_mcs	0.504	0.492	−0.479	0.523
norm_cbb	−0.405	0.773	0.478	0.101
Eigenvalue	2.477	0.803	0.490	0.230
% Variance Explained	61.91%	20.07%	12.25%	5.76%
Cumulative %	61.91%	81.99%	94.24%	100%

PCA of the four Fintech Adoption indicators (normatm, normiui, normmcs, normcbb) indicates that the first principal component has 61.91 percent proposed variance, which is greater than the 50 percent threshold of one-dimensionality (Hair et al., 2019). The four indicators are loaded with over 0.40. Three produces a positive effect; normcbb negative, which is not an exclusion, but a direction of measurement. Interpretive consistency can be applied through the use of reverse coding. These findings confirm that the indicators are the same underlying Fintech Adoption construct, and thus all four are useful to the index.

Pannel B - Principal Component Analysis for Green Finance Indicators

Variable	Component 1	Component 2	Component 3
norm_ans	−0.618	0.424	0.663
norm_rec	0.652	−0.195	0.732
norm_co2e	0.439	0.885	−0.156
Eigenvalue	1.404	0.910	0.685
% Variance Explained	46.82%	30.33%	22.85%
Cumulative %	46.82%	77.15%	100%

Normrec, normco2e and norms describing the green finance in the PCA of normans, normrec, and normco2e have the first one as the normrec that explains the variance of 46.82. This is a value of the interpretation, which is below 50 percent, though relatively reasonable since cumulative variance of the two first components is 77.15 an acceptable value. All loadings are greater than 0.40 suggesting that Adjusted Net Savings (normans), Renewable Energy Consumption (normrec), and Carbon Dioxide Emissions (normco2e) have simultaneous explanatory capacity of the multidimensionality of green finance. Thus, the composite index includes all three proxies.

Pannel C - Principal Component Analysis for Governance Indicators

Variable	Component 1	Component 2	Component 3	Component 4
norm_rq	0.512	−0.240	−0.824	0.039
norm_rl	0.516	−0.224	0.351	−0.749
norm_ge	0.511	−0.328	0.445	0.658
norm_ps	0.459	0.886	0.030	0.065
Eigenvalue	3.605	0.308	0.052	0.034
% Variance Explained	90.13%	7.71%	1.31%	0.85%
Cumulative %	90.13%	97.84%	99.15%	100%

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The first principal component (for the four governance indicators (normrq, normrl, normge, normps) has been analysed and indicates that the first principal component explains very high 90.13 globally which is a very strong indication of one-dimensionality. There is no loading less than 0.40 and the high cumulative variance is one more evidence that these indicators are solid and reliable source of measurement of the quality of governance. The four governance indicators have been retained based on these powerful statistics.

Pannel D - Principal Component Analysis for Economic Sustainable Performance Indicators

Variable	Component 1	Component 2	Component 3
norm_gdp	0.721	0.037	−0.692
norm_ur	0.353	0.840	0.411
norm_icp	0.597	−0.541	0.593
Eigenvalue	1.359	1.030	0.611
% Variance Explained	45.31%	34.33%	20.36%
Cumulative %	45.31%	79.64%	100%

The first two components (normgdp, normur, and normicp) account 45.31% of the variation of the result again where the total variance of the first two components is 79.64%. The three variables are a combination of which the three loadings fall above the range of 0.35-0.40 as a practical range, which is seen to be the basis of the economic sustainability dimension. Therefore, there was no omission of variables.

Pannel E - Principal Component Analysis for Environmental Sustainable Performance Indicators

Variable	Component 1	Component 2	Component 3
norm_fa	0.544	0.739	0.398
norm_fww	0.559	−0.673	0.485
norm_aq	0.626	−0.041	−0.779
Eigenvalue	1.636	0.775	0.590
% Variance Explained	54.52%	25.83%	19.65%
Cumulative %	54.52%	80.35%	100%

The PCA of the environmental indicators (normfa, normfww, normaq) gives a first component of 54.52 an adequate percentage to justify the result of 50 percent. The total variances of the first two terms are 80.35 per cent. All the indicators have a significant value beyond 0.54, which indicates that forest area, freshwater withdrawals, and air quality are all equally significant and related factors to environmental sustainability. The index retains all the three indicators.

Pannel F - Principal Component Analysis for Social Sustainable Performance Indicators

Variable	Component 1	Component 2	Component 3
norm_le	0.592	−0.512	0.623
norm_he	0.637	−0.176	−0.750
norm_ws	0.494	0.841	0.221
Eigenvalue	1.904	0.732	0.363

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Variable	Component 1	Component 2	Component 3
% Variance Explained	63.47%	24.42%	12.12%
Cumulative %	63.47%	87.88%	100%

Finally, the results of the PCA of social indicators (normle, normhe, normws) indicate that the first component accounts 63.47 position of the variance, and the two components have a combined account of 87.88. The three variables are all strongly correlated (above 0.49), which means that life expectancy, health expenditure, and women in parliament are valid measures of the sustainability of the society.

Pannel G - Principal Component Analysis for Composite Sustainable Performance Indicators

Variable	Component 1	Component 2	Component 3
Economic index	0.659	−0.289	0.694
Environmental index	0.333	0.940	0.075
Social index	0.674	−0.182	−0.716
Eigenvalue	1.836	0.900	0.264
% Variance Explained	61.19%	29.99%	8.81%
Cumulative %	61.19%	91.19%	100%

The PCA results of the three sub- indices of Sustainable Performance (Economic, Environmental, and Social) indicate that the first principal component for the unidimensional constructs of the model is established at 61.19 per cent, exceeding a generally accepted small-five threshold (Hair et al., 2019). The factor loadings of all three sub indices are above 0.33, the economic and social indexes in particular present extremely high factors (>0.65). The findings suggest that the various dimensions have a very high common variance and may hence be merged to one aggregated Sustainable Performance index. Further evidence is given by the fact that the total variance of 91.19 percent across the first two components clearly demonstrates that these sub-indexes properly cover the sustainable performance construct and still provide an opportunity to analyse each dimension separately to obtain more in-depth results.

Table 5

Summary of Principal Component Analysis Results for Construct Validation

Construct	No. of Variables	Eigenvalue (Comp1)	% Variance (Comp1)	Cumulative % (Comp1+Comp2)	Decision
Fintech Adoption (FA)	4	2.4766	61.91%	81.99%	Retained
Green Finance (GF)	3	1.4045	46.82%	77.15%	Retained
Governance (WGI)	4	3.6053	90.13%	97.84%	Retained
Economic Sustainability (EcSP)	3	1.3593	45.31%	79.64%	Retained
Environmental Sustainability (EnSP)	3	1.6356	54.52%	80.35%	Retained

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Construct	No. of Variables	Eigenvalue (Comp1)	% Variance (Comp1)	Cumulative % (Comp1+Comp2)	Decision
Social Sustainability (SSP)	3	1.9041	63.47%	87.88%	Retained
Overall Sustainable Performance (SP)	3	1.8358	61.19%	91.19%	Retained

Reliability Testing

Internal consistency was determined using Cronbach's Alpha. This value shows the degree to which items in a group are correlated and therefore, they always measure the same construct (Cronbach, 1951; Nunnally, 1978).

Table 6

Cronbach's Alpha Reliability Statistics for Study Constructs

Construct	No. of Items	Reversed Items	Average Interitem Covariance	Cronbach's α
Fintech Adoption Proxies	4	norm_cbb	0.0204254	0.7760
Green Finance Proxies	3	norm_ans	0.0038661	0.6220
Sustainable Performance (All Proxies Combined)	9	None	0.0076737	0.7408

Table 6 shows the reliability analysis of the Fintech Adoption variable; eight proxy variables with four of these variables being the normcbb variable which is reverse-coded resulted in a Cronbach alpha of 0.7760 which exceeds the generally acceptable Cronbach alpha of 0.70 (Nunnally & Bernstein, 1994). This is an indication of good internal consistency. The Sustainable Performance variable, that incorporates all the college sustainability-related proxies, with alpha of 0.7408, is reasonably reliable. The variable with the highest normals reversed coded, however, that is the Green Finance, had an alpha of 0.6220; a moderate (marginally acceptable) internal consistency. This is a fair degree of reliability in the present state of exploratory macro-level, cross-country research papers.

Discussion

The findings offer strong empirical evidence to build and apply composite indices to measure the adoption of FinTech, green finance, governance quality, and sustainable performance in a huge cross-country panel in 2004-2023. Descriptive statistics show that there is great heterogeneity between countries and through time, which indicates different diffusions of digital financial technologies, institutional quality disparities, and different sustainability practices. The environmental performance mean is significantly greater than the economic and social ones, indicating that the environmental variables are more rapidly responsive to the global policy pressures and the international environmental sustainability obligations. There seems to be more structural constraints on economic and social performance.

The strong conceptual coherence between constructs is reinforced with the help of correlation analysis. The intercorrelations of the governance indicators are very high, in particular, demonstrating the interdependence of the dimensions of institutional quality. Factor-based aggregation is further provided by testing of sampling-adequacy. KMO values were either acceptable or excellent, and the test constructed by Bartlett is highly significant in all constructs. Through Principal Component Analysis, the first principal

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components present in all the indices indicate that the initial principal components can be used to determine a significant proportion of total variance, which meets or is near the expected conventional standards in applied sustainability and macroeconomics.

Despite the green finance and economic sustainability have slightly less first-component variance, its total variance and significant factor loadings call on retention. Here is an inherent multidimensionality of such constructs. The analysis of reliability demonstrates that the tool of analysing FinTech adoption and overall sustainable performance has a high level of internal consistency, whereas the tool of analysing green finance demonstrates an average level of reliability. However, such a high degree of reliability is agreeable for an exploratory, macro-level, cross-country research study.

On the whole, it is possible to note that the available empirical evidence demonstrates that the chosen indicators differ enough, they are highly internally coherent, and they fulfill adequate psychometric standards. The results suggest their combinations into valuable complex measurements. The correlation analysis, tests of sampling-adequacy, PCA, and reliability prove that the developed indices are statistically, theoretically, and functionally suitable and can reflect the multidimensional character of the outcomes of digital finance, environmental finance, institutional quality, and sustainability.

The validated indices hence provided a good background to the examination of the interconnection among financial innovation, green financial systems, governance models, and sustainable development outcomes at the country level. The study also improves the validity of later econometric and policy-based analyses as the methodology used is rigorously exercised at the measurement part of the test. This provides useful lessons to policy makers and scholars who aim at promoting sustainable development with the help of financial innovations and institutional changes.

References:

Apergis, N., & Payne, J. E. (2016). Renewable energy, output, CO_2 emissions, and fossil fuel prices in OECD countries: Evidence from a panel ECM. Energy Economics, 54, 33–43.

Arner, D. W., Barberis, J., & Buckley, R. P. (2015). The evolution of FinTech: A new post-crisis paradigm. Georgetown Journal of International Law, 47, 1271–1319.

Arner, D. W., Buckley, R. P., Zetzsche, D. A., & Veidt, R. (2020). Sustainability, FinTech, and financial inclusion. European Business Organization Law Review, 21(1), 7–35.

Asfahani, H., Sain, Z., & Mariana. (2023). Comparative analysis of educational policies: A cross-country study on access and equity in primary education. EDUJAVARE: International Journal of Educational Research, 1(1), 19–28.

Asongu, S. A., & Nwachukwu, J. C. (2017). Mobile phones and employment in Sub-Saharan Africa. Journal of Development Studies, 53(11), 170–171.

Bartlett, M. S. (1954). A note on the multiplying factors for various χ^2 approximations. Journal of the Royal Statistical Society: Series B (Methodological), 296–298.

Becker, J., & Ólafsdóttir, H. (2023). Measuring green finance: Concepts, proxies and pitfalls. Journal of Sustainable Finance & Investment, 13(2), 245–267.

Demirgüç-Kunt, A., Klapper, L., Singer, D., Ansar, S., & Hess, J. (2018). The Global Findex database 2017: Measuring financial inclusion and the FinTech revolution. World Bank.

Dhanabhakyam, M., & Suresh, S. P. (2024). Exploring the role of fintech innovations in driving sustainability: A study on user adoption and ESG integration in financial services. International Journal of Applied Research, 10(12), 65–69.

ISSN Online: 3007-3154
ISSN Print: 3007-3146

Vol. 4 No. 3 (March) (2026)

Dieleman, J. L., et al. (2018). Past, present, and future of global health financing. The Lancet, 391(10132), 293–303.

Ferreira, D. C., & Marques, R. C. (2021). Public-private partnerships in health care services: Do they outperform public hospitals regarding quality and access? Evidence from Portugal. Socio-Economic Planning Sciences, 73, 100798.

Ghanem, M. E. A. (2024). Corporate management and green finance as drivers of sustainable development: Evidence from Germany. Frontiers in Environmental Economics, 4, 1739606.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2019). Multivariate data analysis (8th ed.). Cengage Learning.

Han, J., & Khan, H. (2014). Governance, institutions and growth: Empirical lessons from Sub-Saharan Africa. Journal of Economic Surveys, 28(1), 71–91.

Hickel, J. (2020). The sustainable development index: Measuring ecological efficiency of human development. Ecological Economics, 167, 106331.

Hoffmann, A., Giovannini, E., Nardo, M., Saisana, M., Saltelli, A., & Tarantola, S. (2008). Handbook on constructing composite indicators: Methodology and user guide. OECD.

Hussain, A., Khattak, A., & Khan, J. (2018). Inflation, unemployment and economic growth in developing economies. Journal of Economic Perspectives, 12(2), 45–59.

Ikram, M., & Akhtar, S. (2021). Sustainability performance and macroeconomic stability: Cross-country evidence. Sustainable Production and Consumption, 27, 890–905.

Jan, A. A., Lai, F. W., & Tahir, M. (2021). Developing an Islamic corporate governance framework to examine sustainability performance in Islamic banks. Journal of Cleaner Production, 315, 128099.

Jolliffe, I. (2011). Principal component analysis. In International encyclopedia of statistical science (pp. 1094–1096). Springer.

Kaiser, H. F. (1974). An index of factorial simplicity. Psychometrika, 39(1), 31–36.

Kaufmann, D., Kraay, A., & Mastruzzi, M. (2011). The worldwide governance indicators: Methodology and analytical issues. Hague Journal on the Rule of Law, 3(2), 220–246.

Keeler, B. L., Polasky, S., Brauman, K. A., Johnson, K. A., Finlay, J. C., O'Neill, A., Kovacs, K., & Dalzell, B. (2012). Linking water quality and well-being for ecosystem services valuation. Proceedings of the National Academy of Sciences, 109(45), 18619–18624.

Meo, M. S., & Abd Karim, M. Z. (2022). The role of green finance in reducing CO_2 emissions. Borsa Istanbul Review, 22(1), 169–178.

Mazziotta, M., & Pareto, A. (2022). Normalization methods for spatio-temporal analysis of environmental performance. Environmetrics, 33(5), e2730.

Moldan, B., Janoušková, S., & Hák, T. (2012). How to understand and measure environmental sustainability. Ecological Indicators, 17, 4–13.

Murphy, M. (2001). Demography: Measuring and modeling population processes. Blackwell.

Nguyen, L., Tran, S., & Ho, T. (2022). Fintech credit, bank regulations and bank performance: A cross-country analysis. Asia-Pacific Journal of Business Administration, 14(4), 445–466.

Nunnally, J. (1978). Psychometric theory (2nd ed.). McGraw-Hill.

Nunnally, J. C., & Bernstein, I. H. (1994). Psychometric theory (3rd ed.). McGraw-Hill.

ISSN Online: 3007-3154
ISSN Print: 3007-3146

Vol. 4 No. 3 (March) (2026)

Park, C. Y., & Mercado, R. V. (2018). Financial inclusion, poverty, and income inequality. Singapore Economic Review, 63(1), 185–206.

Phan, D. H. B., Narayan, P. K., Rahman, R. E., & Hutabarat, A. R. (2020). Do financial technology firms influence bank performance? Pacific-Basin Finance Journal, 62, 101210.

Rusu, R., & Oprean-Stan, C. (2025). The impact of digitalisation and sustainability on inclusiveness. arXiv preprint arXiv:2501.07880.

Sachs, J. D., Lafortune, G., Fuller, G., & Drumm, E. (2023). Sustainable development report 2023. Cambridge University Press.

Sahay, R., Čihák, M., N'Diaye, P., Barajas, A., Bi, R., Ayala, D., Gao, Y., Kyobe, A., Nguyen, L., Saborowski, C., Svirydzenka, K., & Yousefi, R. (2020). The promise of FinTech: Financial inclusion in the post-COVID-19 era. International Monetary Fund.

Sala, S., Ciuffo, B., & Nijkamp, P. (2015). A systemic framework for sustainability assessment. Ecological Economics, 119, 314–325.

Salinas Fernández, J. A., Rodríguez Martín, J. A., & Holgado Molina, M. M. (2014). A synthetic indicator to measure economic and social cohesion. Revista de Economía Mundial, 39.

Sarma, M., & Pais, J. (2011). Financial inclusion and development. Journal of International Development, 23(5), 613–628.

Sharma, P., & Bandyopadhyay, S. (2023). A quantitative framework for sustainability assessment. Clean Technologies and Environmental Policy, 25(9), 2971–2985.

Shiklomanov, I. A., & Rodda, J. C. (2003). World water resources at the beginning of the twenty-first century. Cambridge University Press.

Solarz, M., & Swacha, J. (2021). FinTech adoption in the global financial market: Trends and challenges. Journal of Risk and Financial Management, 14(10), 482.

Udeagha, M. C., & Muchapondwa, E. (2023). Green finance, FinTech, and energy innovation for environmental sustainability. Energy Economics, 122, 106595.

United Nations. (2023). The sustainable development goals report 2023. United Nations.

Wang, J., Zhang, D., & Li, Y. (2023). Green finance, social sustainability, and institutional maturity. Sustainability, 15(3), 2301.

Wang, Y., & Zhi, Q. (2021). The role of green finance in environmental protection. Energy Procedia, 104, 311–316.

Xiong, Y., & Dai, L. (2023). Green finance investment and sustainable development. Renewable Energy, 214, 342–349.

Yan, Z., Shi, R., Du, K., & Yi, L. (2022). Green production process innovation in OECD countries. Applied Economics, 54(59), 6755–6767.

Zeng, D. Z. (2019). Governance indicators and economic performance. Journal of Comparative Economics, 47(3), 789–805.

Zhang, D., Mohsin, M., Rasheed, A. K., Chang, Y., & Taghizadeh-Hesary, F. (2021). Public spending and green economic growth. Energy Policy, 153, 112256.

Zhang, L., Saydaliev, H. B., & Ma, X. (2022). Green finance investment and technological innovation. Renewable Energy, 193, 991–1000.

Zhang, Q., Abdullah, F., Sibghatullah, A., Sohail, M., Mashahadi, F., & Yusof, Y. L. M. (2025). Digital transformation and sustainable performance in the retail industry. Future Technology, 4(3), 269–280.

Zheng, C., Rahman, M. A., Hossain, S., & Alam Siddik, M. N. (2024). Construction of a composite fintech index for financial inclusion. Applied Economics, 56(52), 6498–6515.

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